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Implementation of an upscaled probabilistic fill-and-spill method to simulate wetland-dominated landscapes

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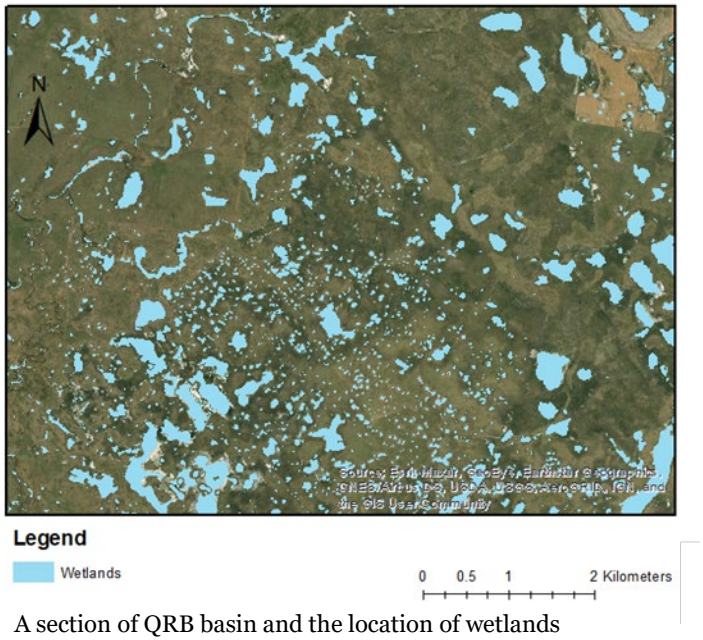
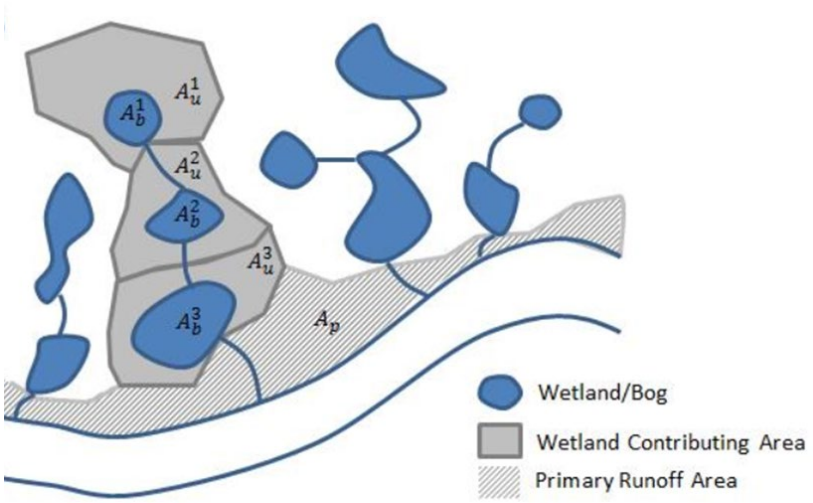
Introduction

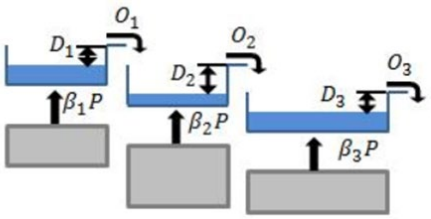
Depressional wetlands in low gradient landscape



A section of QRB basin and the location of wetlands (NWCF2016, wetland classified map)

How to conceptualize the effects of depressional wetlands on hydrological response of the basin?

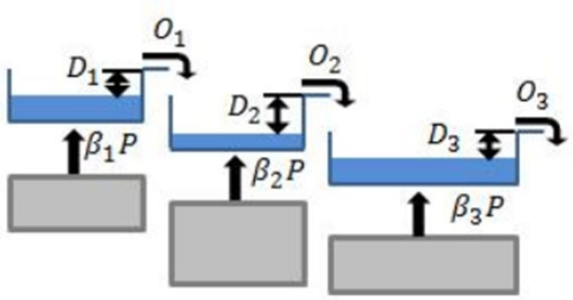




Upscaled Wetland Fill-and-Spill Model (UWFS)

Available water to the single wetland cascade (I_1):

$$I_1 = \left(\frac{A_u^1}{A_b^1} \propto +1\right) \times P = \beta_1 \times P$$



Potential and actual outflow from single wetland (O_1):

