The Role of Eco-Hydraulics in the Restoration of a Degraded Urban Stream

Beverley Hills Creek, St. Catharines, Ontario

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Fluvial Geomorphologist

In association with:

NATURAL CHANNELS

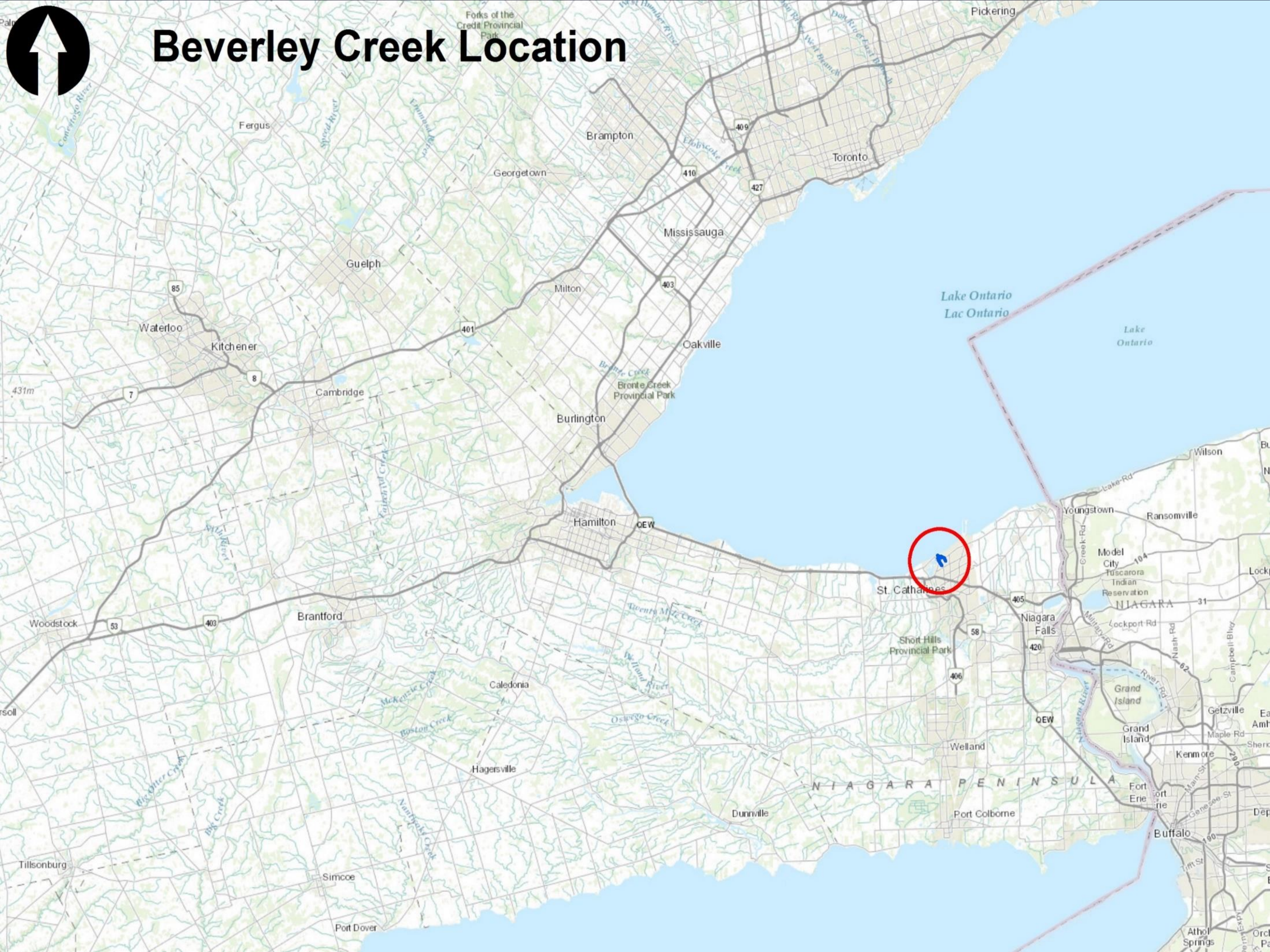
UEM URBAN & ENVIRONMENTAL MANAGEMENT INC. PROFESSIONAL CONSULTING SERVICES

5th International Conference on Natural Channel Systems
27 September 2016 – Session T3D Urban Streams

Presentation Overview

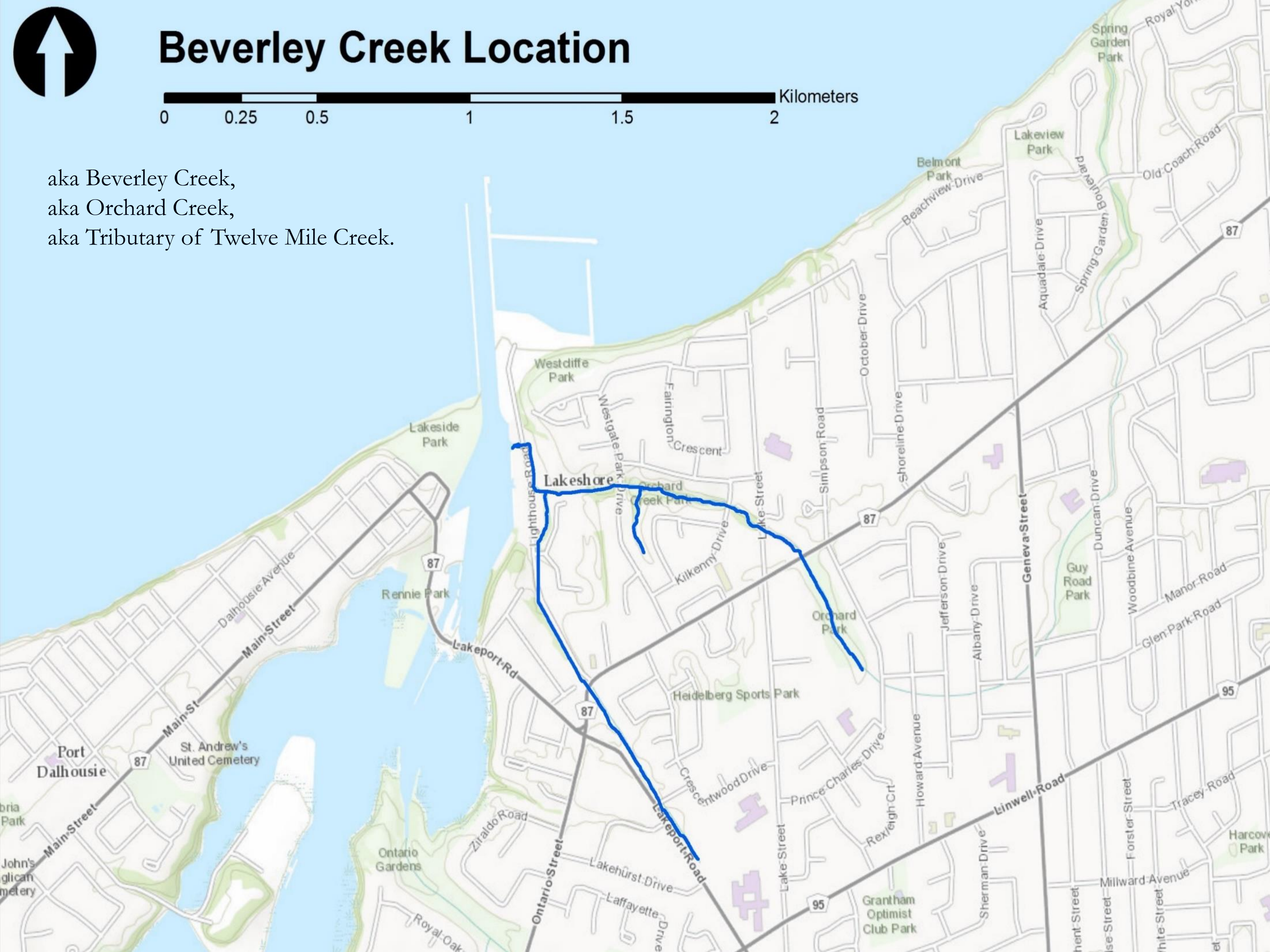
- Urban Stream Segment Restoration:
  - Location,
  - Context.
- The Challenge,
- Solution in the Context of Energy Management,
- Solution with Habitat Features Added,
- Thanks, Questions and Closure.

