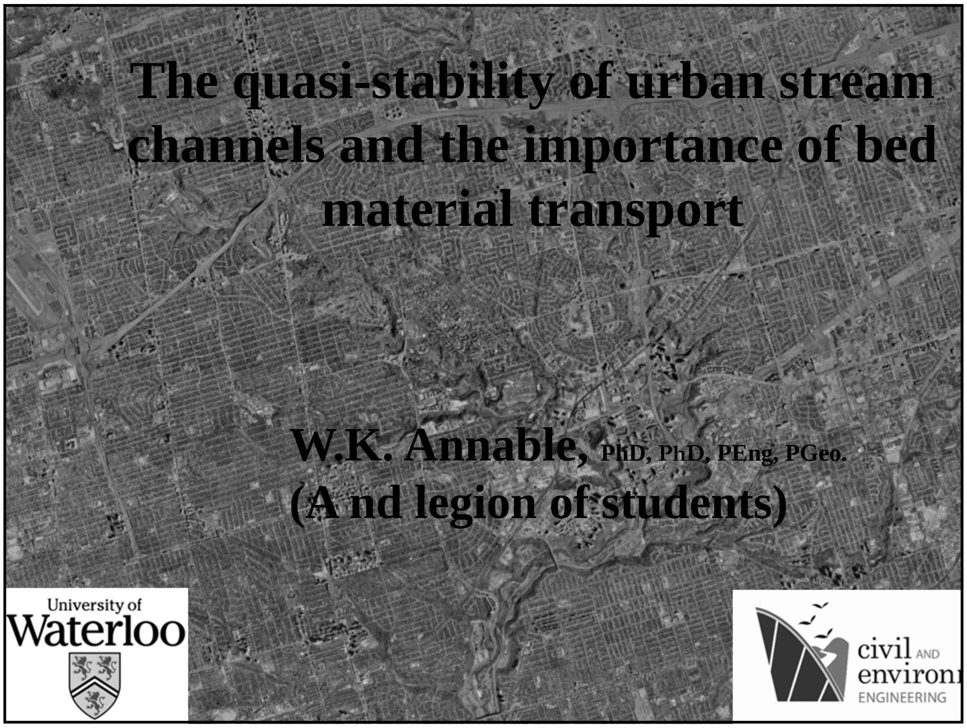
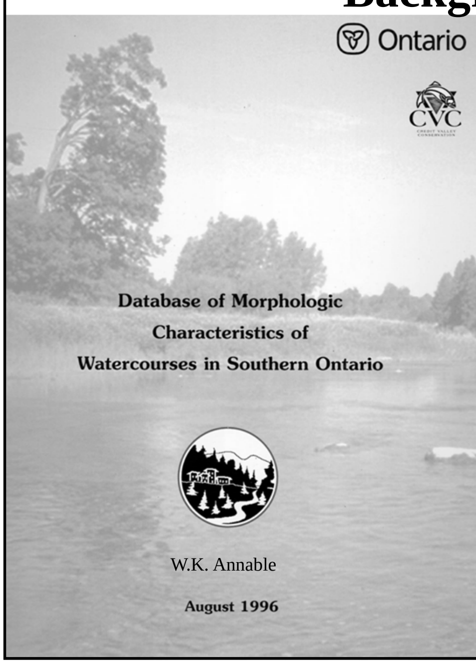


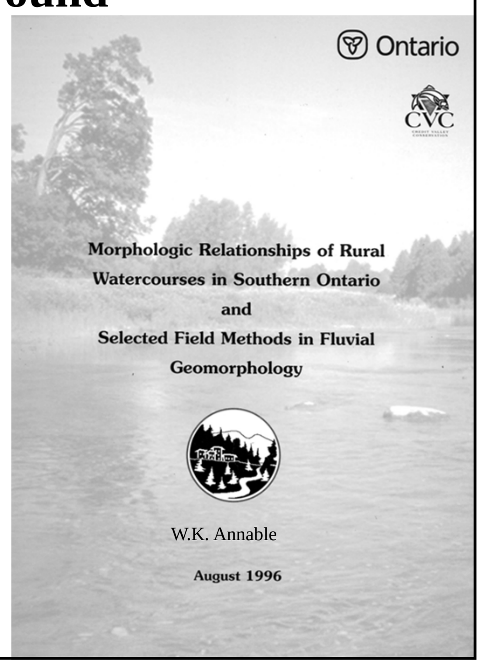
The quasi-stability of urban stream channels and the importance of bed material transport

W.K. Annable, PhD, PhD, PEng, PGeo.
(A nd legion of students)

University of Waterloo
civil AND environ... ENGINEERING

Background





If we are going to design a restoration / rehabilitation project in urban watersheds, what is the quasi-stable condition?

What are the metrics?

What is important?

What are the interdependencies?

Can we apply relationships used in rural / wildland watersheds inter-changeably in urban systems?

