Evaluation of the two stage ditch as a best management practice

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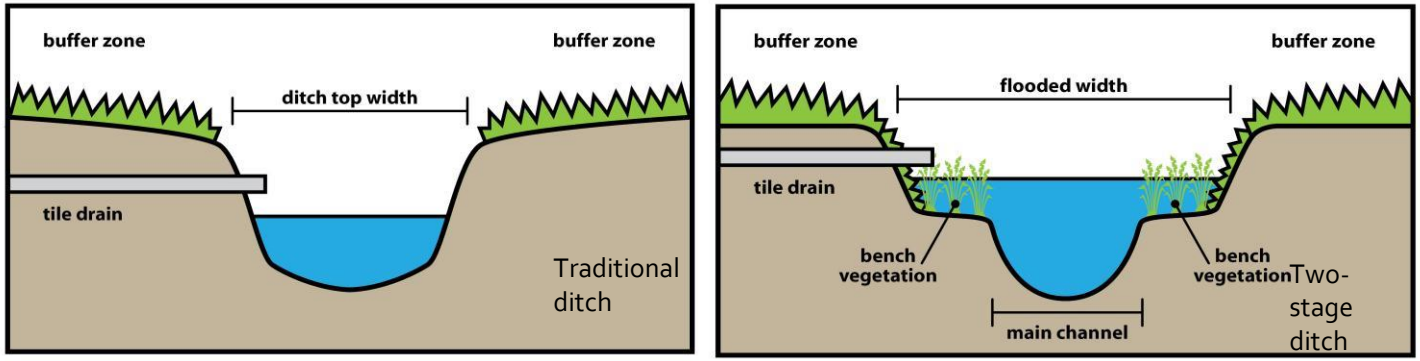
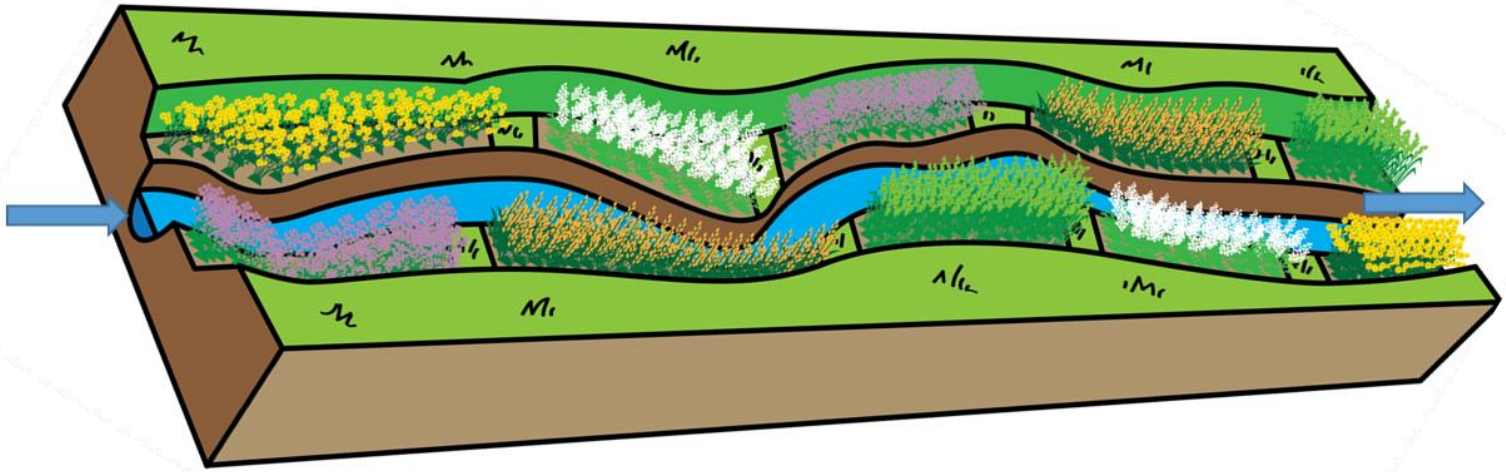
The concept of the two-stage ditch

- Two-stage ditch:
  - Stage 1 : main channel
  - Stage 2 : flood plain bench



- Dissipates the energy of high flows by letting it spread on the benches.
- Allows the sediment to set on the benches instead of being transported downstream.
- Increases the interaction time of the water with the benches and the plants that grow in them.

Impact of the two-stage geometry on in-stream processes



- Studies have shown:
  - Increased bank stability
  - Increased denitrification rates on the benches of the two-stage compared with the slopes of traditional ditches
  - Decreased nutrient concentrations from upstream to downstream

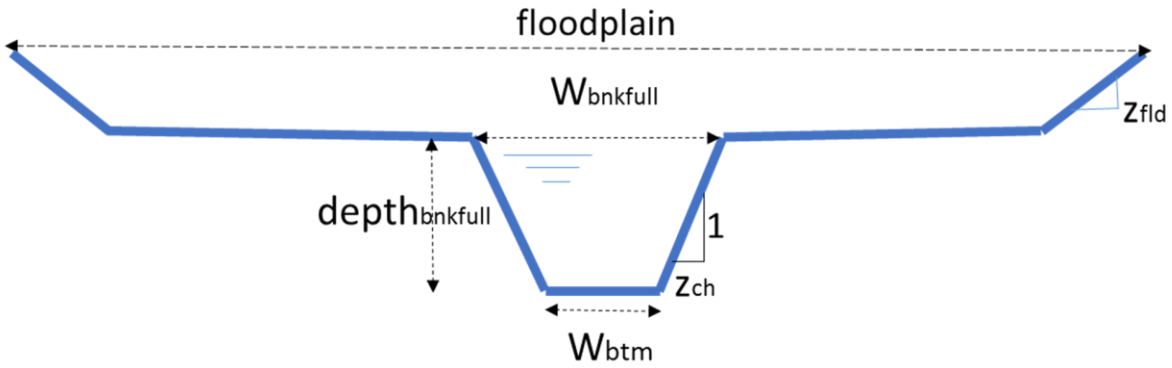
Why the need to model the two-stage ditch?