Beverley Creek Location

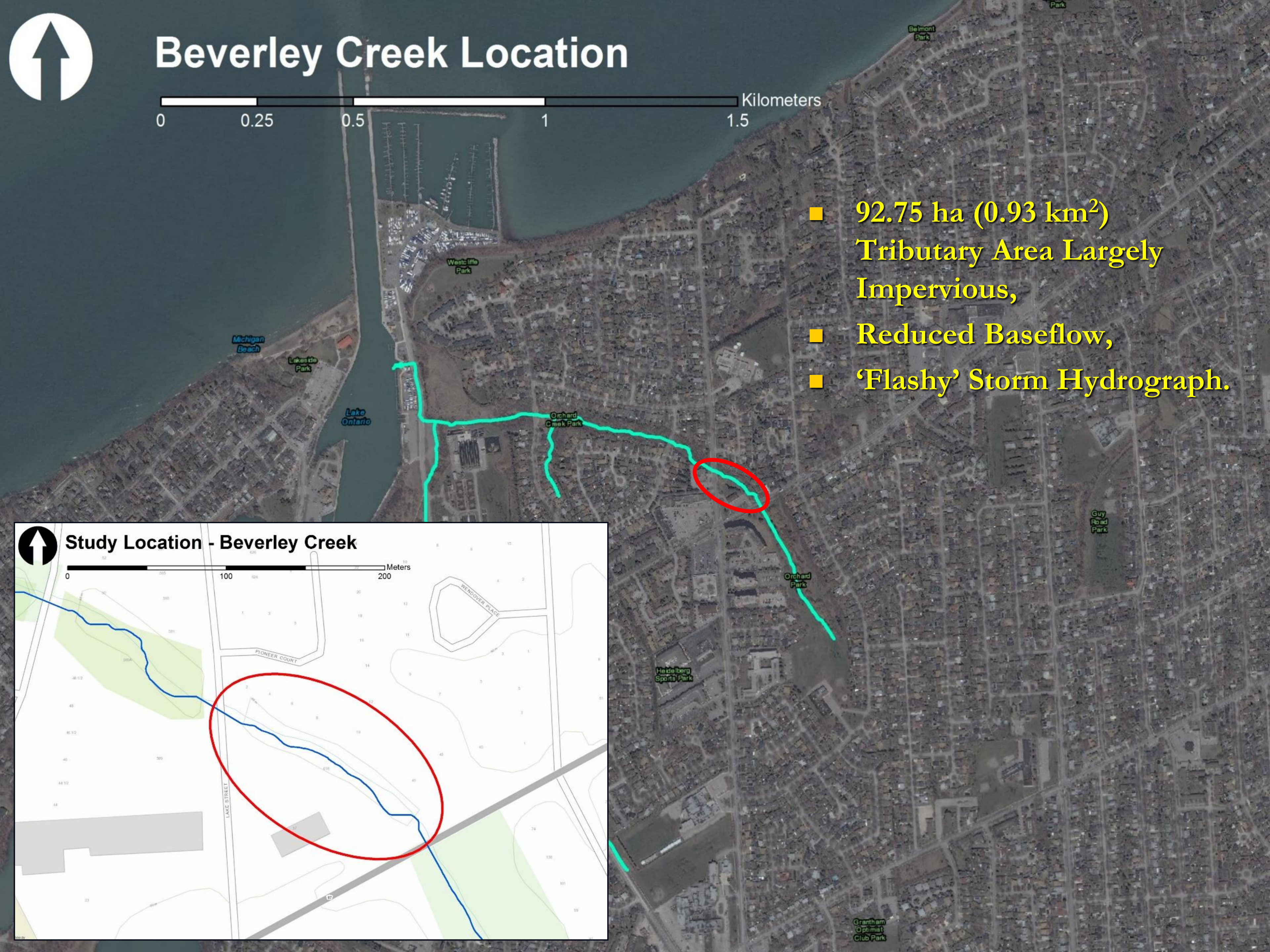


Beverley Creek Location

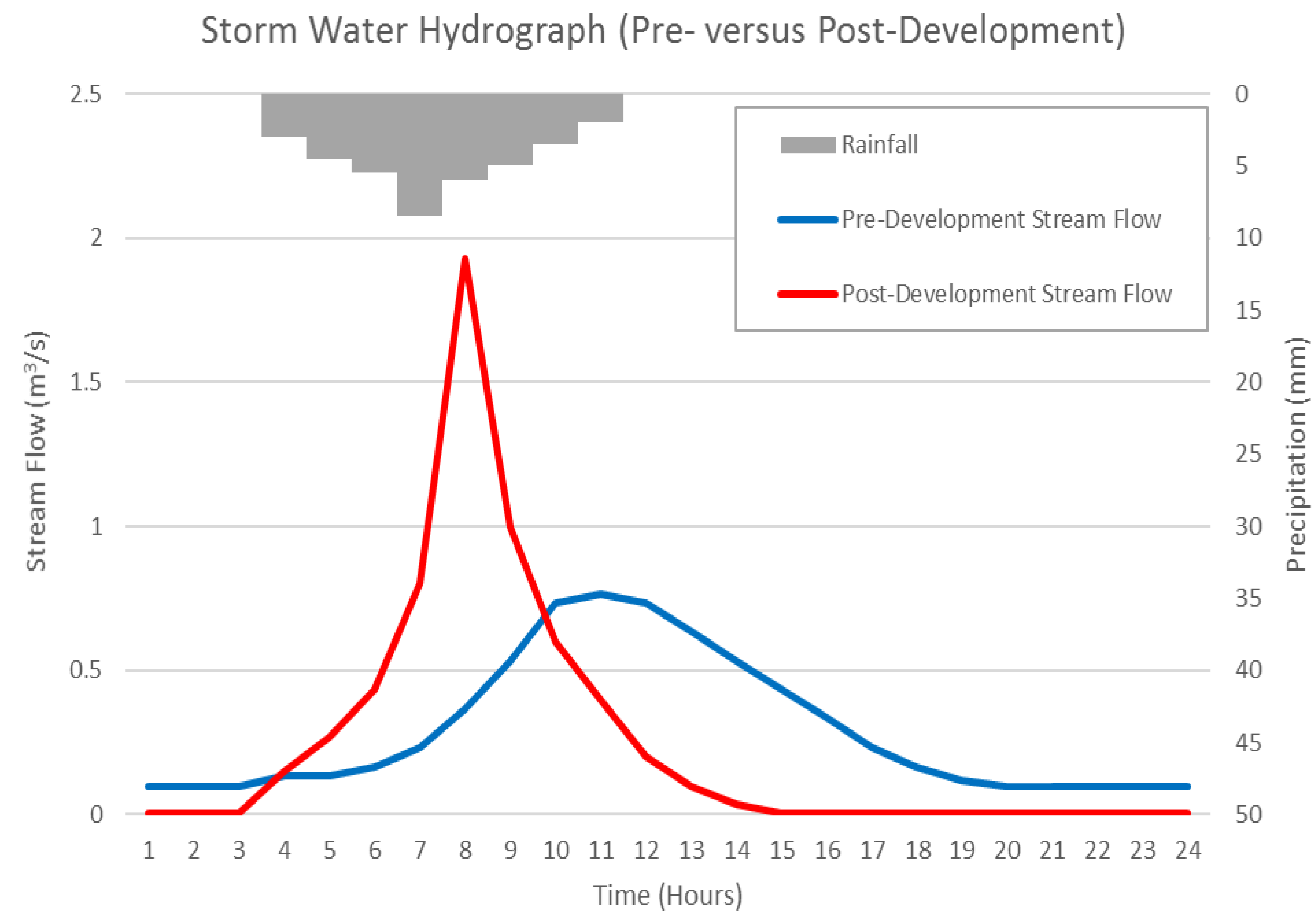
aka Beverley Creek,
aka Orchard Creek,
aka Tributary of Twelve Mile Creek.