RIVER RESEARCH AND APPLICATIONS

River Res. Applic. **27**: 738–753 (2011)

Published online 11 May 2010 in Wiley Online Library
(wileyonlinelibrary.com) DOI: 10.1002/rra.1391

ESTIMATING CHANNEL-FORMING DISCHARGE IN URBAN WATERCOURSES

W. K. ANNABLE,[a,b*] V. G. LOUNDER[a] and C. C. WATSON[b]

[a] *Department of Civil and Environmental Engineering, University of Waterloo, Waterloo, Ontario N2L 3G1, Canada*
[b] *Department of Civil and Environmental Engineering, Colorado State University, Fort Collins, Colorado 80523-1372, USA*

RIVER RESEARCH AND APPLICATIONS

River Res. Applic. **28**: 302–325 (2012)

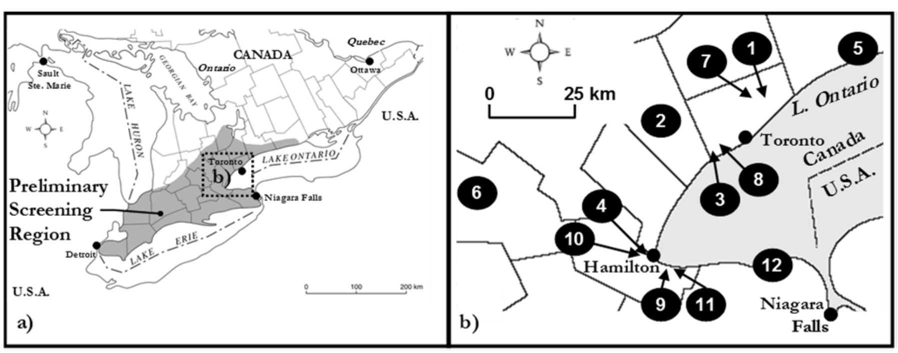
Published online 26 September 2010 in Wiley Online Library
(wileyonlinelibrary.com) DOI: 10.1002/rra.1457

QUASI-EQUILIBRIUM CONDITIONS OF URBAN GRAVEL-BED STREAM CHANNELS IN SOUTHERN ONTARIO, CANADA

W. K. ANNABLE,[a,b*] C. C. WATSON[b] and P. J. THOMPSON[a]

[a] *Department of Civil and Environmental Engineering, University of Waterloo, Waterloo, Ontario, Canada*
[b] *Department of Civil and Environmental Engineering, Colorado State University, Fort Collins, Colorado, USA*

Site Locations



*** Approximately a population of 7,800,000 of the greater Toronto and surrounding areas**

- 168 river reaches were screened associated with gauge stations,

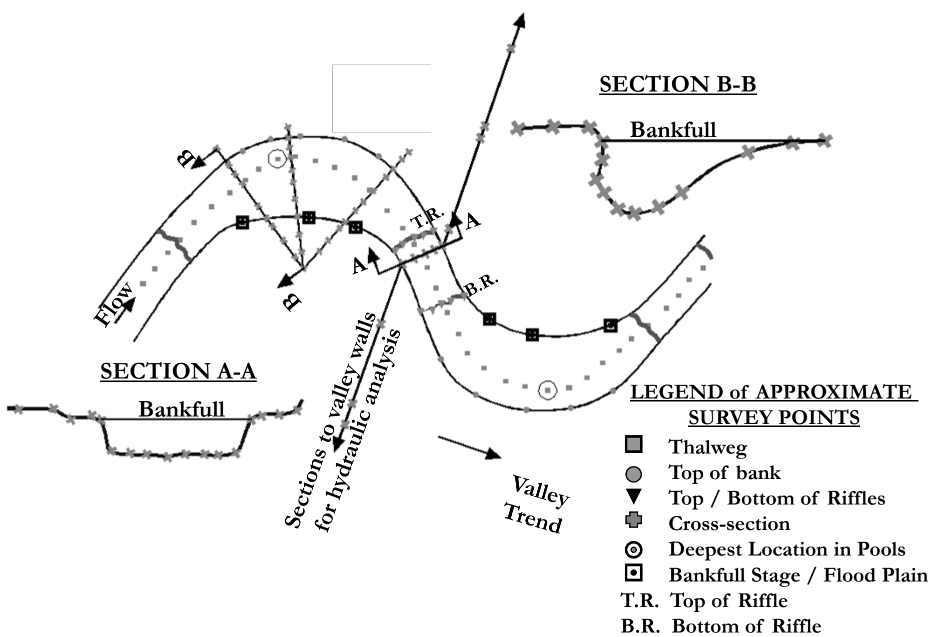
- Culling resulted in 12 quasi-stable urban stream channel reaches that were studied

