Hysteretic and Gatekeeping Depressions Model (HGDM)

- Model calculates connected/fraction of a basin/grid square without calibration
  - All parameters have physical meaning, so can be determined by GIS
  - Means that it can work at sub-basin scales
  - Based on Shook, K., Papalexiou, S., Pomeroy, J.W., 2021. Quantifying the effects of Prairie depressional storage complexes on drainage basin connectivity. Journal of Hydrology 593, 125846.

How it works

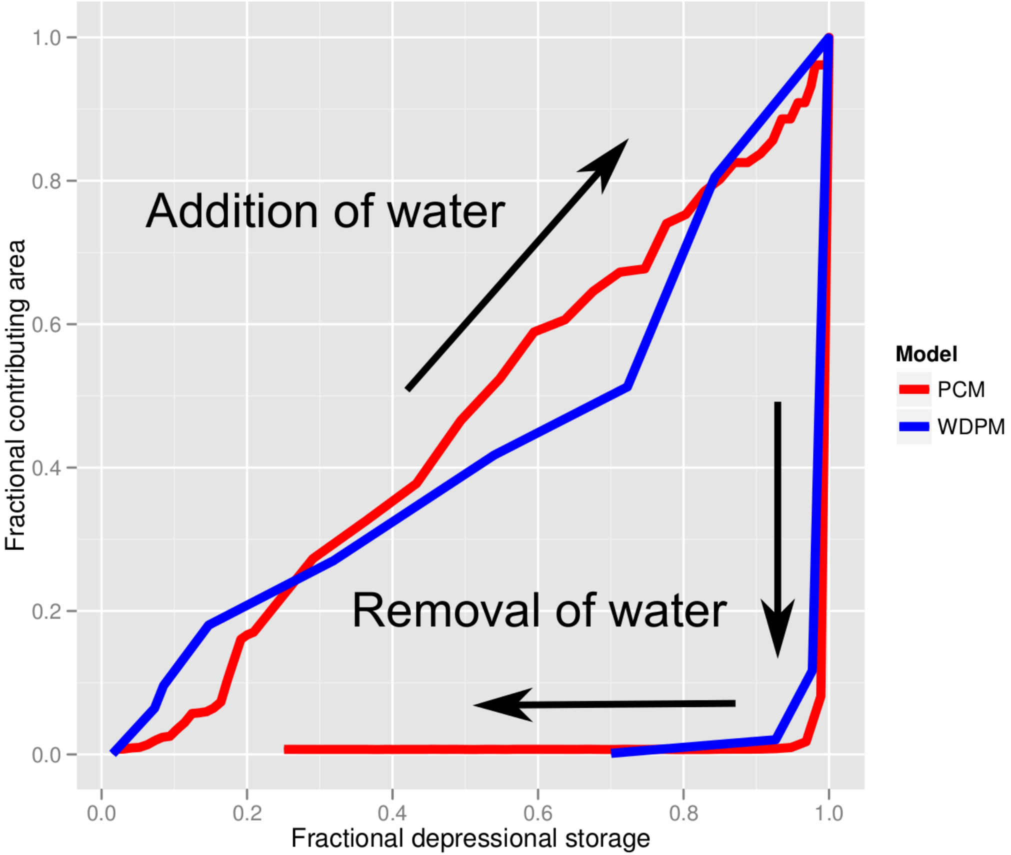
- Calculates varying connected/contributing area fractions caused by 2 types of storage
  - Small depressions: show hysteresis, but not gatekeeping
  - Large depression: shows gatekeeping but not hysteresis