Beverley Creek Location



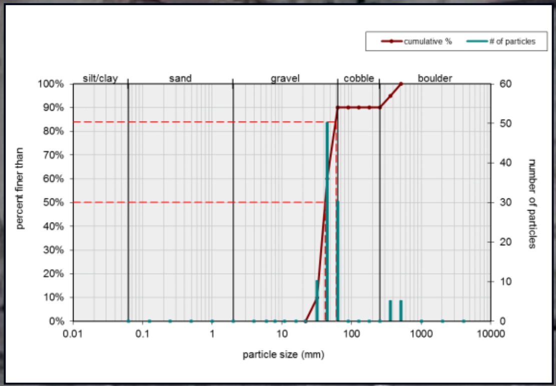
- 92.75 ha (0.93 km^2) Tributary Area Largely Impervious,
- Reduced Baseflow,
- 'Flashy' Storm Hydrograph.



Hydrographs estimated via HEC HMS

Study Location - Beverley Creek

- $Q_{BF} \approx 2.8\ m^3/s$,
- $W_{BF} \approx$ 5 to 6 m,
- $D_{BF} \approx 0.7$ m,
- $V_{BF} \approx 1.0$ m/s,
- W/D ≈ 16 (high ratio),
- ER < 1.2 (severe),
- Threshold Grain Size ≈ 20 mm (per Shields, 1936)
- D84 ≈ 60 mm (2.4 in.) .



Bank Erosion and Severe Entrenchment

‘Levitating’ Culvert footings!?

Bank Erosion and Severe Entrenchment

‘Levitating’ Culvert footings!?

Bank Erosion and Severe Entrenchment

Previous attempts at stabilization …

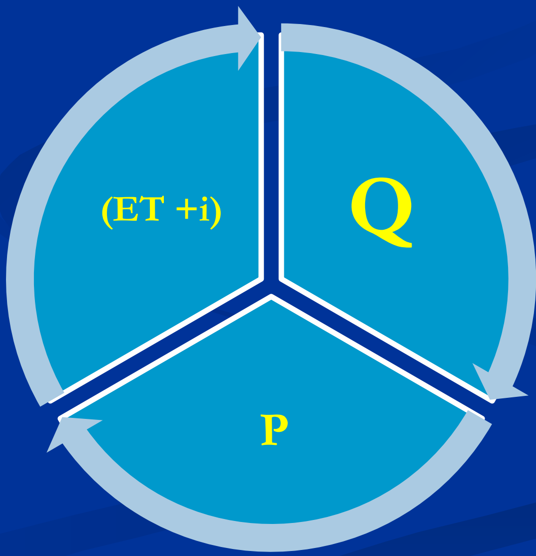
Bank Erosion and Severe Entrenchment

… had not worked over time.

What to do?

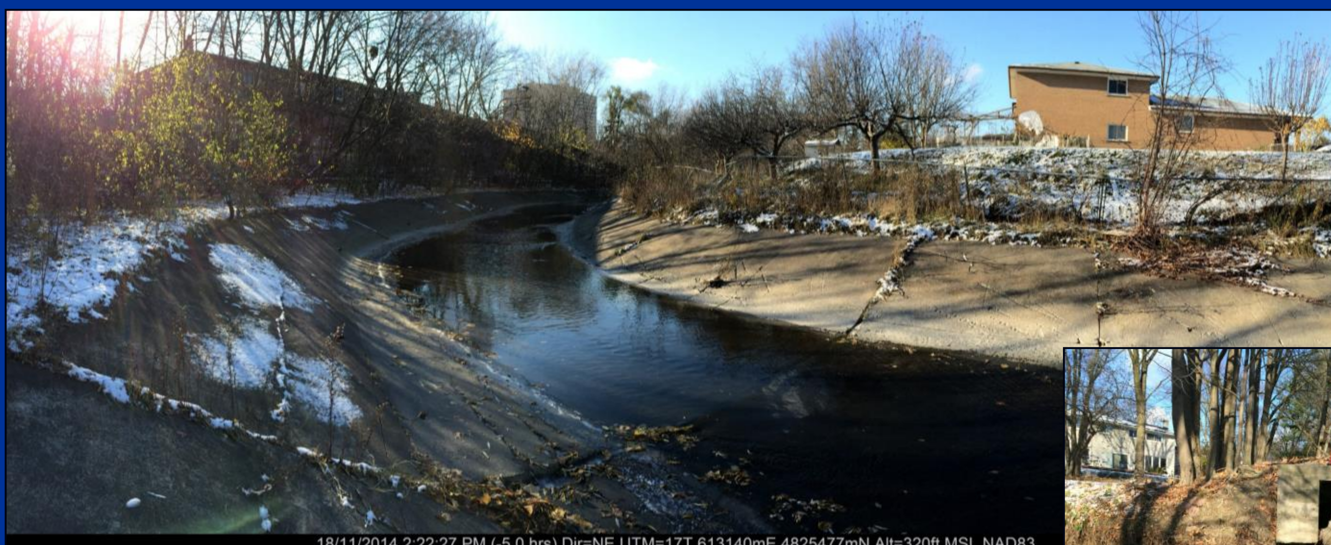
- Damp peaks and/or Divert water from Runoff (Q) back to (ET+i) … LIDs?
  - Retrofit established infrastructure on a large neighbourhood scale … likely not feasible ($ and politics)!

$$Q = P - (ET + i)$$



What to do? (Continued)

- Harden the bed and banks?
  - 1960's approach; lots of evidence for continued failure(s),
  - Push the problem(s) downstream!

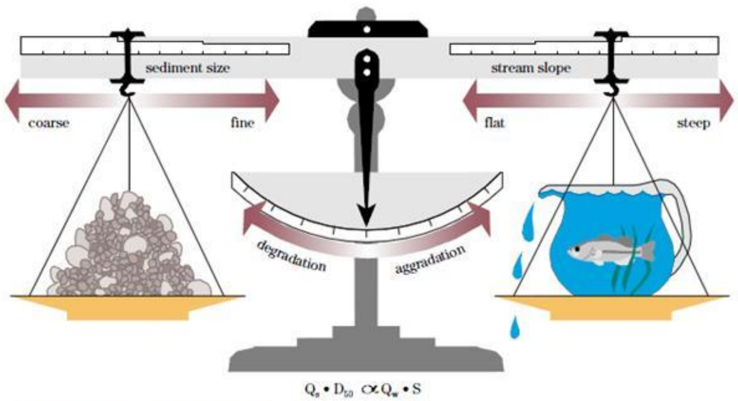


Cooksville Creek, Mississauga, Ontario (November 2014)

Cooksville Creek, reach downstream of concrete lined channel.

What to do? (Continued)

- Opportunities to balance system equilibrium per Lane's Sediment Balance (Lane, 1955)?
  - Limited opportunity; sediment supply 'urbanized',
  - 'Clear Water Discharge' is in fact the problem,
  - Sediment <u>source</u> has been shifted from the upland areas of the watershed to the channel itself!



