Development of Generic Landscape-level Stormwater Retention/Treatment BMP in SWAT

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Acknowledgements

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  - Raghavan Srinivasan, TAMU
  - Ashley Allen, U.S. EPA Office of Water
  - Jeff Arnold and Nancy Simmons, USDA
  - Lawrence Band, University of North Carolina at Chapel Hill
- Existing SWAT watershed models obtained from U.S. EPA (2013) study:
  - "Watershed Modeling to Assess the Sensitivity of Streamflow, Nutrient, and Sediment Loads to Potential Climate Change and Urban Development in 20 Watersheds"
- Initial work funded by U.S. EPA under contract EP-C-07-023

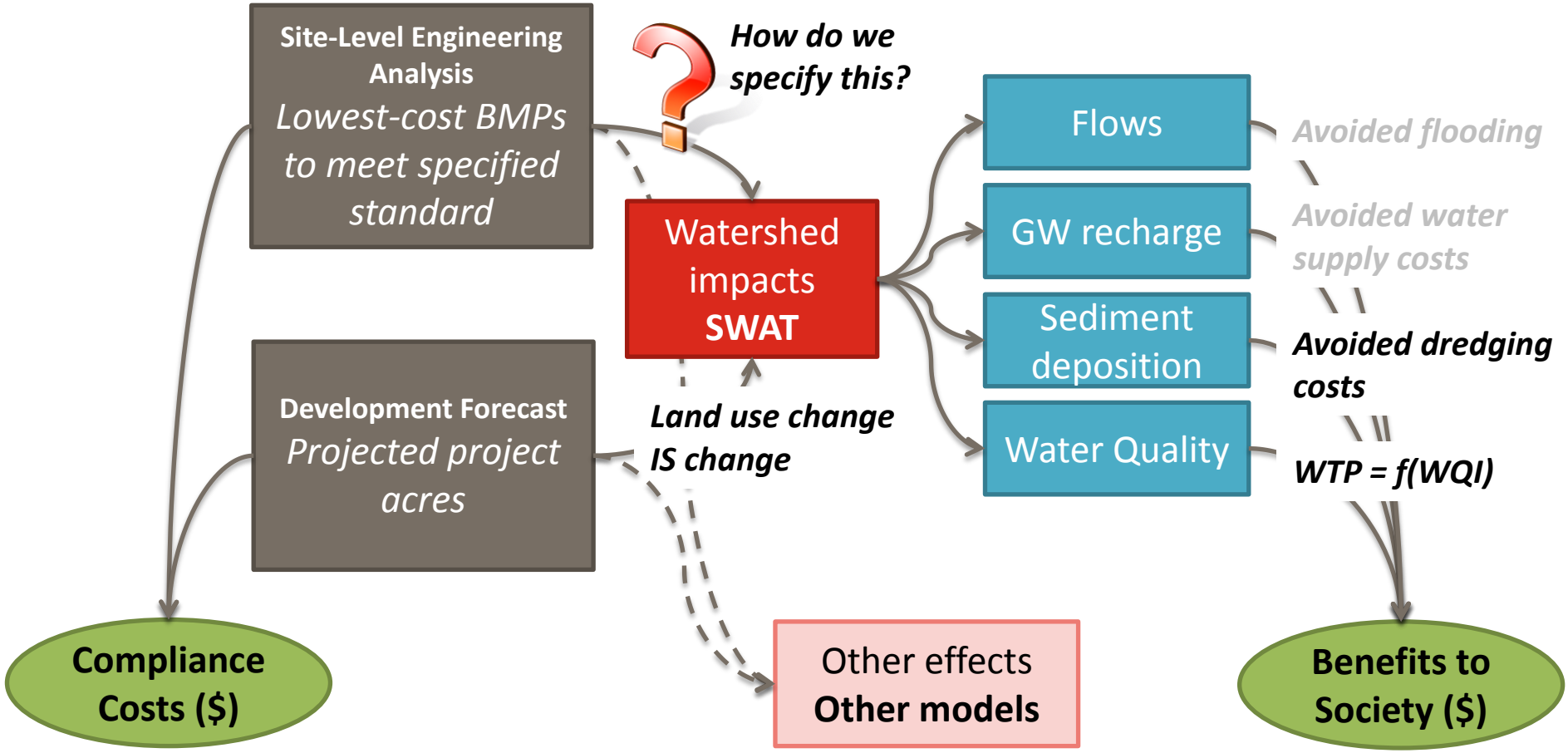
Outline

- Context
- SWAT algorithm and implementation
- Testing
- Next steps

Background

- U.S. Environmental Protection Agency is considering national-level requirements for management and control of urban stormwater
- Non-point sources – in particular urban stormwater runoff – are an important, and growing, cause of surface water impairments
- Rulemaking process requires assessment of the costs, environmental impacts, and societal benefits
  - SWAT used to assess the environmental effects of regulatory options and support benefit estimates through several different valuation frameworks
  - Complement to detailed 1) site-level analysis of model projects and 2) development forecast to 2040
  - Analysis must ultimately provide national estimates

