Stakeholder-designed scenarios to investigate the effect of land use on water partitioning and high flows in New England

Andrew Guswa[1], Brian Hall[2], Chingwen Cheng[3], and Jonathan Thompson[2]

[1]Smith College
[2]Harvard University
[3]Arizona State University

November 24, 2022

Abstract

Decision makers and water managers throughout New England desire to understand how development and land-use change, especially under a changing climate, will affect high flows, flooding, and stormwater. We use the New England Landscape Futures (NELF) project to demonstrate the potential for translating participatory scenarios to simulations of land use and land cover and the resulting effects on streamflow. In addition to projecting recent trends, four other landscape scenarios were co-designed through a structured process that engaged over 150 stakeholders and scientists from throughout New England. Daily streamflows were simulated with the Soil and Water Assessment Tool (SWAT) to investigate how high flows vary among the scenarios for the less developed Cocheco River watershed in southeast New Hampshire and the more urbanized Charles River watershed in eastern Massachusetts. The hydrologic response of each land-use scenario was simulated for both historic weather (1999-2017) and downscaled weather for 2049-2067 from the CCSM 4.0-RCP 8.5 model-pathway from the Community Earth System Model. Differences among the land-use scenarios led to no differences in average annual water yield and ET. Loss of forest and increase in urban area reduces the baseflow contribution to streamflow while increasing storm runoff. This shift in partitioning did not affect the frequency of high flows (5% exceedence). The increase in runoff did lead to a concomitant increase in the average annual maximum flow, and the effect is larger in the Charles River watershed than in the Cocheco. Under the future climate, a combination of increased precipitation and decreased potential evaporation results in increased streamflow relative to the scenarios modeled with the historic weather. As a fraction of precipitation, surface runoff remains the same, and baseflow increases. The frequency of high flows increases, with the 5%-exceedence flow (under historical weather) being met or exceeded 8-9% of the days. Annual maximum flows also increased for the future climate, and the effects of land-use change and climate on annual maximum flows are comparable. These water-related results fit into a larger framework for evaluating ecosystem services associated with socially relevant landscape scenarios.

H21Q – 1955

Stakeholder-designed scenarios to investigate the effect of land use on water partitioning and high flows in New England

Andrew J. Guswa[1], Brian Hall[2], Chingwen Cheng[3], Jonathan Thompson[2]

[1]Picker Engineering Program, Smith College, aguswa@smith.edu; [2]Harvard Forest, Harvard University; [3]The Design School, Arizona State University

Summary

Decision makers and water managers throughout New England desire to understand how development and land-use change, especially under a changing climate, will affect high flows, flooding, and stormwater. We use the New England Landscape Futures (NELF) project to demonstrate the potential for translating participatory scenarios to simulations of land use and land cover and the resulting effects on streamflow. In addition to projecting recent trends, four other landscape scenarios were co-designed through a structured process that engaged over 200 stakeholders and scientists from throughout New England.

Daily streamflows were simulated with the Soil and Water Assessment Tool (SWAT) to investigate how high flows vary among the scenarios for the less developed Cocheco River watershed in southeast New Hampshire and the more urbanized Charles River watershed in eastern Massachusetts. The hydrologic response of each land-use scenario was simulated for both historic weather (1999-2017) and downscaled weather for 2049-2067 from the CCSM 4.0-RCP 8.5 model-pathway from the Community Earth System Model.

Differences among the land-use scenarios led to no differences in average annual water yield and ET. Loss of forest and increase in urban area reduces the baseflow contribution to streamflow while increasing storm runoff. This shift in partitioning did not affect the frequency of high flows (5% exceedance). The increase in runoff did lead to a concomitant increase in the average annual maximum flow, and the effect is larger in the Charles River watershed than in the Cocheco. Under the future climate, a combination of increased precipitation and decreased potential evaporation results in increased streamflow relative to the scenarios modeled with the historic weather. As a fraction of precipitation, surface runoff remains the same, and baseflow increases. The frequency of high flows increases, with the 5%-exceedance flow (under historical weather) being met or exceeded 8-9% of the days. Annual maximum flows also increased for the future climate, and the effects of land-use change and climate on annual maximum flows are comparable. These water-related results fit into a larger framework for evaluating ecosystem services associated with socially relevant landscape scenarios.

