Empirical Trends in Hydrologic Response to Rain Events

in Urbanizing Watersheds

Toronto Region of the Great Lakes Basin, Canada

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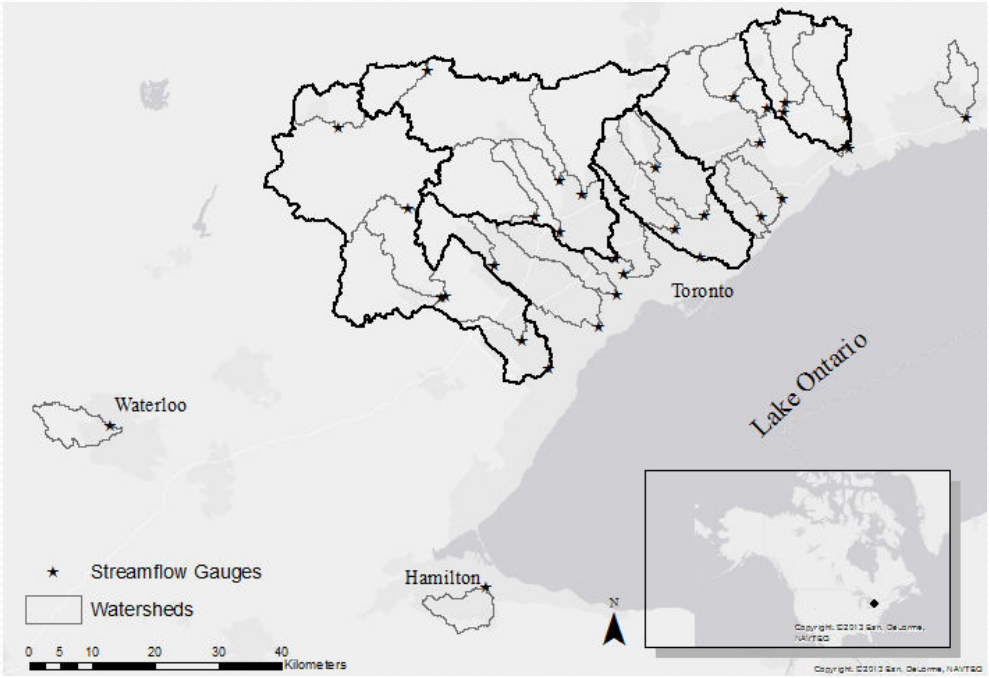
Presentation Overview

- Research location, data, question
- Results: total runoff, event characteristics
- Conclusions and implications

