Climate Change Effects on Forest Hydrology

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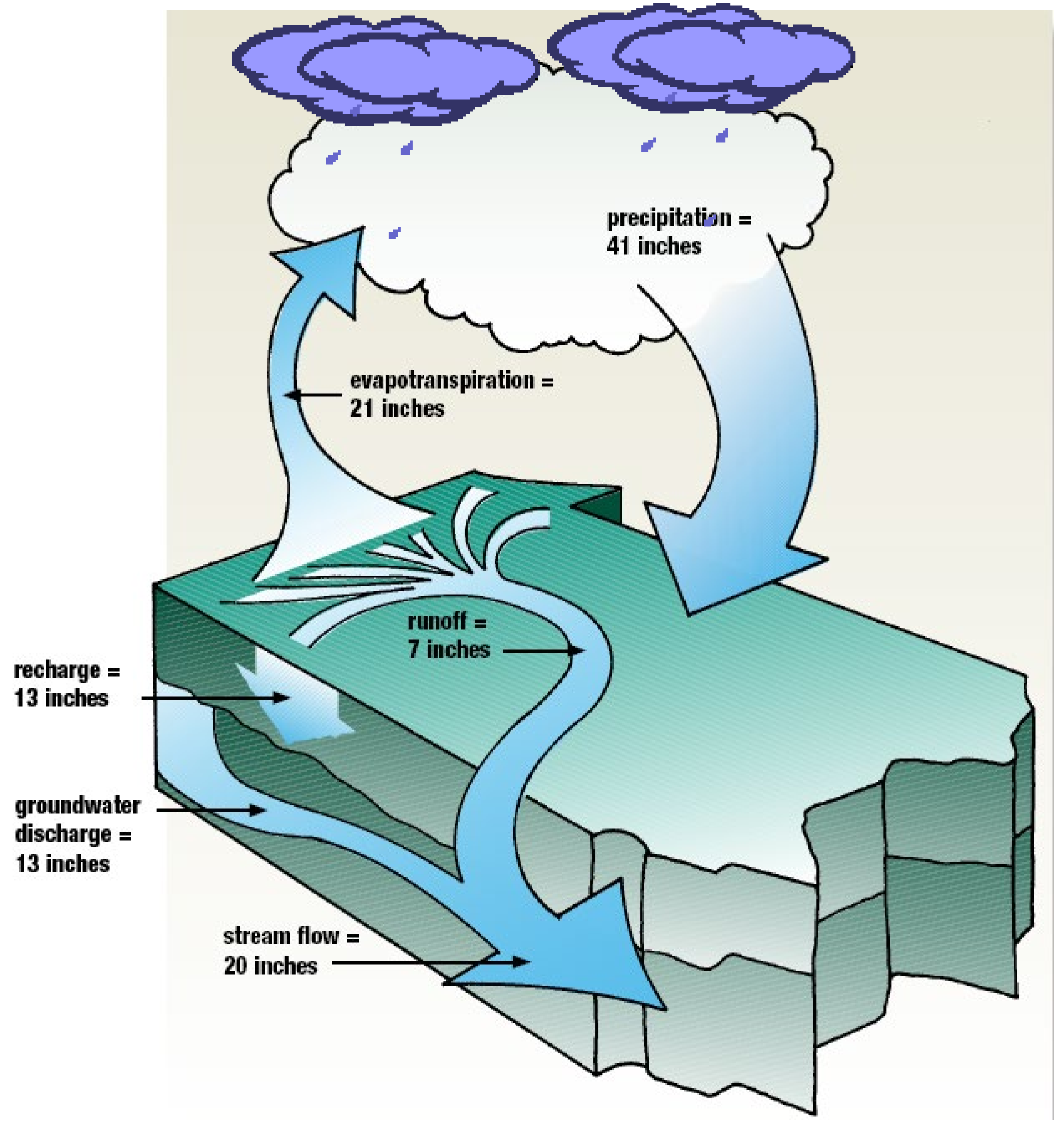
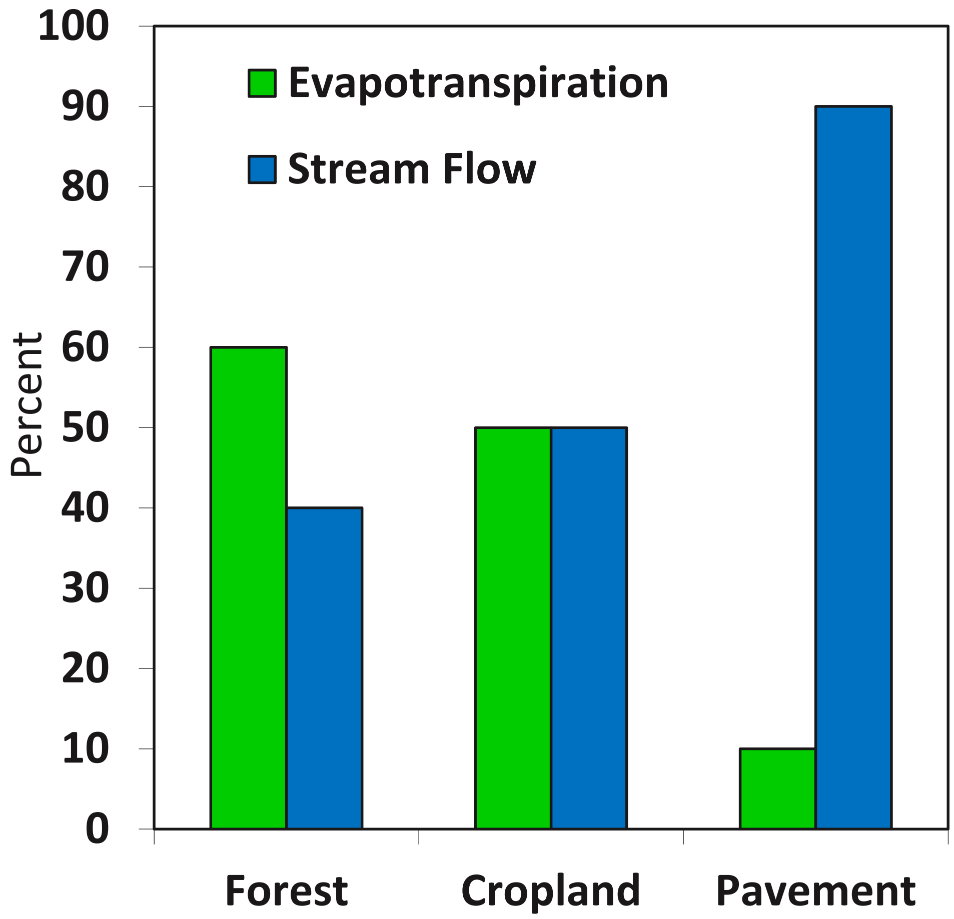
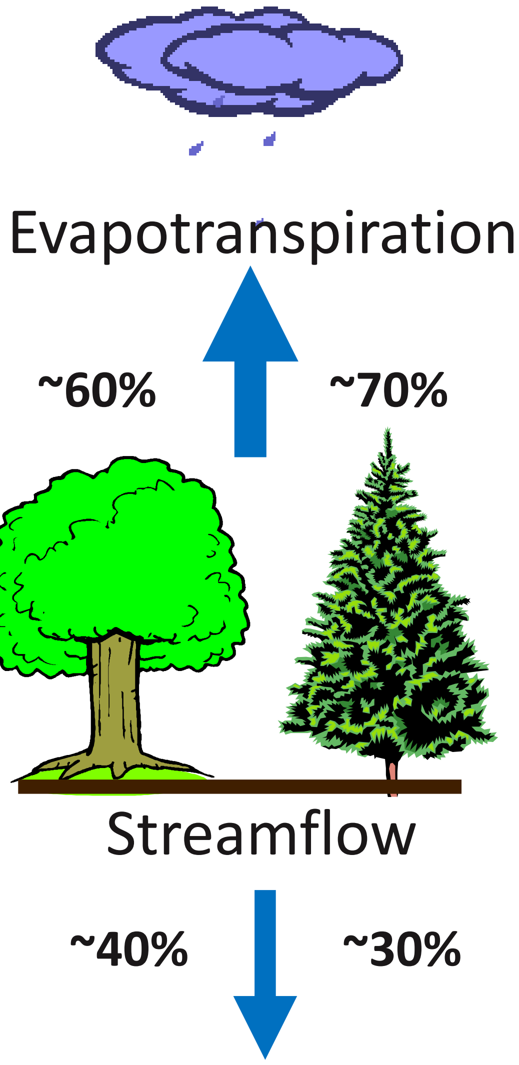
The Hydrology of Forested Watersheds