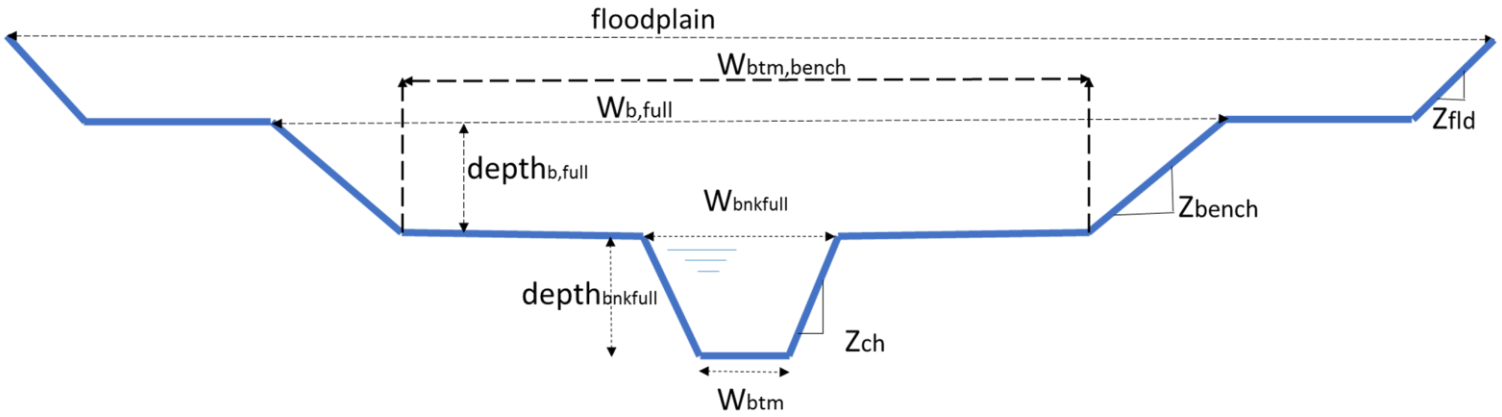
- Studies conducted have focused on two-stage ditches designed primarily for the purpose of increasing bank stability and maintaining a certain conveyance capacity.
- Field evaluation of the two-stage system is limited to certain stream reaches and specific cross-sectional dimensions.
- Representing the two-stage ditch in a physically-based model will allow evaluation of the potential of increased implementation of this practice.

Why SWAT?

- SWAT has been widely used to evaluate agricultural BMPs.
- SWAT has a channel water and nutrient routing scheme that is separate from the HRUs, which is essential for representing this in-stream practice.
- The use of sub-basins that drain to one particular reach, makes it ideal to look for a best location to implement a two-stage ditch.

Channel routing changes (channel geometry)





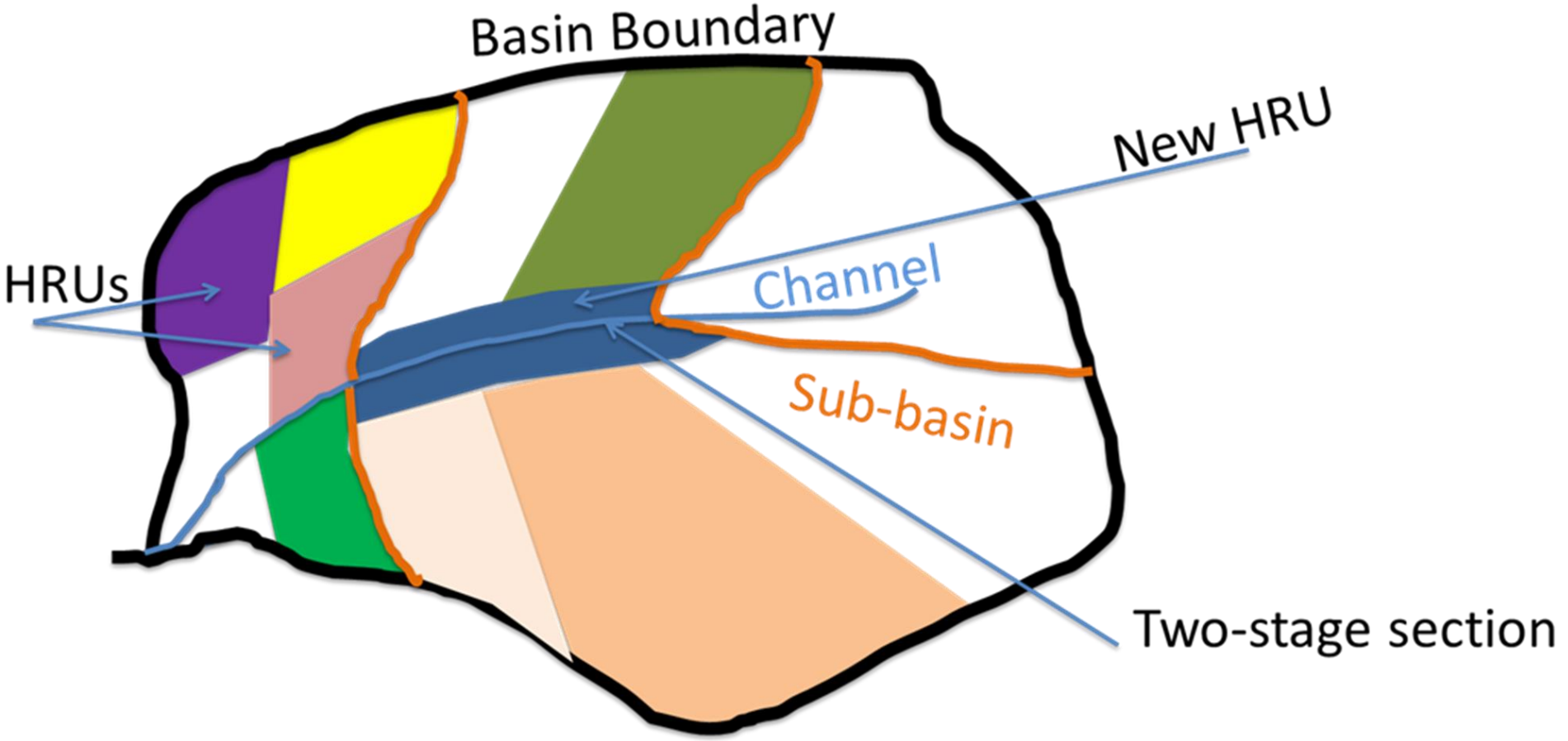
Changes made to the code (water routing)

- New calculations of cross-sectional area of flow and wetted perimeter
- Flow rates and velocities
- Transmission losses are re-assigned from bank storage to a new HRU

Changes made to the code (sediment routing)