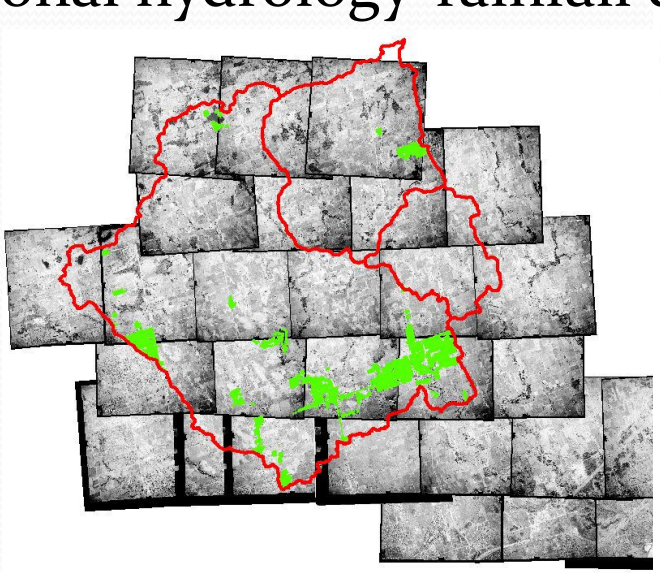
Research location and dataset



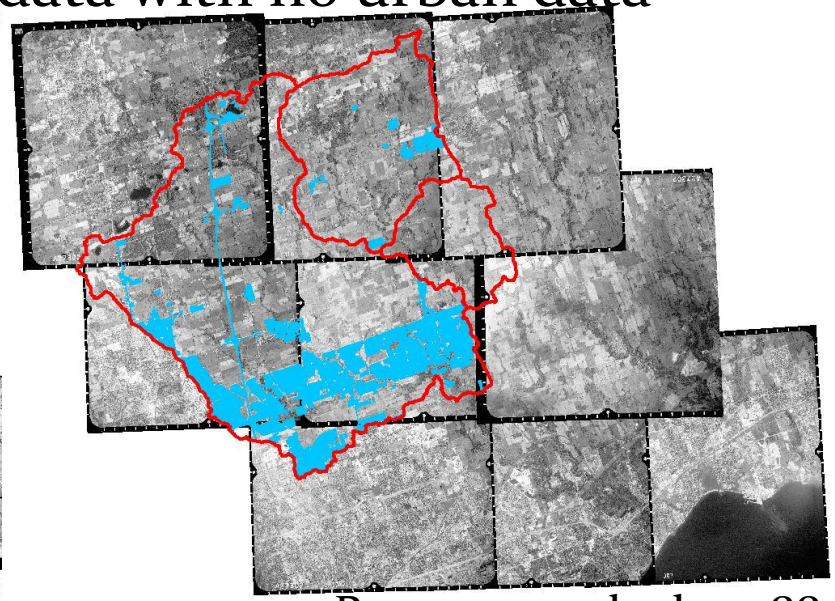
- Canadian Great Lakes Basin
- Toronto region
- 27 watersheds
- 11 river systems
- Hydrologic data: 15-minutes
- Rain data: 1 hour, but patchy
- 1969 to 2010
- May 26 to November 15
- 93 observations
- Urban: drained by engineered urban systems

Urban Land Use

- Watershed sizes: 37.5 km² to 806 km²
- Urban land cover < 0.1% to 87%
- Additional hydrology-rainfall data with no urban data