Urban watershed summary characteristics

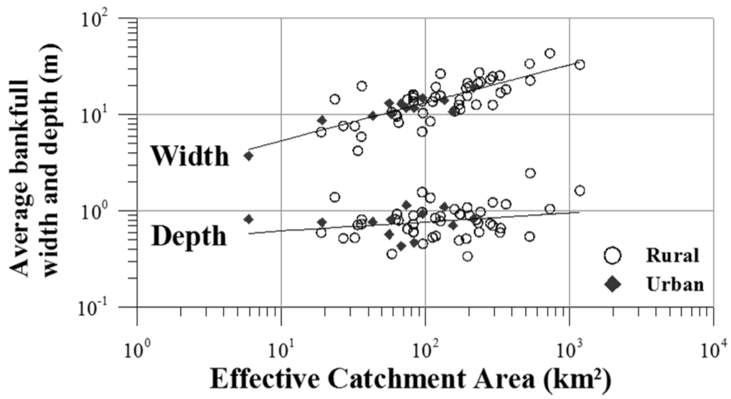
Site Reference No.	Gauge†	Station Name	Effective Catchment Area (km^2)	Urban land use (%)	Channel Morphology	Cross-section Relief	Adjacent Land Use
1	02HC005	Don River at York Mills	95.5	72	Riffle-pool	Semi-confined	Golf course
2	02HC017	Etobicoke Creek at Brampton	67.7	24	Riffle-pool	Floodplain dominated	Park
3	02HC030	Etobicoke Creek below QEW	215.4	62	Riffle-pool	Floodplain dominated	Park
4	02HB012	Grindstone Creek near Aldershot	83.9	13	Riffle-pool	Floodplain dominated	Park
5	02HD013	Harmony Creek at Oshawa	43.0	44	Riffle-pool	Floodplain dominated	Golf course
6	02GA024	Laurel Creek at Waterloo	57.5	34	Riffle-pool	Floodplain dominated	Park
7	02HC029	Little Don River at Don Mills	135.1	70	Riffle-pool	Floodplain dominated	Park
8	02HC033	Mimico Creek at Islington	73.8	87	Riffle-pool	Floodplain dominated	Park
9	02HA014	Redhill Creek at Hamilton	56.3	66	Riffle-pool	Floodplain dominated	Park
10	02HB007	Spencer Creek at Dundas	156.0	9	Run-pool	Semi-confined	Urban
11	02HA022	Stoney Creek at Stoney Creek	19.2	15	Riffle-pool	Floodplain dominated	Park
12	02HA027	Walker Creek at St. Catherines	5.9	99	Riffle-pool	Floodplain dominated	Park

Note: † Environment Canada Operated Gauge Stations and associated site designations

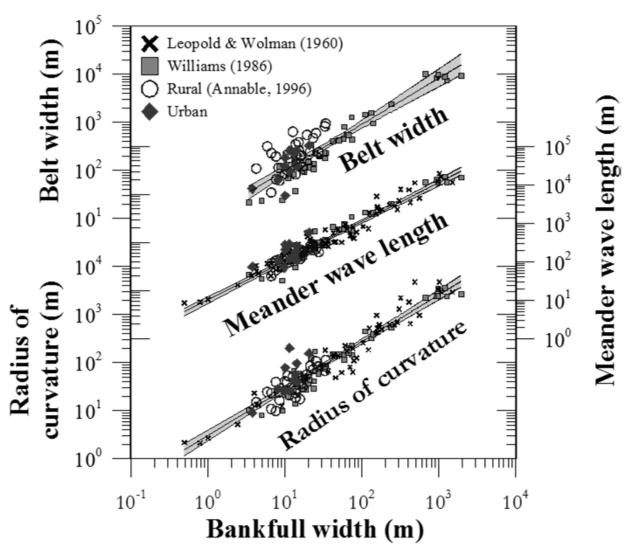
River Survey Detail



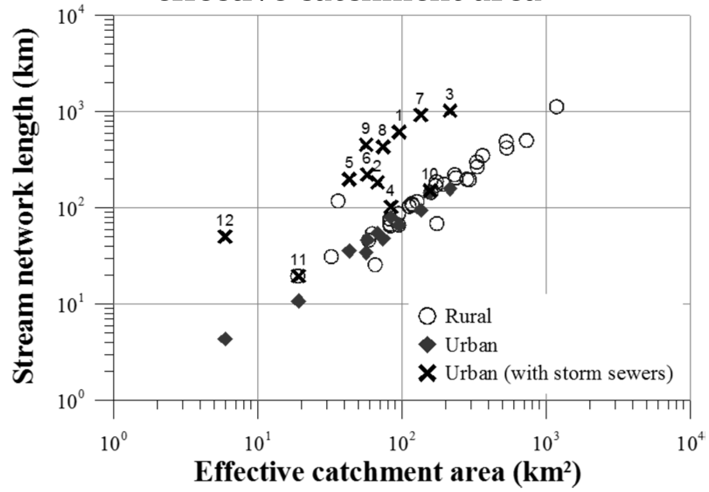
Average bankfull width and depth versus effective catchment area