Small depressions

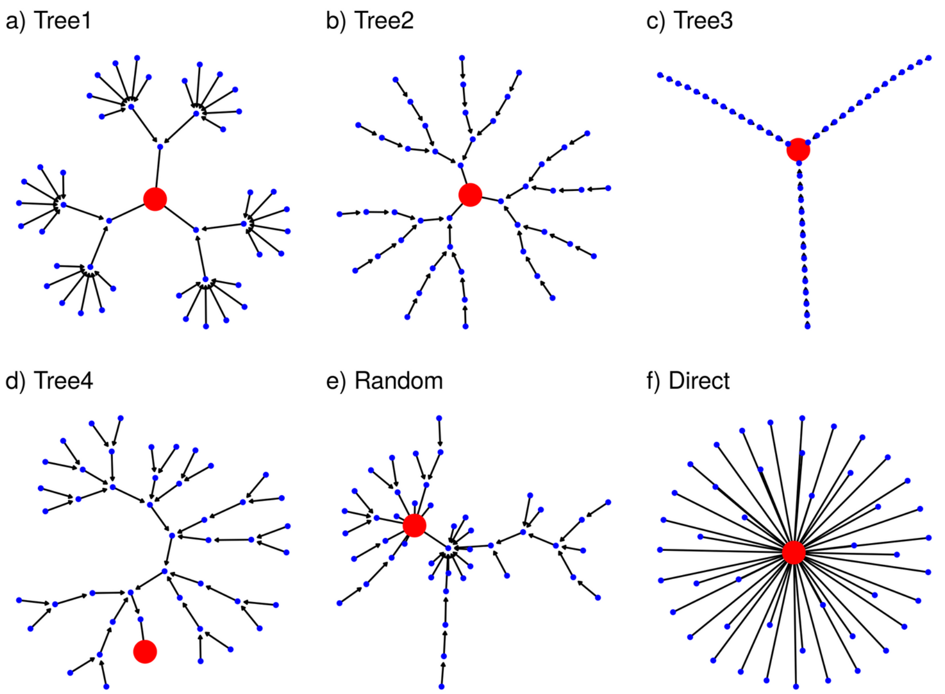
- The relationship between water storage and the connected/contributing fraction is hysteretic
  - Connected/contributing fraction is zero after evaporation/infiltration because all depressions are below their outlets
  - Refilling of depressions differs from initial filling, because depressions empty differently from their filling

PCM and WDPM connected/contributing fractions

- Smith Creek sub-basin 5
- Few large depressions, so good example of effects of small depressions



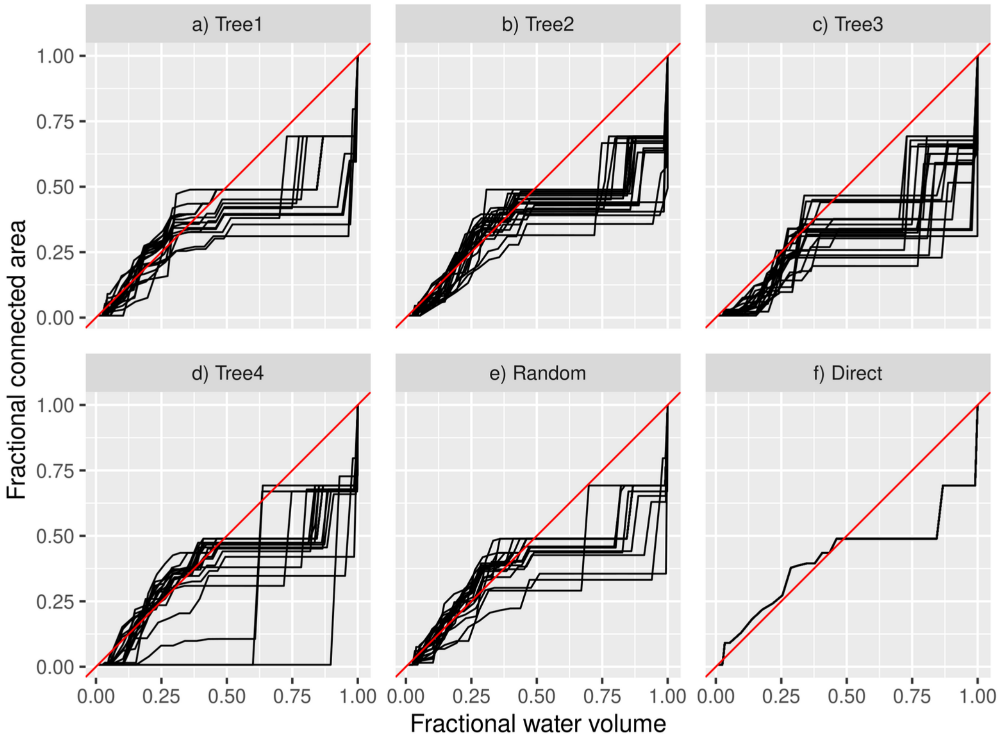
Effects of number and arrangement of depressions