Pennsylvania Hydrologic Budget

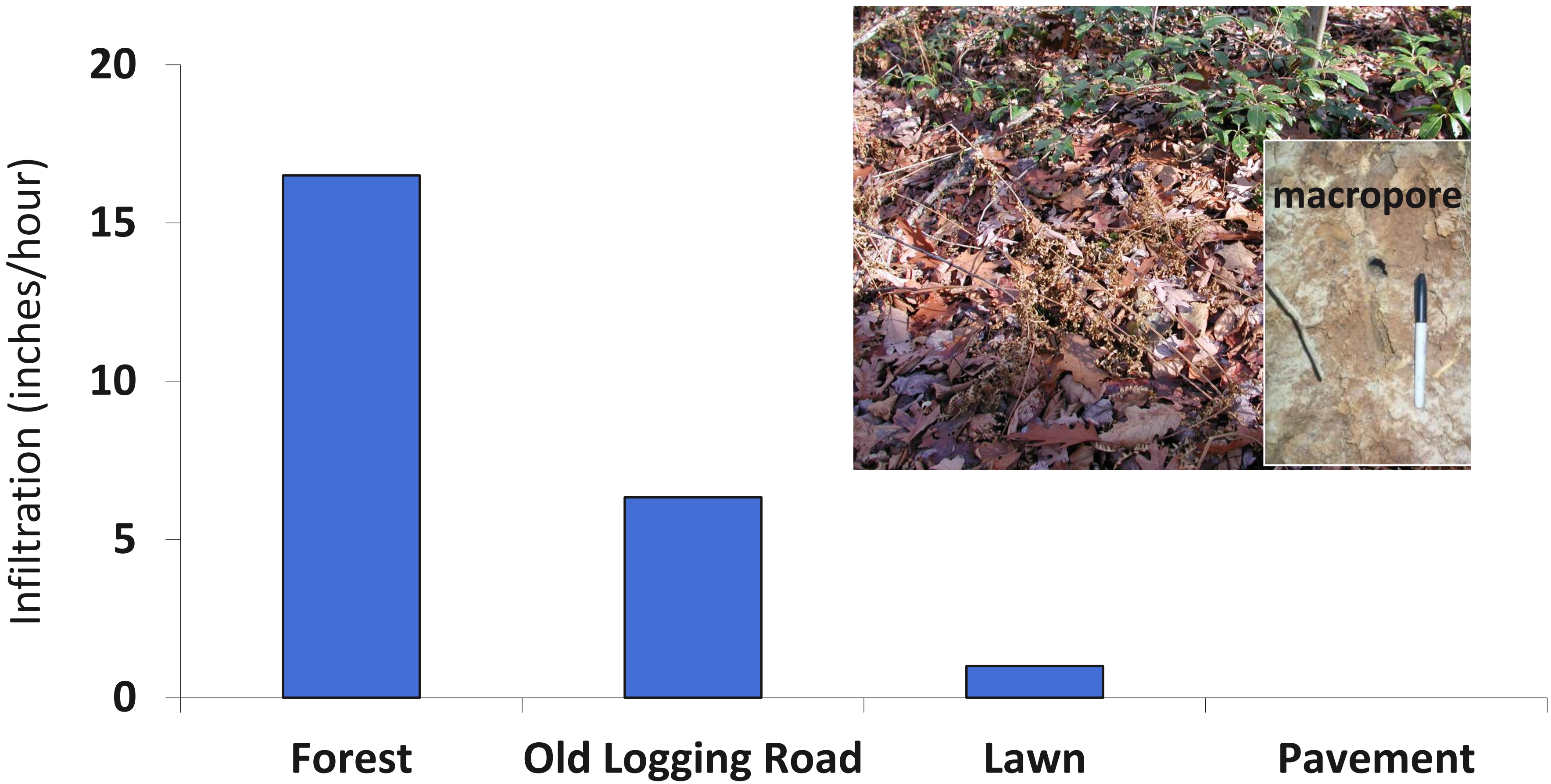


Hydrologic Budget by Land Cover

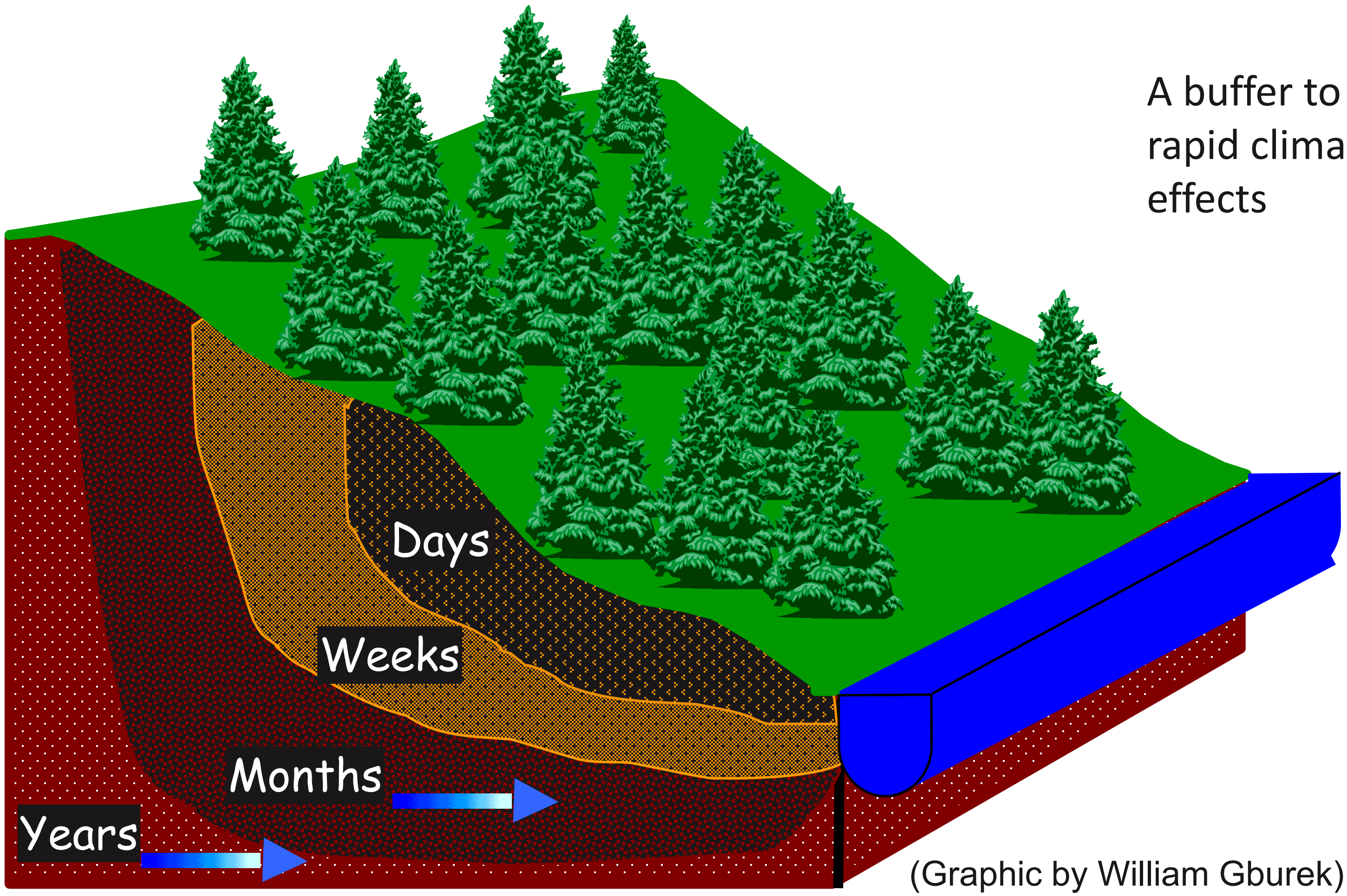




Forests = High Water Infiltration Rates



High Infiltration Results in Subsurface Flow



A buffer to rapid climate effects

(Graphic by William Gburek)

What is the average age of water in small streams at low flow?

Modeling Forest Watershed Residence Time

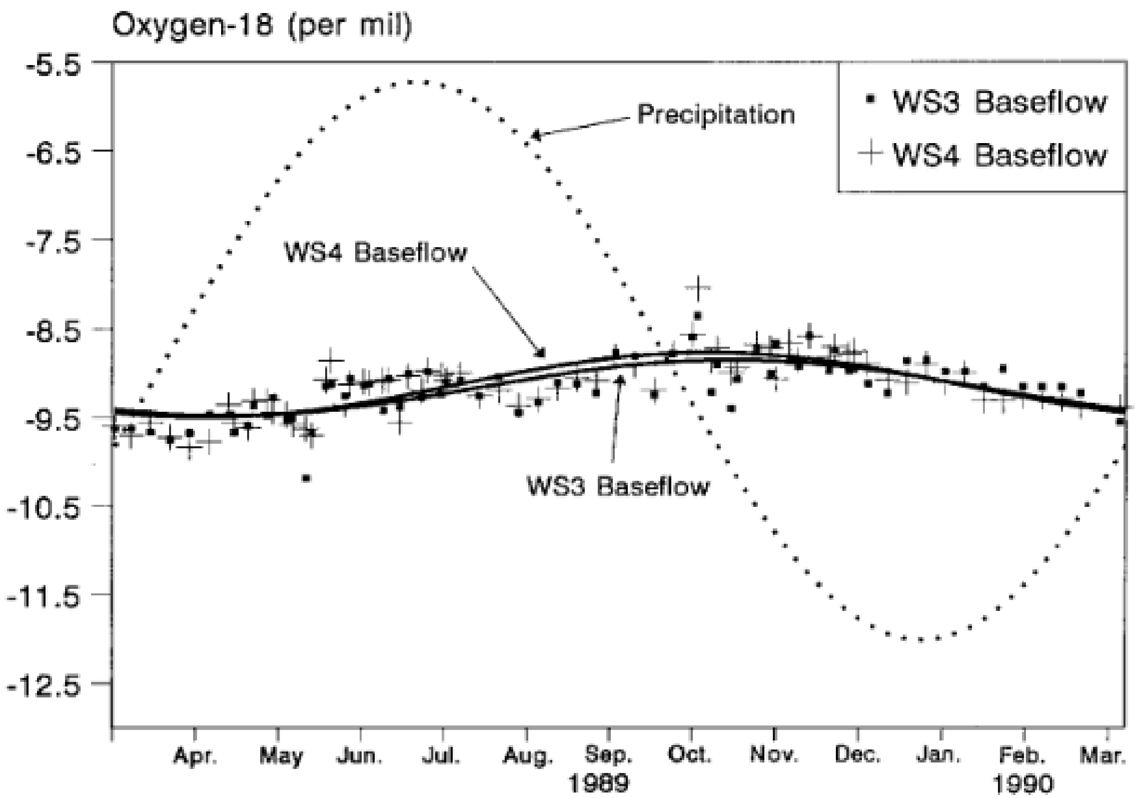
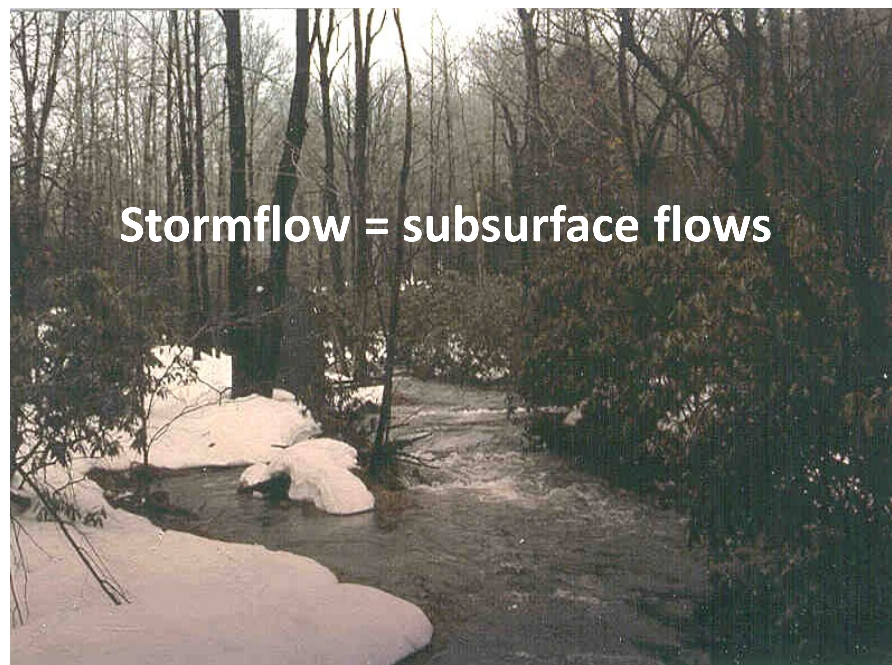


