Blackbird: Towards Regional Flood Mapping and Inundation Forecasting Under Climate Change

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Western Flood Mapping Conference

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Motivation

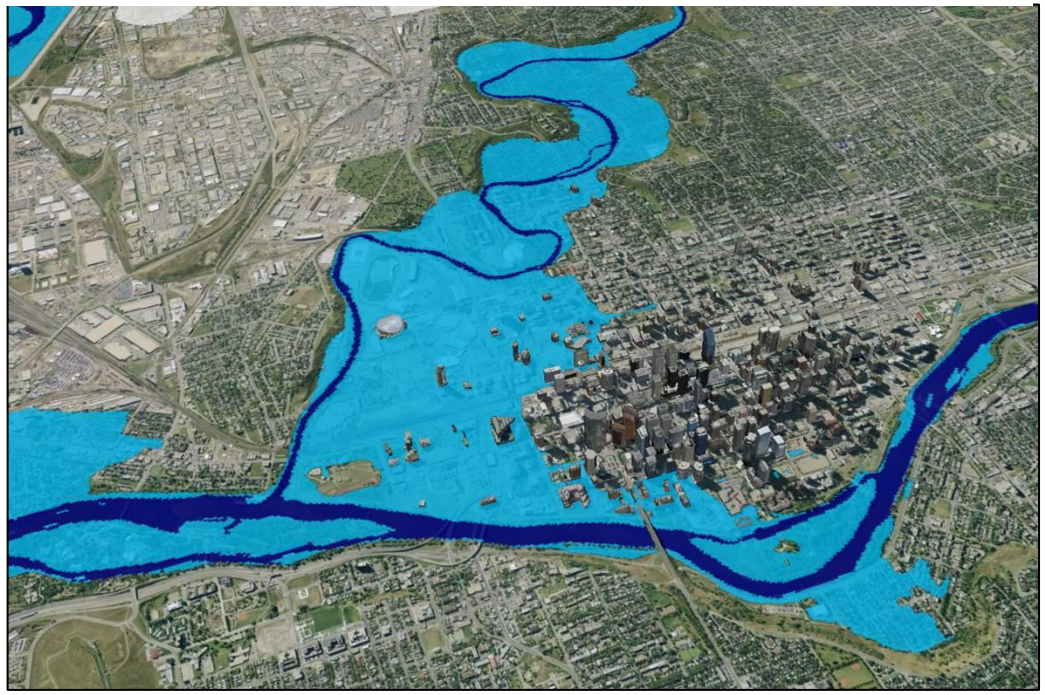
Insurers warn federal government Canada can't wait a decade to update flood maps