From Rosgen (1996), from Lane, Proceedings, 1955.
Published with the permission of American Society of Civil Engineers.

Source:
https://riverrestoration.wikispaces.com/Sediment+transport+models

What to do? (Continued)

- Watershed is irreversibly changed (urbanized); no longer a "Natural" Channel!
- Too much energy in this urbanized system! Manage E! Threshold Channel Design …
- 'Play' with the Channel's Energy Balance
  - (minimize energy wherever possible without loosing conveyance efficacy).
- While we are there (dissipating energy), stabilize with NCD techniques and build habitat features ("Build it and they will come").

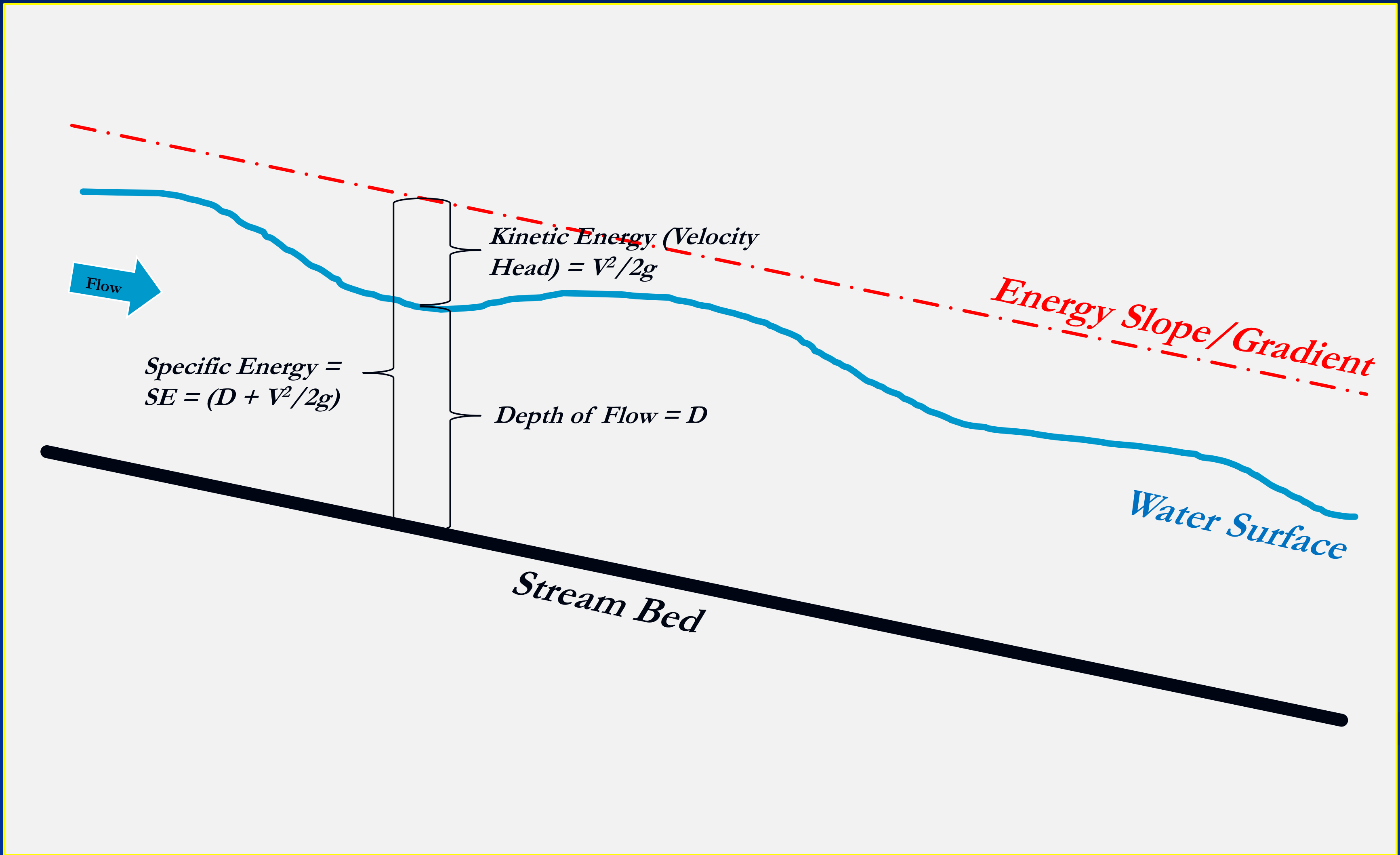
Manage the Energy in the Stream!
(Review and/or Primer)