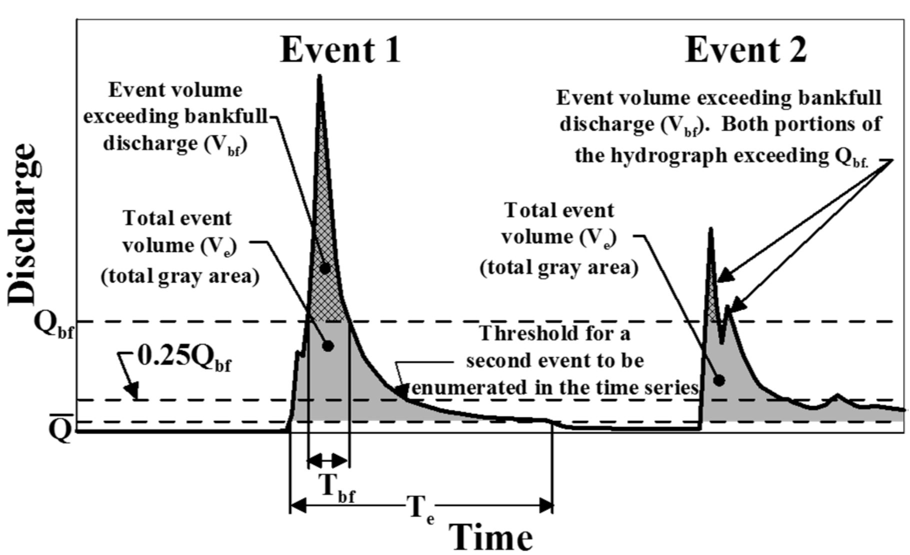
Meander Geometry Relationships



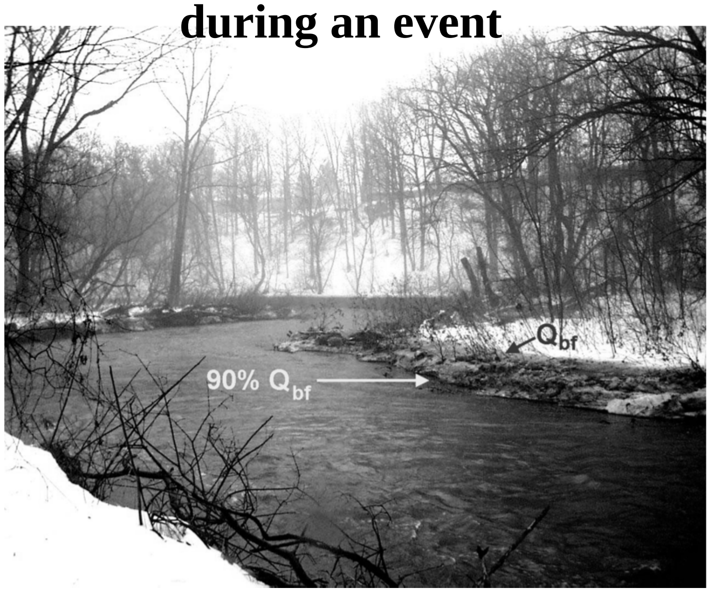
Stream (and storm sewer) channel length versus effective catchment area

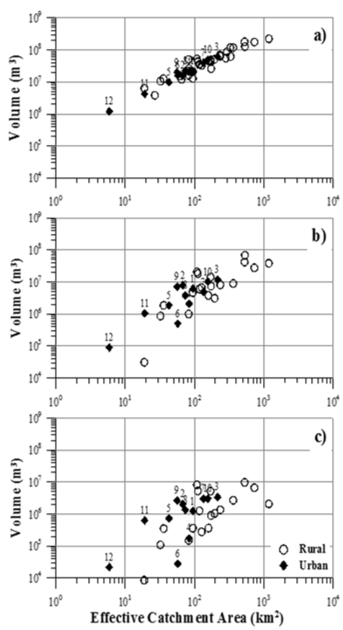


Event Definition



The most reliable way to estimate bankfull discharge is to observe the flow during an event