Most maps are, on average, 20 to 25 years out of date

Thomson Reuters · Posted: Mar 04, 2020 1:31 PM EST | Last Updated: May 5, 2021

Don't count on Canada-wide, high-resolution flood modelling anytime soon

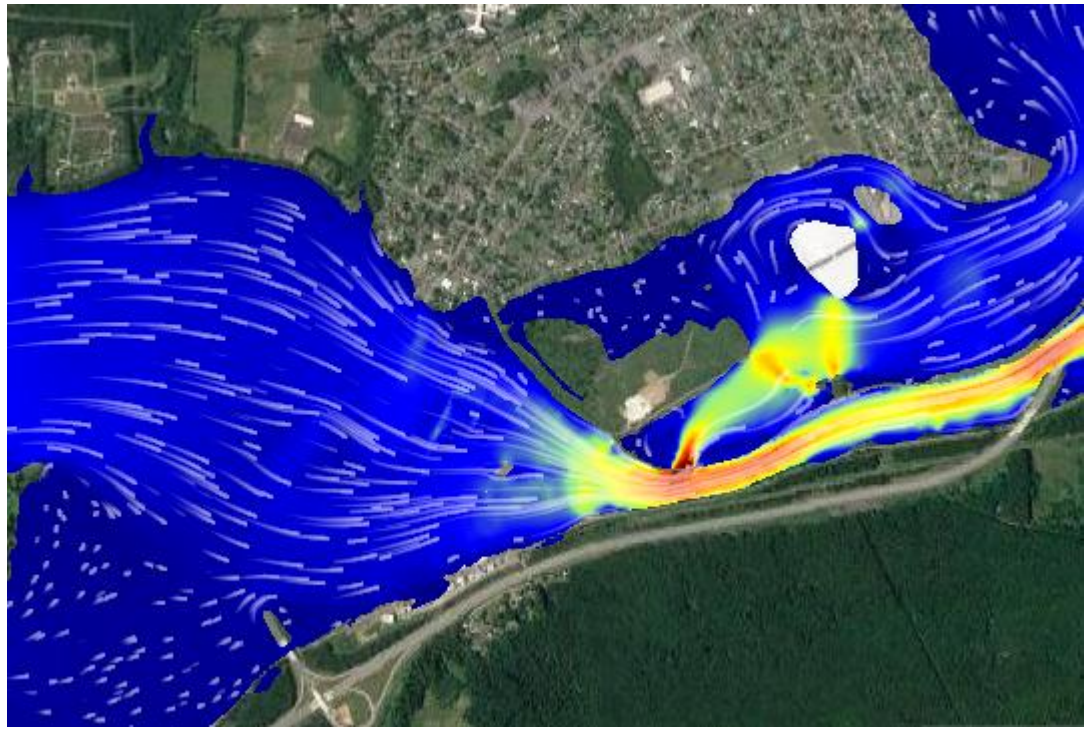
October 10, 2019 **by Greg Meckbach**



Current Challenges with flood mapping

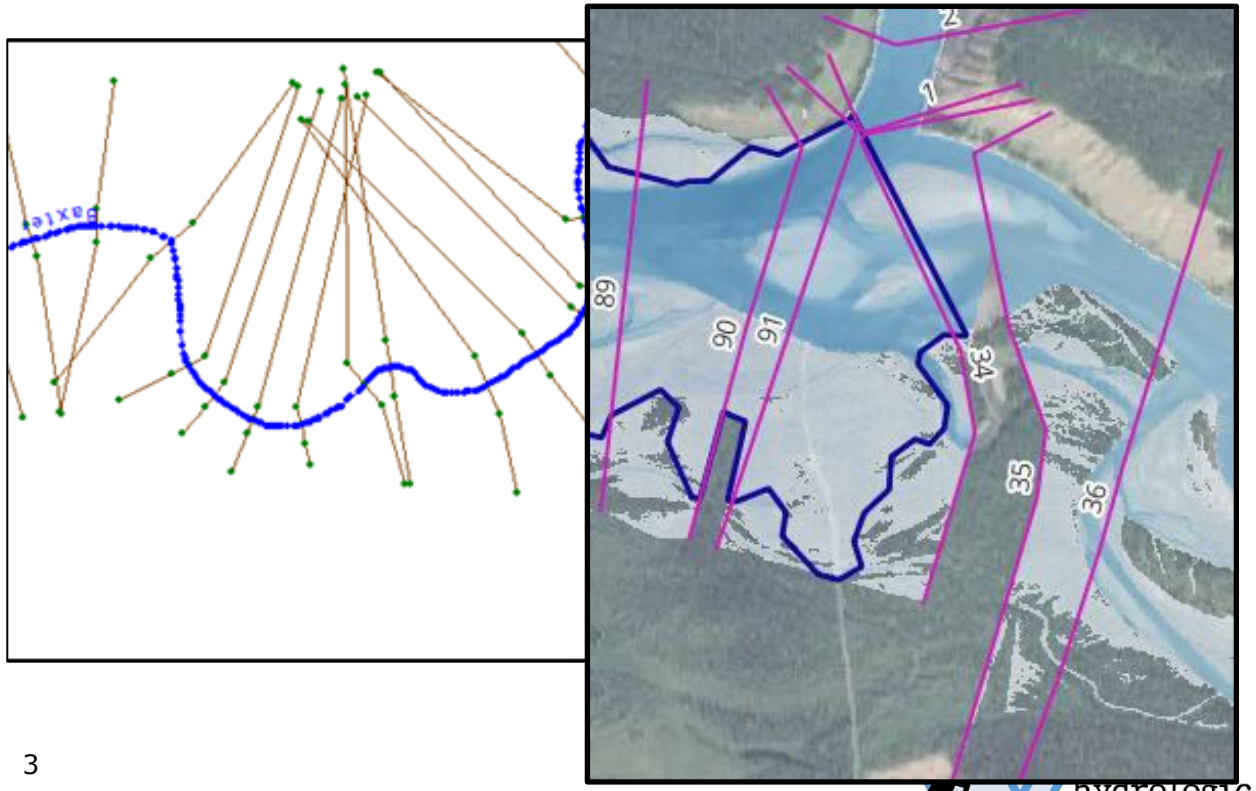
Stability of 2D models, high effort,

Runtime not suitable for real-time runs



Overlapping sections and interpolation of 1D sections, also high effort

Resolving landscape connections and false positives



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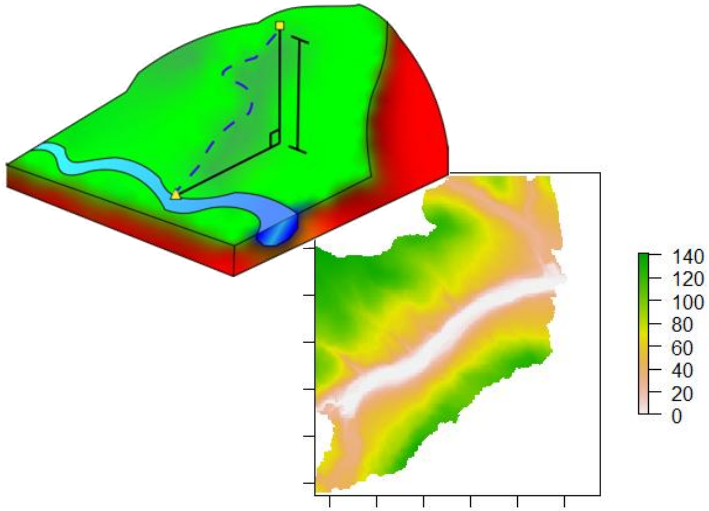
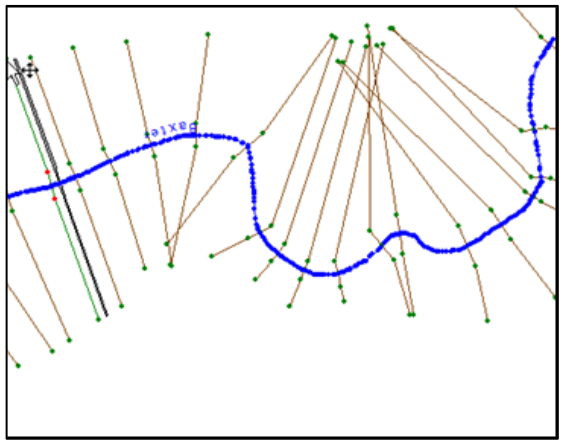
HAND-based methods