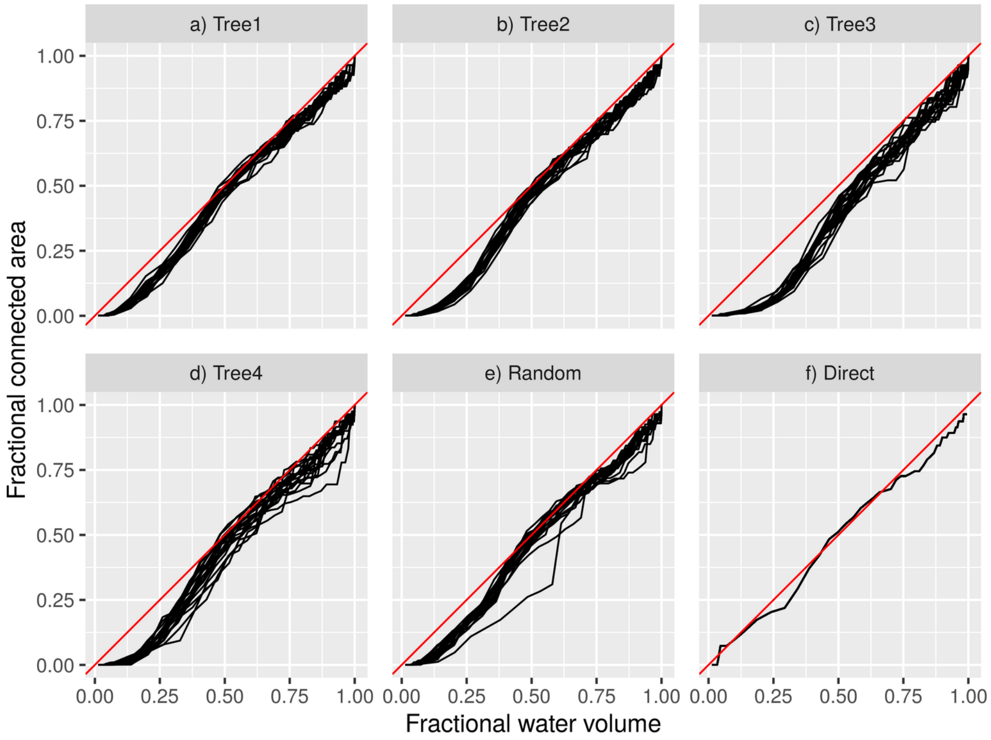
- Shook et al (2021) used synthetic networks of depressions
- Allowed analysis of effects of number of depressions and their spatial arrangement on connected fractions

As the number of depressions increases, their spatial arrangement becomes less important…