Figure 5. Seasonal oxygen-18 variations in baseflow on Fernow catchments WS3 and WS4 (March 1989–March 1990). Sine waves fitted to precipitation and baseflow data are shown for reference

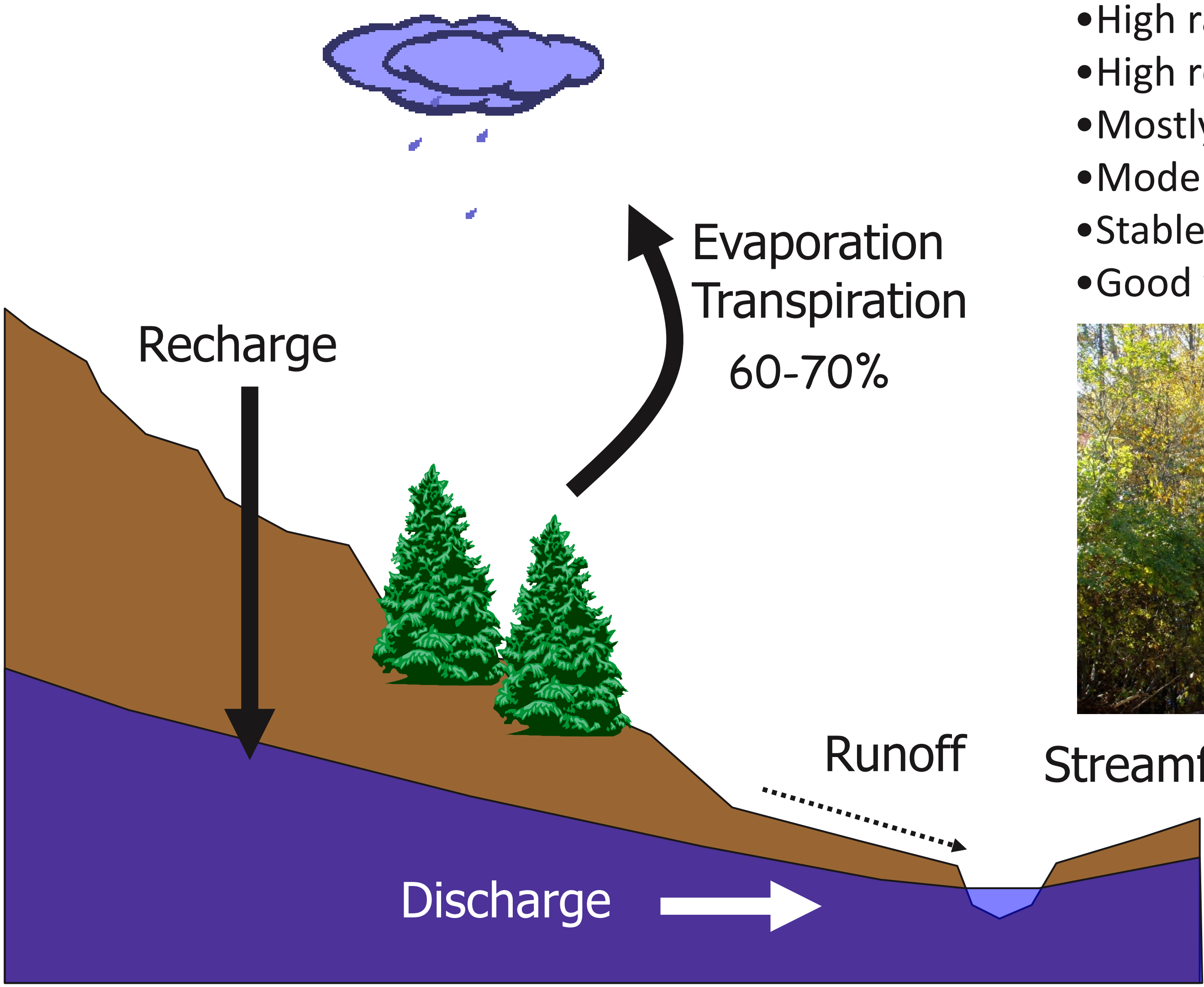
Residence Time = many months to a year or more

DeWalle, D.R., P.J. Edwards, B.R. Swistock, R.J. Drimmie, and R. Aravena. 1997. Seasonal isotope hydrology of three Appalachian forest catchments. *Hydrological Processes.* 11:1895-1906.


Low flow = 100% groundwater


Stormflow = subsurface flows

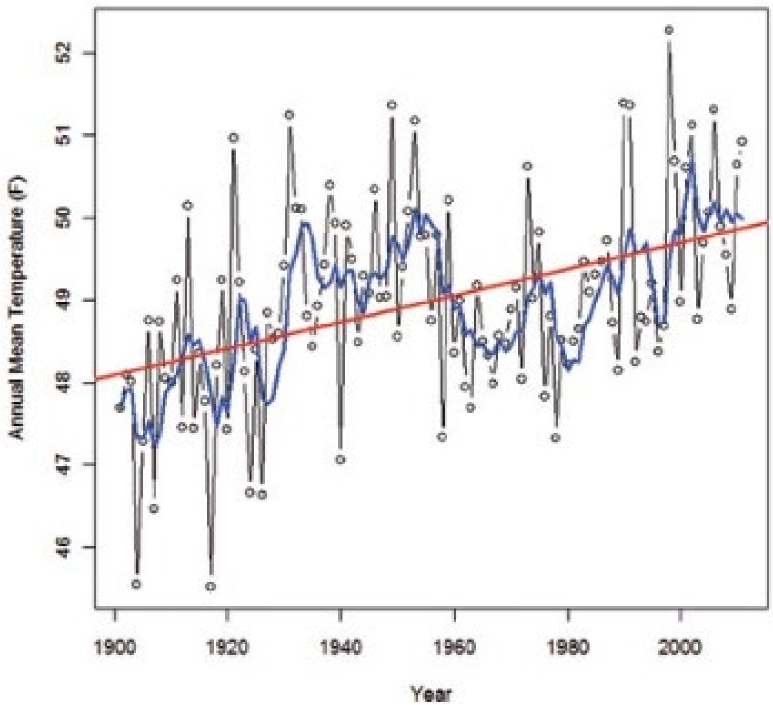
Forest Hydrological Processes



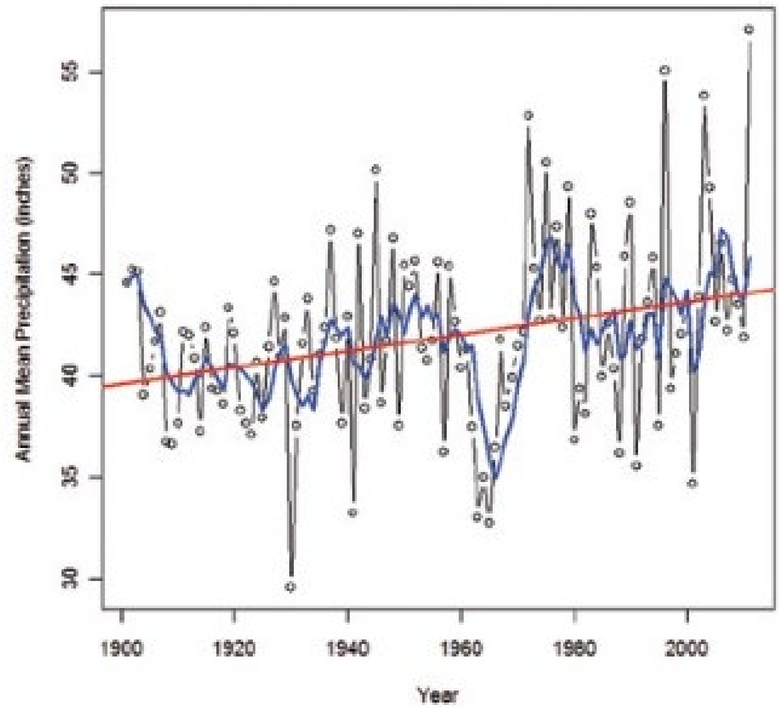
- High rate of evapotranspiration
- High recharge rates
- Mostly subsurface flow
- Moderated flows, cool water
- Stable banks
- Good water quality

Streamflow = 30-40%

Mid Atlantic Changing Temperature and Precipitation



Mean Annual Temperature – increasing 0016˚F per year.