1D hydraulic model



Quasi-2D outputs

Combining best of approaches to maintain ***speed*** and ***accuracy***

Can also be applied in ***real-time*** and at ***large scales***

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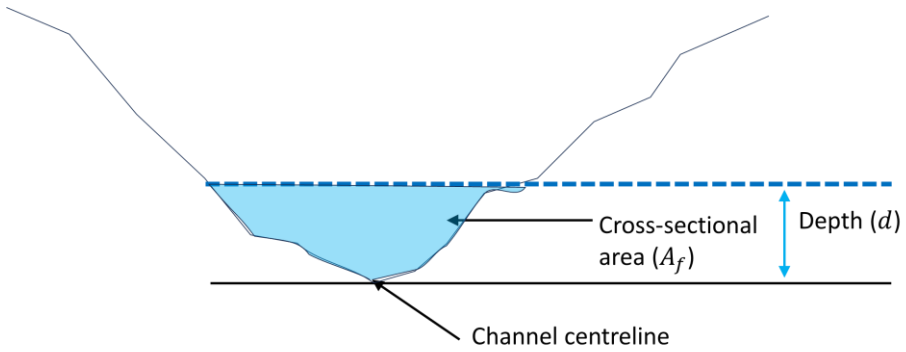
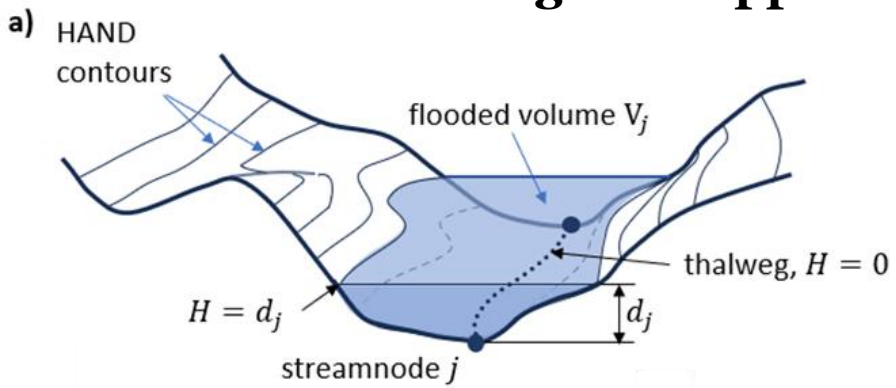
Methodology - Reach-Integrated Areas

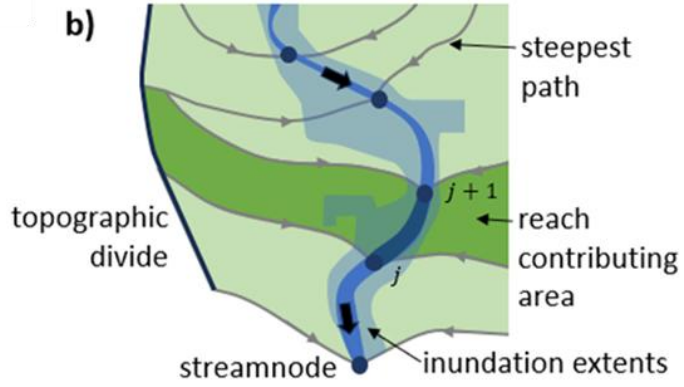
- Reach-integrated properties computed instead of cross-section properties
- Viewed as 3D areas and normalized by reach length