46 depressions arranged randomly

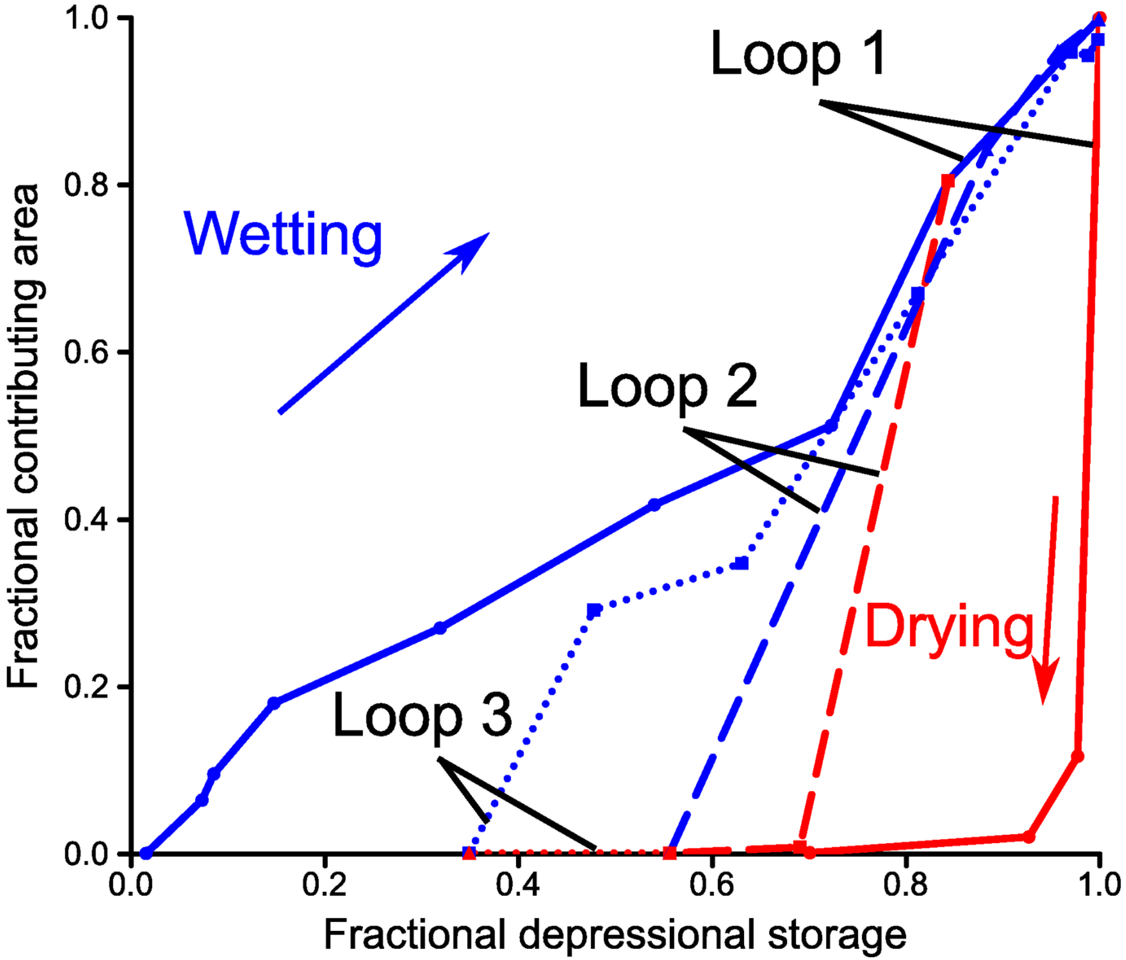


736 depressions arranged randomly



WDPM emptying and re-filling

- Smith Creek sub-basin 5
- Shows hysteretic loops

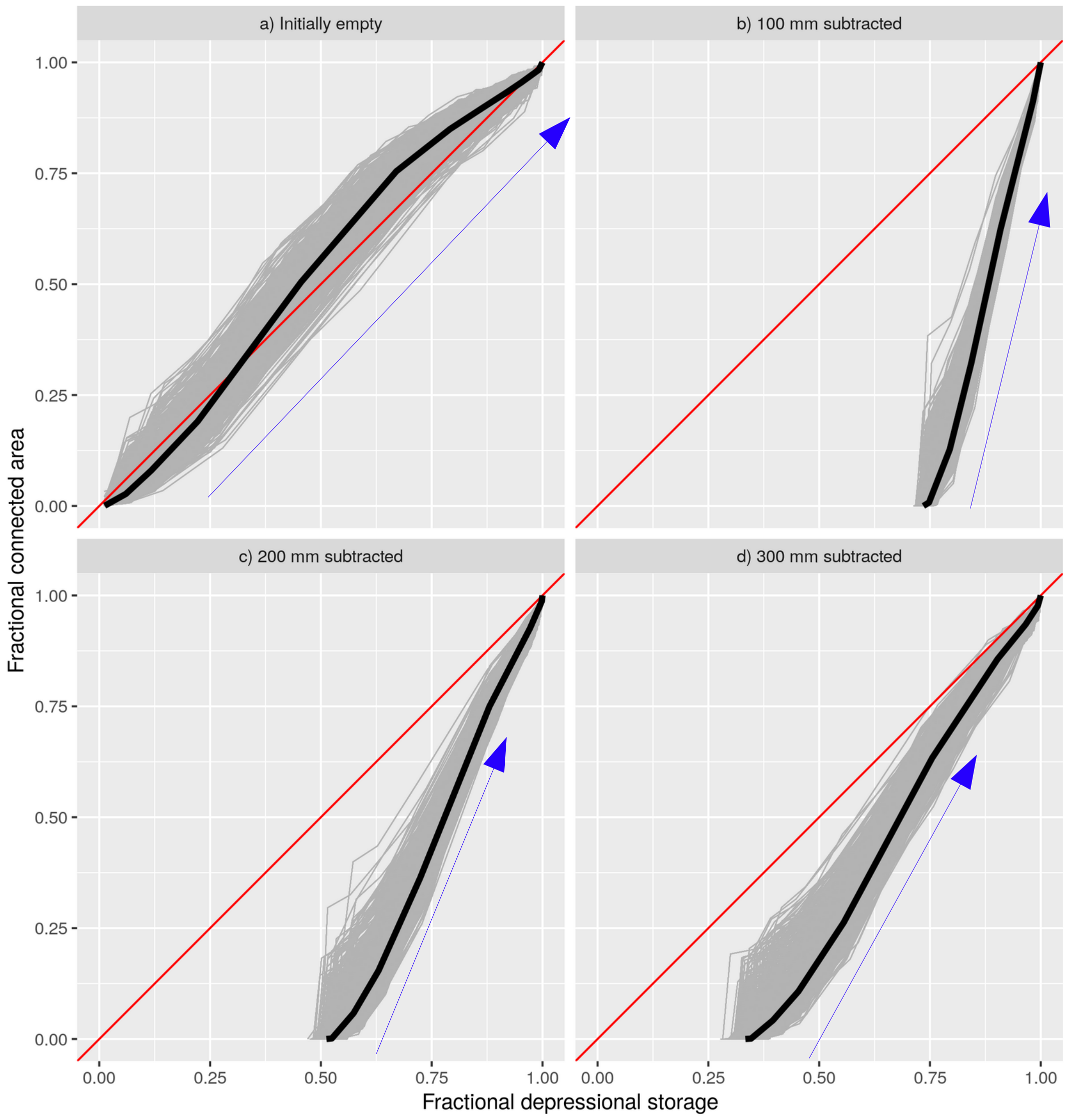


Filling curve simulations