- New calculations of:
  - Bank Shear Stress
  - Potential Bank Erosion
  - Area ratio of water in flood plain to total cross sectional area
  - Sediment deposition rates

Channel routing changes (nutrient routing)



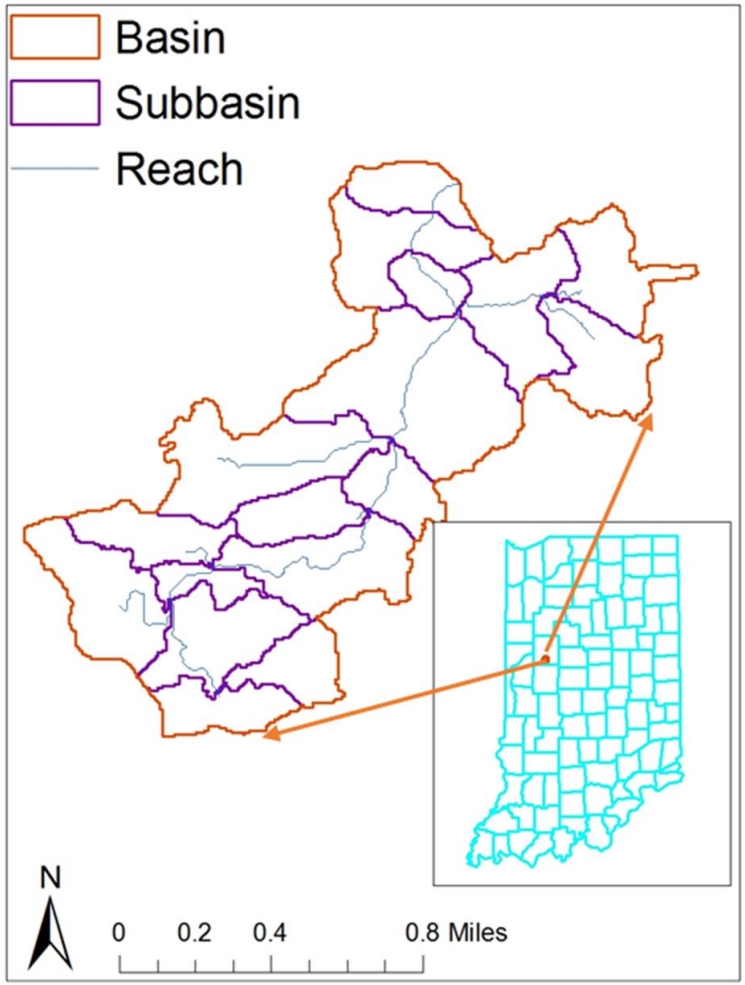
What goes into the new HRU?

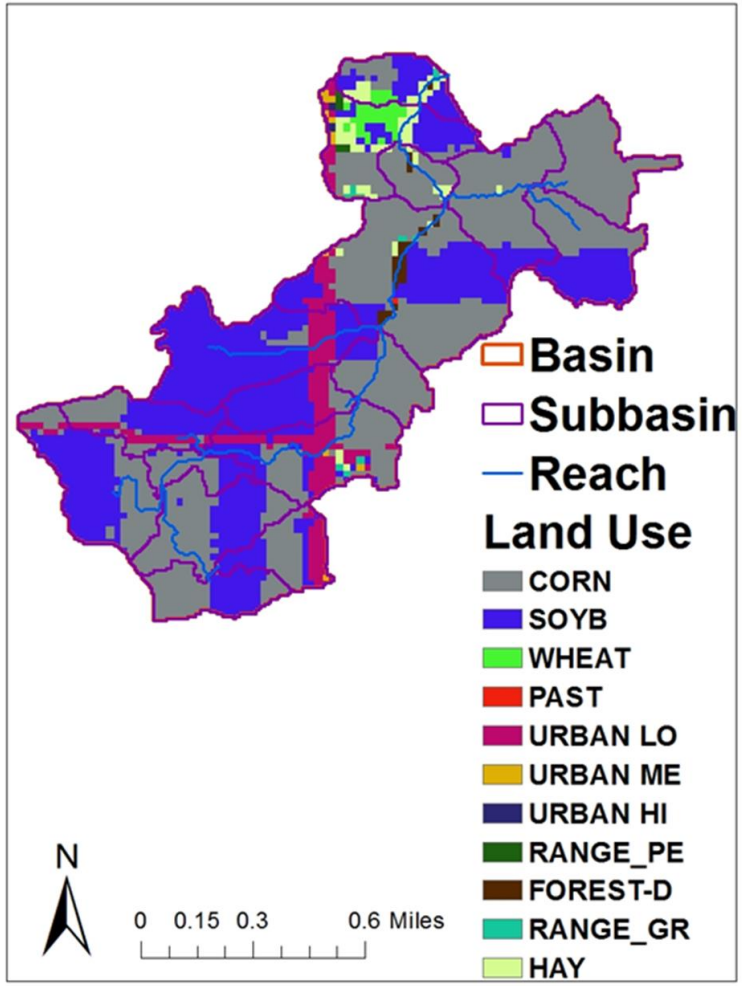
- The new HRU has the same characteristics as an adjacent to the stream HRU but with a different management operation file.
- All the weather inputs that go into the HRUs of the sub-basin.
- Transmission losses from the channel
- Soluble nutrients contained in the transmission losses
- Sediment that settles on the benches of the two-stage
- Sediment-bound nutrients from the sediment settling on benches

Channel routing changes (new parameters)