Cross-section approach



Reach-integrated approach

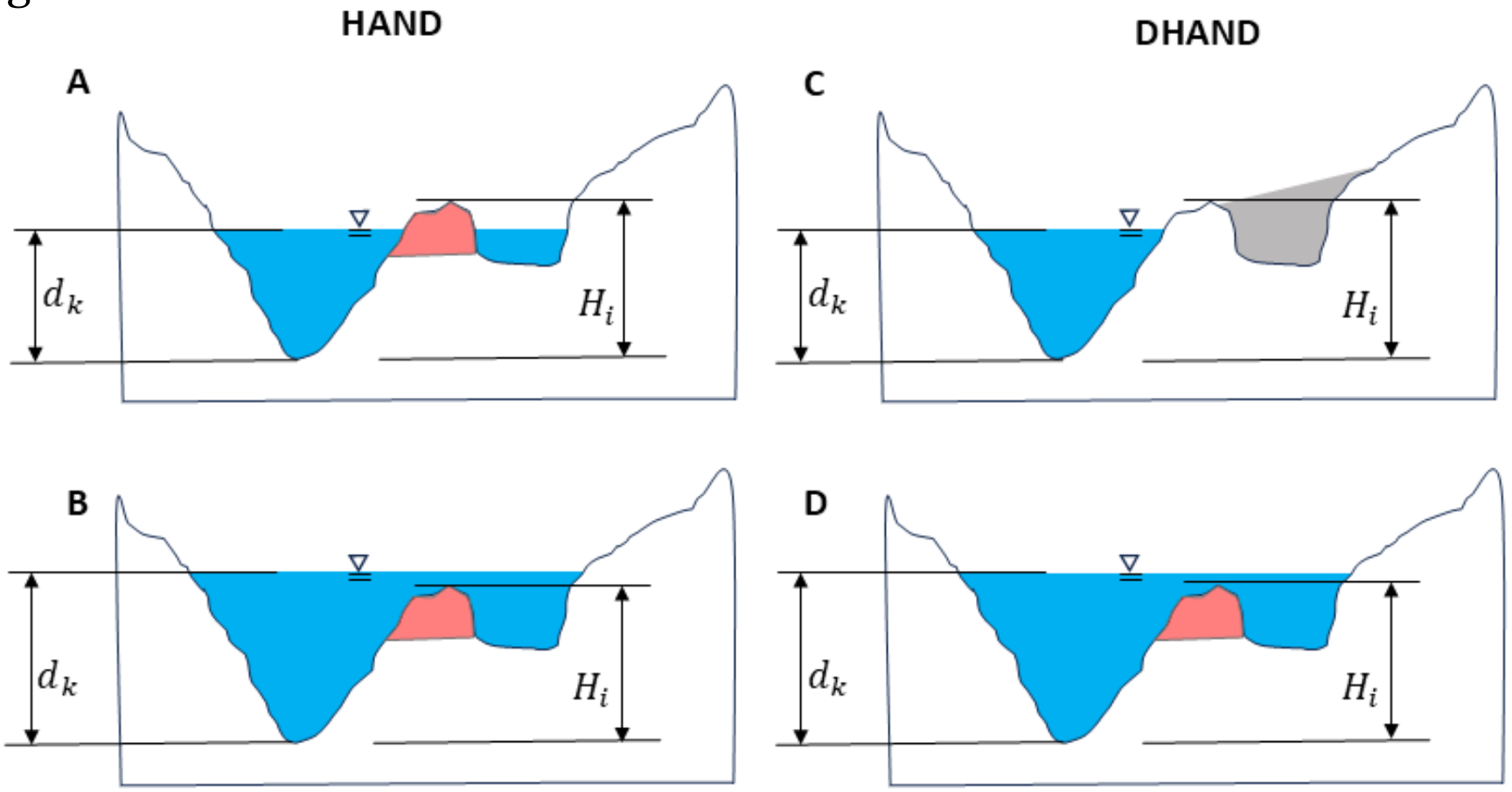




Reach-integrated properties
Based on work of Zheng et al. (2018)

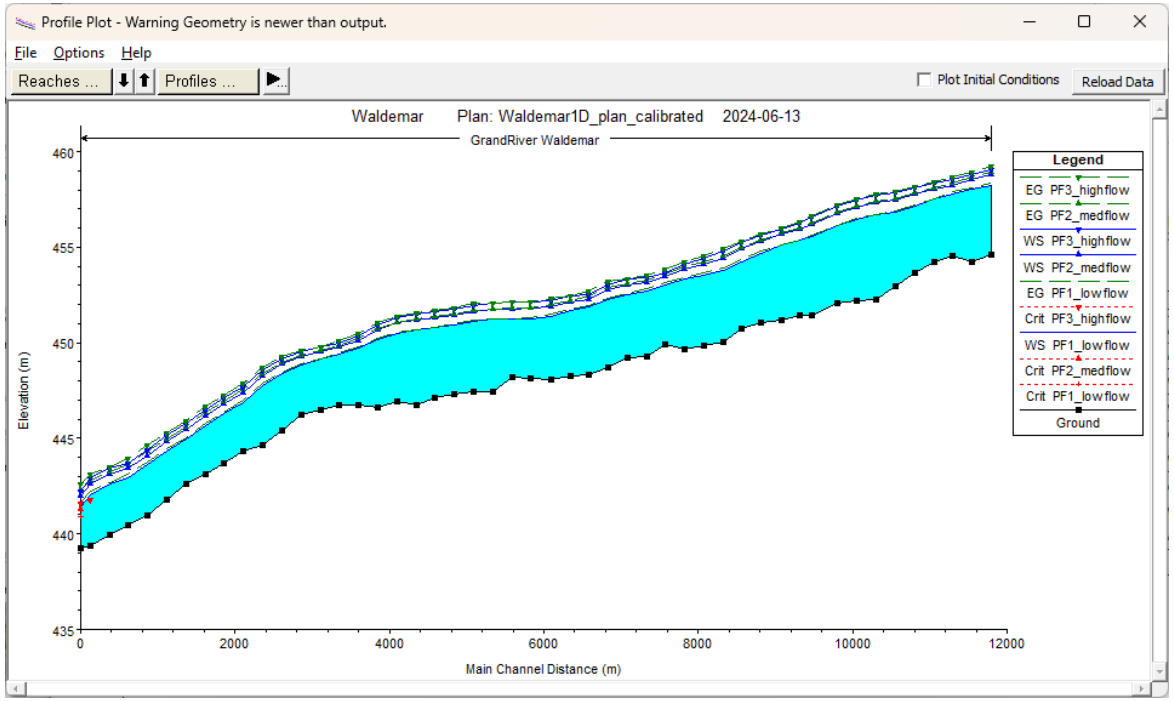
Methodology – Dynamic HAND (DHAND)

- Novel method developed – Height Above Nearest Drainage (HAND) applied as function of depth, Dynamic HAND (DHAND)
- Conditional breaching/filling to maintain landscape connections
- Default HAND leads to false positives
- Used in pre- and post-processing of inundated areas



Methodology – One-Dimensional Hydraulic Modelling

- Uses standard step method for steady flows
- Same methodology applied in HEC-RAS 1D (can ~emulate RAS 1D)
- Where things differ:
  - Pre-processing with reach-integration (if used)
  - Post-processing and mapping with HAND/DHAND