Mean Annual Precipitation – increasing 0.04 inches per year.

Mid-Atlantic Forest Ecosystem Vulnerability Assessment and Synthesis: A Report from the Mid-Atlantic Climate Change Response Framework Project, U.S. Forest Service, Northern Research Station, General Technical Report NRS-181, October 2018.

Evapotranspiration Trends

Overall, Increased ET due to:

- Increased air temperature throughout the year
- Increasing moisture availability
- Lengthening of the growing season

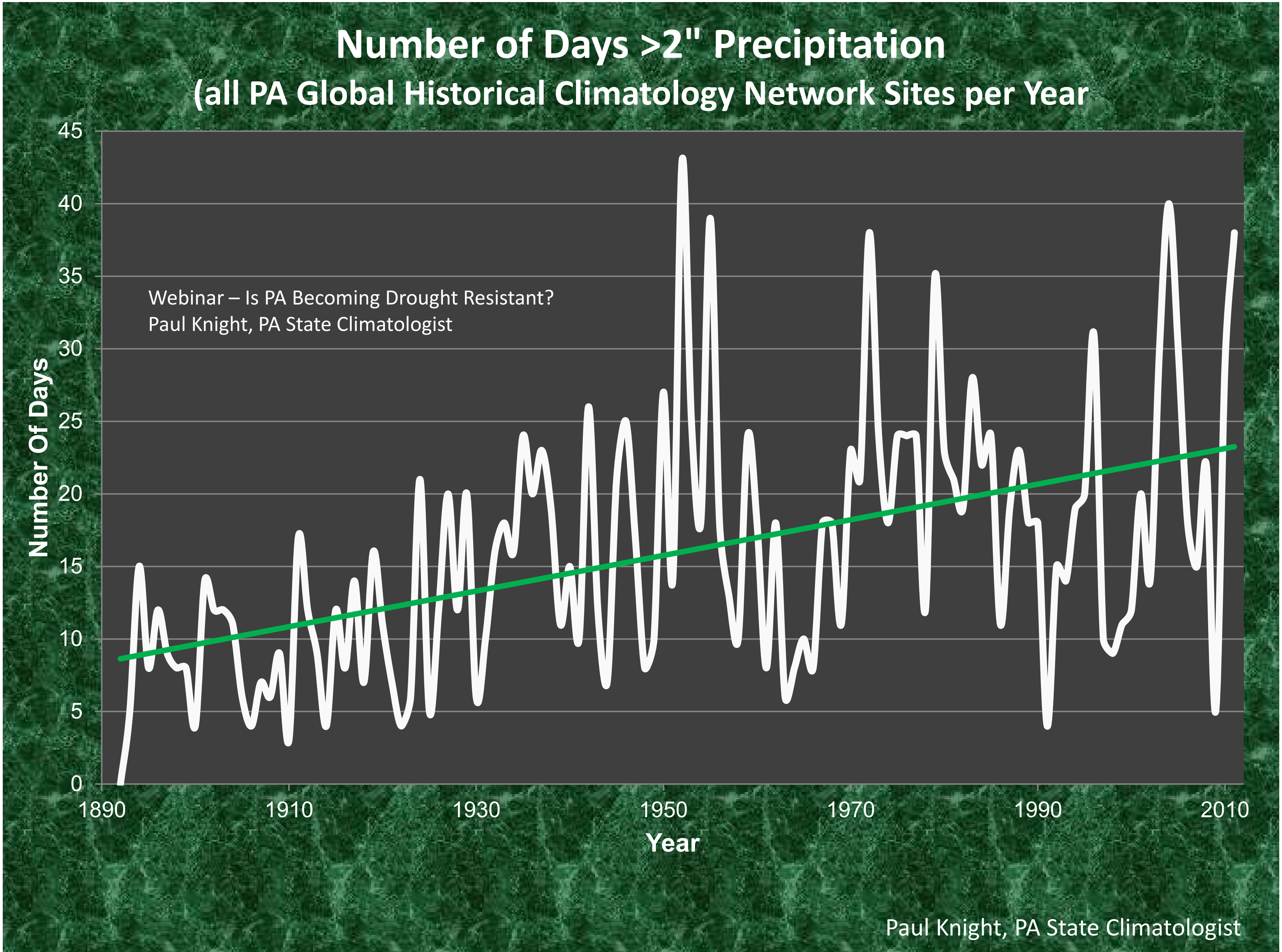
Evapotranspiration in winter will decrease with a decreasing snowpack and hence reduced sublimation (Hayhoe et al., 2007).

(PA Climate Impacts Assessment, 2013).

Precipitation Trends

- Increase in winter precipitation (but less snow)
- Small to no overall increase in summer precipitation. Potential increase in extreme heavy precipitation events
- More extreme precipitation is already occurring

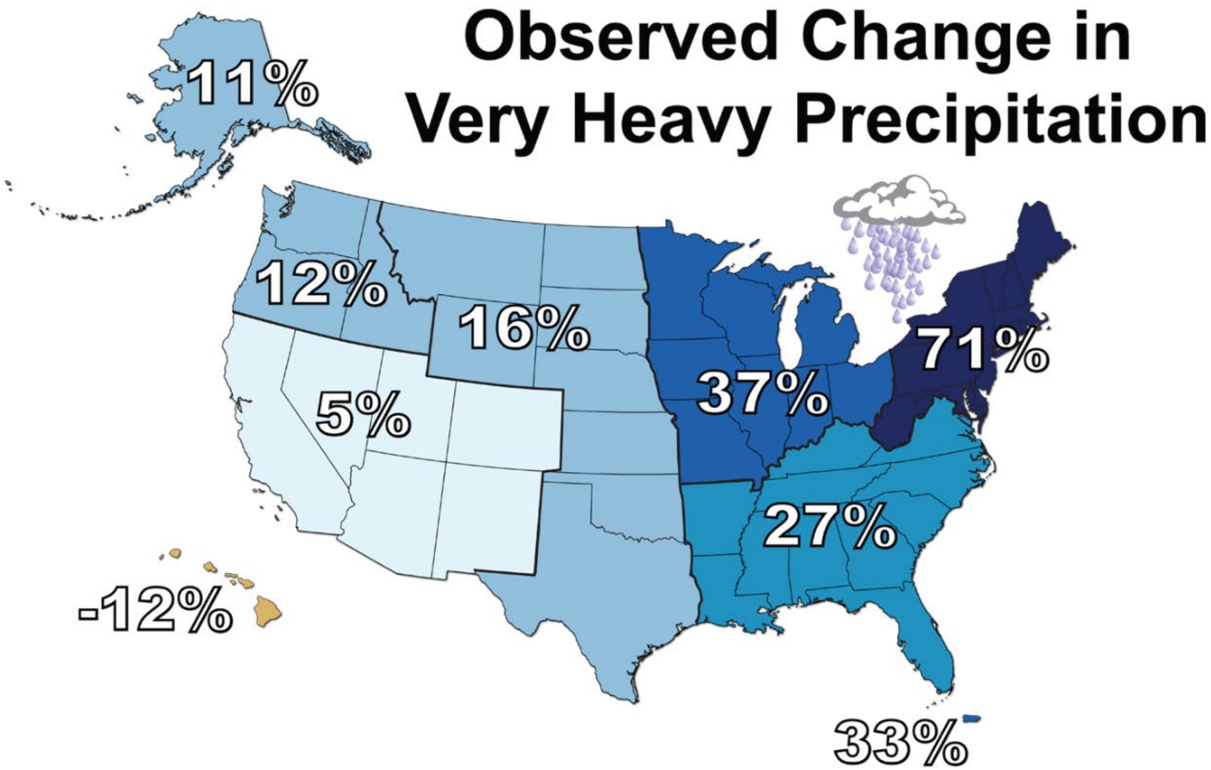
(PA Climate Impacts Assessment, 2013).



Number of Days >2" Precipitation
(all PA Global Historical Climatology Network Sites per Year
Webinar – Is PA Becoming Drought Resistant?
Paul Knight, PA State Climatologist
Number Of Days
45
40
35
30
25
20
15
10
5
0
1890
1910
1930
1950
1970
1990
2010
Year
Paul Knight, PA State Climatologist