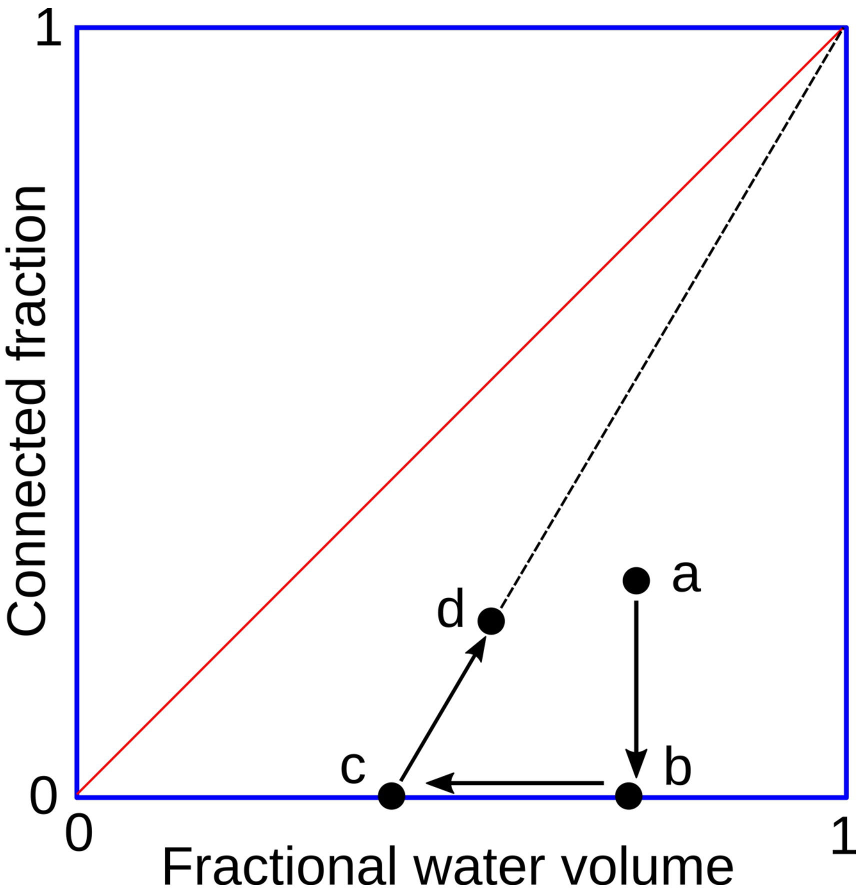
Based on

1. Pareto II distribution of depression areas
2. Hyashi-van der Kamp area-volume scaling
3. Copula between depression and basin areas

- 10,000 realizations of 1,000 depressions



Linear hysteresis model



Model state = (FWV, CF)