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Blackbird Workflow

DEM, Land Cover, Streamflows

Reach-integrated pre-processing

1D Standard Step Method to obtain depths at nodes

Mapping using DHAND

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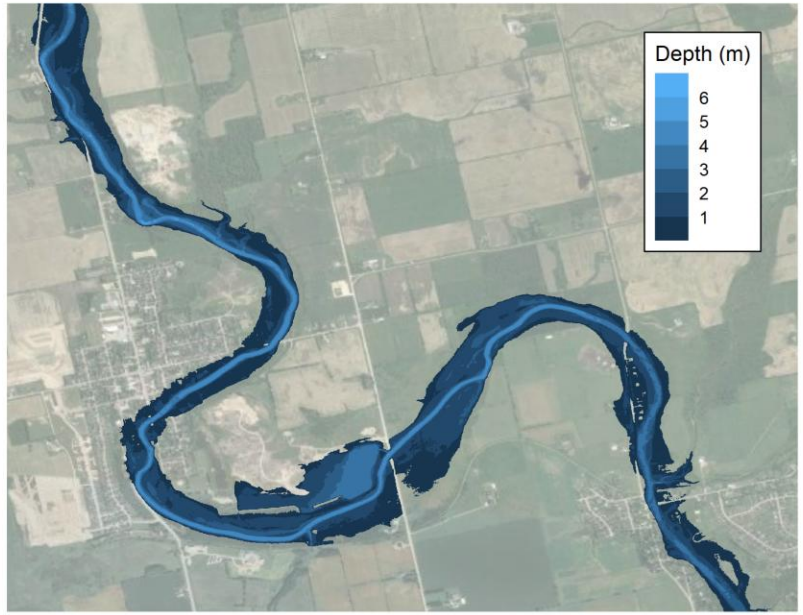
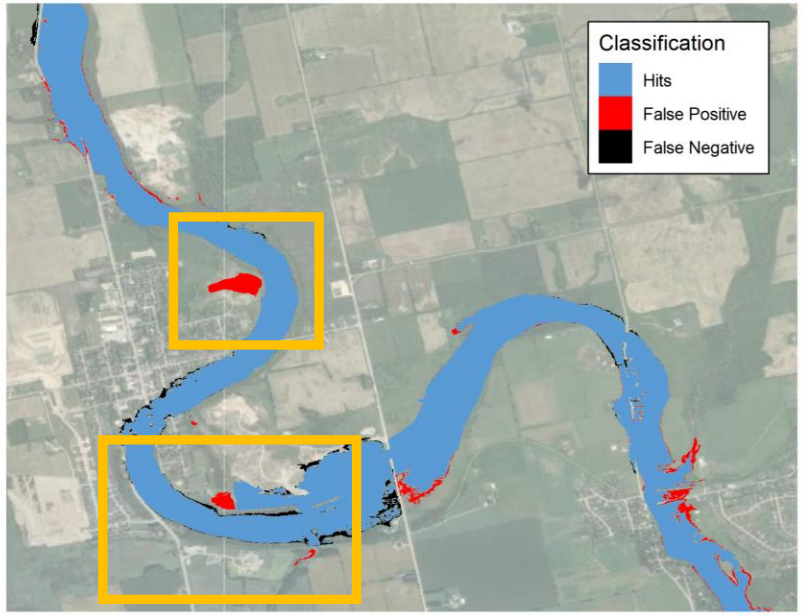
Case Study – Waldemar

- Benchmarked against 2D
  - HAND-Manning
  - HEC-RAS 1D
  - Blackbird
- 2D ~10,000 times slower
- Blackbird was the only model to avoid false positives due to landscape disconnection