SWAT as a Regulatory Assessment Tool



Considerations for Developing the Aggregate Stormwater BMP

1. Integrate outputs from detailed site-level analysis
   - Lowest-cost selection among 42 BMPs for over 30 different types of representative projects/sites
   - Multiple (parallel) BMPs per development project for five different source areas
   - Used to estimate compliance costs for the regulation and other benefit categories (e.g., carbon sequestration, energy savings)
2. Build on existing SWAT capabilities
3. Flexible representation of BMPs
   - Infiltration
   - Treatment to specified effluent limits
   - Surface discharge at specified rate (after treatment)
4. Distributed
   - Allow for finest level of detail/specification possible in SWAT

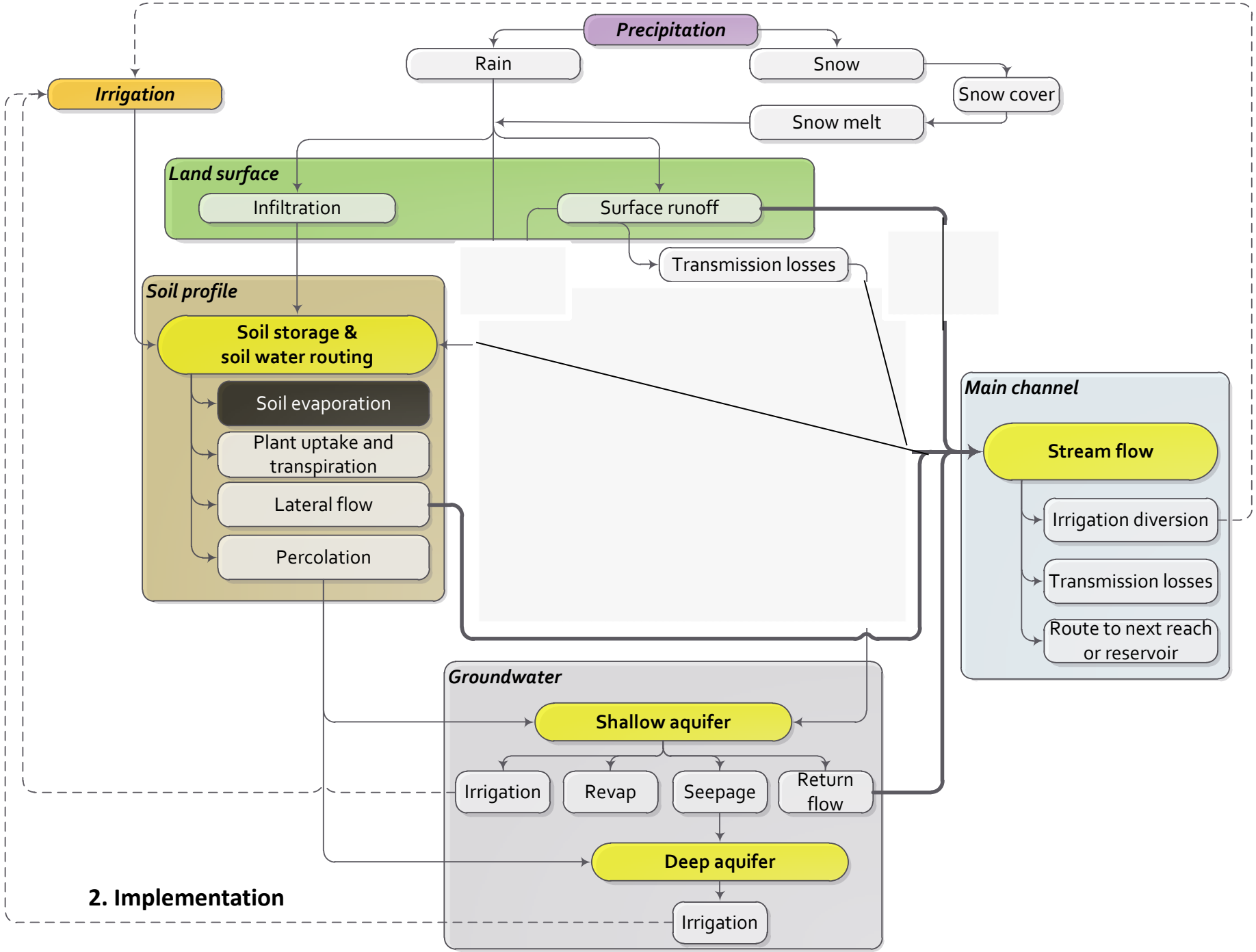
Implementation in SWAT

- Code modifications (primarily *pothole.f*):