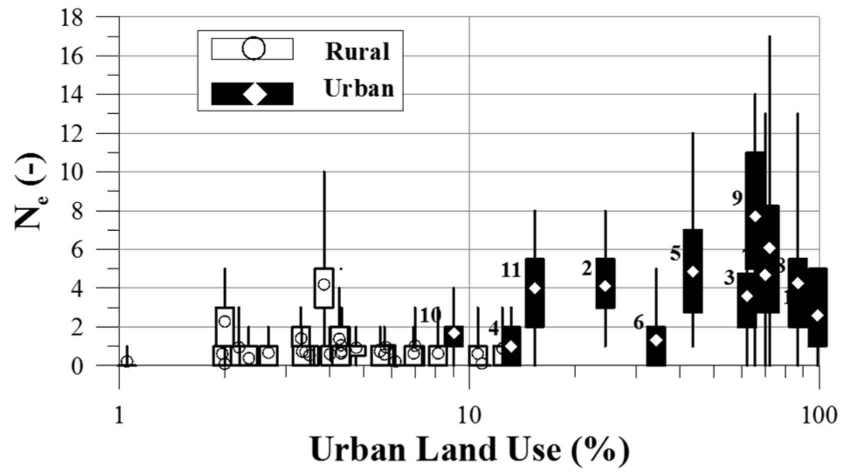


Annual flow volume

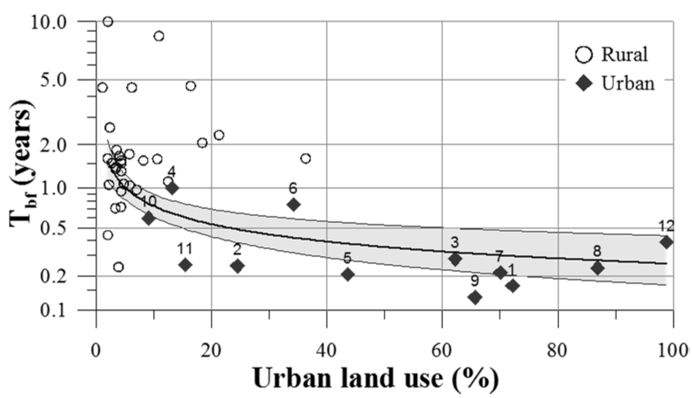
Cumulative volume of events where bankfull is exceeded

Cumulative volume of flow exceeding bankfull discharge

Median annual frequency of bankfull discharge (or greater)



Bankfull return period versus watershed urban land use



This is not a new concept

Guidelines For Determining

Flood Flow Frequency

Bulletin # 17B
of the
Hydrology Subcommittee

Revised September 1981
Editorial Corrections March 1982

INTERAGENCY ADVISORY COMMITTEE
ON WATER DATA

U.S. Department of the Interior
Geological Survey
Office of Water Data Coordination
Reston, Virginia 22092

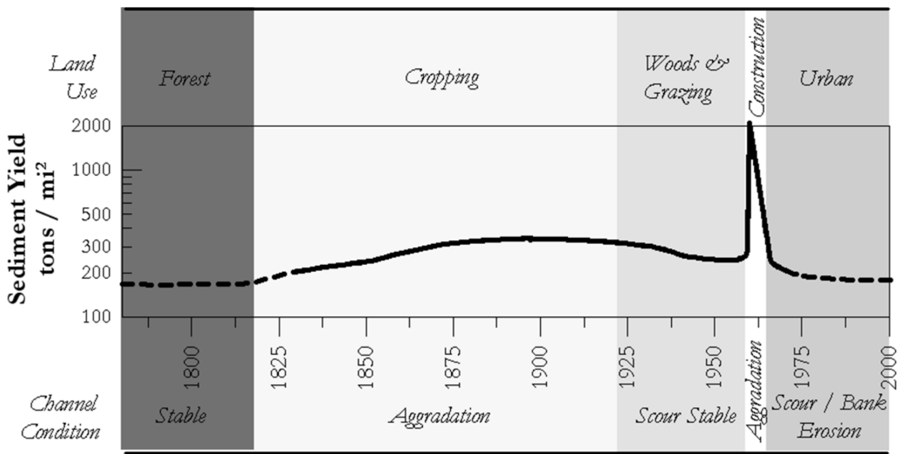
"Watershed history and flood records should be carefully examined to assure that no major watershed changes have occurred during the period of record…….

Special effort should be made to identify those records which are not homogeneous. Only records which represent relatively constant watershed conditions should be used for frequency analysis."

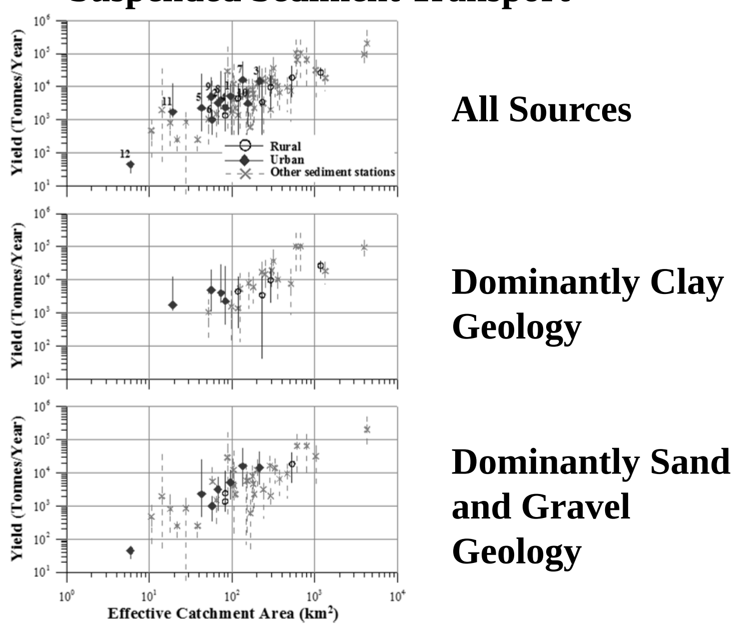
The danger in assuming the 1.5-year return period.