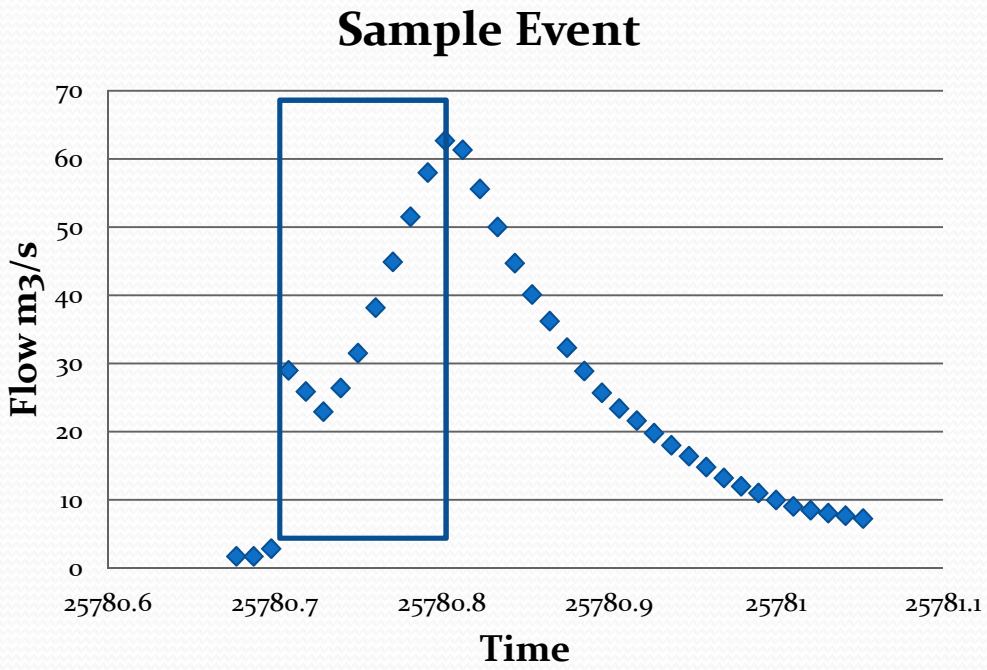


Rouge watersheds, 1974



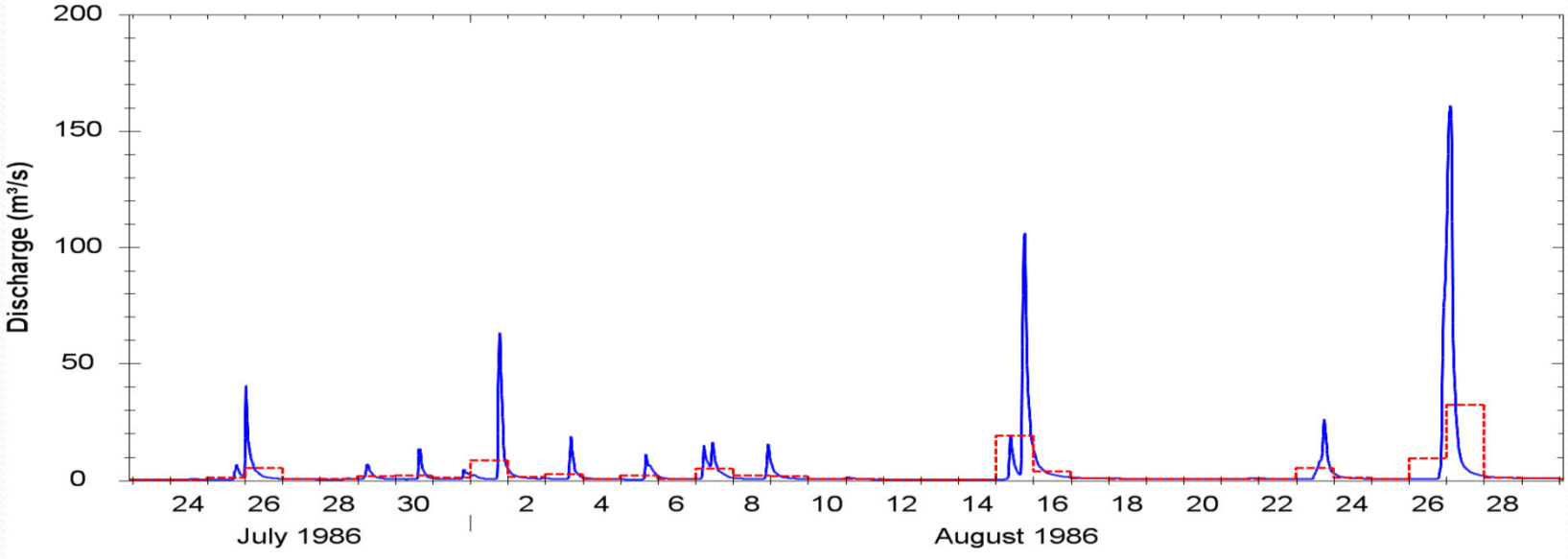
Rouge watersheds, 1988

Research Questions



- Flow regime changes associated with urban land use?
  - Event rising limb
  - Aquatic community stress
  - Total runoff (mm/season)
  - Event flow (m^3/s)
  - Event acceleration (m^3/s^2)
- Urban threshold effects?
- Watershed scale effects?

Benefits of Higher Resolution Flows



Comparison of daily flow records (red) with 15 minute flow record (blue)
Source: Peter J. Thompson, *Event Based Characterization of Hydrologic Change in Urbanizing Southern Ontario Watersheds via High Resolution Stream Gauge Data*, Masters Thesis, April 2013, Figure 3.3

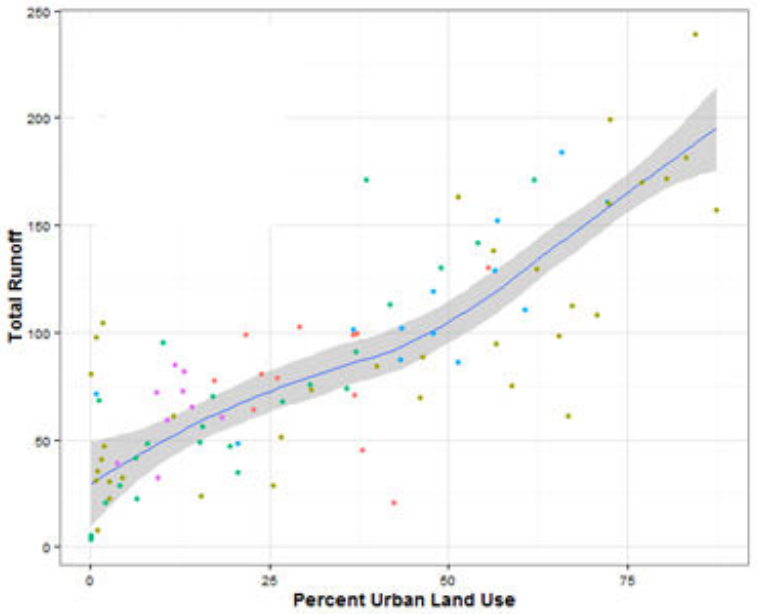
Results: Rainfall

- No statistical trends in rainfall during study period
- Trends assessed for:
  - Total rainfall
  - Frequency of rain events
  - Maximum intensity (1 hour)
  - Total hours with rain
  - Rain event depth per event

