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Using two-dimensional hydraulic modeling to quantitatively assess fish habitat improvements

Nick Hodges and Joanna Eyquem

5th International Conference on Natural Channel Systems
September 27, 2016

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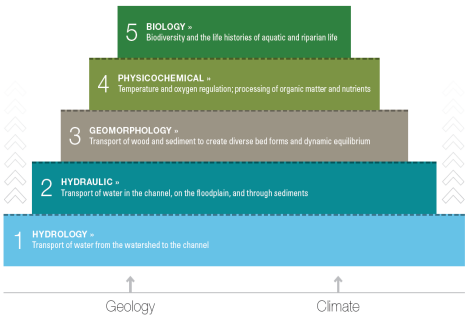
Sustainable River Management



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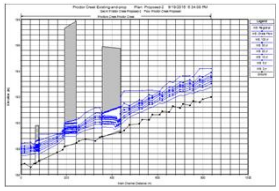
HEC-RAS 1D: The Previous Industry Standard

- First version released by USACE, July 1995.
- Widespread use in flood risk and erosion control studies



- Depth and width averaged results - does not reflect velocity and shear stress variations within the cross-section.
- Limits use for geomorphological and physical habitat studies

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2D Hydraulic Modeling

- Several 2D modeling packages have been available, going back over 40 years…

MIKE Powered by DHI

ISIS

Flood Modeller Webinars
Introducing Flood Modeller

TUFLOW

… UK Environment Agency tested 14 packages in 2010…

… and the technology is still developing.

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a) Developments in 2-D Modeling
b) Case Study: Humber River
c) Application to Fisheries Habitat Improvements
d) Application and Alternatives

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River 2D

- 2D hydrodynamic model intended for use on natural streams and rivers
- Developed at the University of Alberta through funding from DFO
- Developed from 2001 – last updated 2010
- Tailored for Aquatic Habitat Assessment

RIVER2D

UNIVERSITY OF ALBERTA

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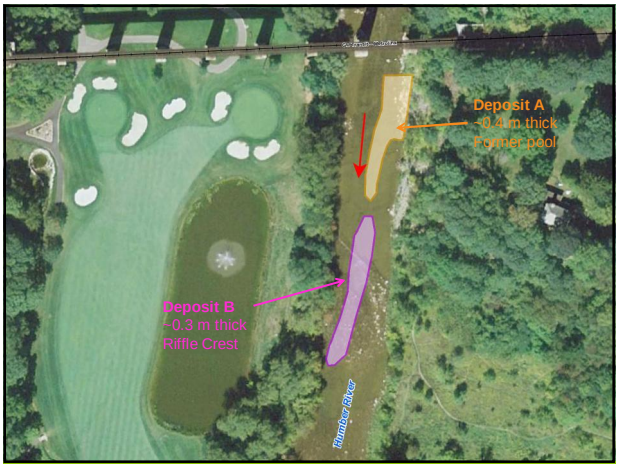

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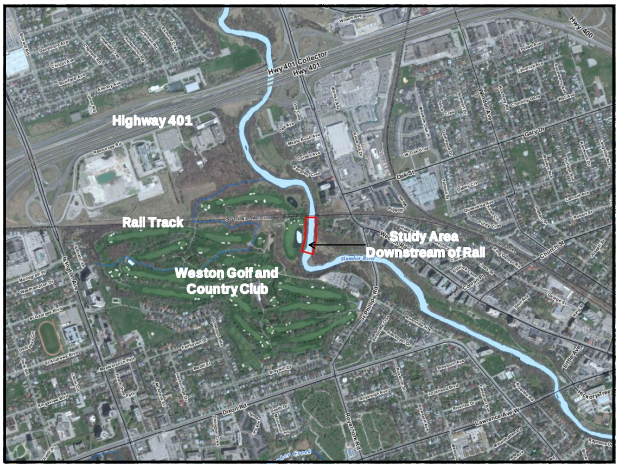
Case Study: Humber River

- July 8, 2013 – A high intensity precipitation event occurred in the Greater Toronto Area
- Rip-rap temporary coffer dam at the Humber River rail crossing was entrained and deposited immediately downstream in the channel.
- Concern regarding potential bank erosion
- AECOM retained to determine if, and when, the deposited material would be transported downstream



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Hydrodynamic Modelling Inputs

- Terrain data (bathymetry, channel survey, LiDAR)
  - Finer the resolution the better, represented by nodes
  - Cross-sections 2-5m apart for this study
- Substrate characterization
  - Required for calibration and habitat assessment
- Water surface elevations
  - Required as an input variable and for calibration
- Hydrometric data from a Water Survey of Canada gauge ~1.5 km downstream of study site to determine relevant flows