National Climate Assessment

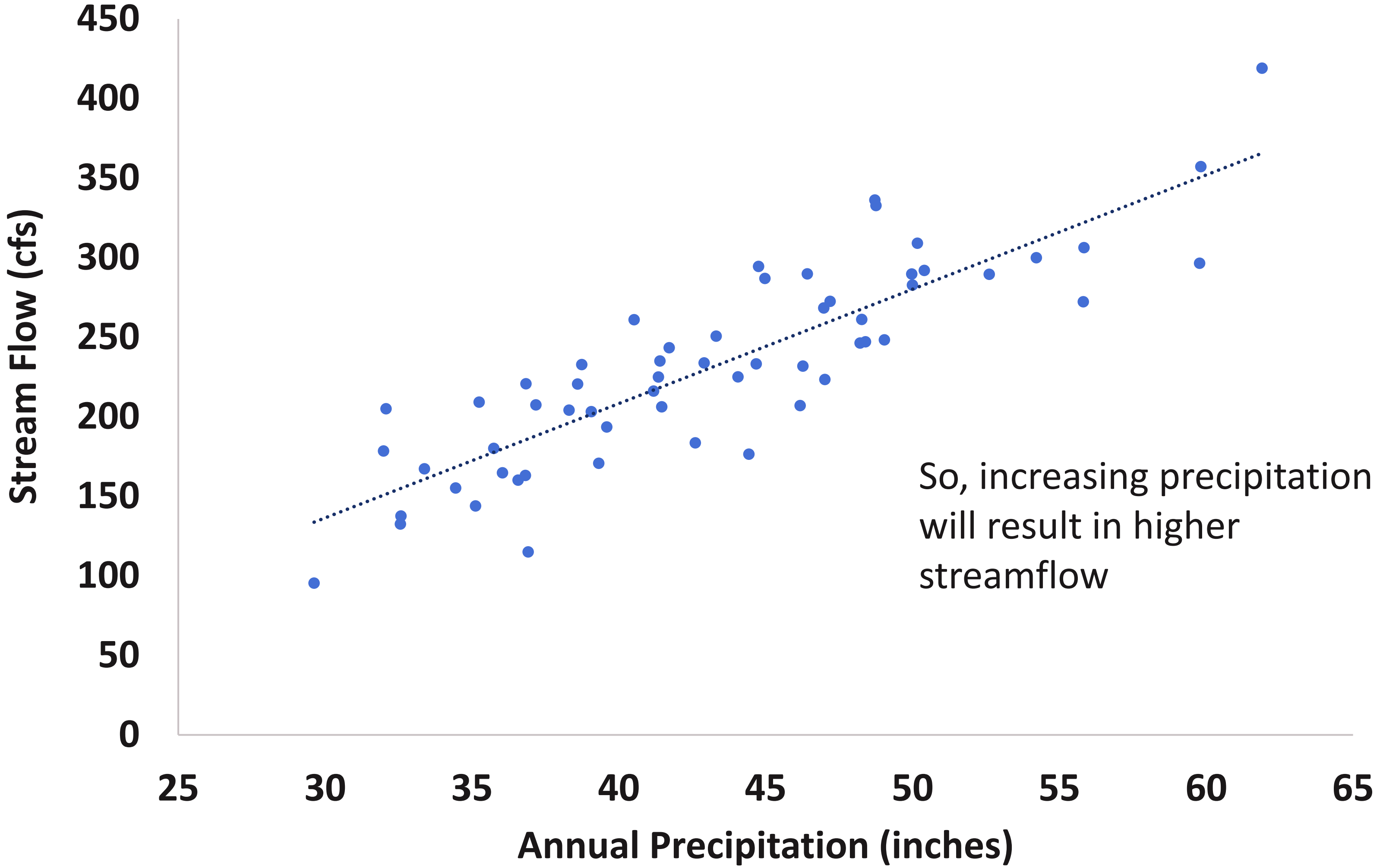
released on May 6, 2014



Source: Paul Knight, PA State Climatologist

Precipitation Controls Streamflow

(Buskill Creek, Pennsylvania)



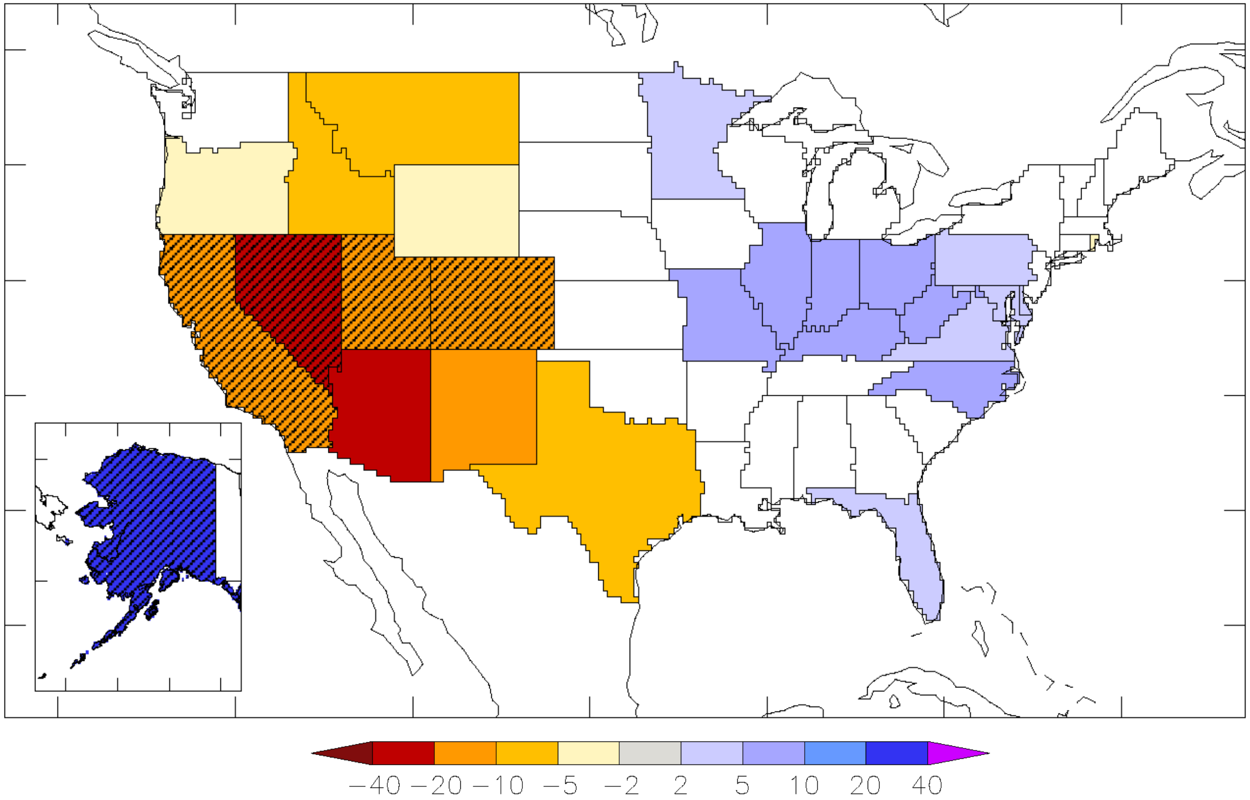
Stream Flow Changes

- Overall **INCREASE** due to
  - Higher winter runoff (rain instead of snow)
  - Increase in groundwater from greater recharge (infiltration of rainfall) due to reduced frozen soil and higher winter precipitation when plants are not active and evapotranspiration is low
  - More extreme flows from higher intensity storms

- Somewhat offset by
  - Increased evapotranspiration from longer growing season and more moisture
  - Decrease of large rain on snow events in spring

(Pennsylvania Climate Impacts Assessment, 2013)

Predicted Streamflow Changes



Model-Projected Changes in Annual Runoff, 2041-2060. Percentage change relative to 1900-1970 baseline. Any color indicates that >66% of models agree on sign of change; diagonal hatching indicates >90% agreement. (Reproduced from online supplement to **Milly, P.C.D., K.A. Dunne, A.V. Vecchia**, Global pattern of trends in streamflow and water availability in a changing climate, *Nature*, 438, 347-350, 2005.)

Substantial Decrease in Snow Cover Extent and Duration

- Reduced rain on snow floods!
- More rapid groundwater recharge in winter/spring