$$E = Z + D + V^2/2g$$

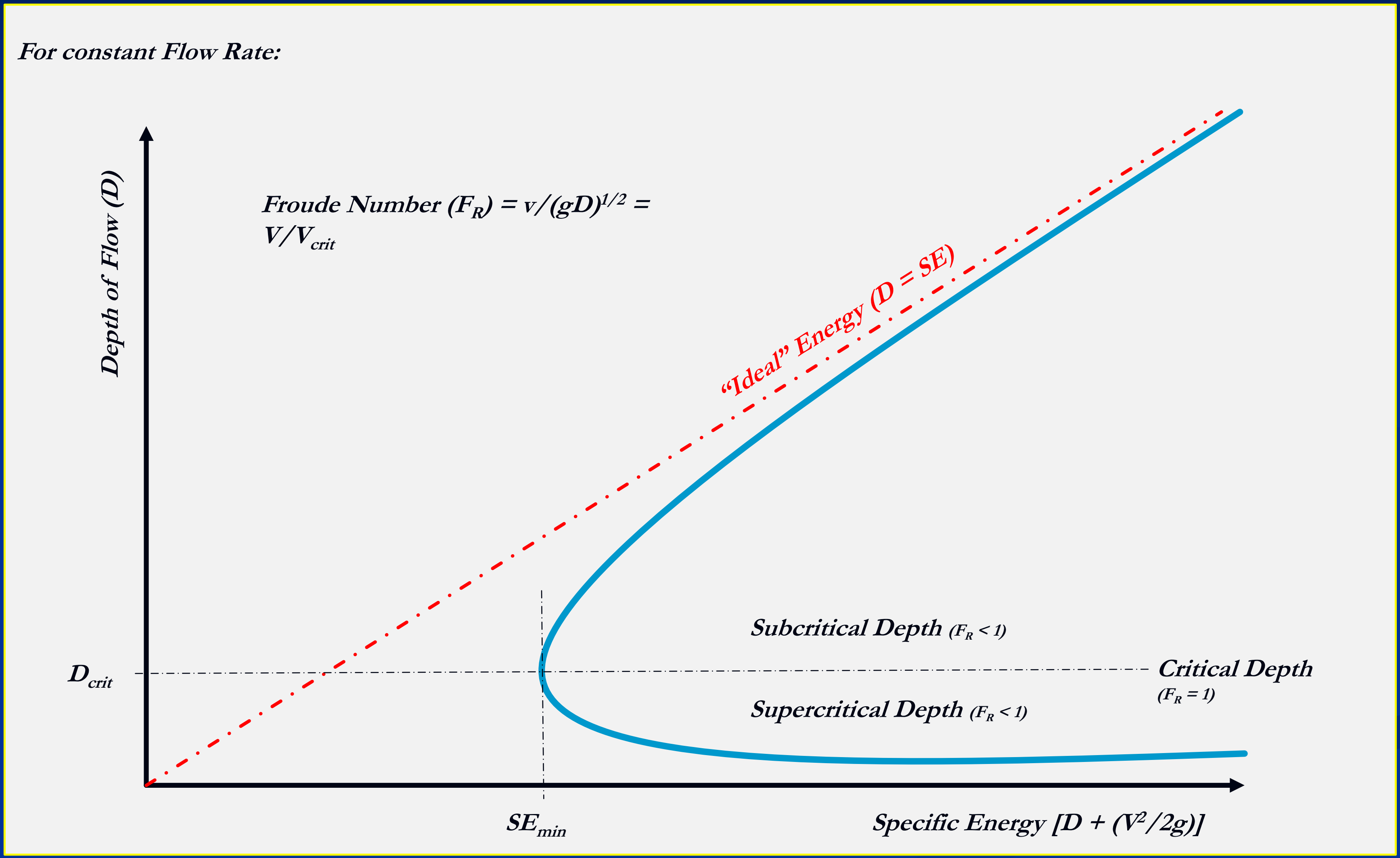
Daniel Bernoulli, 1738

- Conservation of Energy:
  - Potential Energy, in metres (Z) +
  - Depth of Flow, in metres (D) +
  - Kinetic Energy, in metres ($V^2/2g$) … a function of velocity, aka Velocity Head.
- Specific Energy (SE) is ($D + V^2/2g$) or Depth + Kinetic Energy (velocity head).

Energy Budget in the Stream (graphic)



Specific Energy in the Stream (graphic)

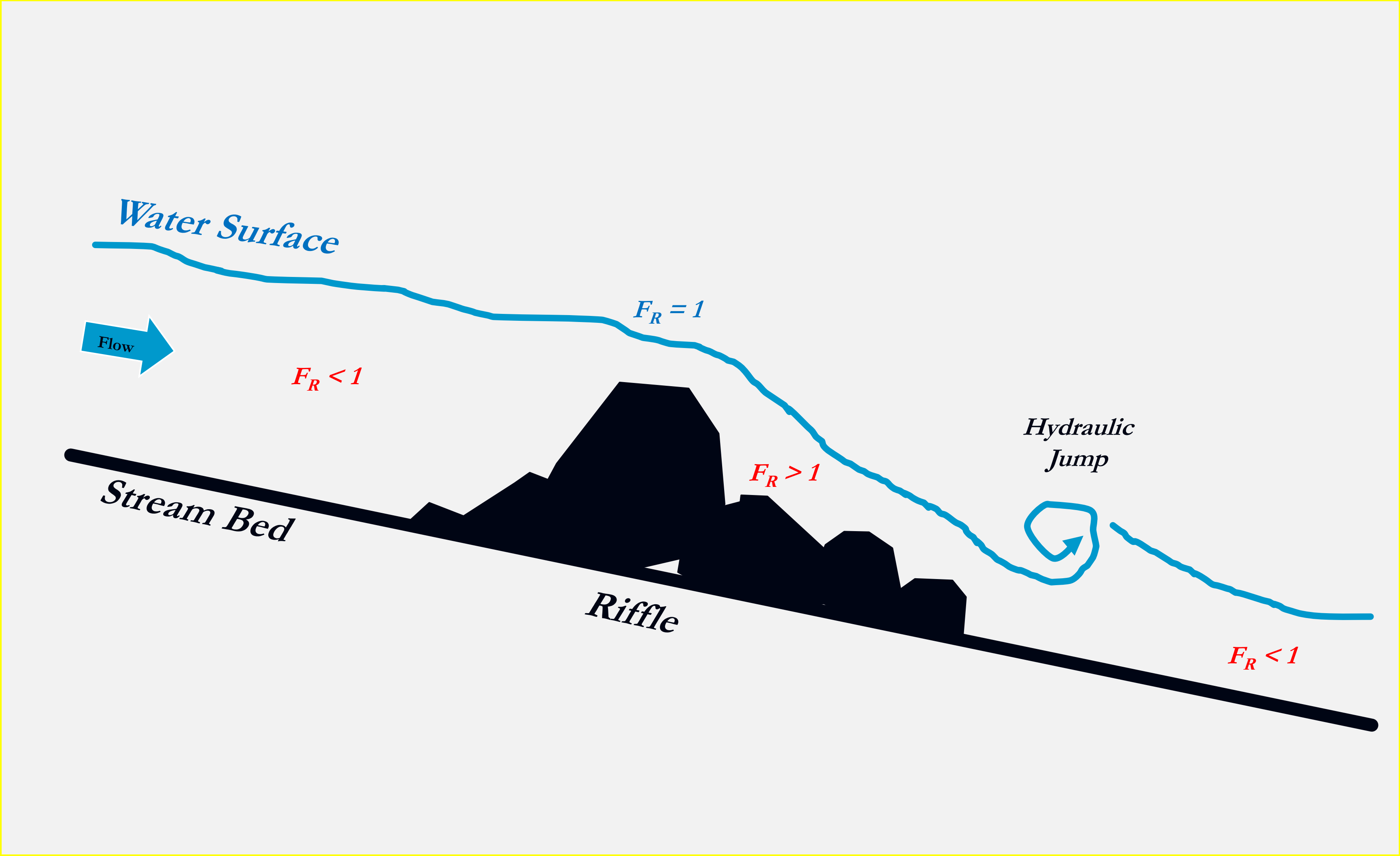


What does this all mean?

- If we are worried about erosion: $E = Z + D + V^2/2g$
  - We want to minimize energy (SE) through the reach!
- Minimum energy (SE_{min}) happens at critical depth (D_{crit}) and thus V_{crit} …
- In natural systems (that have evolved equilibria), these are Riffle Crests!


Nith River, Paris, Ontario (September 2007)

Natural Channel Riffle (Schematic)



Natural Channel Riffle (Reality)

Created Riffle Analogues (J-Hook Vanes), Nith River, Paris, Ontario (October 2013); near $Q_{BF} \approx 60\ m^3/s$

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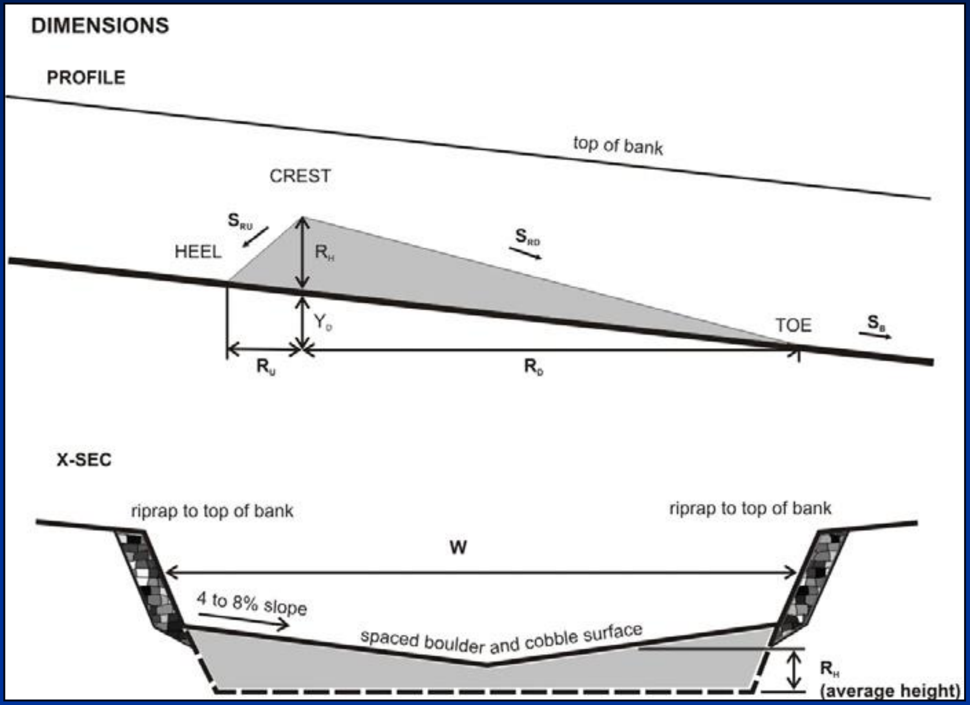
We Can Design & Build Riffles (NCD)

