Characterizing hydrologic alterations following urbanization using gradient and long-term approaches

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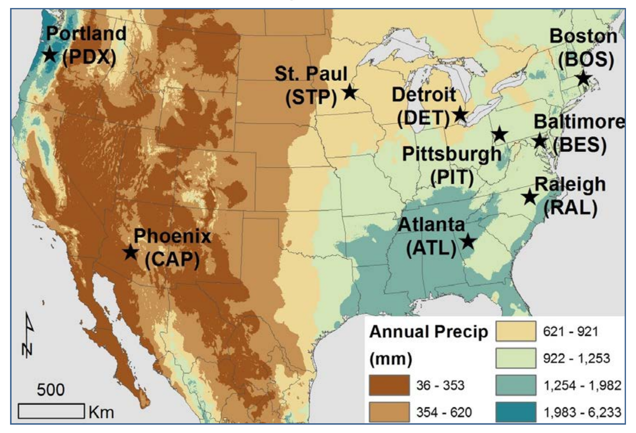
INTRODUCTION

- The urban stream syndrome is a conceptual model of the physical, chemical, and biological consequences of changes occurring in aquatic ecosystems.
- However, processes leading to stream impairment vary among cities due to differences in physical environment and urban development.
- Clarifying the linkages between development history and hydrologic changes will improve our ability to predict potential future impacts on stream systems.

Research Questions

1. Do urban gradient and long-term approaches provide consistent results?
2. Can physiographic factors explain variability in the hydrologic response among cities?
3. Are hydrologic changes gradual or abrupt during development?