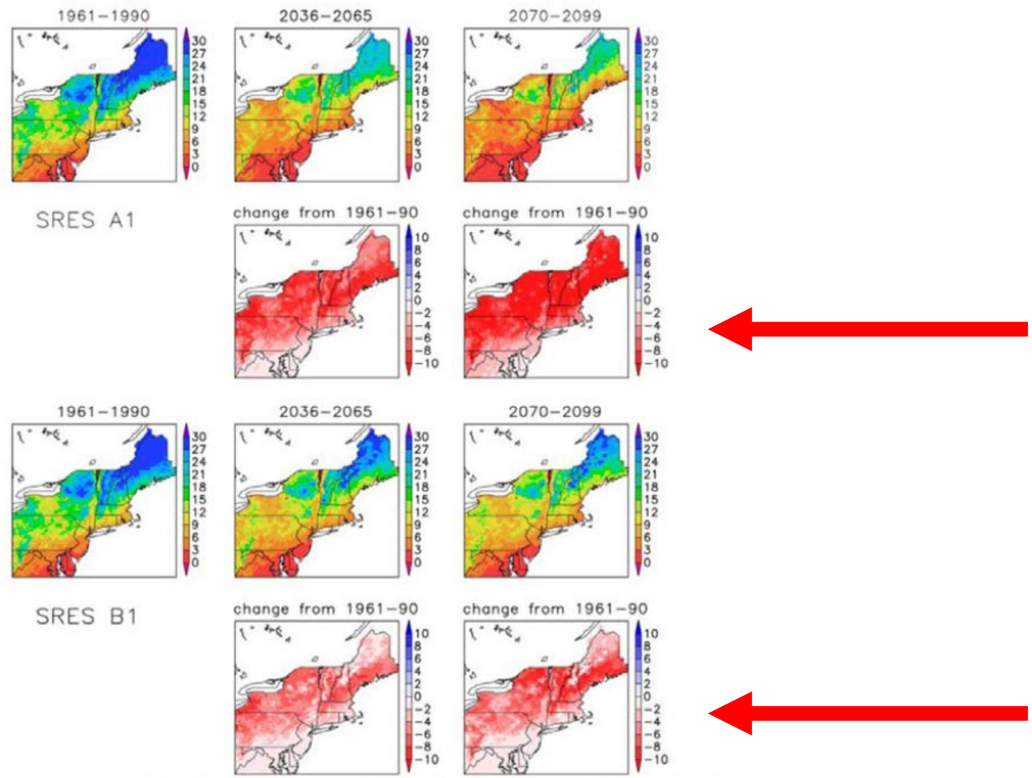
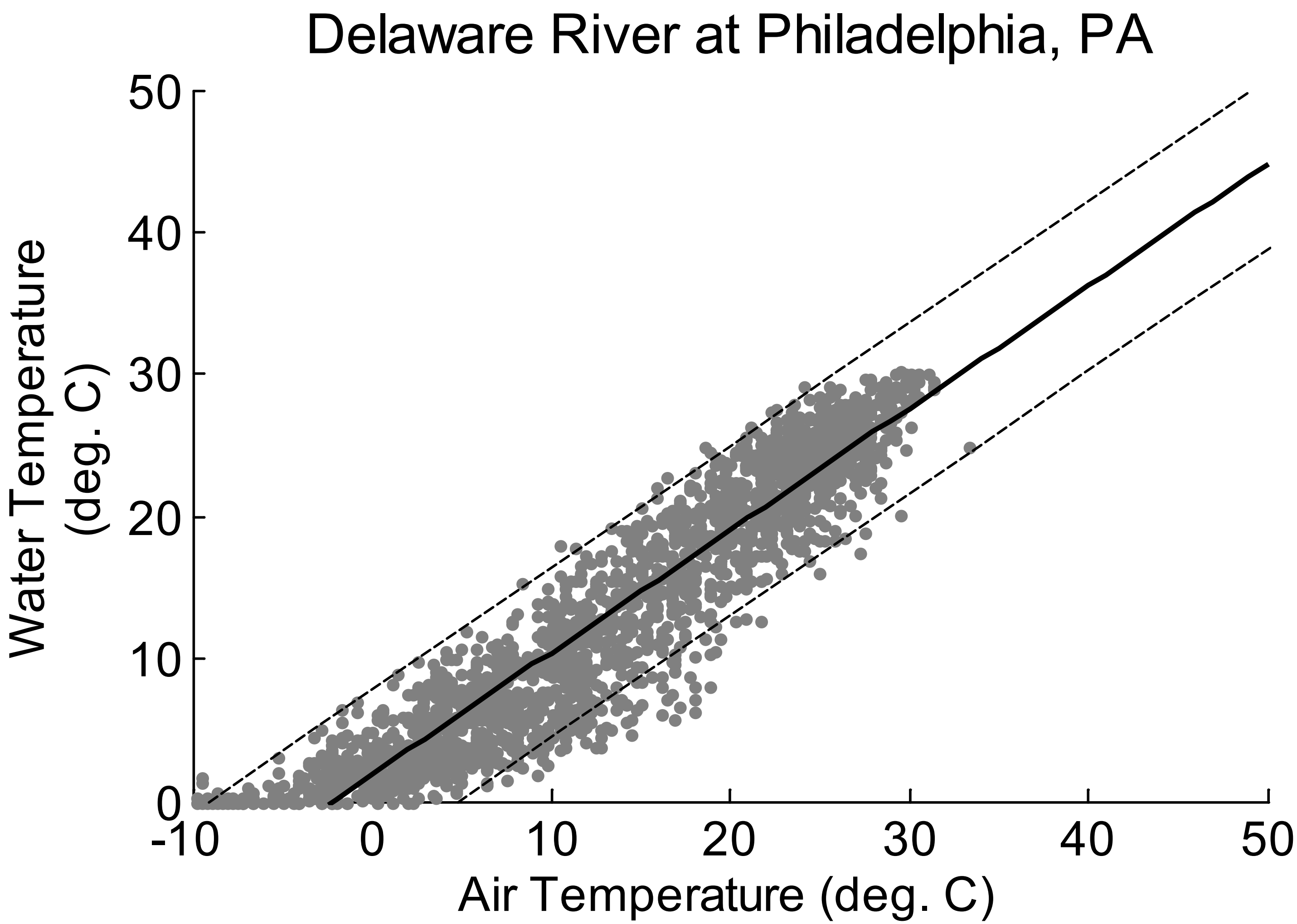


Figure 5.1. Results of HadCM3 and PCM GCM-output driven simulations with the VIC land-surface model. Plots show snow-covered days per month from December to February averaged over 30-year periods. 'Change' refers to the difference between the period 1961-1990 and future periods (Hayhoe et al., 2007).

(PA Climate Impacts Assessment, 2013)

Water Temperature Increases Will Occur



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Forested Watershed Temperature Sensitivity

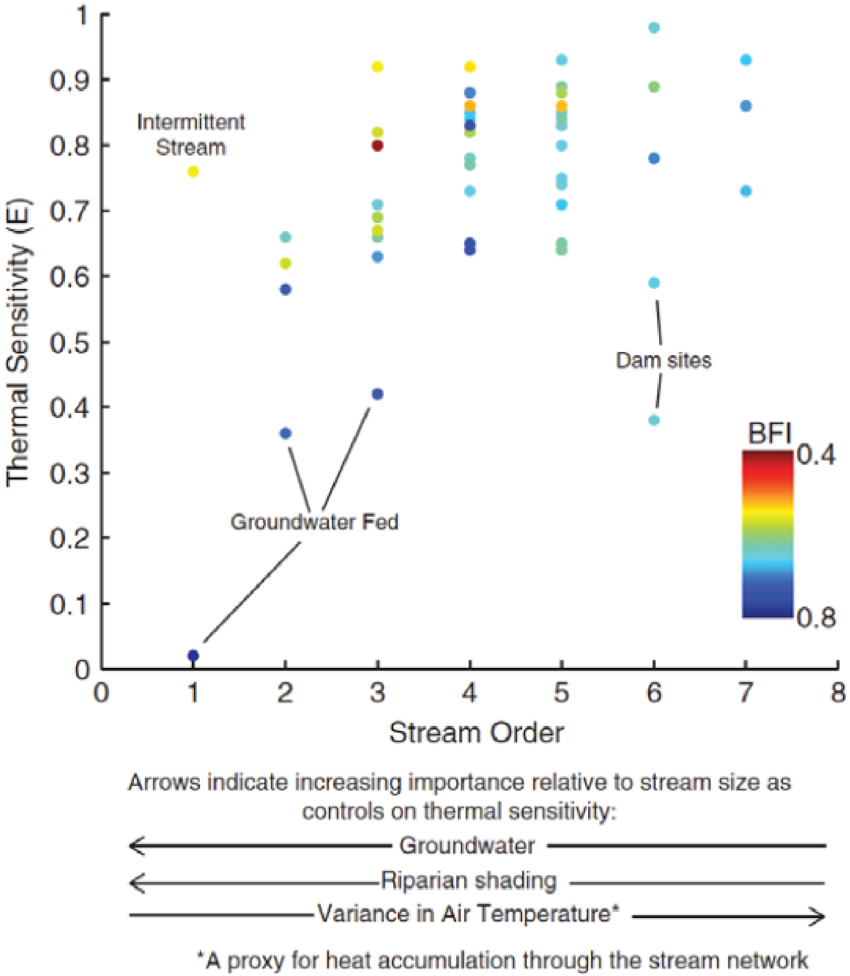
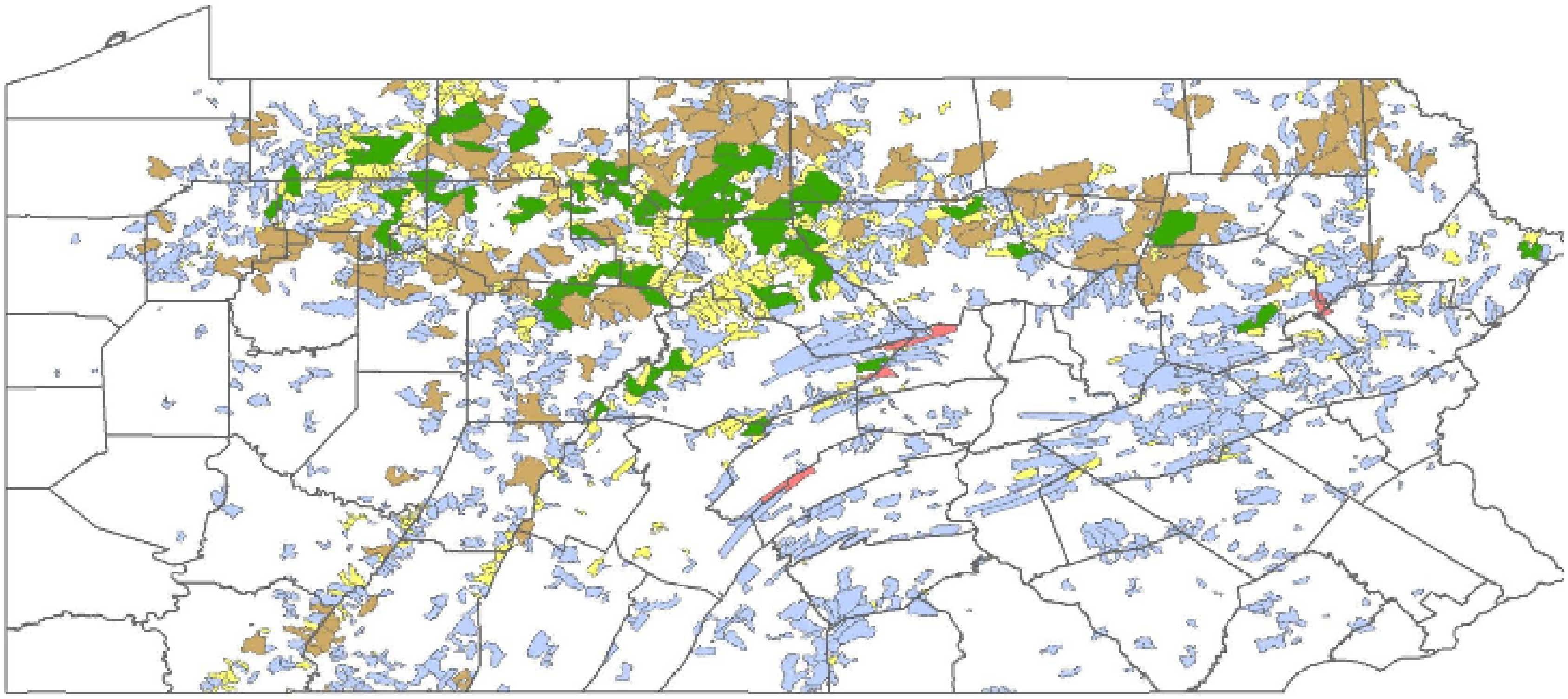


Figure 5.6. Stream order (SO) versus thermal sensitivity, across 57 Pennsylvania streams. Color highlights baseflow contribution, in terms of BFI. Sites where thermal sensitivity is influenced by a unique site condition are noted on the figure. General controls on thermal sensitivity and their influence relative to stream size are conceptualized at the bottom of the figure (Kelleher et al., 2011).