Ø Conducted 18 flow simulations ranging from 2.6 m^3/s (summer base flow) to 160 m^3/s (~5 year return flow)

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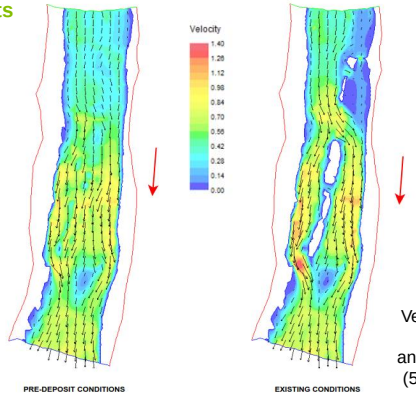
Outputs



Velocity at mean annual flow (5.7 m^3/s)

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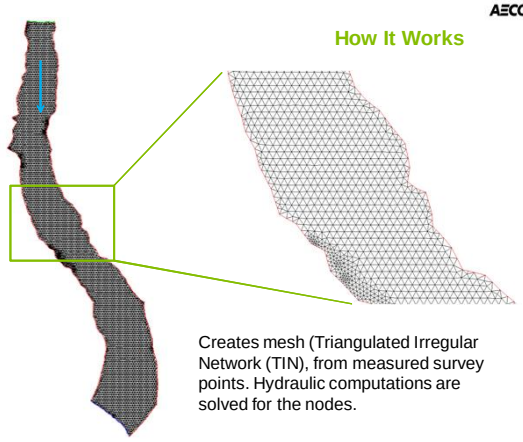
How It Works



Creates mesh (Triangulated Irregular Network (TIN), from measured survey points. Hydraulic computations are solved for the nodes.

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Geomorphological Analysis Application

- Compared modelled bed **shear stresses** to critical shear stress of deposited material:
  - **Deposit A**: starts to become entrained at 160 m^3/s (~5 year return event)
  - **Deposit B**: starts to become entrained at 20 m^3/s and the majority of the deposit is entrained during the 2 year flow event (~110 m^3/s)
- Verified potential influence on **bank erosion**:
  - At base to mean annual flows, some velocity vectors point towards the river banks as Deposit B acts as a medial bar, but flows do not have the capacity to cause excess bank and bed erosion.
  - During higher flow conditions, the deposited material is submerged and the velocity vectors are pointed in the downstream direction

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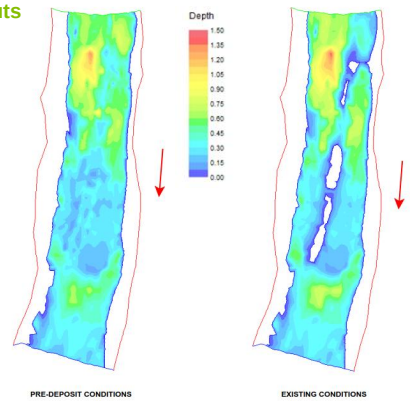
Outputs



Depth at mean annual flow (5.7 m^3/s)

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River 2D and PHABSIM

- Physical Habitat Simulation Model (PHABSIM): within River 2D
- PHABSIM developed by US Geological Survey
- Simulates relationship between streamflow and physical habitat using hydraulic parameters and habitat suitability criteria
- Output: Weighted Usable Area (WUA) offers quantitative assessment of habitat quality

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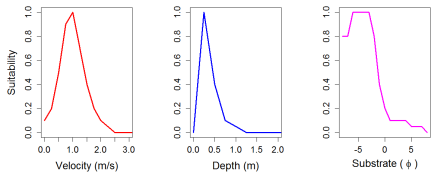
PHABSIM: Inputs, Variables and Outputs

- Input: Velocity, Depth, Substrates
- Variables: Habitat Suitability Index (HSI) (e.g. life stages)
- Output: Weighted Usable Area (WUA)

Adult Rainbow Darter Preference Curves



Source: Minnesota's Department of Natural Resources

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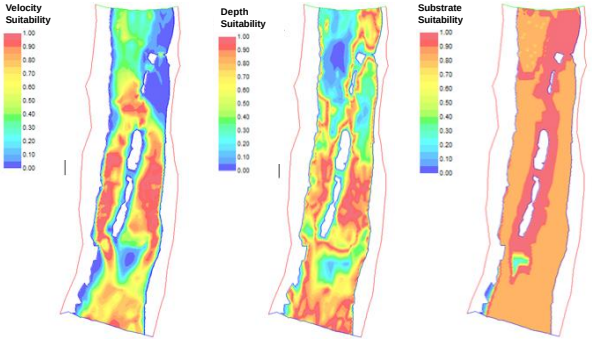
Example: Mapping Outputs