Approach

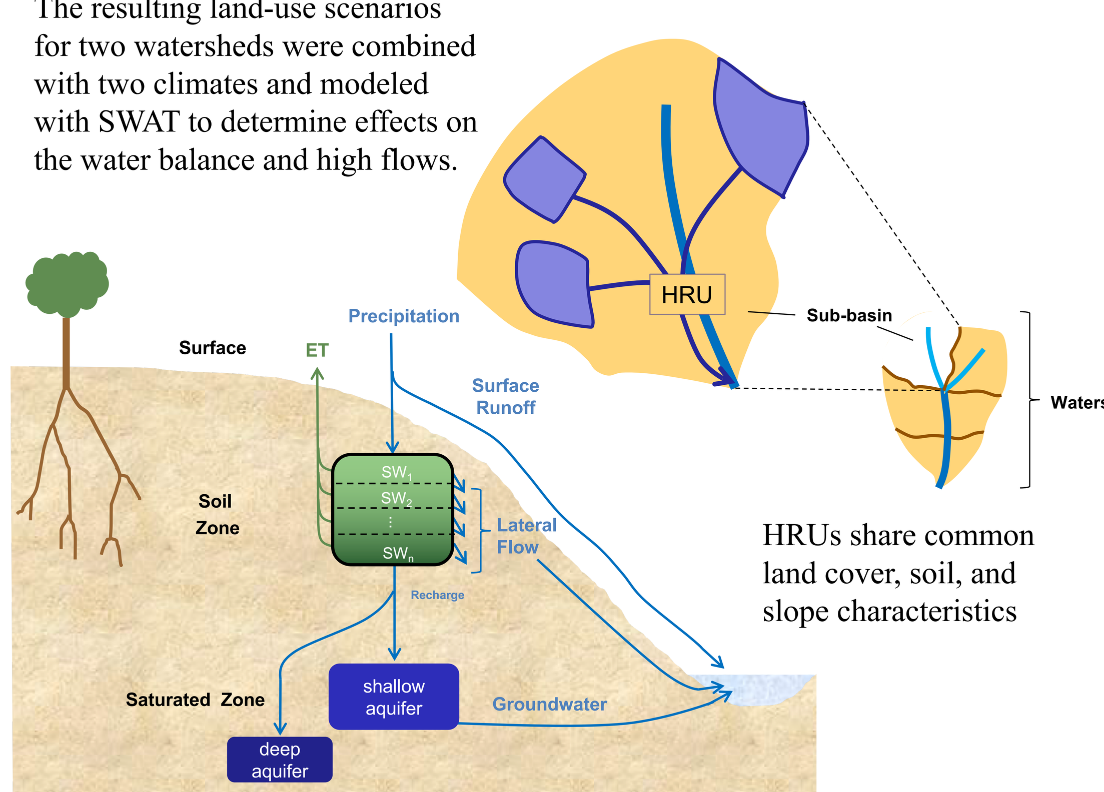
Over 200 stakeholders were engaged to envision the New England landscape in 2060 under two dominant drivers of change:

- Socio-economic connectedness (local to global)
- Natural resource innovation (low to high)

These drivers are combined to create 2x2 scenarios of future land use for New England.