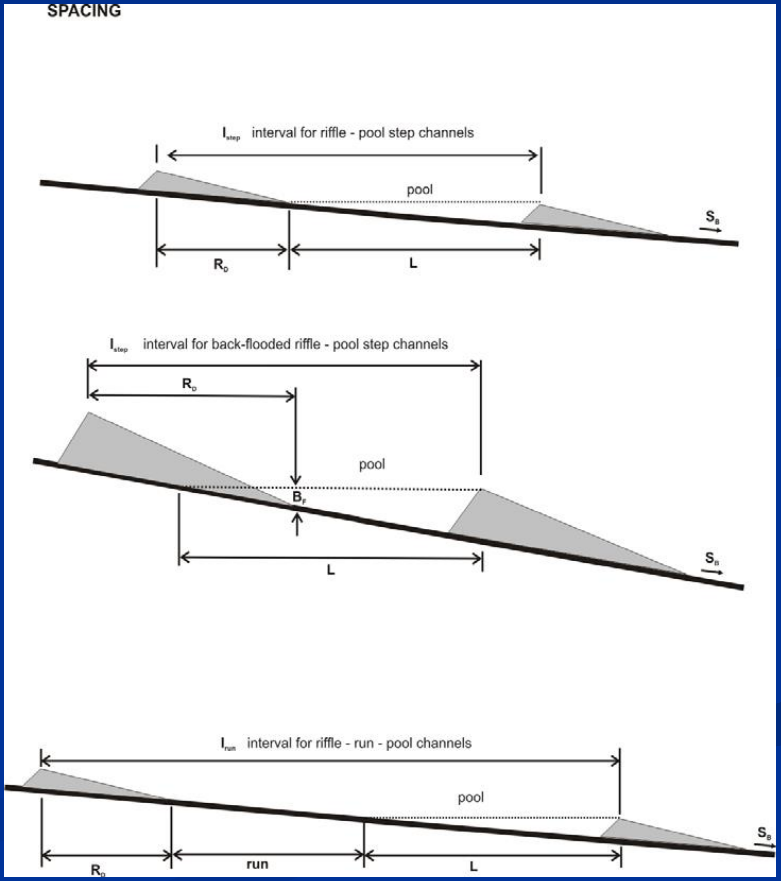


Source:
Newbury, R. (2008). Stream Restoration Design Manual. Fredericton, New Brunswick, Canada: Canadian Rivers Institute, University of New Brunswick.

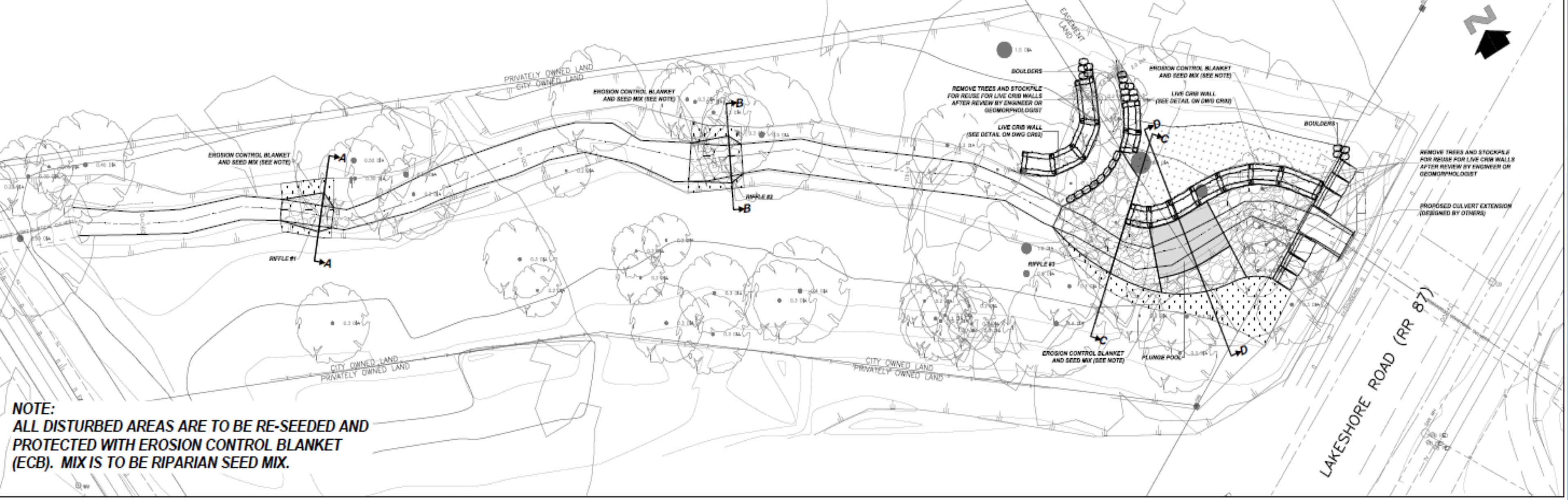
With Permission.

Newbury Weirs

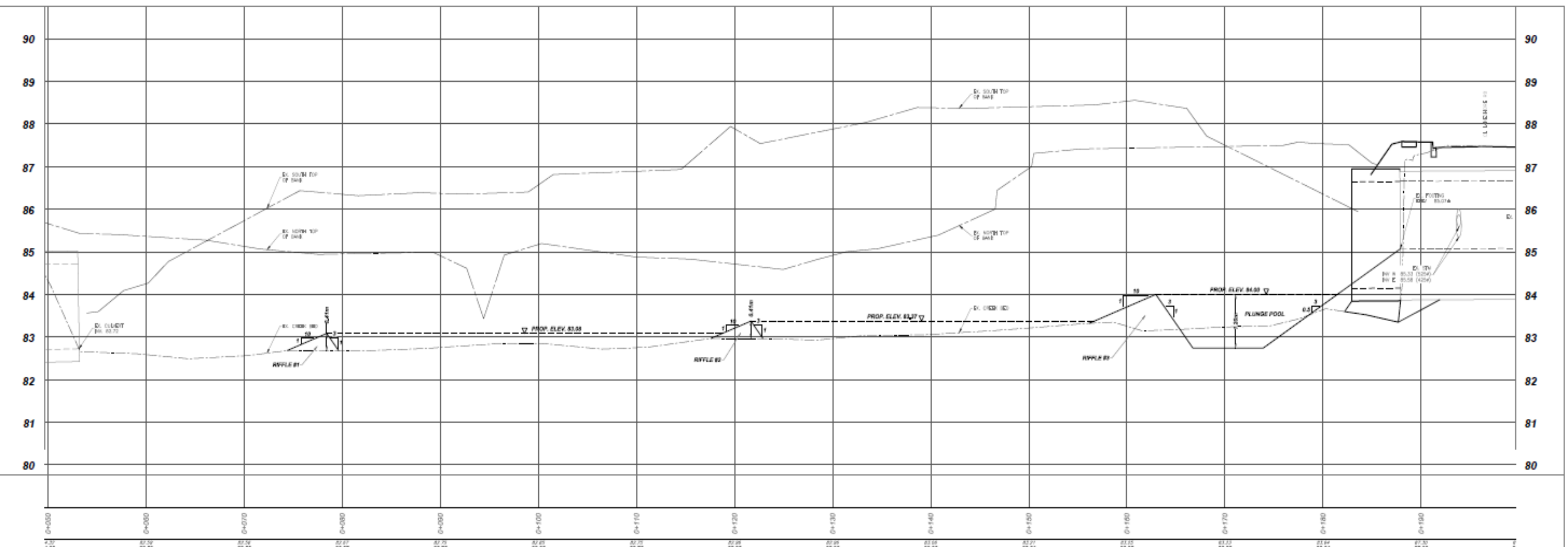
(aka Rocky Ramps or Created Riffles)



'Force' criticality at regular intervals in the stream to dissipate energy.