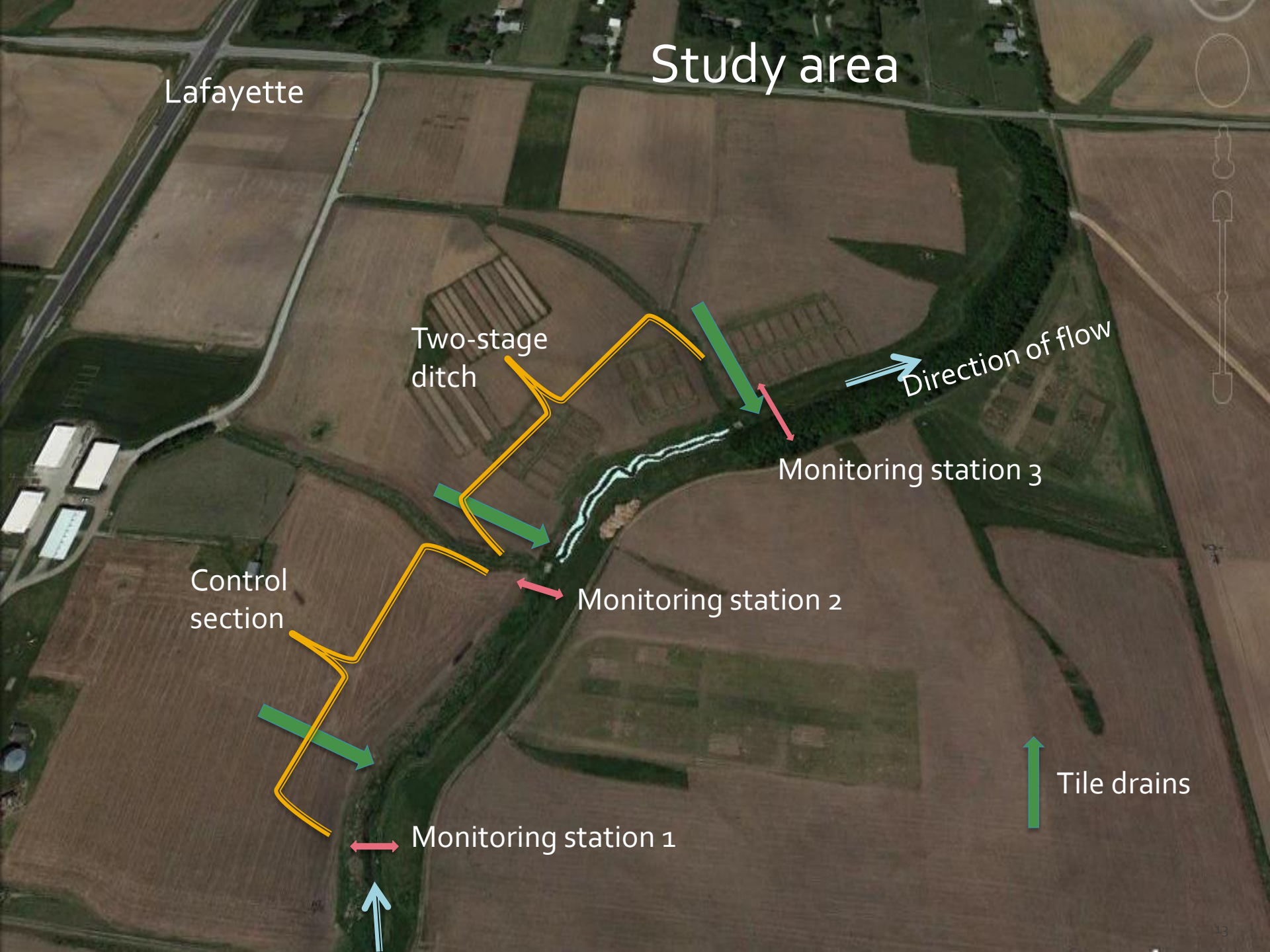
Parameter name	Definition	Input File	Source of potential values
$W_{btm,bench}$	Bottom width of the two-stage channel (m)	.rte	Data from surveying
z_{bench}	The inverse of the slope for the banks of the two-stage channel	.rte	Data from surveying
tsd_hru	The new HRU created that represents the two-stage ditch benches	.rte	
ts_n	Manning's "n" value for the two-stage channel	.rte	Range: 0.025 – 0.065. Median value: 0.05
k_tsd	Effective hydraulic conductivity of the two-stage channel alluvium (mm/hr)	.rte	Range: 0.025 mm/hr - >127mm/hr. Possible values for two-stage benches: 1 – 2.5 mm/hr.
$depth_{b,full}$	Average depth of the two-stage channel, as measured from the bench surface to the top of the banks (m)	.rte	Data from surveying