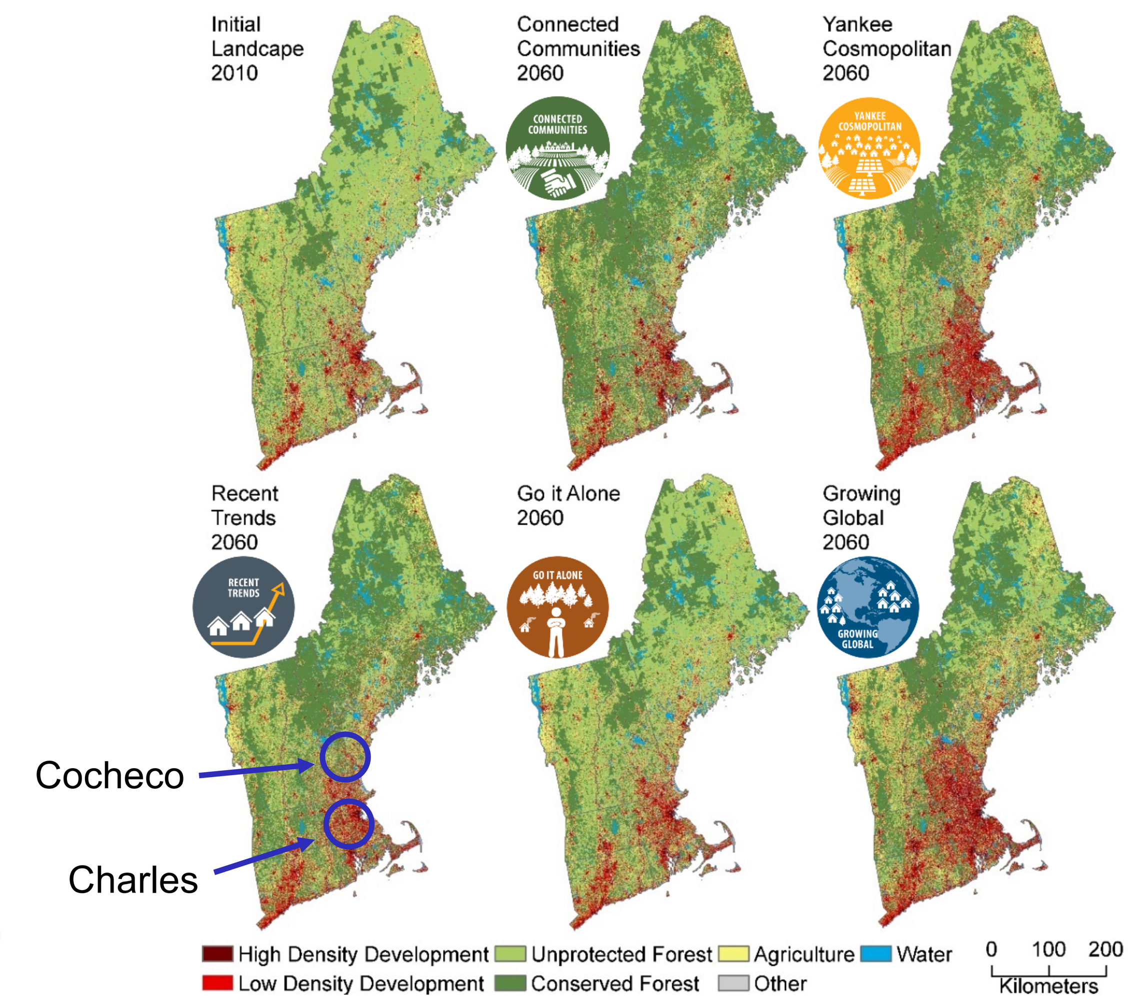
To learn more about this process and outcomes, please visit:
https://harvardforest.fas.harvard.edu/voices-land

The resulting land-use scenarios for two watersheds were combined with two climates and modeled with SWAT to determine effects on the water balance and high flows.