Initial condition = a

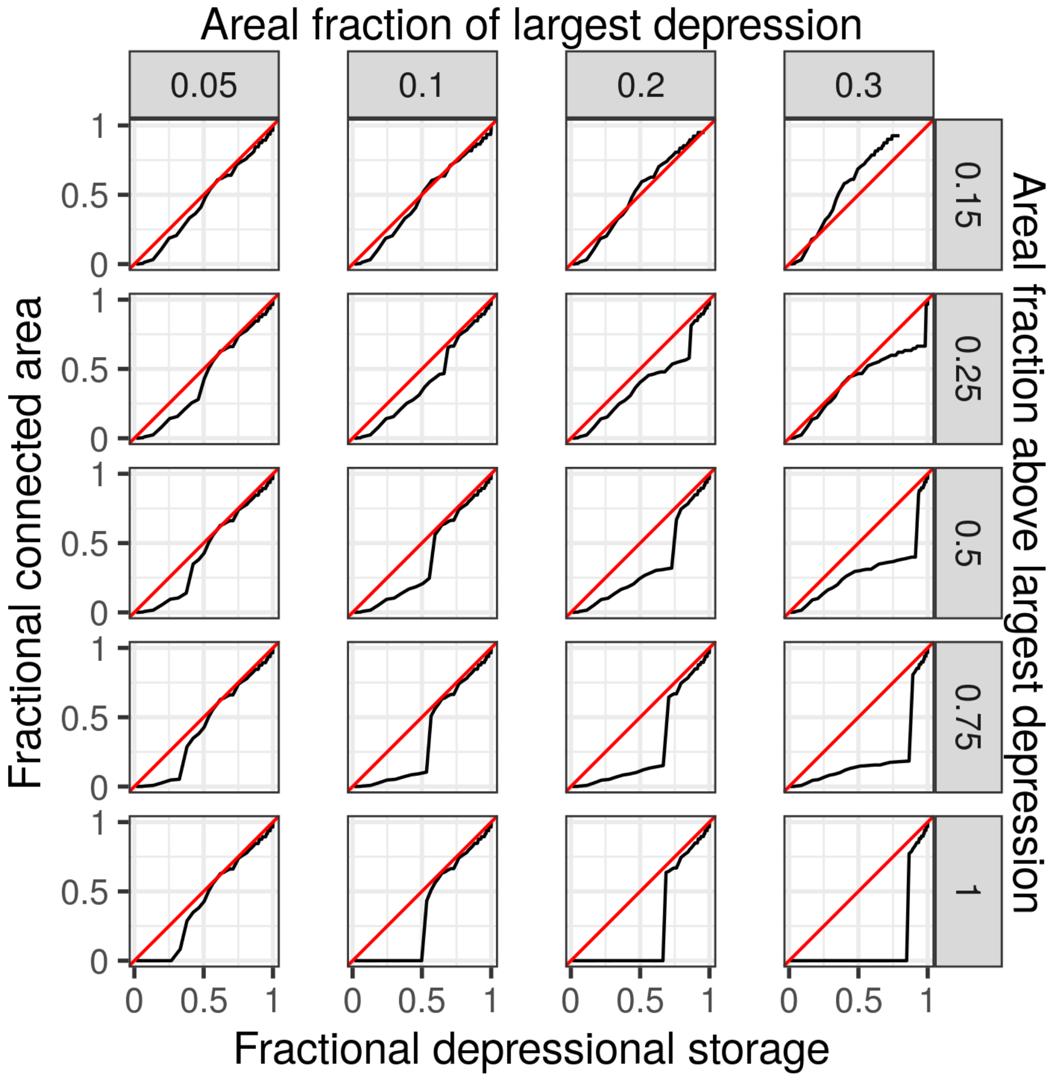
Water removed -> b

More water removed -> c

Water added -> d

Large depression

- In the real world, the largest depression will often be larger than predicted by a Pareto distribution
- If largest depression is large (> ~2% of total area) its gatekeeping is also large