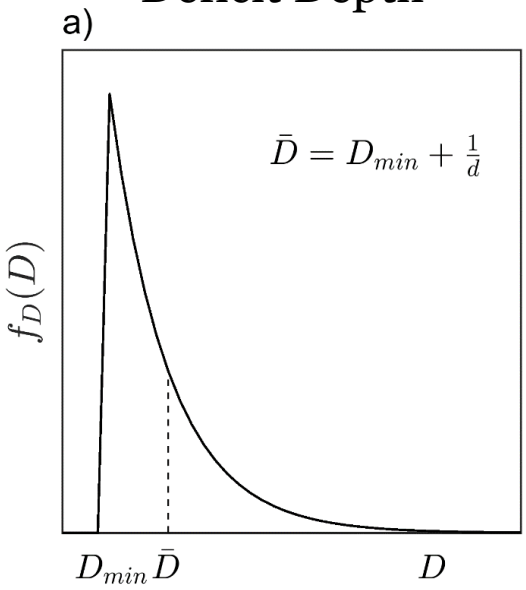
$$O_1^* = \beta_1 P - D_1, \;\; O_1 = \max(O_1^*, 0)$$

β - Concentrating factor
D- wetland deficit
A_b- wetland/bog area
A_u- contributing area

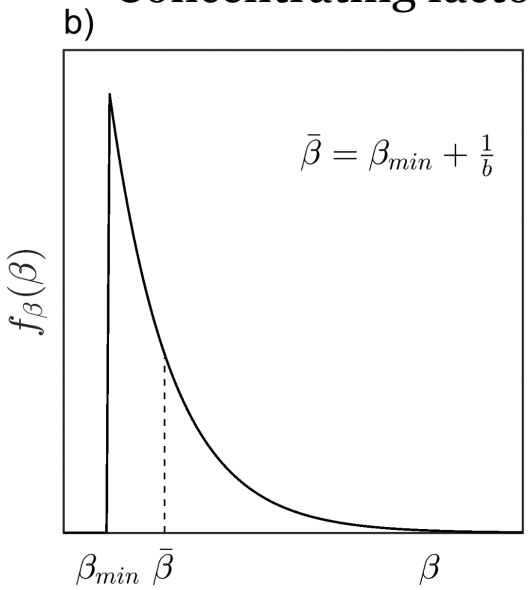
Upscaled Wetland Fill-and-Spill Model (UWFS)

- Defining the spatial heterogeneity of the watershed

Deficit Depth



Concentrating factor



- Distribution of outflow from the basin:

$$f_{O_1^*}(O_1^*) = \int_{-\infty}^{\infty} f_{\beta P}(x) f_D(x - O_1^*) dx$$

Analytical vs Monte Carlo solution

To find actual runoff from the basin

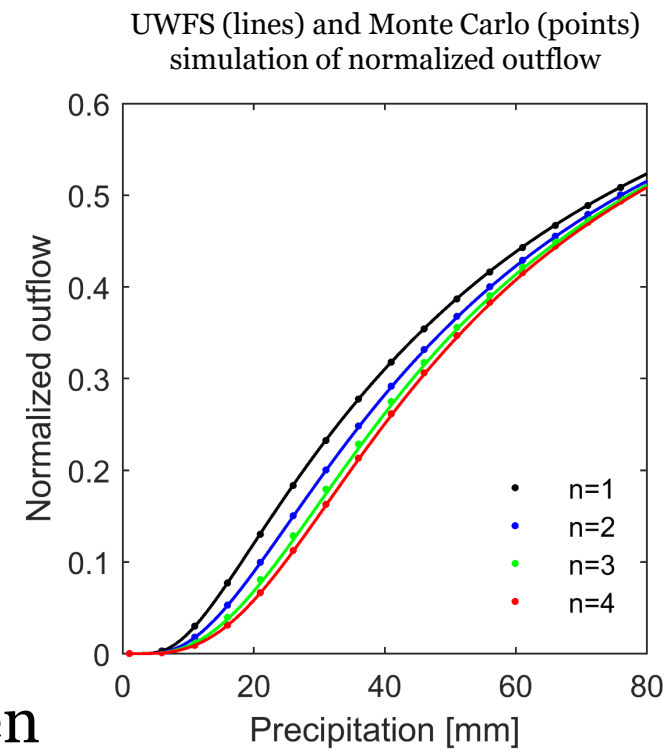
- Analytical solution to Mean outflow:

$$\langle O \rangle = \int_0^\infty O f_O(O) dO$$

- Monte-Carlo solution:

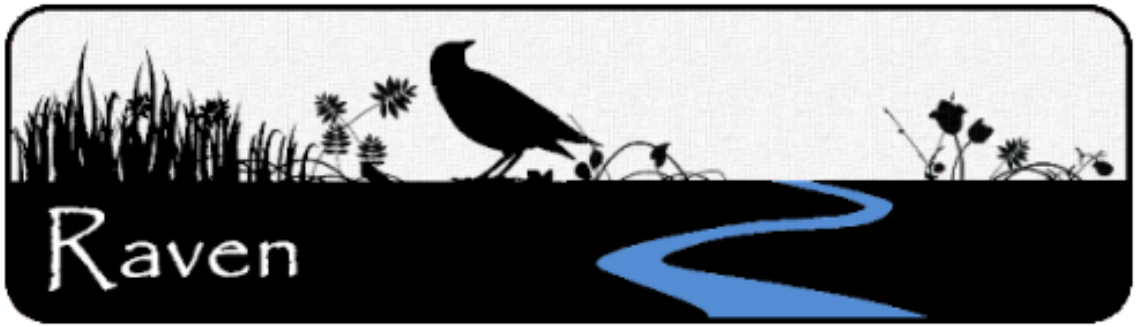
We sample from the deficit and concentrating factor distribution and then solve the water balance equation:

$$O_1^* = \beta_1 P - D_1, \;\; O_1 = \max(O_1^*, 0)$$



UWFS algorithm in RAVEN

- Raven is a fast and flexible hydrologic modelling framework
- It has over 100 hydrological process algorithms
- It is open access and new hydrological processes could be implemented in the source code written in C++.



http://raven.uwaterloo.ca/

Case study: Moose jaw river watershed

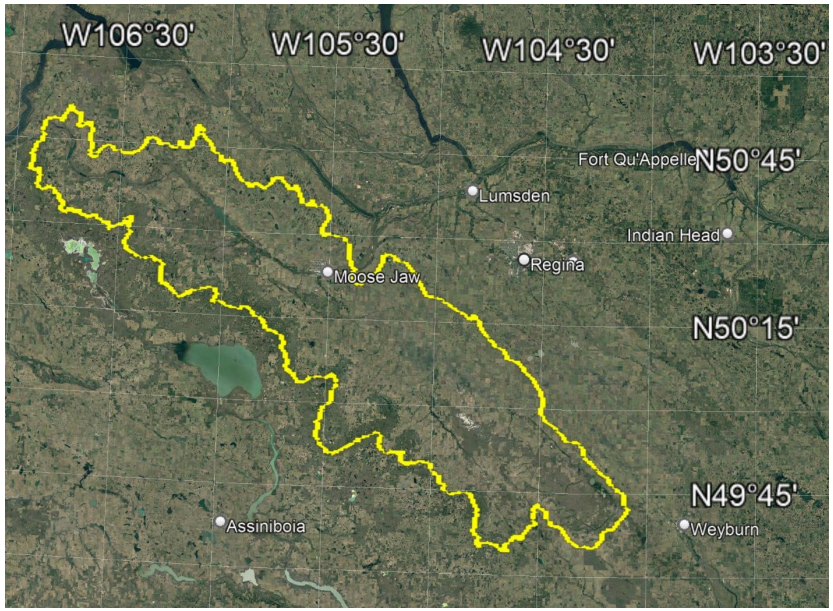
Located inside Qu'Appelle River Basin in Saskatchewan, Canada

Area: 9,230 km^2
Study period 2000-2017

Meteorological forcing data:
RDRS-v2 (CaSPAr website)

Historical hydrometric data of the stream flow:
Water Survey Canada

The shapefiles of the Qu'Appelle river basin and its sub-basins:
ECCC hydro network