Watershed used to evaluate the model
Watershed area = 2.7 km^2

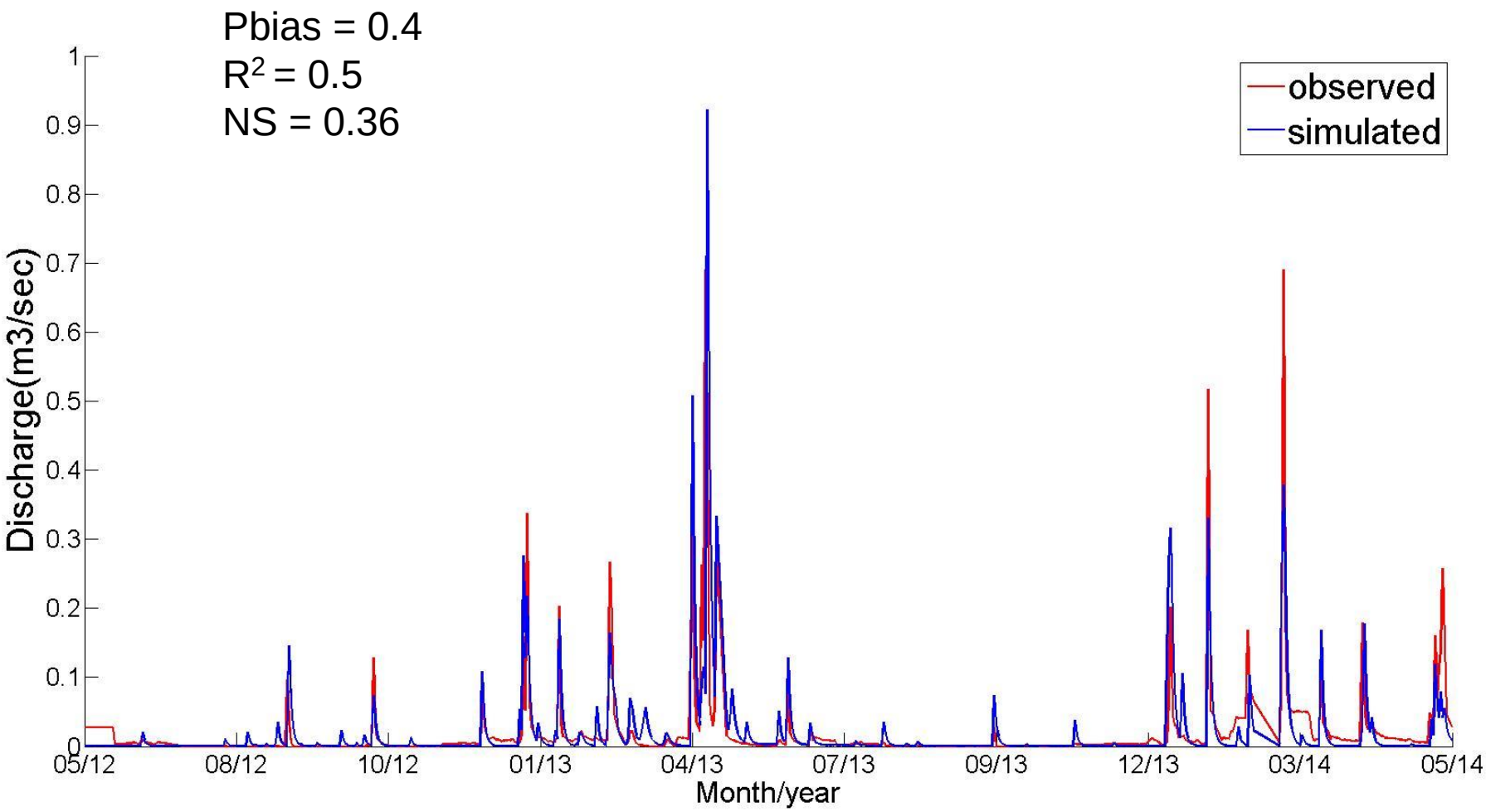




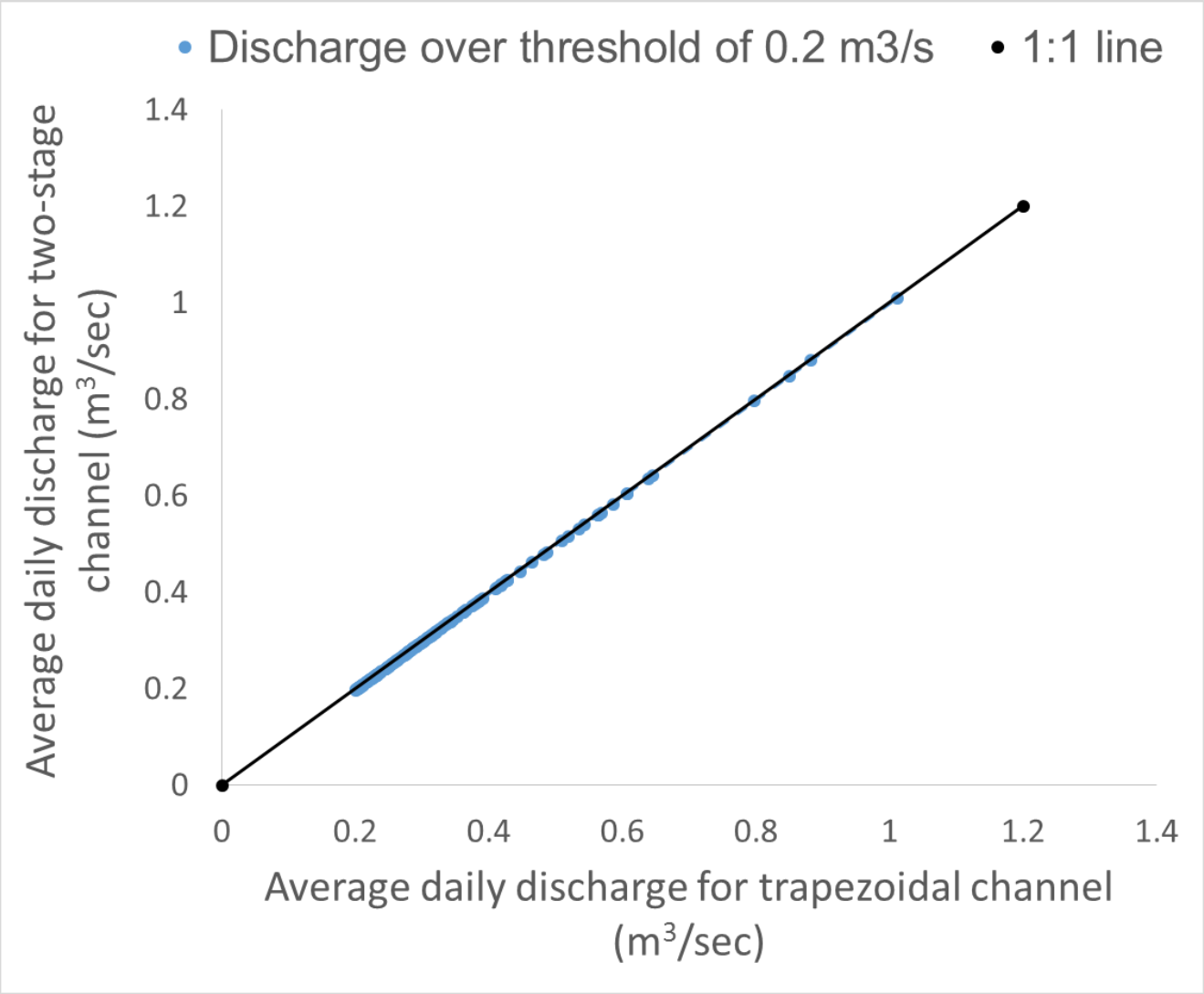
Land use data source: Cropland Data Layer (CDL, 2009)


Study area
Lafayette
Two-stage ditch
Direction of flow
Monitoring station 3
Control section
Monitoring station 2
Tile drains
Monitoring station 1