  - Its location in the basin will control the gatekeeping
- When large depressions are modelled individually, their behaviour is not hysteretic



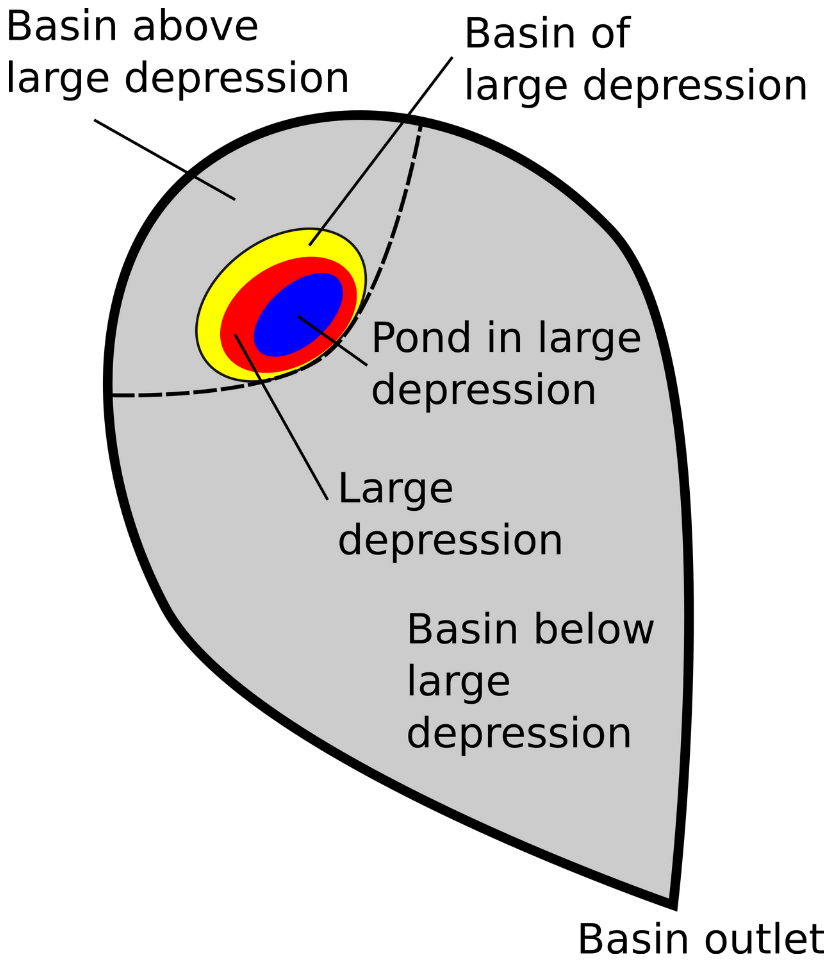
PCM simulation of effects of location of 1 large depression in a basin