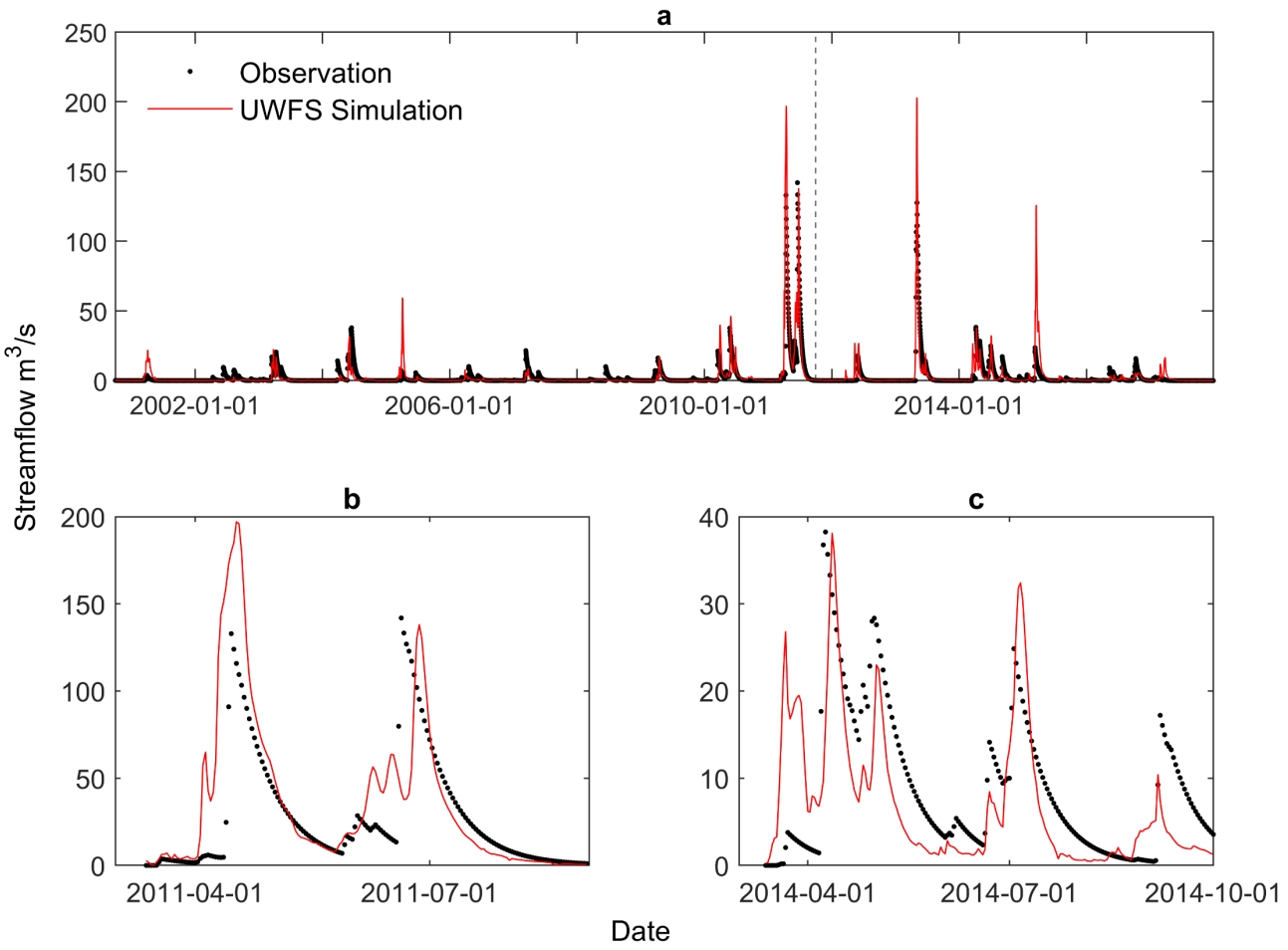


Calibration using OSTRICH

- Parameter estimation at this basin is been done using Ostrich.
- Ostrich is configured to optimize the Raven model using Dynamically Dimensioned Search (DDS) Algorithm.
- A total of 23 parameters (water balance, land use, and soil parameters) and thousands of iterations are set for optimization.

Metric	NSE	KGE	PBIAS
Calibration	0.61	0.68	5%
Validation	0.65	0.6	20%

Results


a
b
c
Observation
UWFS Simulation
Streamflow m^3/s
Date
250
200
150
100
50
0
40
30
20
10
2002-01-01
2006-01-01
2010-01-01
2014-01-01
2011-04-01
2011-07-01
2014-04-01
2014-07-01
2014-10-01

Concluding remarks

- The upscaled fill-and-spill model presented here is the first closed form upscaled runoff model which explicitly considers lateral flow based concentrating water and wetland connectivity

- A low-parameter physically-based wetland model

- UWFS model is able to accurately simulate timing and peak magnitude of streamflow in low gradient landscape.

References

- http://raven.uwaterloo.ca/
- https://wateroffice.ec.gc.ca/search/historical_e.html
- https://caspar-data.ca/
- https://www.canada.ca/en/environment-climate-change.html
- https://www.ducks.ca/initiatives/canadian-wetland-inventory/

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