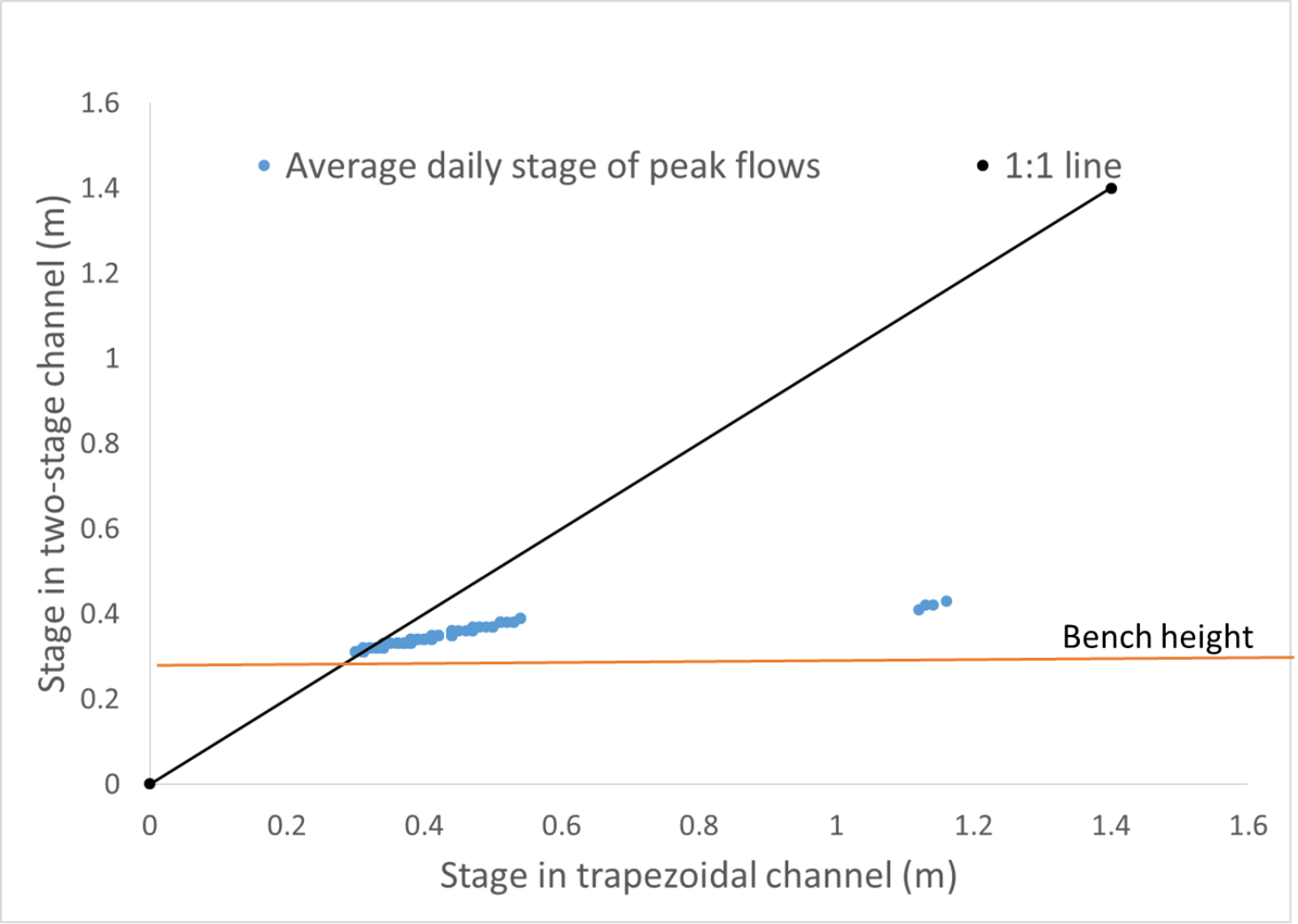
Discharge calibration



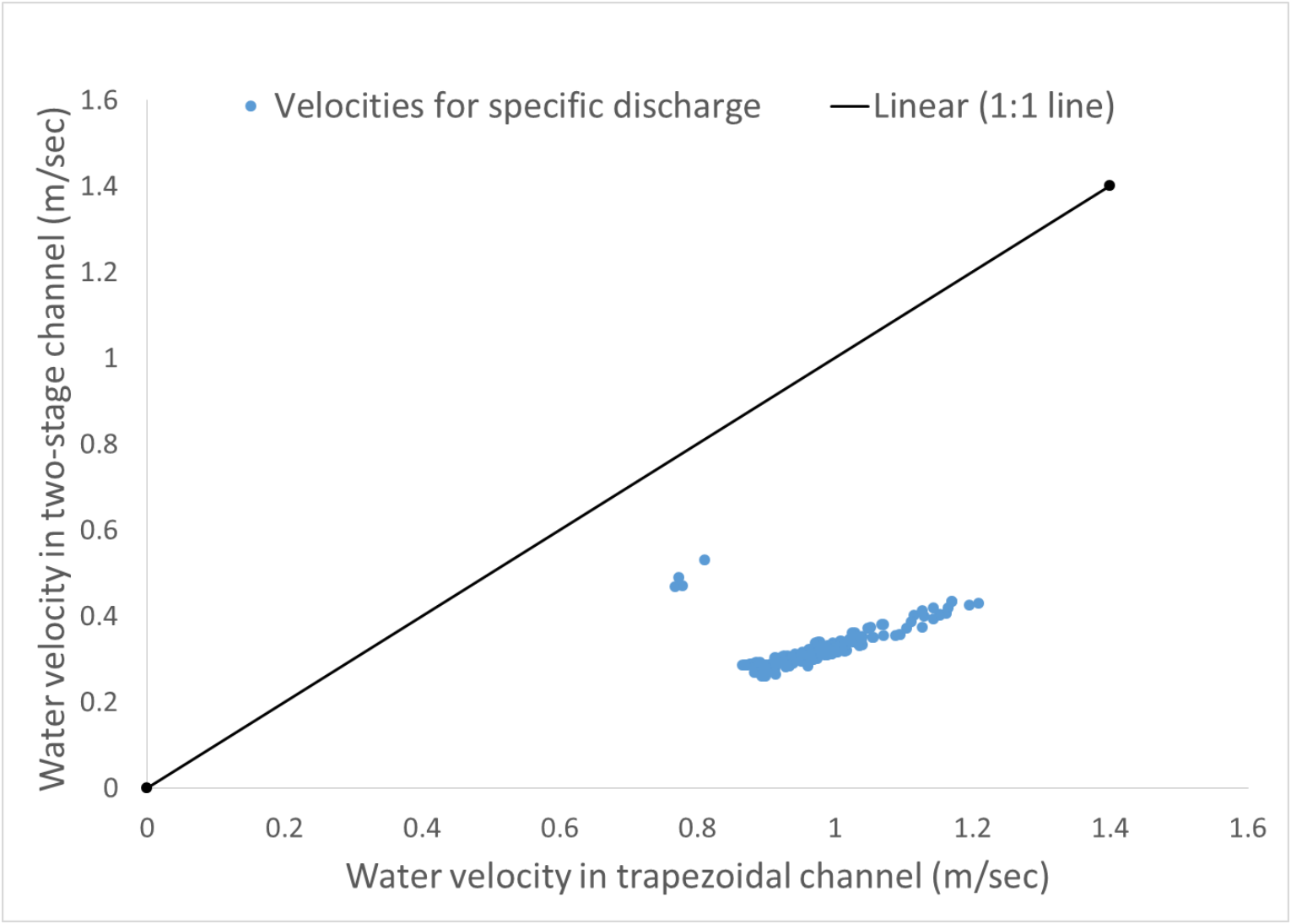
Comparison of peaks over threshold series