Study Cities

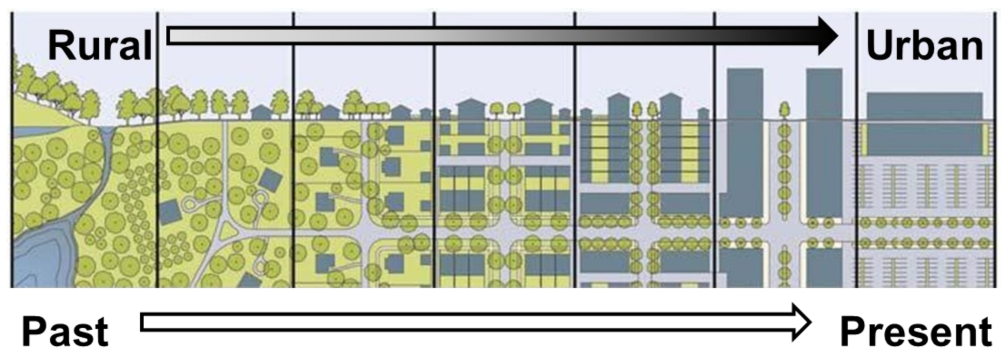


METHODS

Two Approaches

1. Long-Term Watershed Study
2. Urbanization Gradient Study

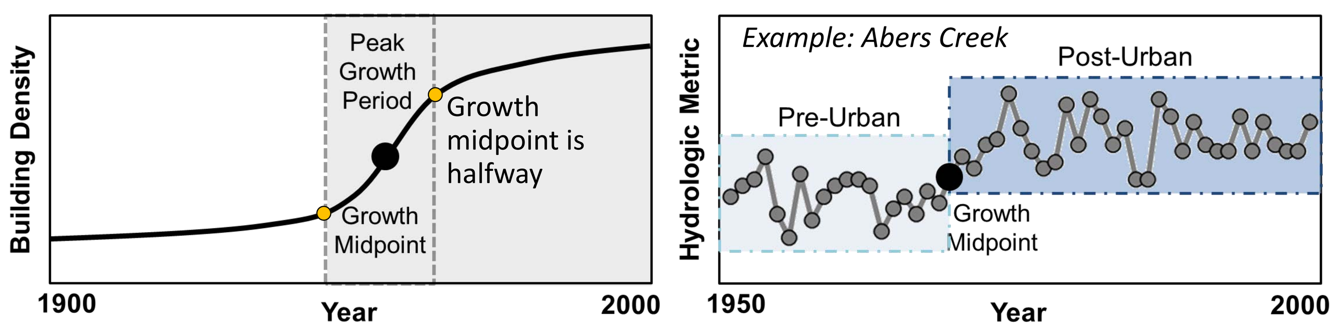
Urbanization Gradient Approach



Long-Term Watersheds

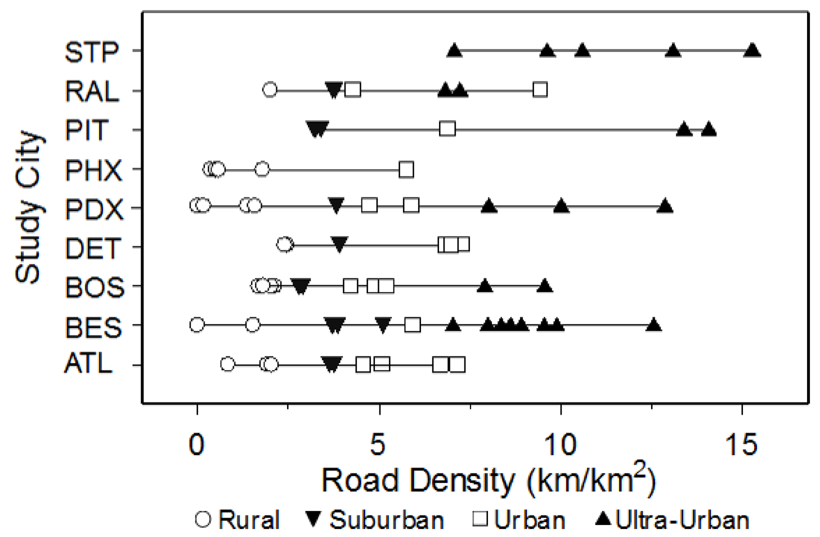
- Six watersheds in Baltimore, MD, Boston, MA, and Pittsburgh, PA.
- Parcel-level property tax assessment records were used to reconstruct development and identify pre– and post-urbanization periods.
- USGS stream flow records used to calculate annual hydrologic metrics.

Growth Midpoint Identified during Peak Growth Period



Urbanization Gradients

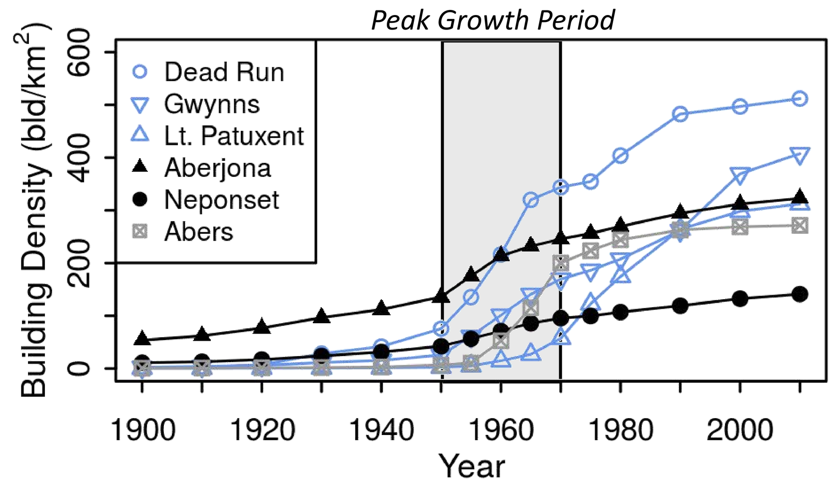
- Total of 76 watersheds in 9 cities.
- Road density used to classify watersheds.
- Hydrologic metrics were averaged annually over 2000 to 2012.