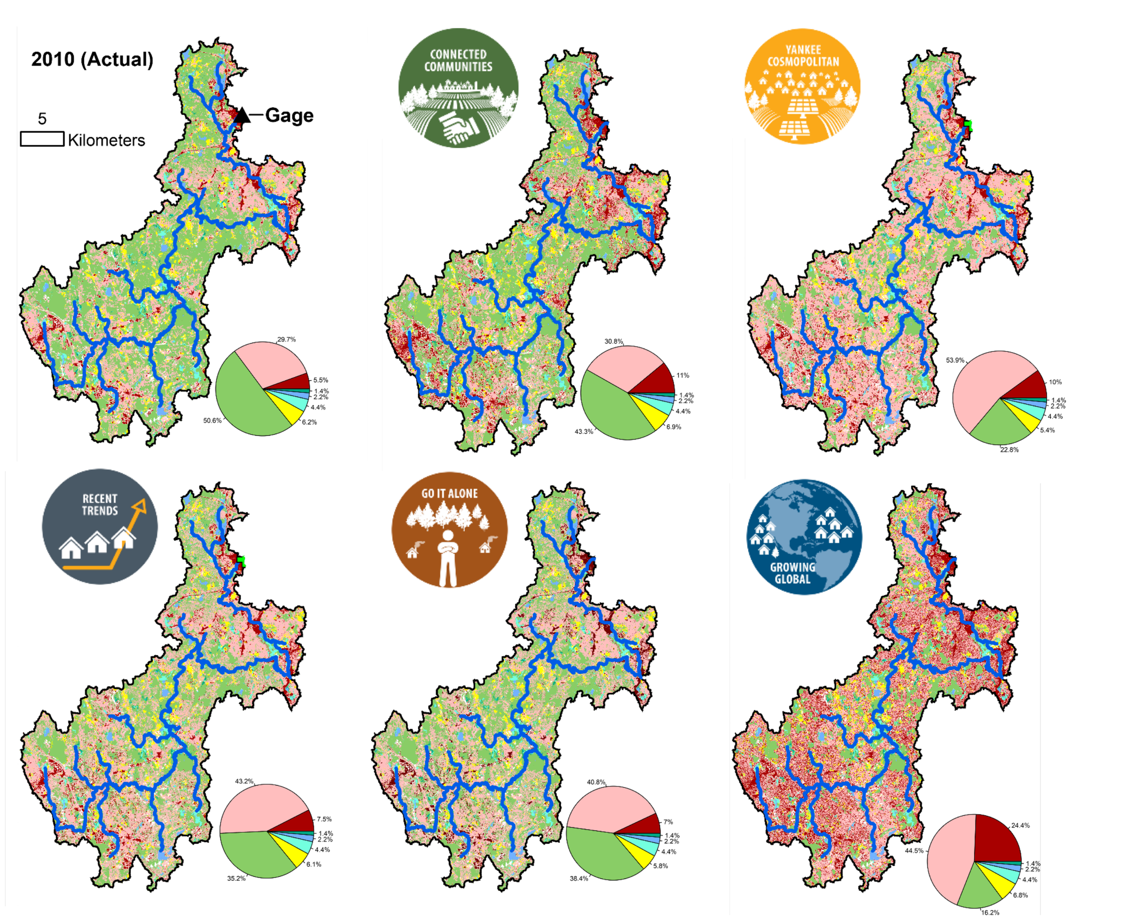


HRUs share common land cover, soil, and slope characteristics

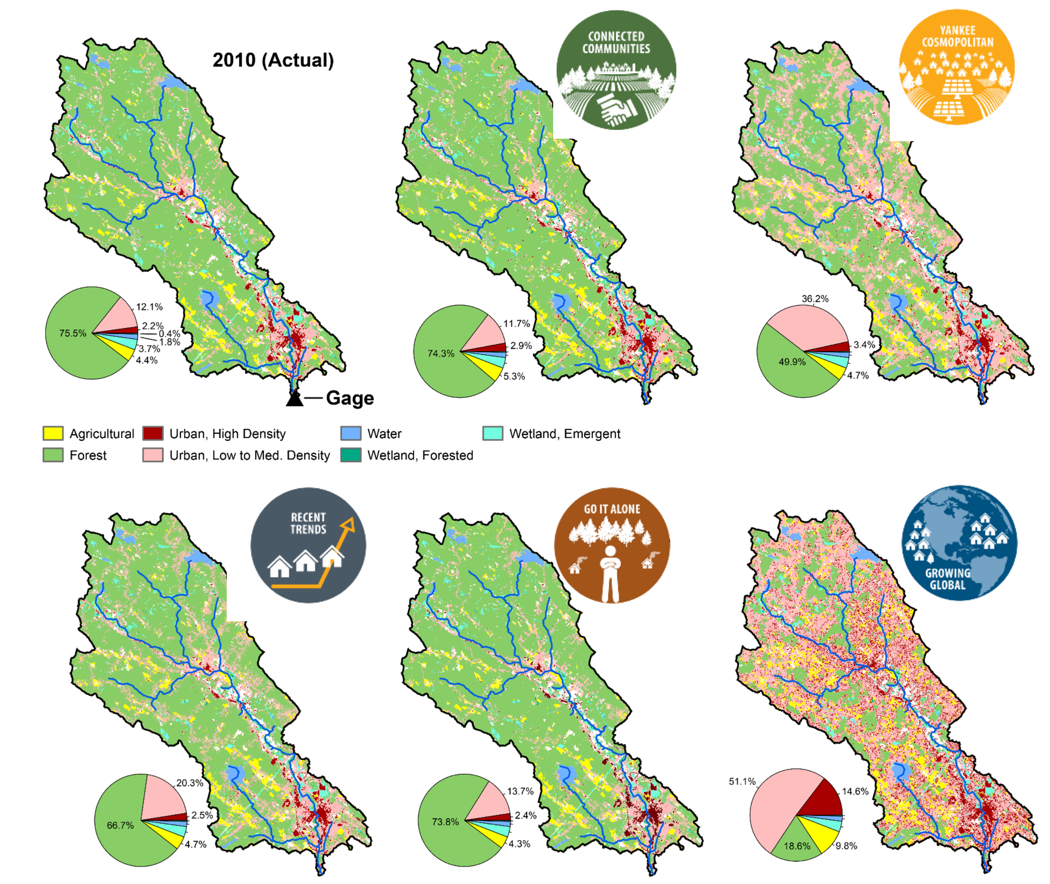
Scenarios – future land use and climate



Charles River Watershed, 648 km^2
Urban land varies from 35% to 69% of landscape