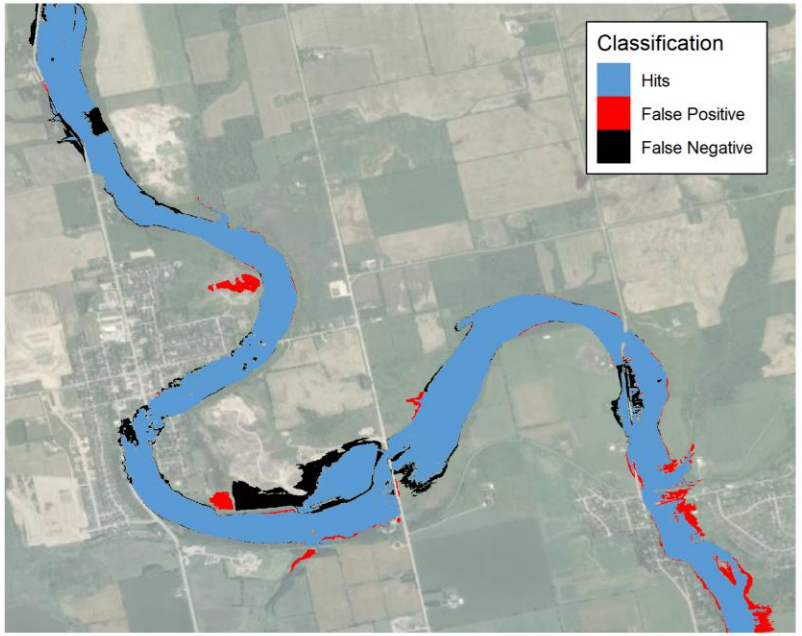
A - HEC-RAS 2D Model Depths



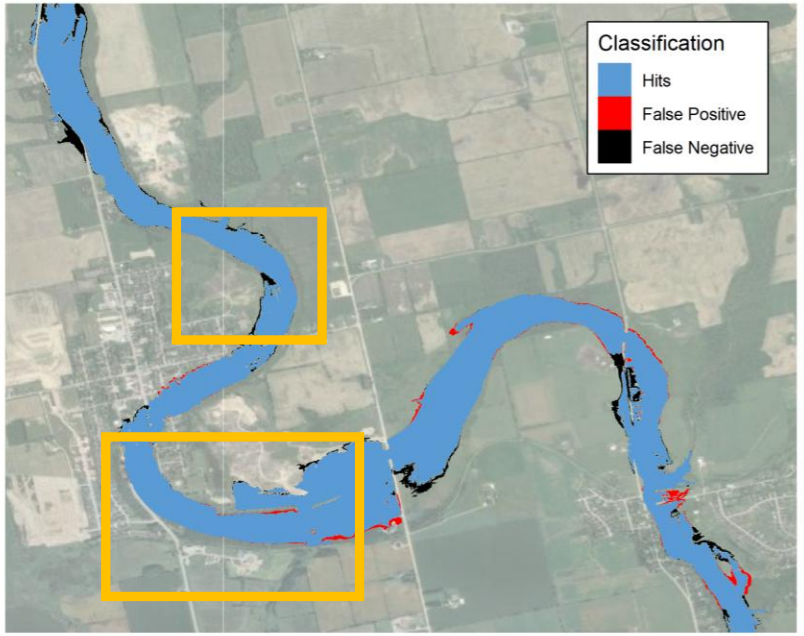
C - HEC-RAS 1D Model Comparison



B - HAND-Manning Model Comparison

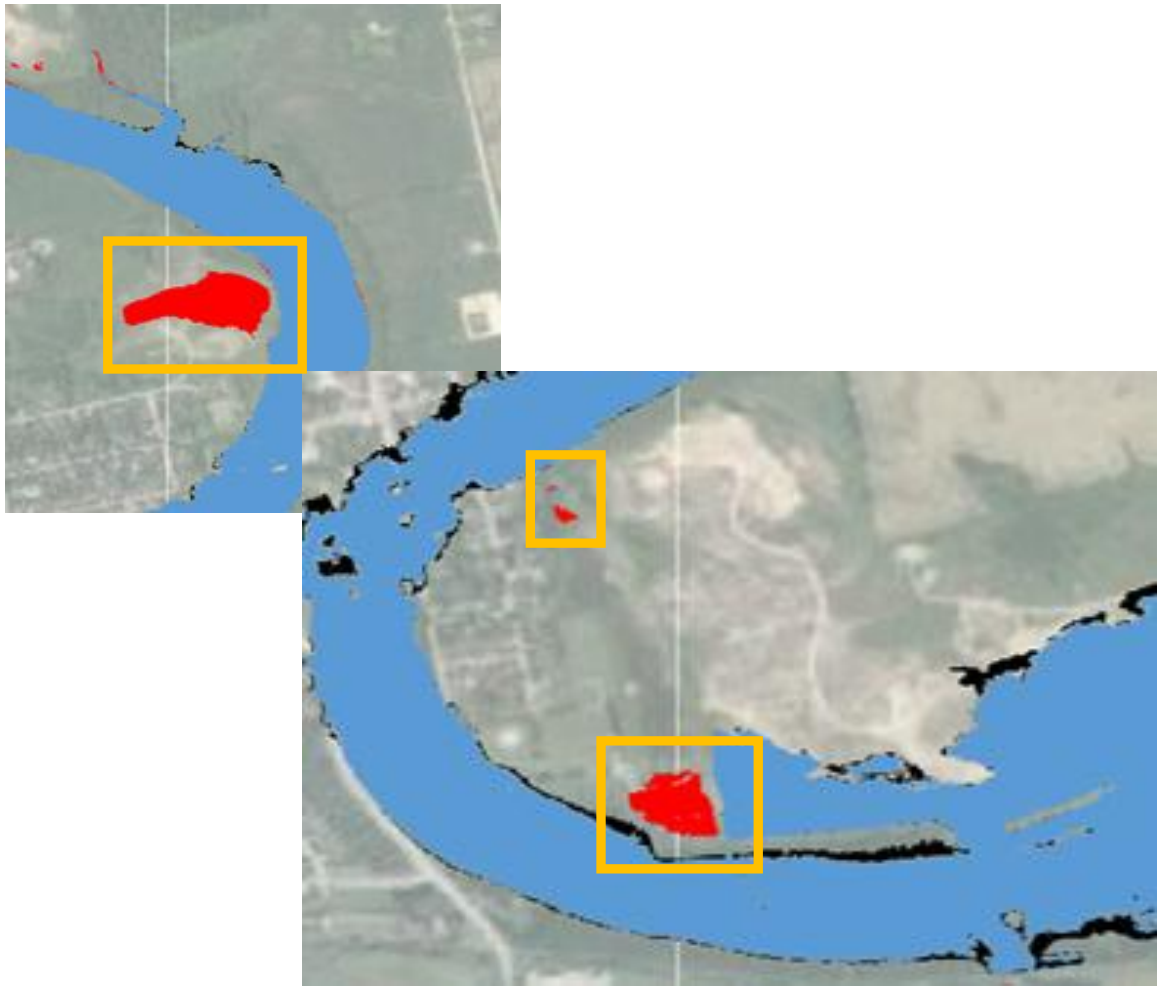


D - Blackbird Model Comparison

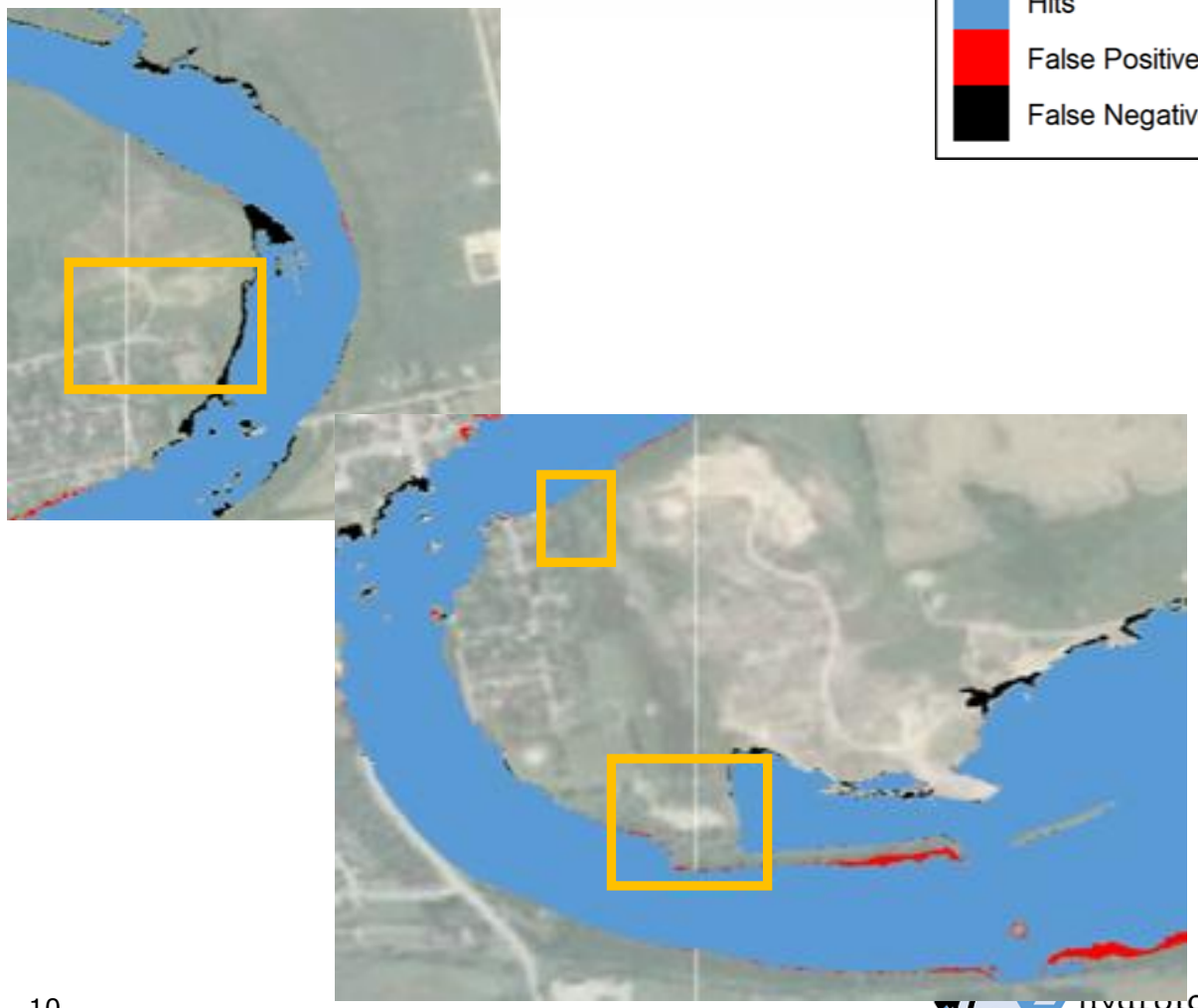


Case Study – Waldemar

C - HEC-RAS 1D Model Comparison



D - Blackbird Model Comparison



Blackbird C++ Alpha Version Available Now!!

Fast

- Blackbird methodology
- C++ Speed

Flexible

- Command line .exe
- Insert into workflows

Familiar

- Raven-like setup

https://heronhydrologic.ca/blackbird/

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Input Files

- Blackbird Input Text Files
  - .bbi file – primary input file
  - .bbg file – geometric info
  - .bbb file – boundary conditions
- GIS Files
  - .tif and .shp – geospatial data
  - .nc – to be added!

```
## Blackbird Model Input File (.bbi)
#

### General Model Setup Options ----
:ModelType STEADYFLOW