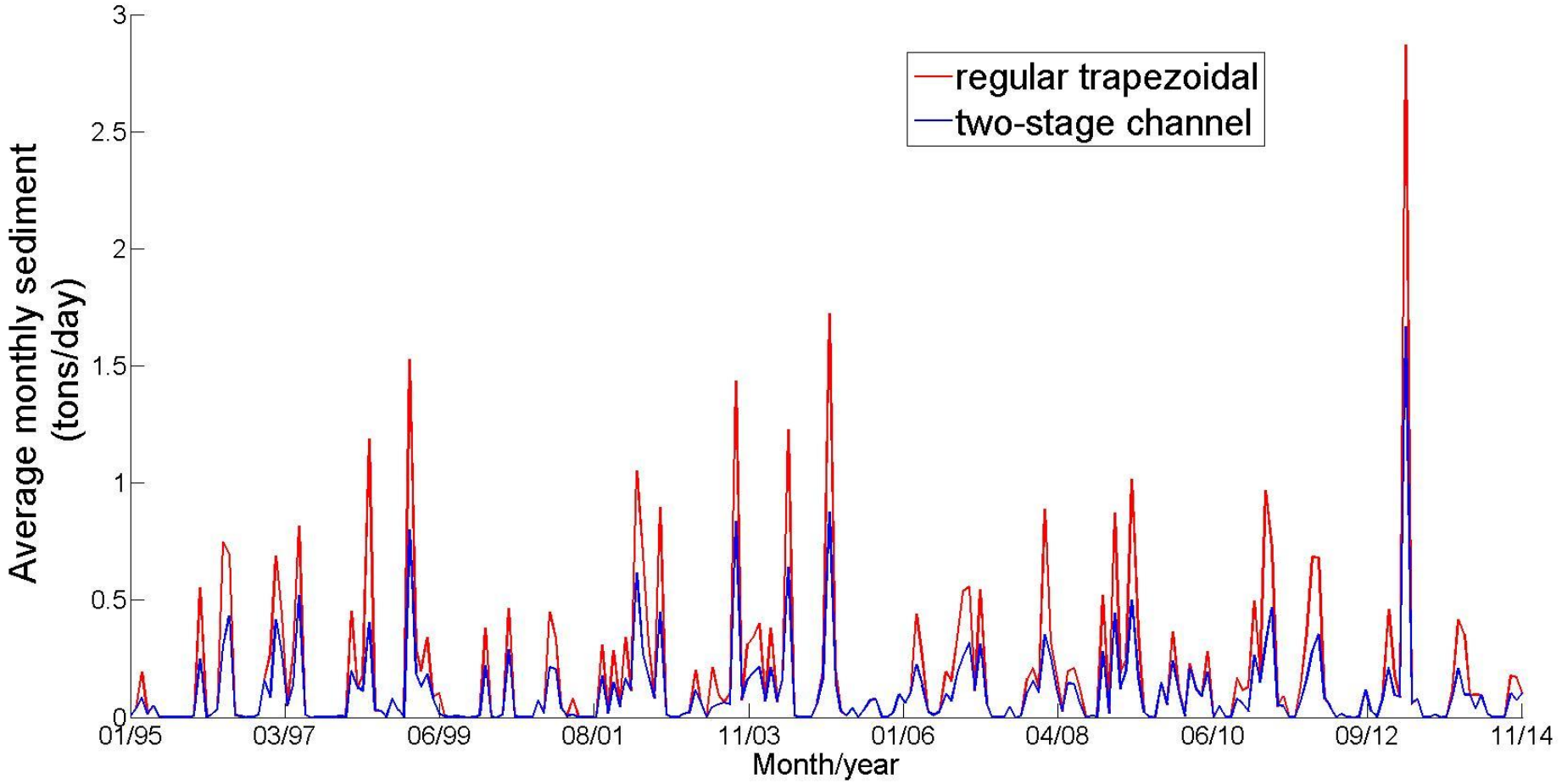
Stage when peaks are over threshold



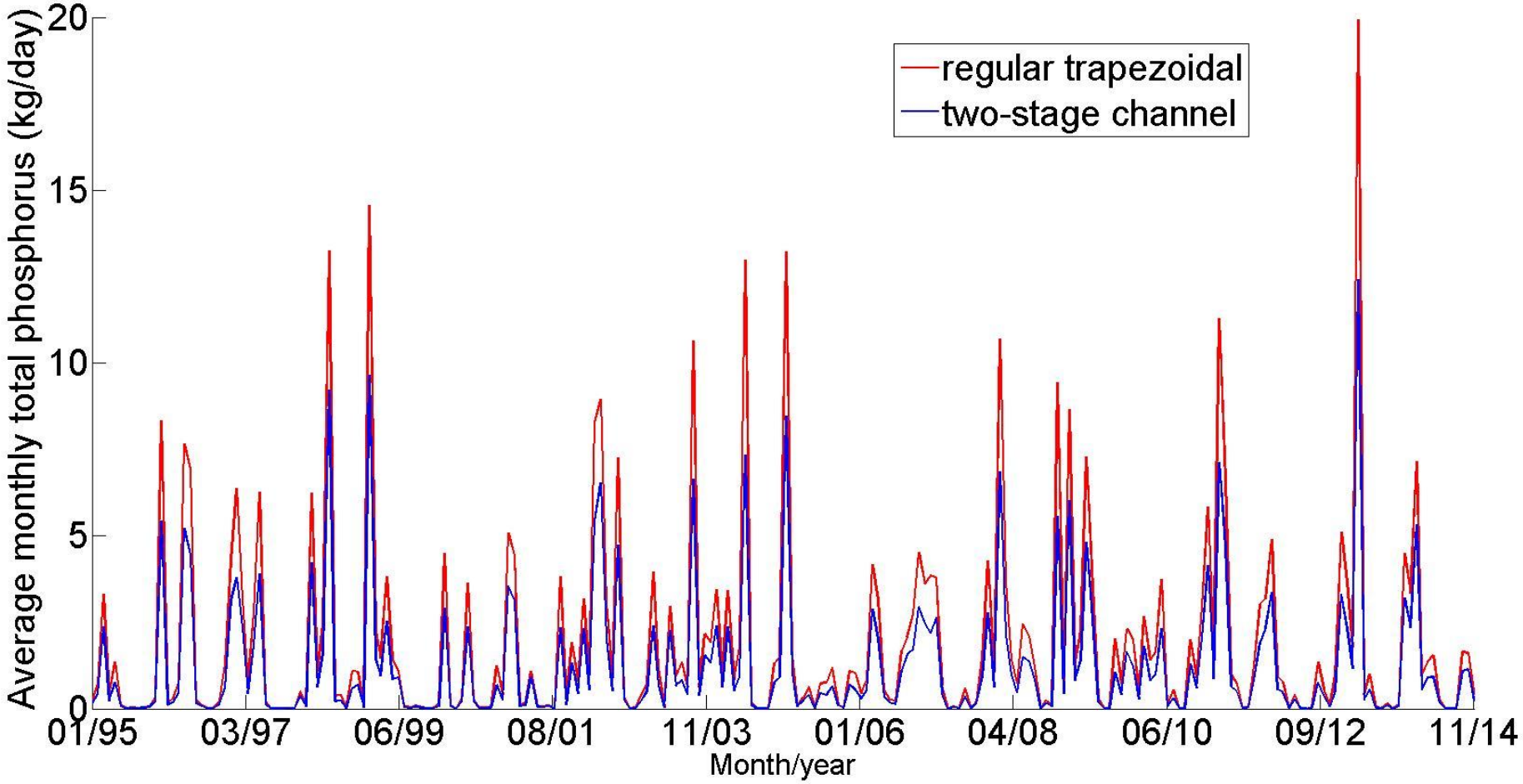
Velocities when peaks are over threshold