RESULTS

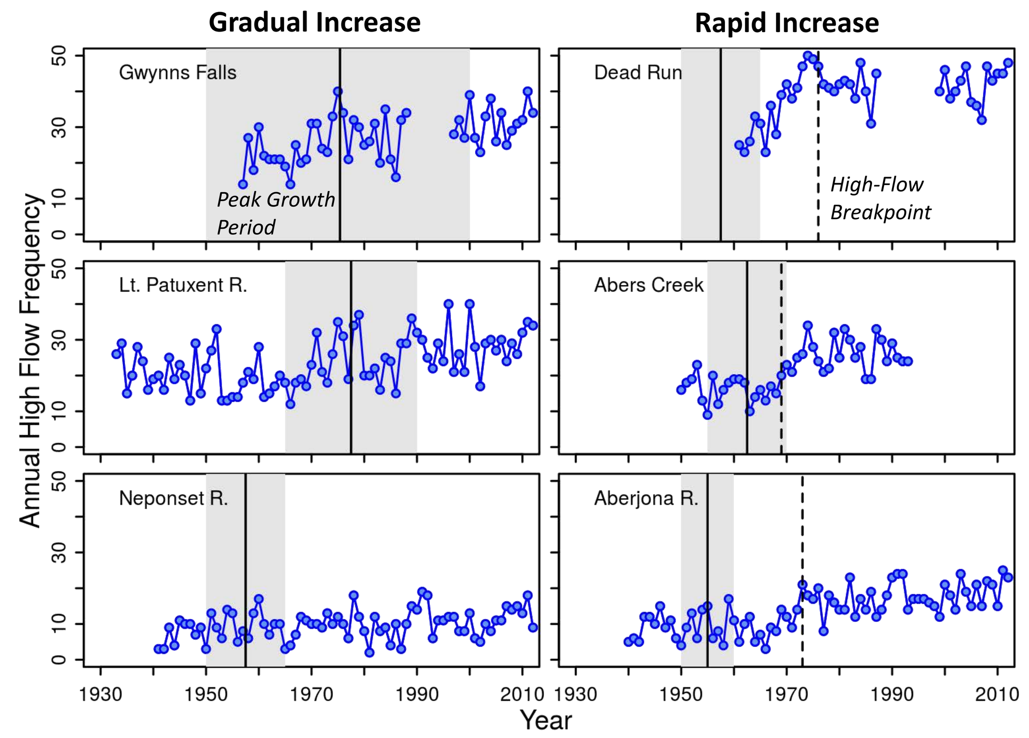
Watershed Development History

- Development was limited prior to 1950.
- Peak growth period typically occurred between 1950 and 1970.
- Growth plateaued after 1970.



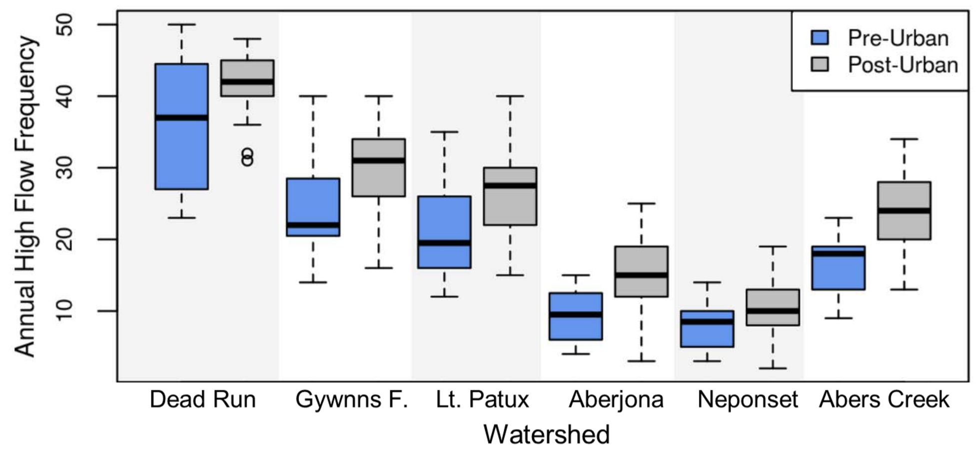
Long-Term Increases in High-Flow Event Frequency

- Significant increases in frequency of high-flow events.
- Gradual increases in Gwynns Falls, Little Patuxent River, and Neponset River.
- Step increase in Dead Run, Abers Creek, and Aberjona River between 1960 and 1975.
- High-flow frequency breakpoints occurred in Abers Creek (1969), Aberjona River (1973), and Dead Run (1976).