:RegimeType SUBCRITICAL
:Tolerance 0.003
:IterationLimit 50
:WSLSplit 0.7
:ToleranceNormalDepth 0.001
:IterationLimitNormalDepth 50
:WSLSplitNormalDepth 0.4
:MaxRHRatio 2
:MinRHRatio 0.5
:ExtrapolateDepthTable TRUE
:NumExtrapolationPoints 20
:FrictionSlopeMethod US_FRICTION
:EnforceDeltaLeff FALSE
:ReachLengthDelta 0.3
:ManningCompositeMethod EQUAL_VELOCITY
:SilentRun FALSE
:DHANDMaxDepth 9
:DHANDDepthStep 0.05
```


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Output Files

- Blackbird_errors.txt
  - Errors and warnings
- HydraulicOutput.csv
  - Hydraulic info of each streamnode
- bb_results_depth_<flow_profile_index>.tif
  - Depth rasters of each flow profile

nodeId	reachId	station	flow	wsl	depth
2	1	284.53	156.2	458.07	3.17
3	1	554.37	156.2	457.84	3.22
4	1	831.99	156.2	457.55	2.89
5	1	1100.17	156.2	457.05	2.78
6	1	1383.86	156.2	456.71	3.20
7	1	1669.21	156.2	456.35	3.14
8	1	1943.54	156.2	456.08	3.49
9	1	2222.54	156.2	455.82	3.54
10	1	2498.58	156.2	455.29	3.20