Trends identified occurred prior to detectable changes in climate

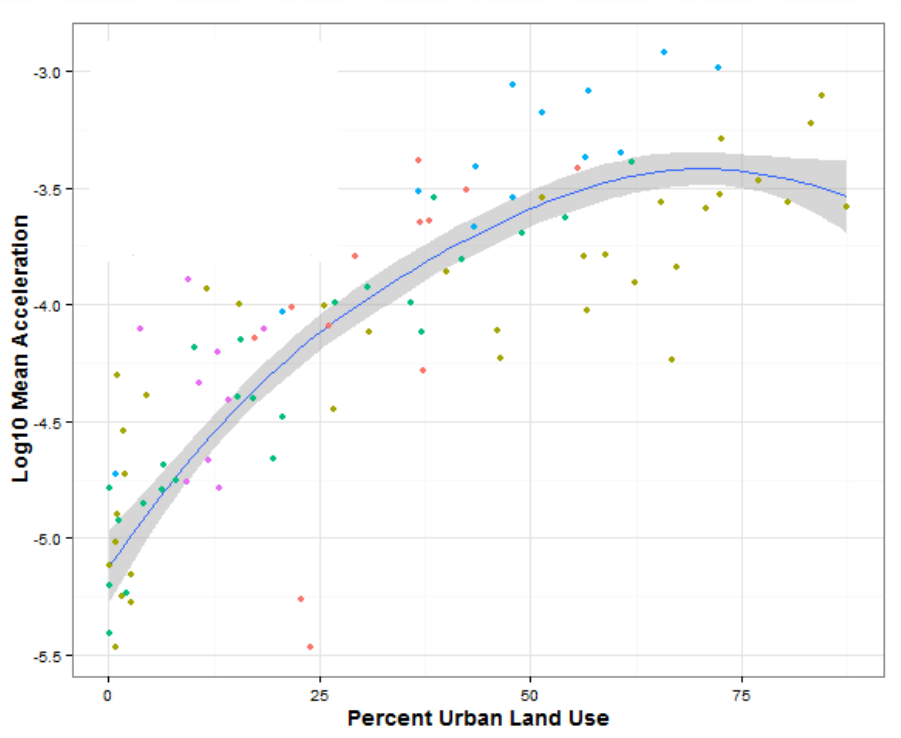
Results: Total Runoff (mm per season)

- Runoff highly influenced by urban land use; model terms include square of urban percent, plus 2 positive interaction effects with watershed size and rain
- Temporal study:
  - Don (311 km²) and Humber (806km²)
  - 1969 and 2010 (42 years)
  - 45% increase in total runoff