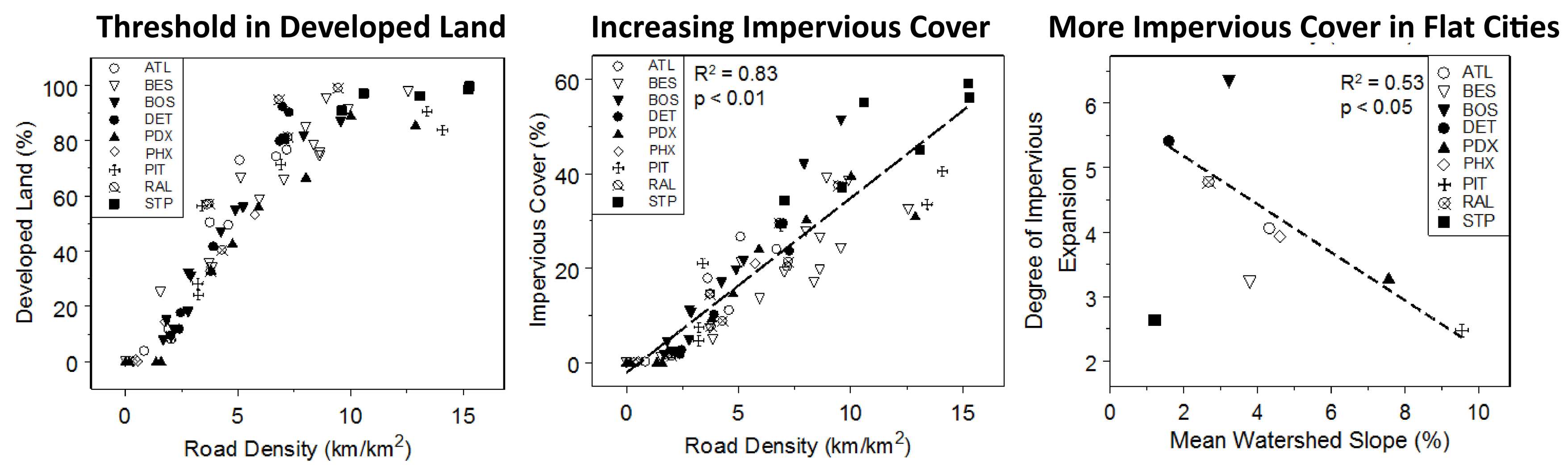
Long-Term Shifts in High-flow Frequency

- Significant differences in pre– and post-developments periods in all the study watersheds except Dead Run.
- Abers Creek had the largest high-flow frequency shift, from a mean of 16 high-flow events per year to a mean of 24 events per year.



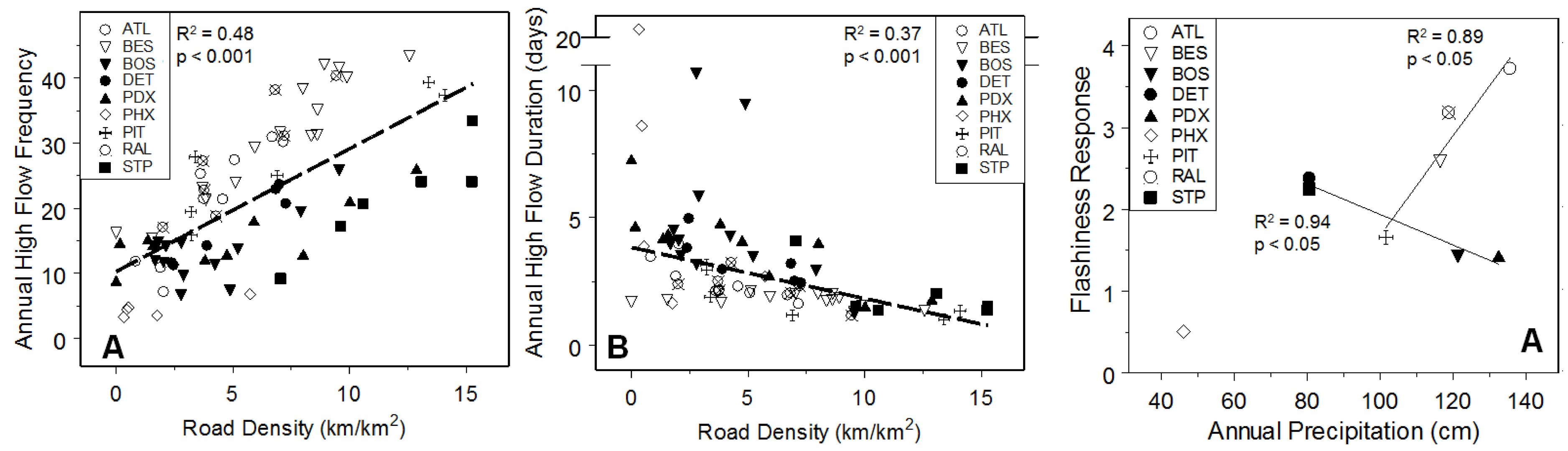
Space for Time Urbanization Gradients

- Similar amounts of developed land, impervious surfaces, and sewer service among the nine urbanization gradients.
- Mean watershed slope had the strongest relationship with the degree of impervious expansion.