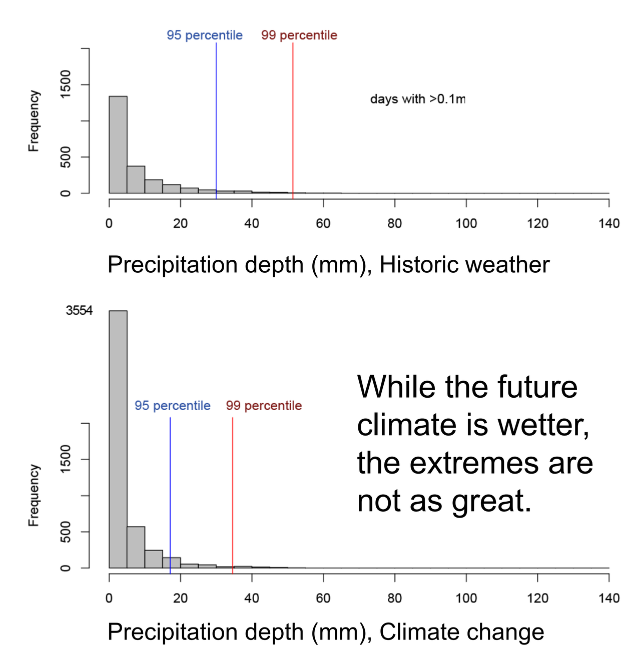


Cocheco River Watershed, 207 km^2
Urban land varies from 14% to 66% of landscape



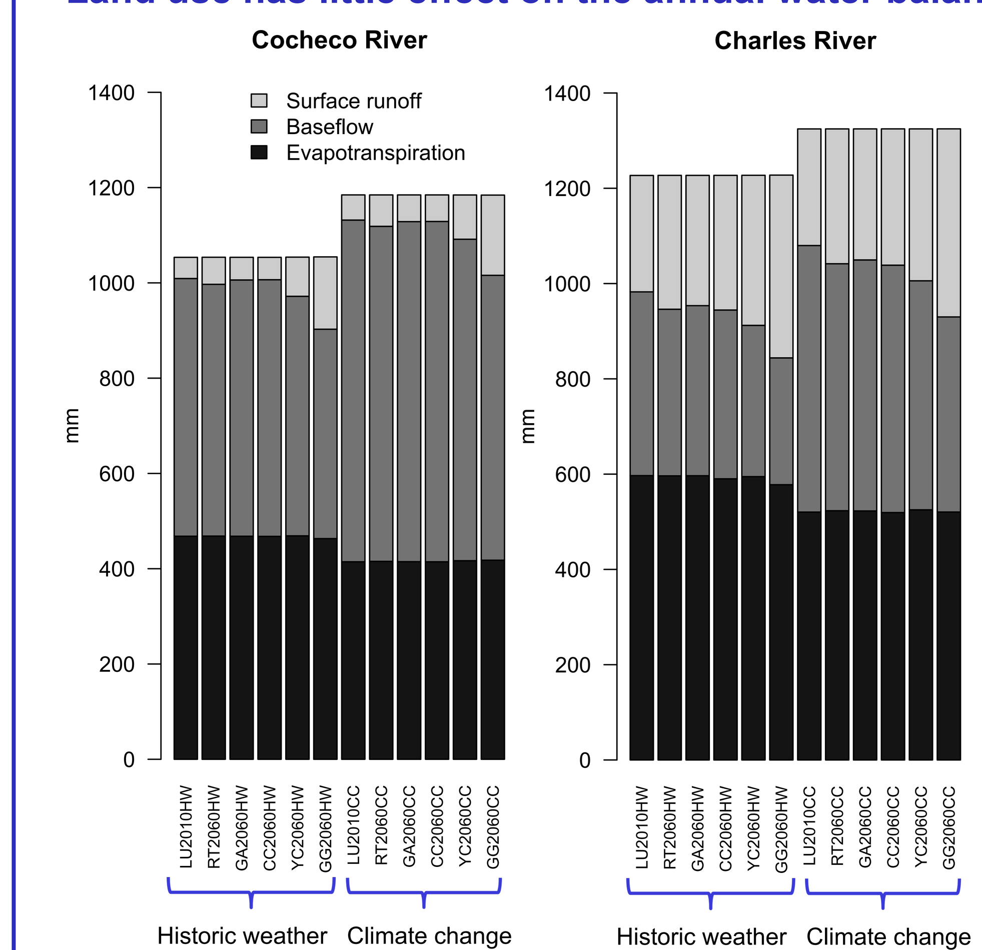
Relative to historic weather, the future climate is warmer, wetter, and cloudier, with more days with precipitation.