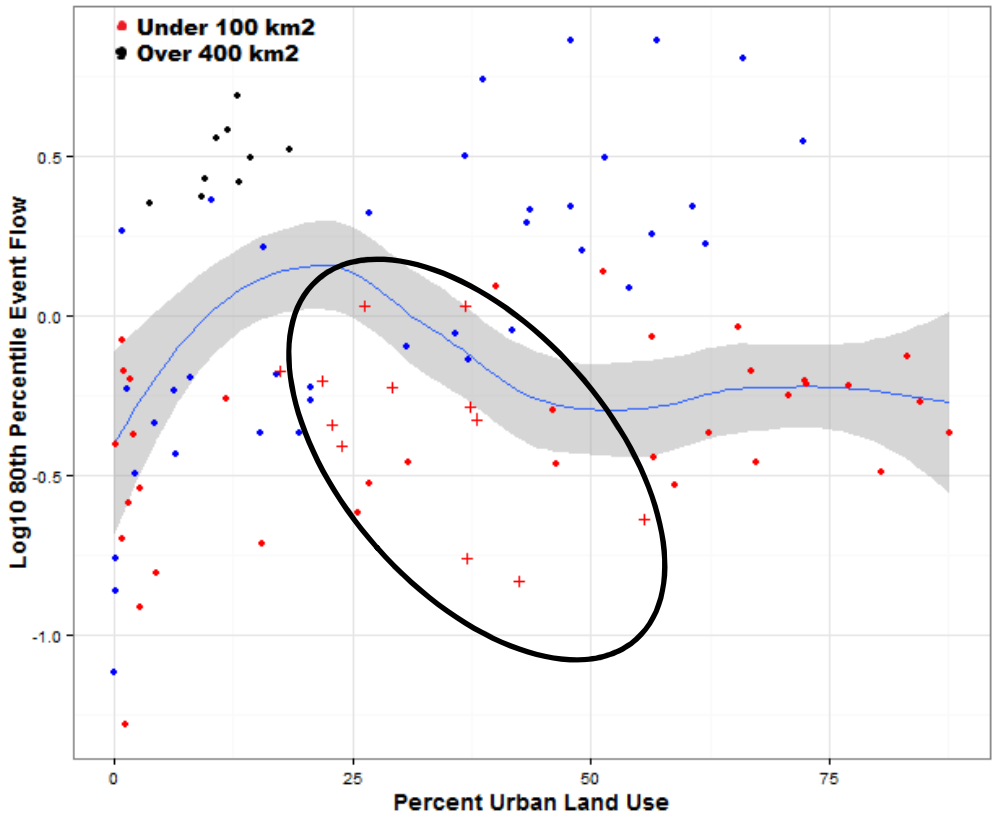


Results: Event Flow Acceleration (m^3s^{-2})

- Acceleration: increase from one 15-minute interval to the next; observations > 0
- Initial rate of increase higher; up to ~50% urban cover

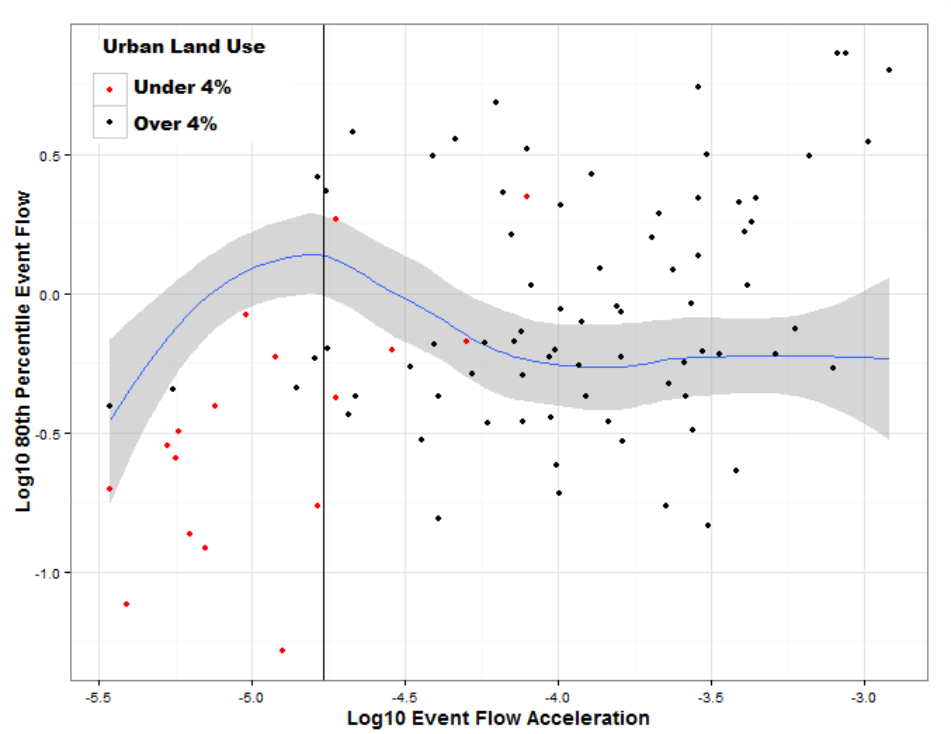


Results: Event Flow



- 80th percentile rising limb flows
- Model not adequate for full story
- Very small watersheds (less than 60km^2) negative trend; available urban cover 17-56%
- Event flow response of watersheds <100km^2 stable versus larger areas (range?)

Results: Event Flow vs Acceleration



- For urban cover <~4%, acceleration and event flows positively correlated
- Otherwise, acceleration increases with no increase in 80th percentile event flows
- Separate test: urban cover effect begins ~4% in watersheds with low baseflow

Conclusions and Implications

- Very low rates urban cover initiate hydrologic change
  - Mitigation requires a watershed-scale approach (e.g. riparian zone not sufficient)
- Event flows of small watersheds stable in available range of urban cover; watershed storage capacity is 'dried out'
  - Larger watersheds? Data gaps
  - Research warranted for water budgets in the Great Lakes Basin
- Cumulative urban effects
  - Land development, flood risk, infrastructure design, habitat protection
- Loss of hydrologic stability due to urbanization
  - Climate changes and urban infrastructure resilience
- Theoretical support for maximization of total and event flows

Questions

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