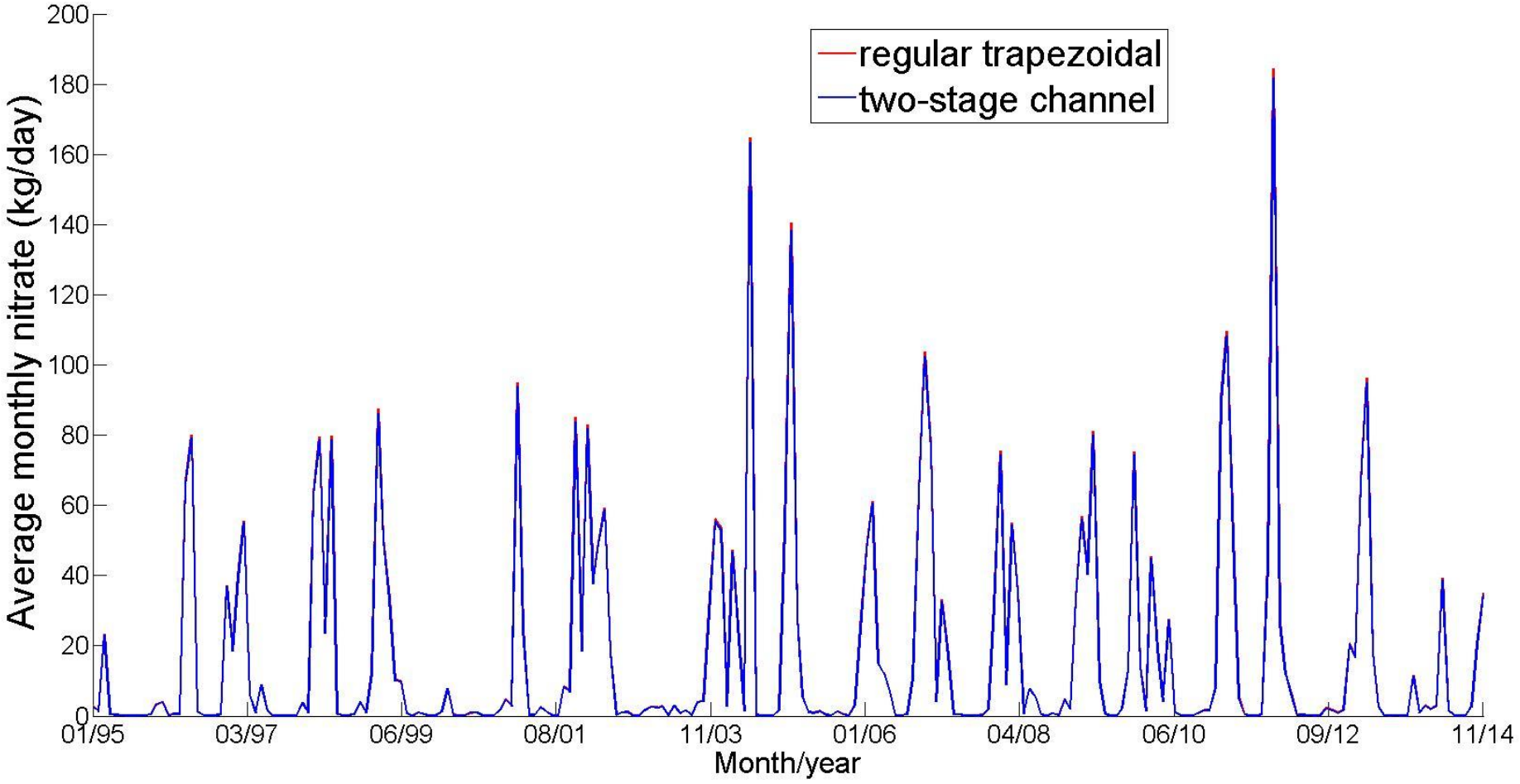
Average monthly sediment out of the two-stage and trapezoidal channel for the period Jan, 1995 – Dec,2014



Average monthly total phosphorus out of the two-stage and trapezoidal channel for the period Jan, 1995 – Dec,2014



Average monthly nitrate-N out of the two-stage and trapezoidal channel for the period Jan, 1995 – Dec,2014



Take home message

- Using the current watershed to demonstrate the model, the two-stage has shown good performance in:
  - **Conveyance capacity: <1% reduction**
  - **Reducing peak velocities : ~ 66%**
  - **Decreasing sediment yields: ~ 70% during peak flows**
  - **Reducing amount of phosphorus loads: ~ 36%**
  - **Reducing Nitrate-N loads: ~ 12%**
- Future work will more fully evaluate the new algorithm with respect to water exchange between the benches and channel and differences in nutrient loads.

Thank you !

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NRCS Natural Resources Conservation Service

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