NOTE:
ALL DISTURBED AREAS ARE TO BE RE-SEEDED AND PROTECTED WITH EROSION CONTROL BLANKET (ECB). MIX IS TO BE RIPARIAN SEED MIX.



REVISION	DATE	INT.
ISSUED FOR NPCA APPROVAL	2014-12-02	BG/IS

NOTES/LEGEND

1. THE POSITION OF POLE LINES, CONDUITS, WATERMAINS, SEWER AND OTHER UNDERGROUND AND OVERGROUND UTILITIES AND STRUCTURES IS NOT NECESSARILY SHOWN ON THE CONTRACT DRAWINGS AND, WHERE SHOWN, THE ACCURACY OF THE POSITION OF SUCH UTILITIES AND STRUCTURES IS NOT GUARANTEED. BEFORE STARTING WORK, THE CONTRACTOR SHALL INFORM HIMSELF OF THE EXACT LOCATION OF ALL SUCH UTILITIES AND STRUCTURES AND SHALL ASSUME ALL LIABILITY FOR DAMAGE TO THEM.
2. PROPERTY LINES WERE PLOTTED USING REGISTERED PLANS AND BARS LOCATED IN THE FIELD. TO VERIFY THE ACCURACY OF THESE PROPERTY LINES, A LEGAL SURVEY SHOULD BE PERFORMED PRIOR TO CONSTRUCTION.

DRAFTING: EL
DESIGN: IS
CHECKED BY: BG
APPROVED BY: BG

Niagara Region PUBLIC WORKS

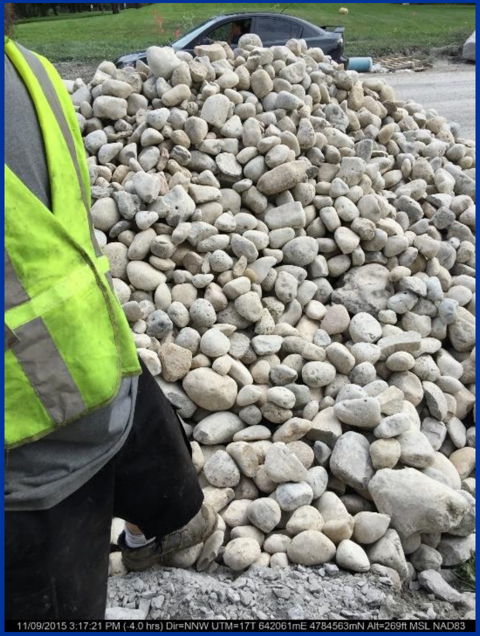
UEM URBAN & ENVIRONMENTAL MANAGEMENT INC. PROFESSIONAL CONSULTING SERVICES

2014-T-105 CONTRACT (RN 14-05)
RECONSTRUCTION OF REGIONAL ROAD 87
(LAKESHORE ROAD)
BEVERLY CREEK FROM LAKESHORE RD. TO LAKE ST.
ST.CATHARINES
PLAN & PROFILE

CONSULTANT FILE No. 13-107
DATE FEB 2014
SCALE Hor : 1:200 m; Ver : 1:50 m
REF. No. #
DWG No. 13-107-CR01

Energy Management Strategy Beverley Creek

1. Restore & stabilize the culvert bottom:
   - Determine stable particle sizes: D_{84} x 2.0 FS = 60 mm x 2.0 = at least 120 mm or 5 in. sub-rounded cobble,
   - Bring bed elevation to top of footing inside culvert (embed),
   - Increased roughness will decrease velocity (friction).



5"+ sub-rounded limestone cobble

Habitat Value

- Embedded Culvert provides turbulence/aeration + insect habitat.

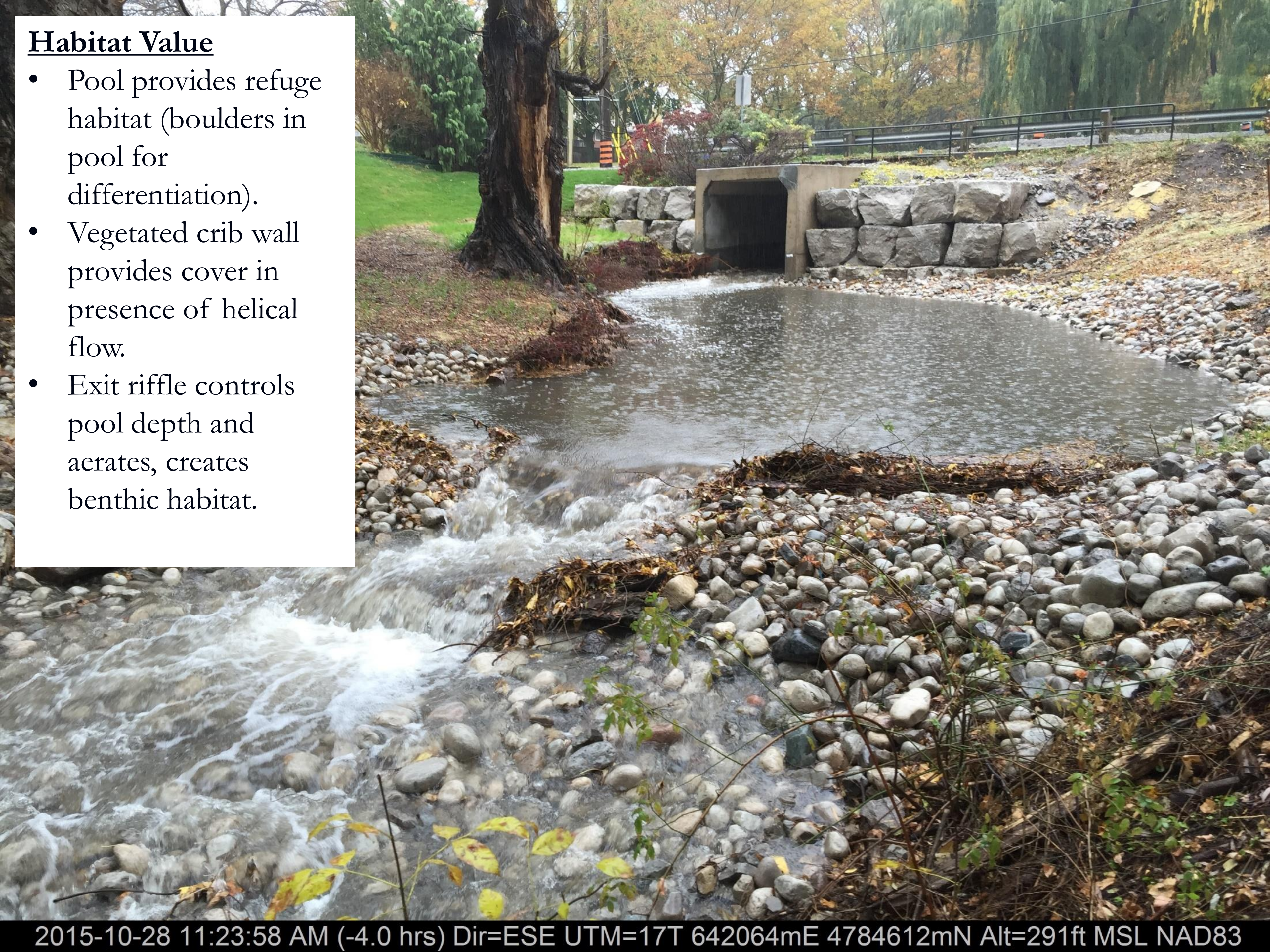
Energy Management Strategy
Beverley Creek

2. First riffle in conjunction with plunge pool:
   - Plunge pool created at culvert outlet to fully dissipate culvert exit energy (expansion of flow cross section),
   - Flows taken down 10H:1V grade of 5”+ sub-rounded stone (friction),
   - Flow lines directed to bank with a live/vegetated crib wall shaped into a spiral curve (helical flow steered into pool).