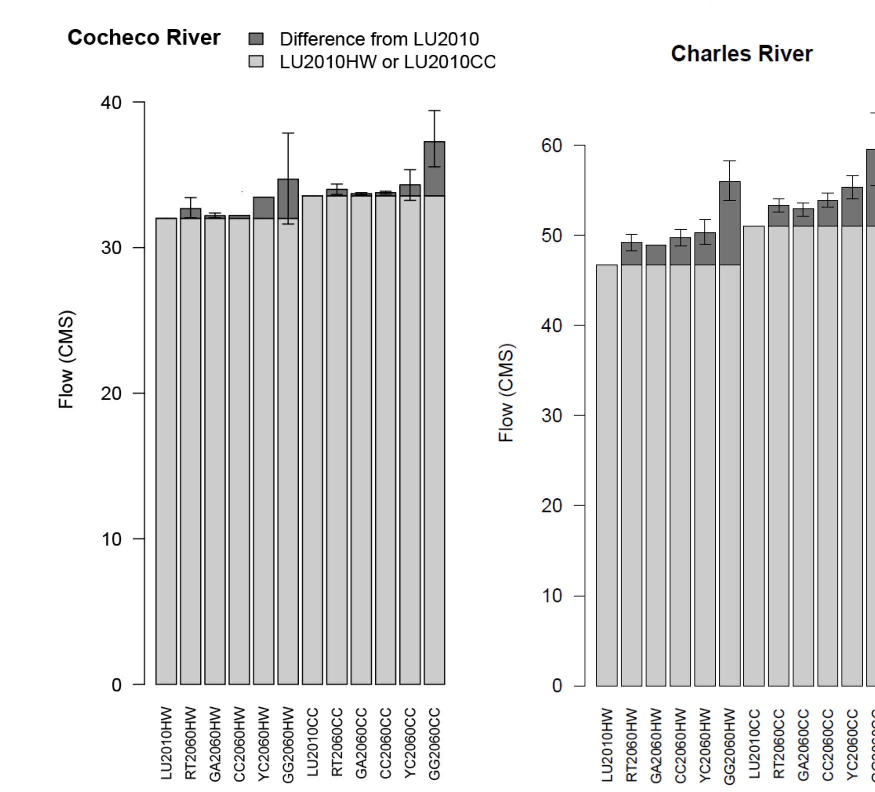
	Charles River Watershed		Cocheco River Watershed	
Annual Average	Historic Weather 2002-2017	Climate Change 2052-2067	Historic Weather 2002-2017	Climate Change 2052-2067
Precipitation (mm)	1237	1345	1059	1194
PET (mm)	971	673	822	554



Land use affects storm runoff and peak flows

Land use has little effect on the annual water balance.