- **Bankfull discharge may be significantly lower,**
- **If the 1.5 year return is used, one has essentially designed an incised channel,**
- **Anticipate potentially rapid rates of channel change,**

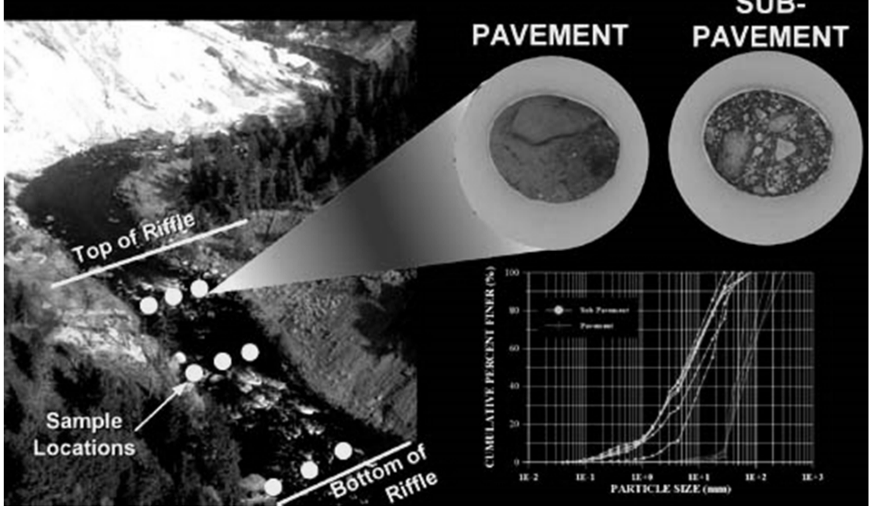
A cycle of sedimentation and erosion in urban river channels (Wolman, 1967)