Urban Gradient Increases in High-Flow Events

- High-flow frequency and road density were positively related among all watersheds except Phoenix.
- High-flow duration was variable at low-moderate levels of development, but converged to an average of 1.5 days.
- Two divergent relationships between flashiness response and precipitation among the cities.



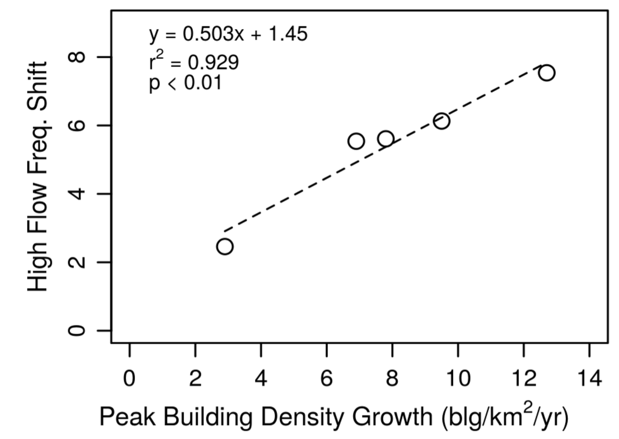
DISCUSSION

Physiography Shapes Our Cities

- Physiographic features can be important mediators of the intensity of urbanization and hydrologic alterations.
- Landscapes with flatter topography are easier to develop.
- Landscapes with lakes and wetlands have high water storage capacity.
- Natural features can provide some hydrologic buffering which dampens hydrologic response.

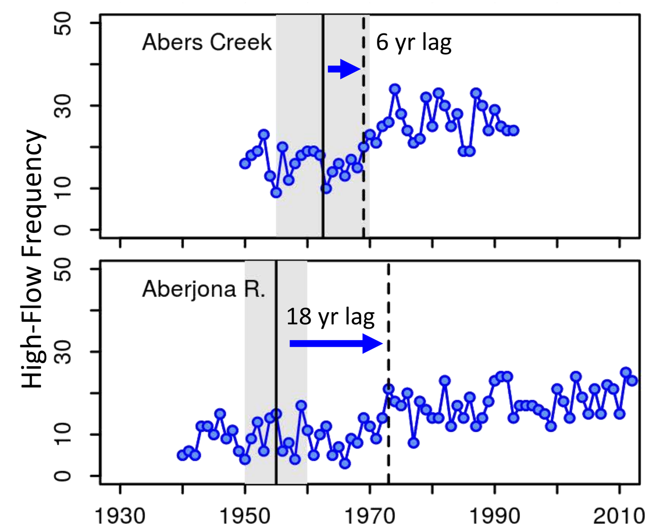
Peak Growth Period and Flow Shifts

- The peak growth period had strong influence on high-flow-frequency changes.
- More growth, larger changes in high-flow events.



Timing of Flow Changes

- High-flow lags were observed in the watershed with the highest building density in each city.
- The shortness of the response lag in Abers Creek was likely linked to the timing and intensity of development.
- Highway and commercial development after the peak growth period were closely associated with the hydrologic changes in Aberjona River.



Long-term verses Gradient Studies

- Long-term results indicated rapid urbanization can lead to large, non-linear shifts in the flow regime.
- Long-term approach suggested urbanization trajectory has a strong influence on the magnitude and timing of hydrologic changes.
- Urbanization gradient approach indicated gradual, linear hydrologic change.

CONCLUSIONS

1. Refining hypotheses from the urban stream syndrome concept to incorporate heterogeneity in hydrologic changes and temporal lags in flow response will improve our ability assess and identify mechanisms driving declines in urban aquatic ecosystem.
2. The relationship between physiography and hydrology response reflects differences in lithography among cities which influences aspects of glacial history, storage capacity, development intensity, and infrastructure.
3. Clarifying the linkages between development history and hydrologic changes will improve our ability to predict potential future impacts on stream systems as urban areas continue to expand.

Acknowledgements

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