Native Brook Trout Stressors



EBTJV brook trout patch

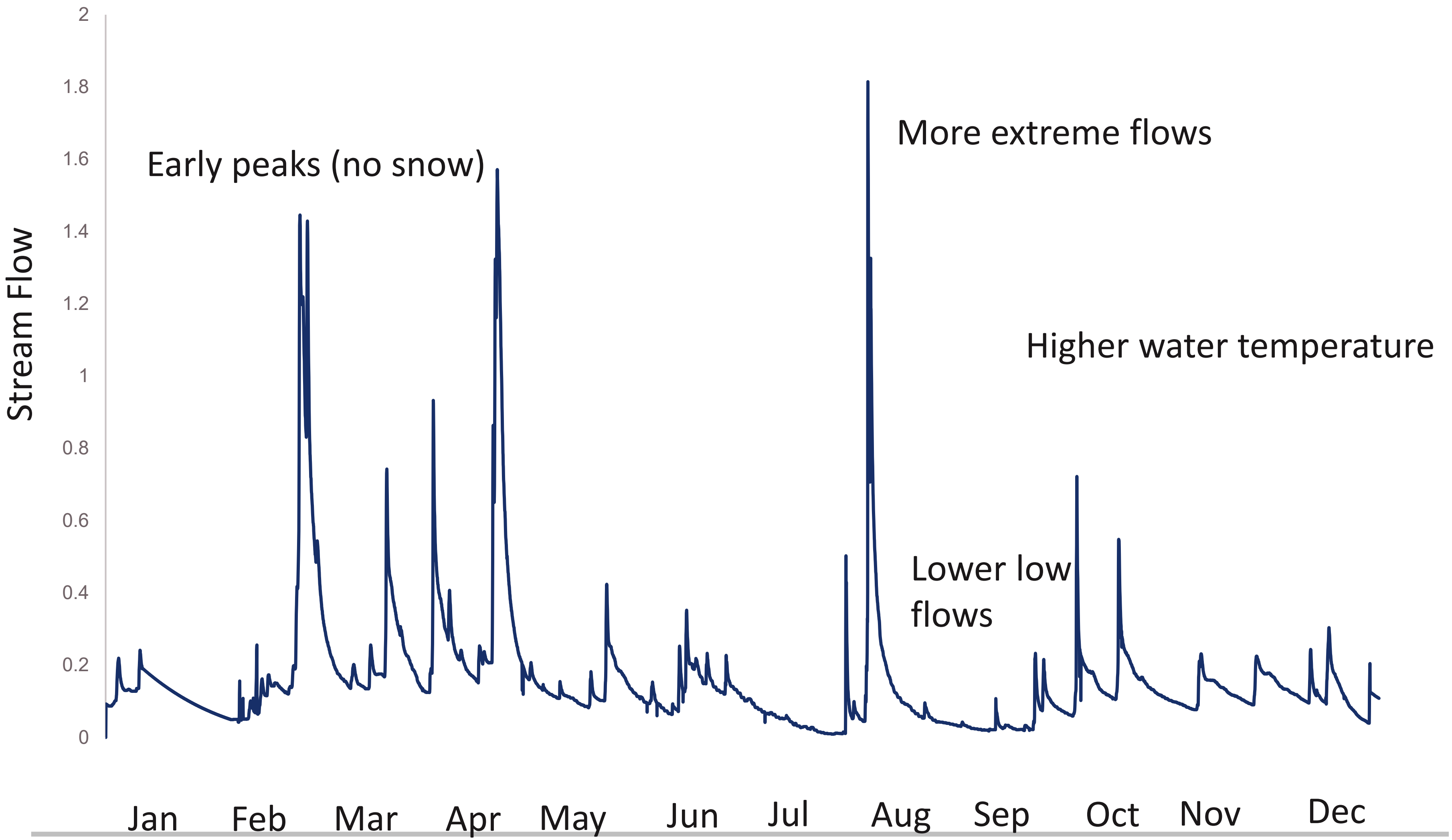
- Stronghold
- Impaired: Population
- Impaired: Habitat
- Impaired: Climate
- Impaired: Multiple categories

All: 1,761 populations
Strongholds: 3% of populations

Stressor:
Population: 27% of populations
Habitat: 7% of populations
Climate Change: 0.2% of populations
Multiple factors: 63% of populations

Source: Shawn Rummell, Trout Unlimited

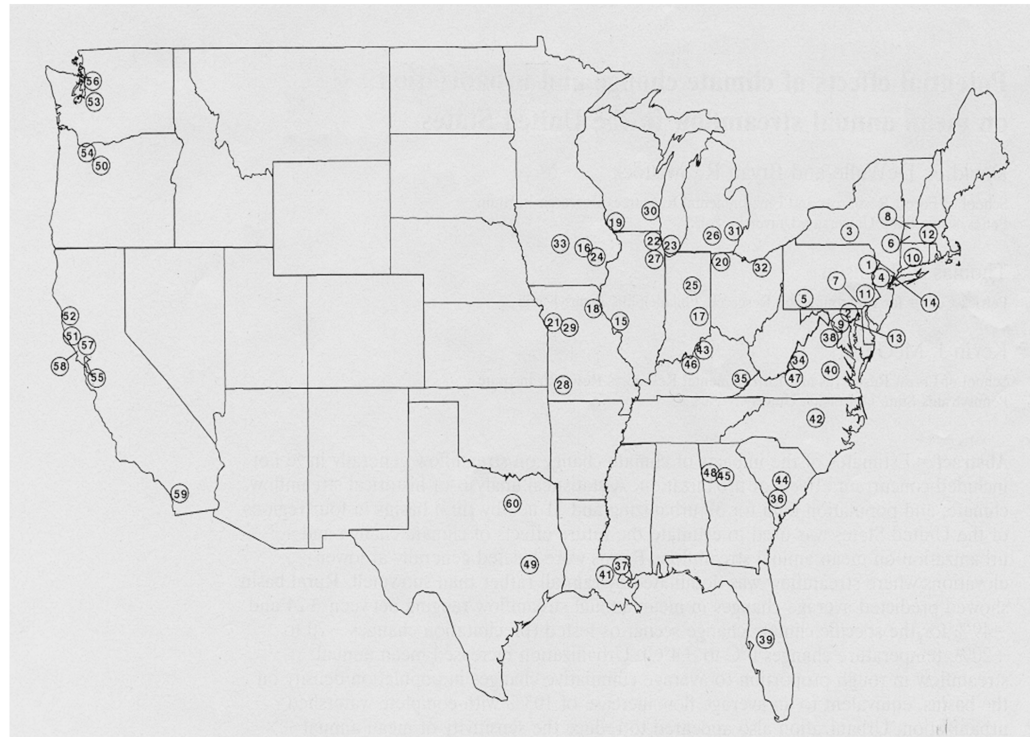
Changing Stream Hydrographs

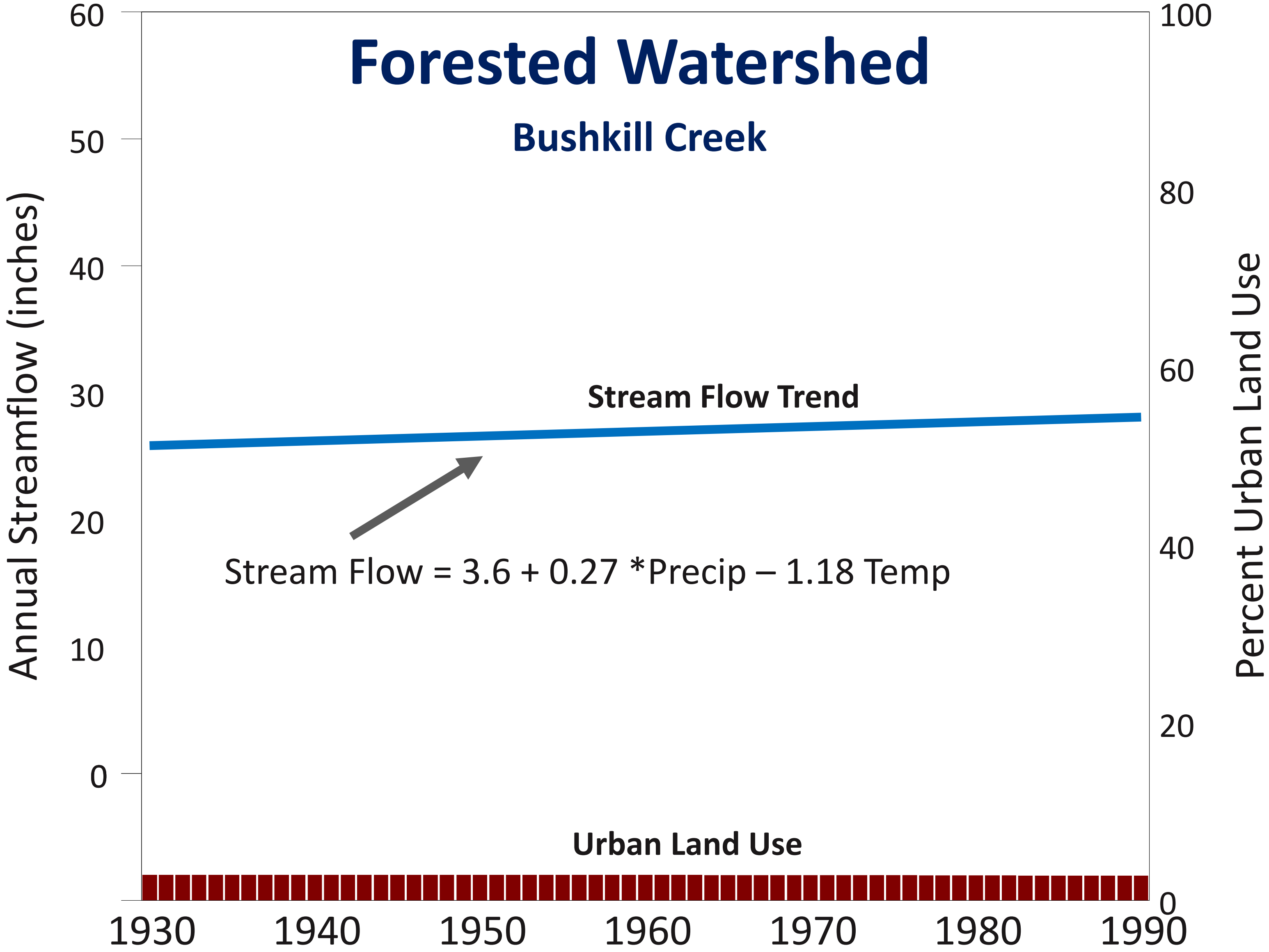


Climate Change on Forested and Urbanizing Watersheds

(Funded by U.S. Environmental Protection Agency)

- 39 urbanizing watersheds
- 21 forested (rural) watersheds
- Analyzed 1930-1990
- Concept – past period of record provides climatic variability that will provide clues to future changes
- How do urbanizing watersheds respond relative to forested watersheds?