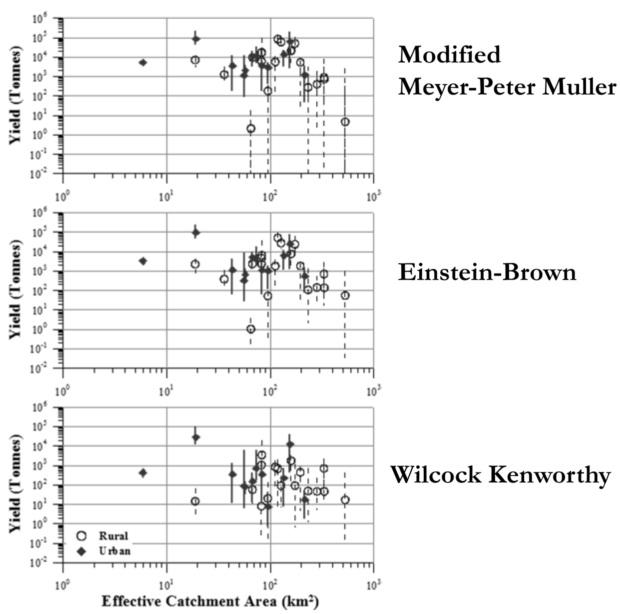
Suspended Sediment Transport



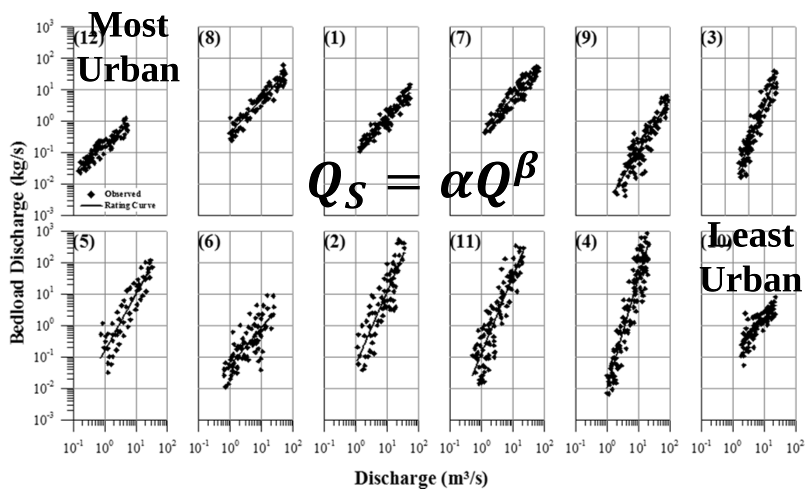
PAVEMENT AND SUB-PAVEMENT SAMPLING

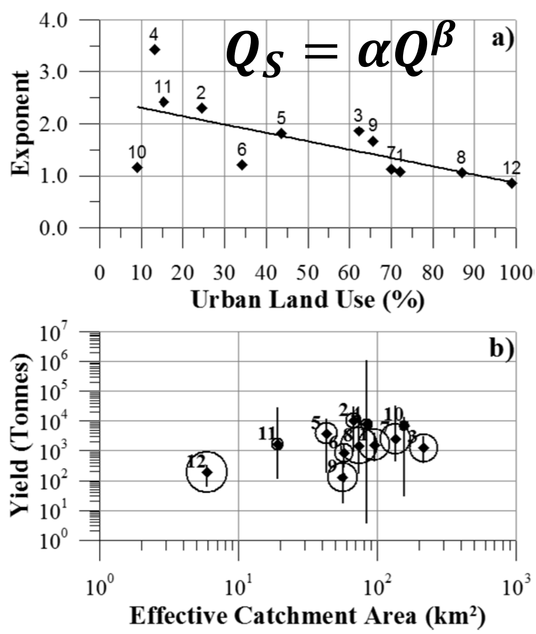


Bedload Transport Capacity

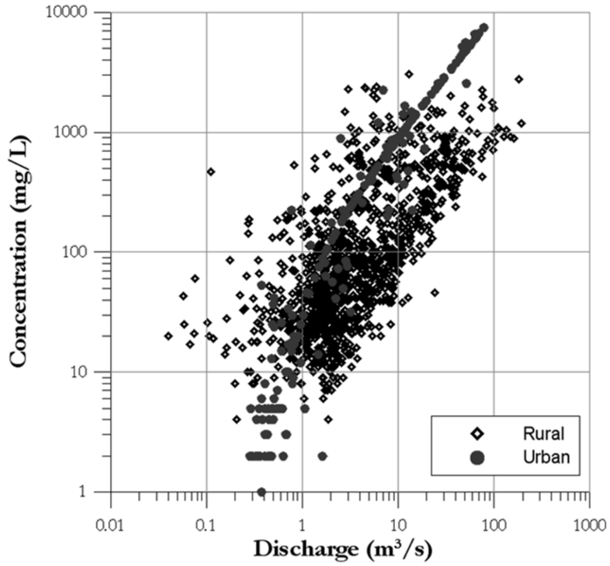


Bedload Rating Curves of 12 Urban Streams in southern Ontario, Canada

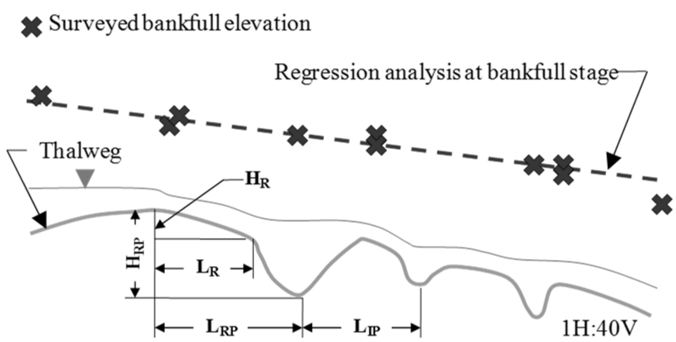




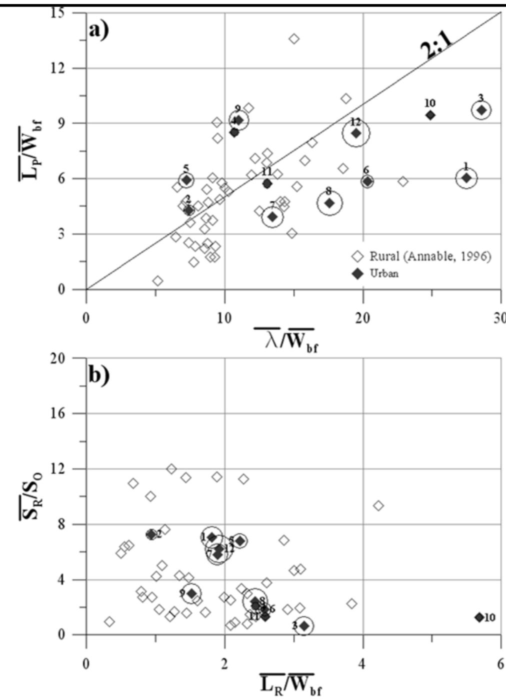
Comparison of rural and urban suspended sediment rating curves



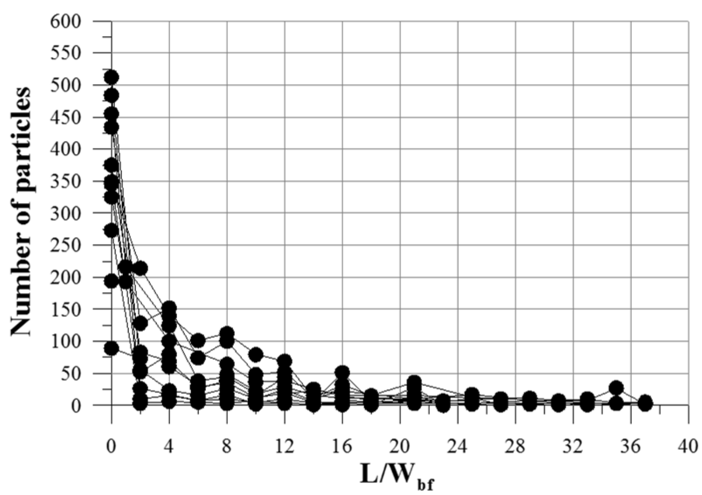
Longitudinal Profile Detailing



Riffle and pool characteristics



Clast Tracking



Change in Morphology frequency

-Elongated meander wave lengths

- Typically two or three riffles on a straight section between bends separated by intermediate pools.