Plunge pool and vegetated crib wall at embedded culvert outlet.

Habitat Value

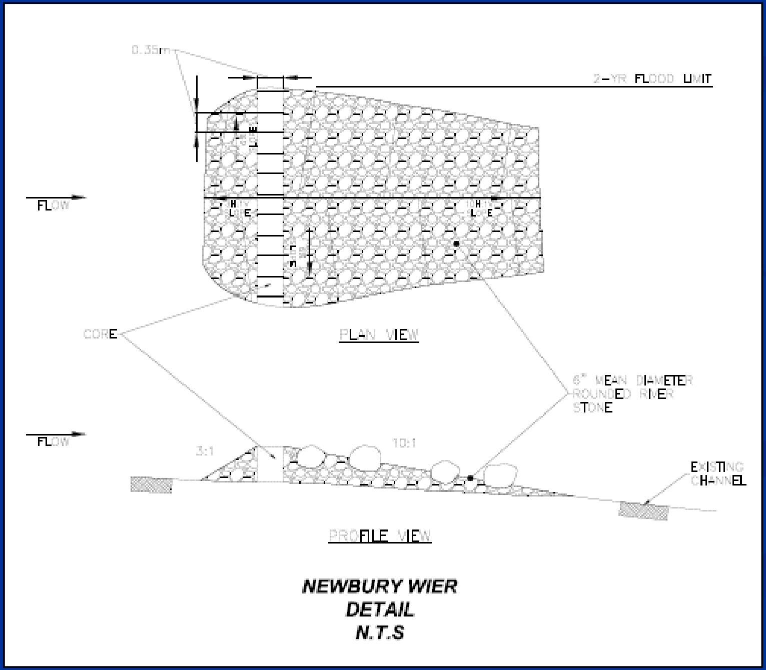
- Pool provides refuge habitat (boulders in pool for differentiation).
- Vegetated crib wall provides cover in presence of helical flow.
- Exit riffle controls pool depth and aerates, creates benthic habitat.



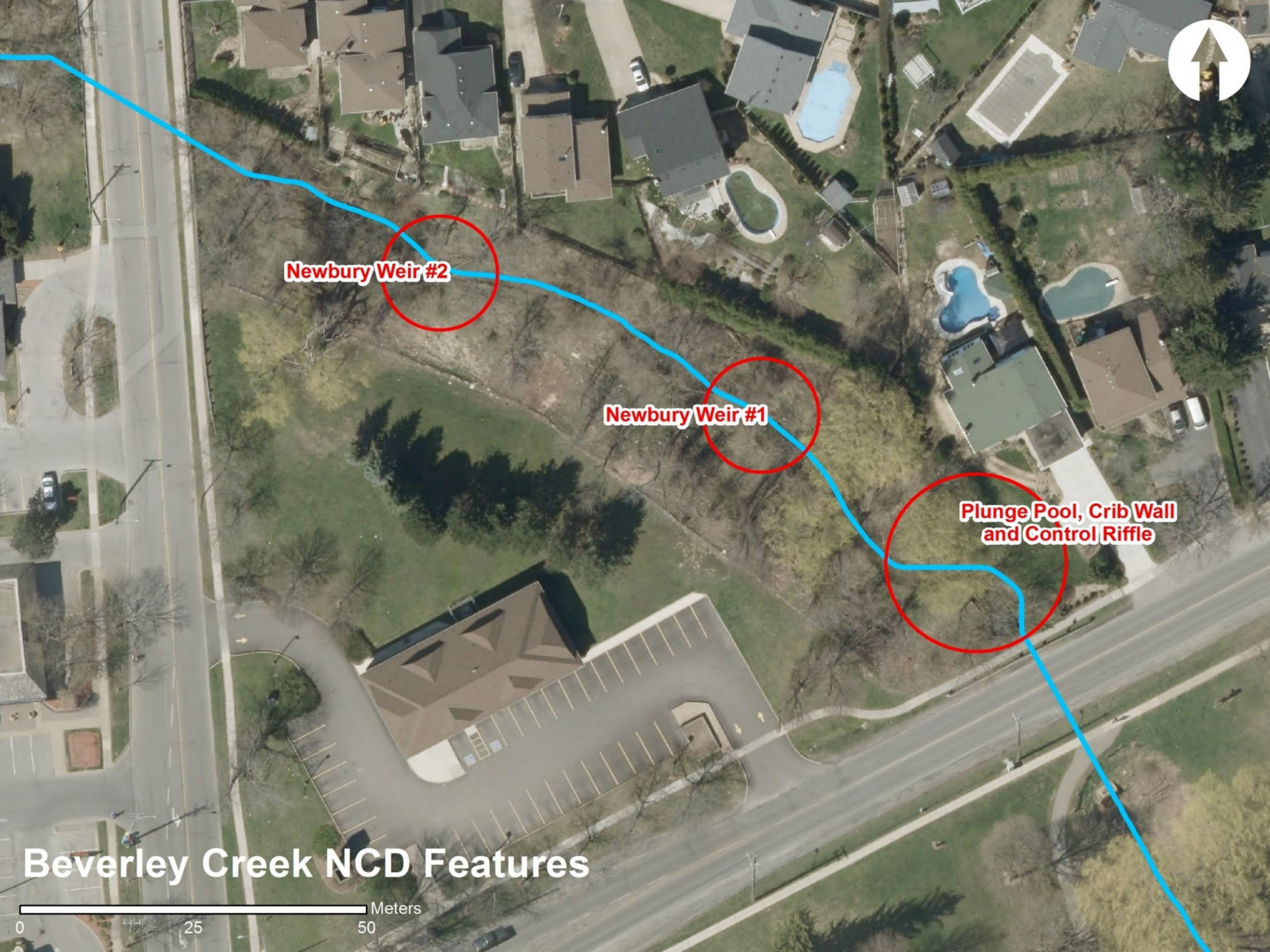
2015-10-28 11:11:38 AM (-4.0 hrs) Dir=WNW UTM=17T 642083mE 4784588mN Alt=276ft MSL NAD83

Energy Management Strategy Beverley Creek

3. Place Rocky Ramps/Newbury Weirs:
   - Two required to force criticality through ±100 metre reach, pools stepped to riffle toes,
   - Mix of (2.0 FS x D_{84}) cobble, oversized (boulder) particles, and smaller particles (D_{50} = coarse gravel) to make for varied structure.



Rocky Ramp/Newbury Weir Detail, (UEM Consulting 2014).


Newbury Weir #2
Newbury Weir #1
Plunge Pool, Crib Wall and Control Riffle
Beverley Creek NCD Features
Meters
0
25
50

Habitat Value

- Riffle provides turbulence/aeration + insect habitat.
- Riffle boulders provide eddy currents/resting habitat.

$F_R < 1$
$F_R = 1$
$F_R > 1$
2015-10-28 11:22:15 AM (-4.0 hrs) Dir=NNE UTM=17T 642034mE 4784624mN Alt=279ft MSL NAD83

'One Storm' Post-Construction

‘One Year’ Post-Construction

Questions

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Please feel free to contact UEM at:

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Thanks to:
St. Catharines
Niagara Region