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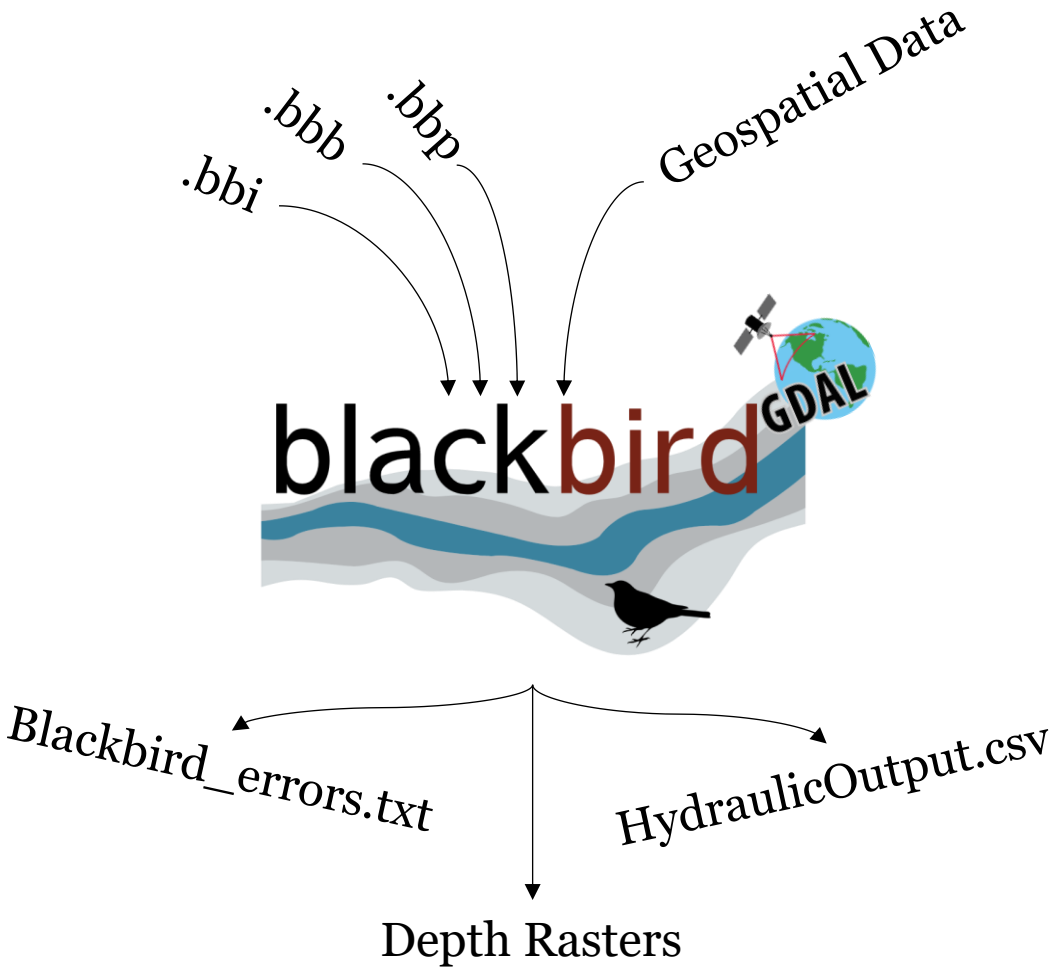
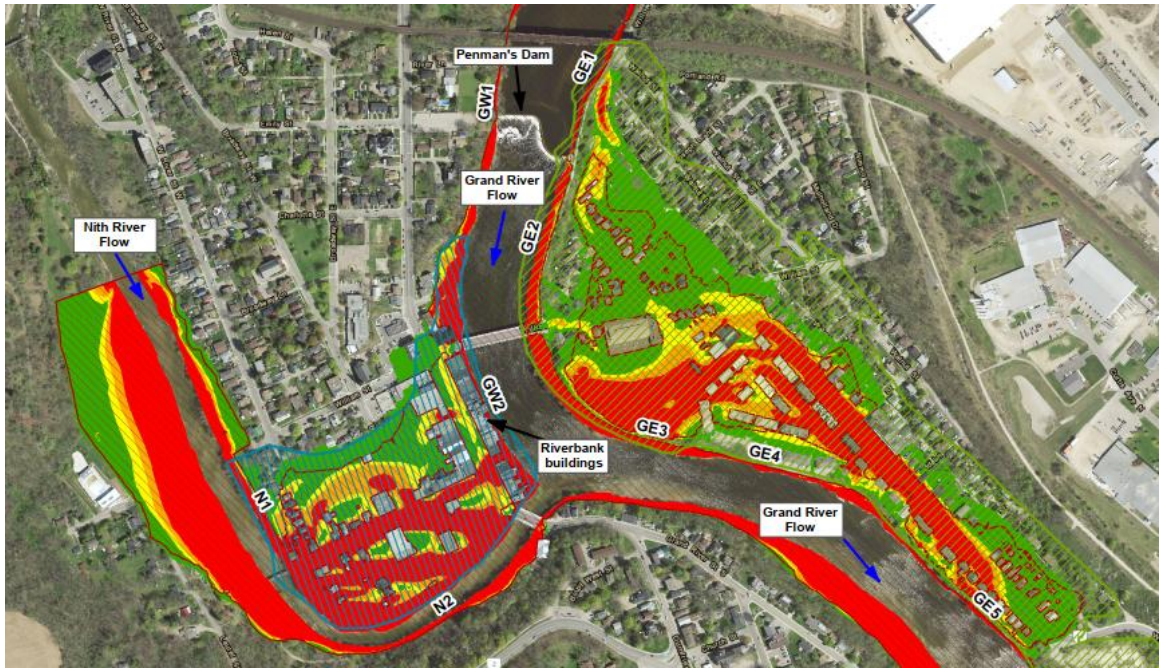
Running Blackbird

- Download blackbird.exe
- Download and configure GDAL
- Ensure input files are set up
- Run Blackbird!
  - blackbird.exe <modelname>
- Check warnings and use output



Climate Change Considerations

- Traditional approach of reviewing flood map PDF files won't cut it in the future
- Consider:
  - Extreme events
  - Joint probabilities at confluences
  - Localized storms and timing of peaks
- Climate Change analysis
  - Multiple scenarios (RCP 4.5 or 8.5)
  - Parametric and flow uncertainty



- Running slow 2D models and archiving results once is not the right approach!

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Ongoing and Future Projects

- Applying Blackbird to a challenging area with mapping completed under FHIMP through a pilot project with NRCAN
  - Flat terrain, overlapping floodplains
  - Cross-section issues
  - Multiple hydraulic structures
- Investigating how Blackbird can regionalize hydraulic structures efficiently

- Actively looking for co-applications under FHIMP to test Blackbird – Contact us if interested!

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Conclusions

- Blackbird is a new approach to hydraulic modelling and flood mapping
- Maintains speed and scalability in producing flood maps while maintaining quality
- Suitable for regional scale flood mapping approaches, inundation forecasting
- Blackbird.exe can be tied directly into workflows, such as FEWS
- Free executable available now with sample files and User's Manual
  - heronhydrologic.ca/blackbird

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Questions?

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Blackbird Resources

- Download it free today! heronhydrologic.ca/Blackbird
- Blackbird User's Manual
- Blackbird pre-print article
- Blackbird R package
- Drop us a line - hello@heronhydrologic.ca

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