Suitability for Rainbow Darter at mean annual flow (5.7 m³/s) for existing conditions

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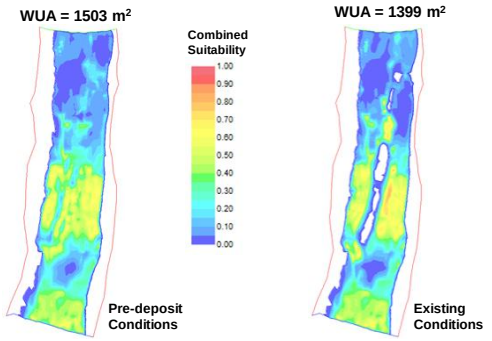
Example: Combined Suitability Mapping



Combined suitability for Adult Rainbow Darter at mean annual flow (5.7 m³/s)

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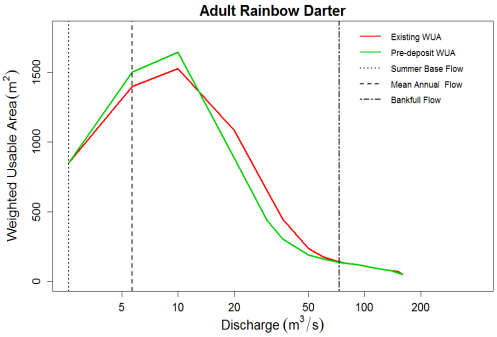
Example: Changing WUA with Discharge



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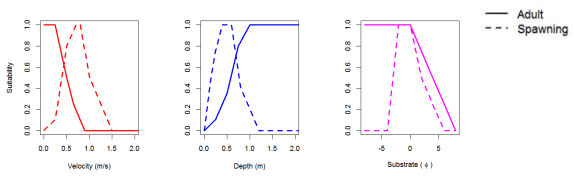
Knowledge Gaps

- HSI's are required and would need to be developed for each species, and their life stages.
- PHABSIM approach does not take into account all variables (e.g. Temperature, Vegetation).

Conceptual Redside Dace HSI



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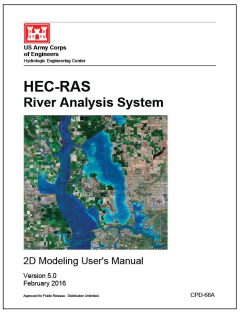
Alternatives: HEC-RAS 5.0 2D

- Officially Released March 4th, 2016
- Public Domain
- No License Fees

New Features:

- 2D and Combined 1D/2D Unsteady Flow Modeling
- New RAS Mapper (to ultimately replace HEC-GeoRAS)



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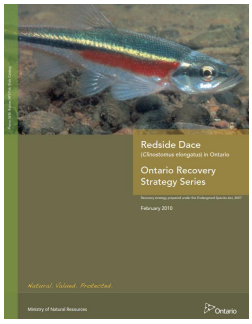
Applications:

- **Refinement** of channel design based on spatial modelled outputs
- **Quantifying** positive or adverse impacts on fish habitat

Ø Stream Restoration/ Habitat Enhancement;
Ø Post Construction Monitoring;
Ø Permitting – Species at Risk/ Overall Benefit;
Ø Species Recovery Initiatives.



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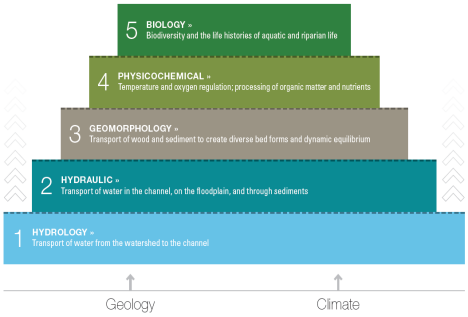
Best Application of Available Tools Will Require Teamwork!



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Alternatives: Limitations of River 2D

- Relatively small number of possible grid cells in model
  - Small reach capability OR
  - Model resolution has to be degraded
- Not appropriate for steep gradient channels
- Model instability
- Less widely applied by hydraulic specialists than HEC-RAS (QA/QC more challenging)

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Key Messages

- 2D modeling offers significant opportunities for refined and quantitative assessment of changes in physical fish habitat.
- Wider application should be actively encouraged to develop our skill base in Canada.
- True multidisciplinary project teamwork is required.