Potential causes

-Sediment pulsing

- bedform manifestations to dissipate additional stream energy

Continuing Investigation

- Morphological Surveys (Form)
  - Longitudinal profiles
  - Cross sections
  - Diagnostic bed sampling
- Sediment Tracking / Sampling (Process)
  - Bedload measurements (Helley-Smith)
  - Inter-event-based particle tracking (RF-ID transponders)
- Longitudinal inventories
  - Floodplain relief
  - Bank heights
  - Riparian vegetation
  - Water surface characteristics (flood flow)
  - Infrastructure

Upper Left: RF-ID Tag
Right: Morphological Surveys using GPS
Lower Left: Helley-Smith Sampler

Schumm, 1979 – River Metomorphisim

Increase in discharge

$$Q_W^+ \approx \frac{W^+ D^+ \lambda^+}{S^-}$$

Change in Hydrology

Change in sediment supply

$$Q_S^+ \approx \frac{W^+ \lambda^+ S^+}{D^- \Omega^-} \quad and \quad Q_S^- \approx \frac{W^- \lambda^- S^-}{D^+ \Omega^+}$$

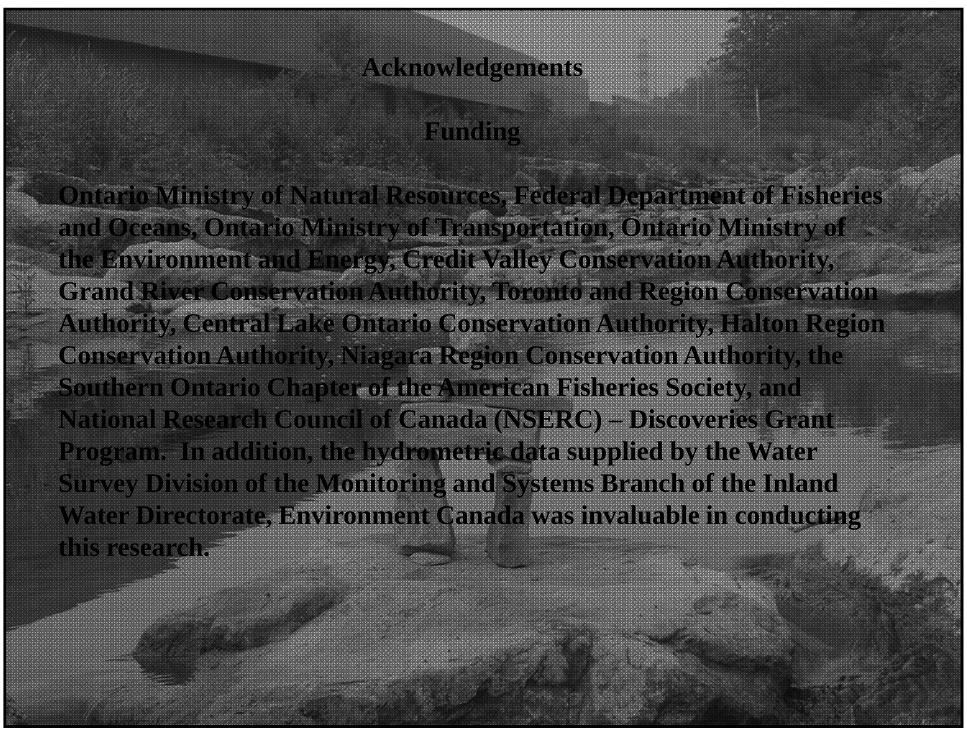
Early Urban Build Out

Increase in discharge and change in sediment supply

$$Q_W^+ Q_{Bed}^+ \approx \frac{W^+ \lambda^+ \varpi^+}{\Omega^-} S^\pm D^\pm \quad and \quad Q_W^+ Q_{Bed}^- \approx \frac{D^+ \Omega^+}{S^- \varpi^-} W^\pm \lambda^\pm$$

Analogous to the Urban Condition

Q_w = Discharge
W = Width
D = Depth
λ = Meander Wave Length
S = Slope
Ω = Sinuosity
ω = Width : Depth Ratio
Q_{Bed} = Bedload Transport



Acknowledgements

Funding

Ontario Ministry of Natural Resources, Federal Department of Fisheries and Oceans, Ontario Ministry of Transportation, Ontario Ministry of the Environment and Energy, Credit Valley Conservation Authority, Grand River Conservation Authority, Toronto and Region Conservation Authority, Central Lake Ontario Conservation Authority, Halton Region Conservation Authority, Niagara Region Conservation Authority, the Southern Ontario Chapter of the American Fisheries Society, and National Research Council of Canada (NSERC) – Discoveries Grant Program. In addition, the hydrometric data supplied by the Water Survey Division of the Monitoring and Systems Branch of the Inland Water Directorate, Environment Canada was invaluable in conducting this research.


QUESTIONS ?