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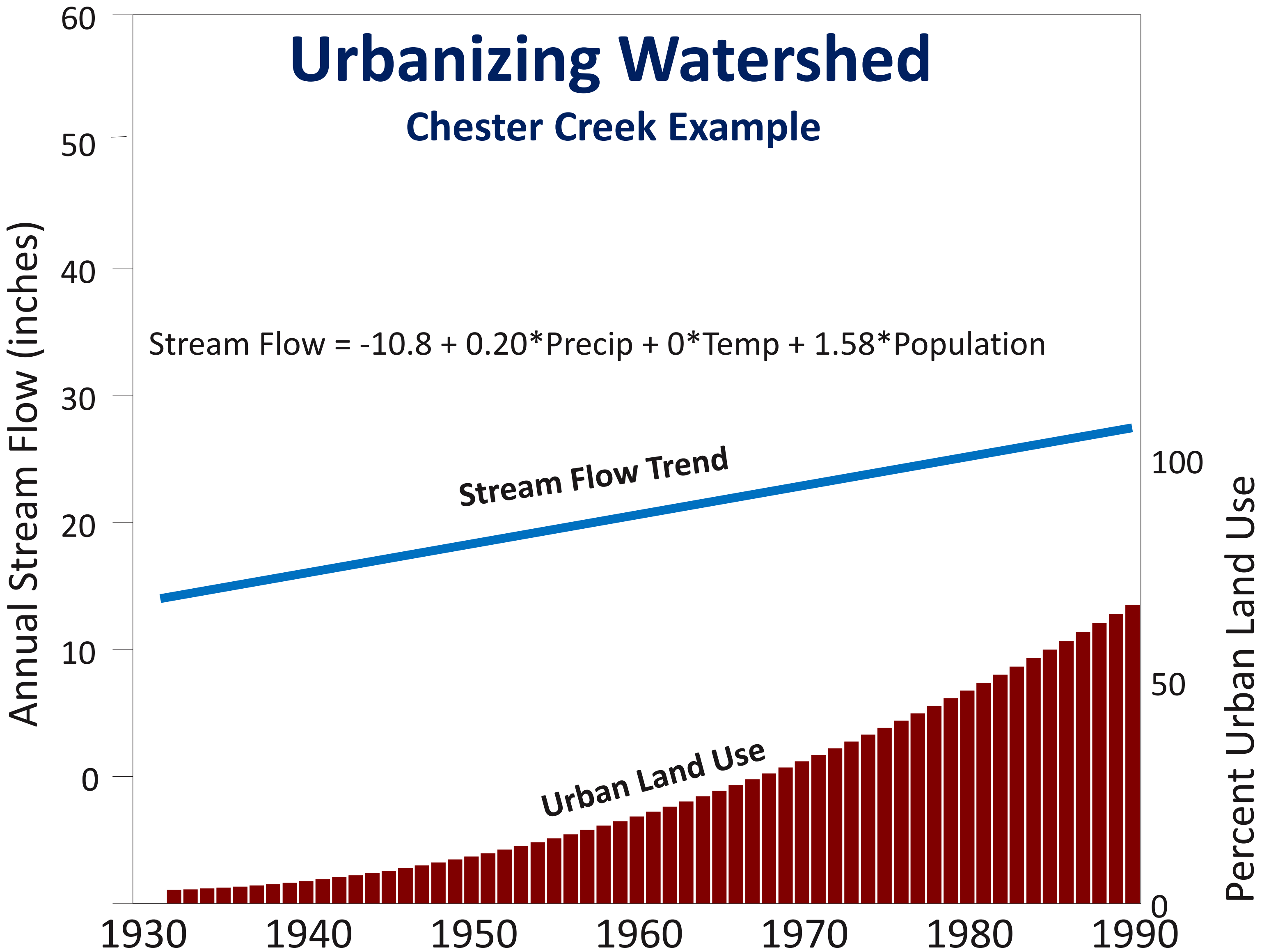
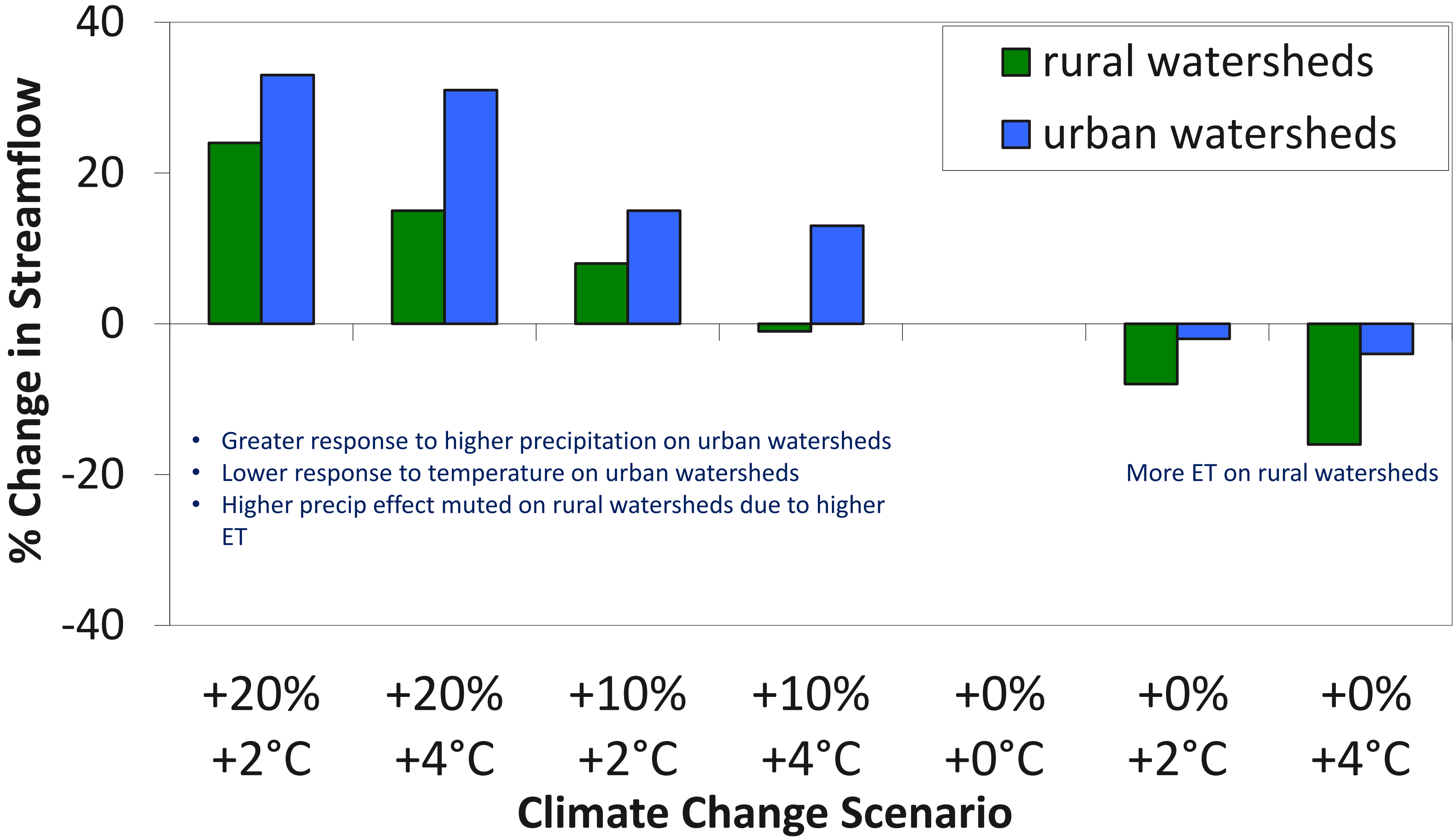

Urbanizing Watershed
Chester Creek Example
Stream Flow = -10.8 + 0.20*Precip + 0*Temp + 1.58*Population
Stream Flow Trend
Urban Land Use
Annual Stream Flow (inches)
Percent Urban Land Use
60
50
40
30
20
10
0
100
50
0
1930
1940
1950
1960
1970
1980
1990

Percent Change in Mean Annual Flow for Climate Change Scenarios



Summary

- Change to forested watershed hydrology will include:
  - Increased precipitation including more extreme events and less snow
  - Increased evapotranspiration due to more moisture, higher temperature, and longer growing season
  - Overall increased streamflow and more extreme flows resulting from greater groundwater and higher precipitation
  - Increased stream temperatures

- Water impacts on urbanizing watersheds will be more extreme but dominated by land use changes