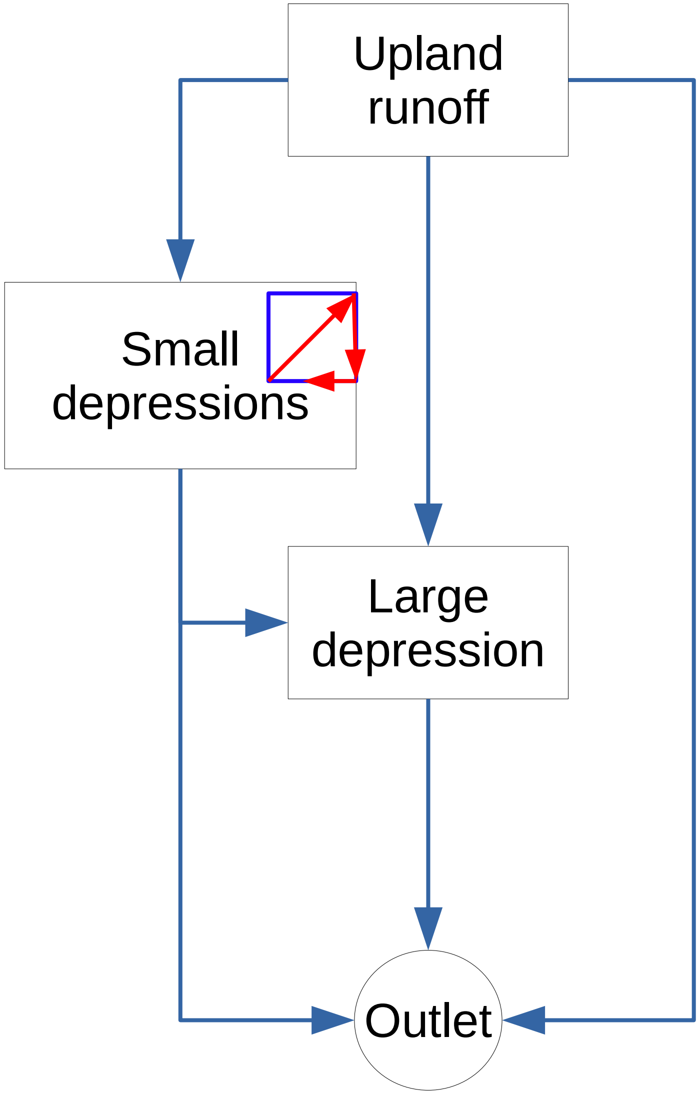
- If the largest depression is small then its location in the basin is not very important
- When the depression is large, its location in the basin matters

Large depression model

Large depression is filled by

1. Direct precipitation
2. Runoff from its basin
3. Flows from small depressions above it





HGDM

- Upland runoff goes to small depressions, large depression and outlet
- Small depressions contribute flow to large depression and outlet
- Large depression only contributes to outlet when filled

HGDM state variables/parameters

- State variables
  - Small depression storage depth, and connected fraction
  - Large depression storage depth
- Parameters
  - Fraction of basin/grid occupied by small depressions
  - Max storage depths of small and large depressions
  - Fraction of basin/grid above large depression
  - Basin/grid fraction of large depression basin
  - Masaki-van der Kamp area-volume scaling for small and large depressions (to get area of direct rainfall/evaporation)

HGDM functions

- Function to add/subtract runoff/direct precip to small depressions
- Function to compute connected/contributing fraction of basin controlled by small depressions
- Function to add/remove water from large depression
- Functions to calculate current areas of water in large and small depressions
- Function(s) to route flows among units