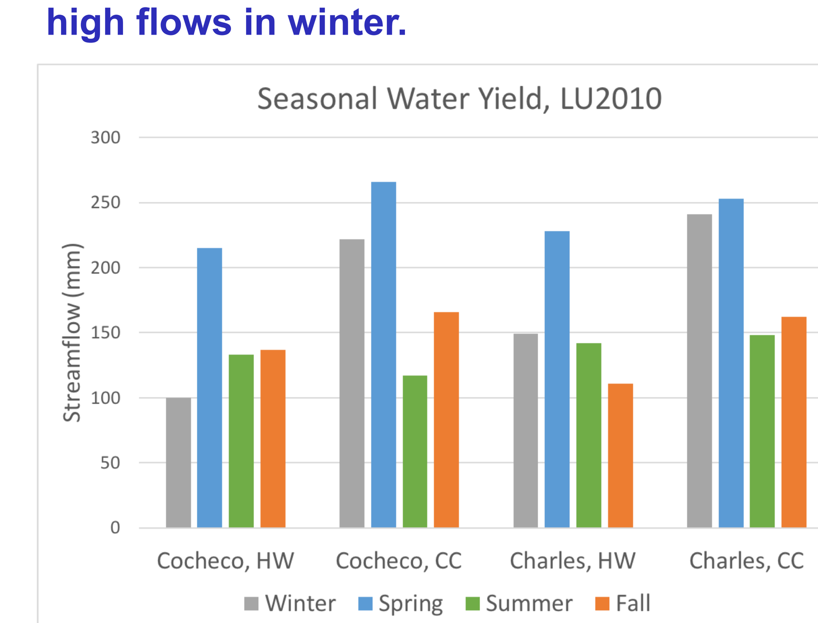


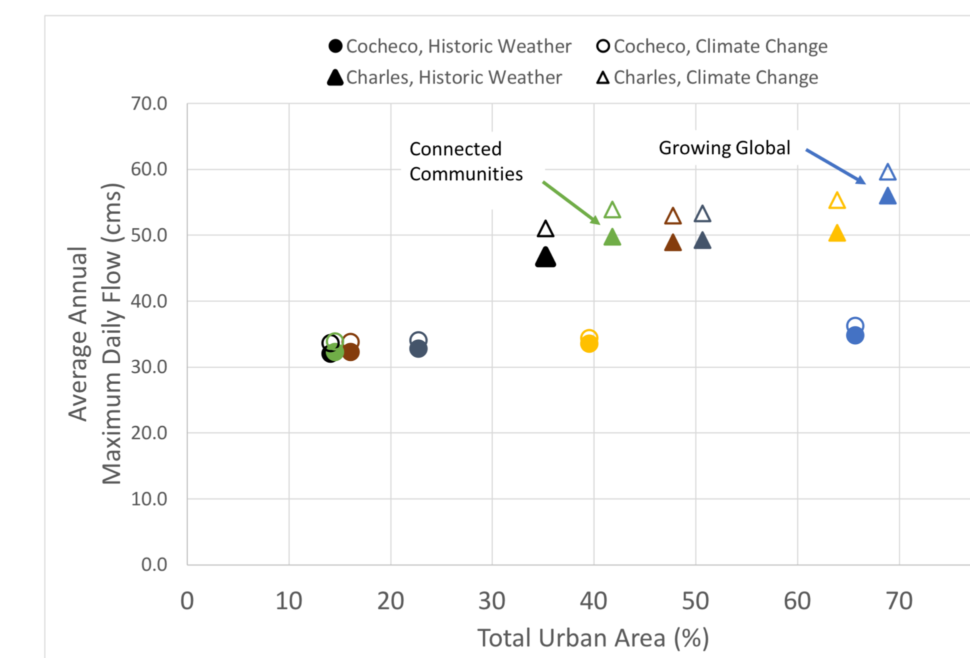


Peak flows increase with increasing urbanization.

The maximum effect is approximately 10% for the Cocheco and 20% for the Charles, nearly twice the effect due to climate change.

Climate change affects the water balance and seasonality, with more streamflow and high flows in winter.





The frequency and timing of the 5%-exceedance flow is affected more by climate than land use across the scenarios.