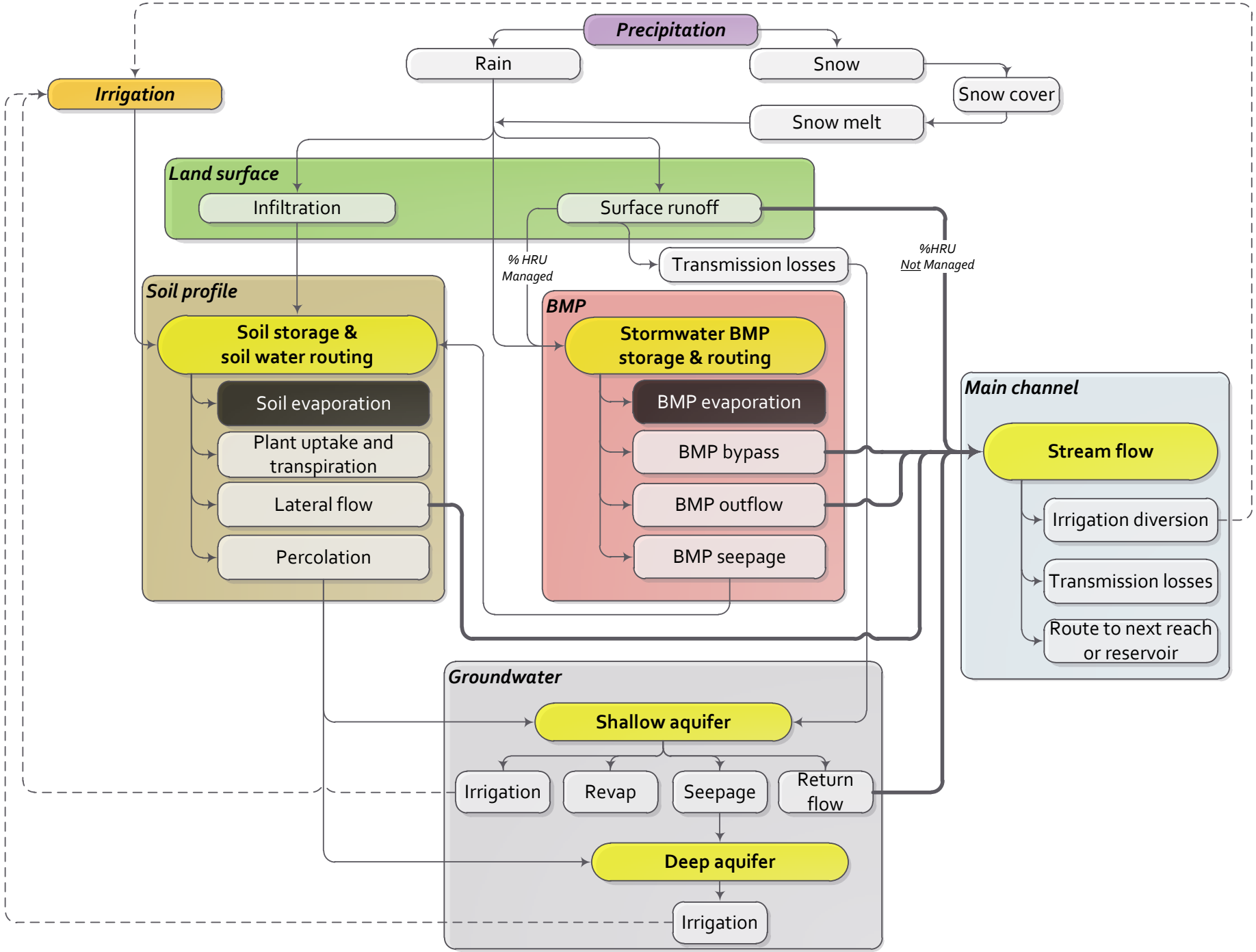
  1. Simply modify the existing SWAT pothole: Promising, but noticed several issues…
  2. Improve BMP representation: Allow one “pothole” per HRU instead of one per subbasin

- Specifications of BMP parameters in HRU file:
  - Fraction of HRU area managed
  - Aggregate BMP discharge rate (if treated discharge allowed)
  - Aggregate BMP volume
  - Treated discharge effluent concentrations (nitrogen, phosphorus, sediment)

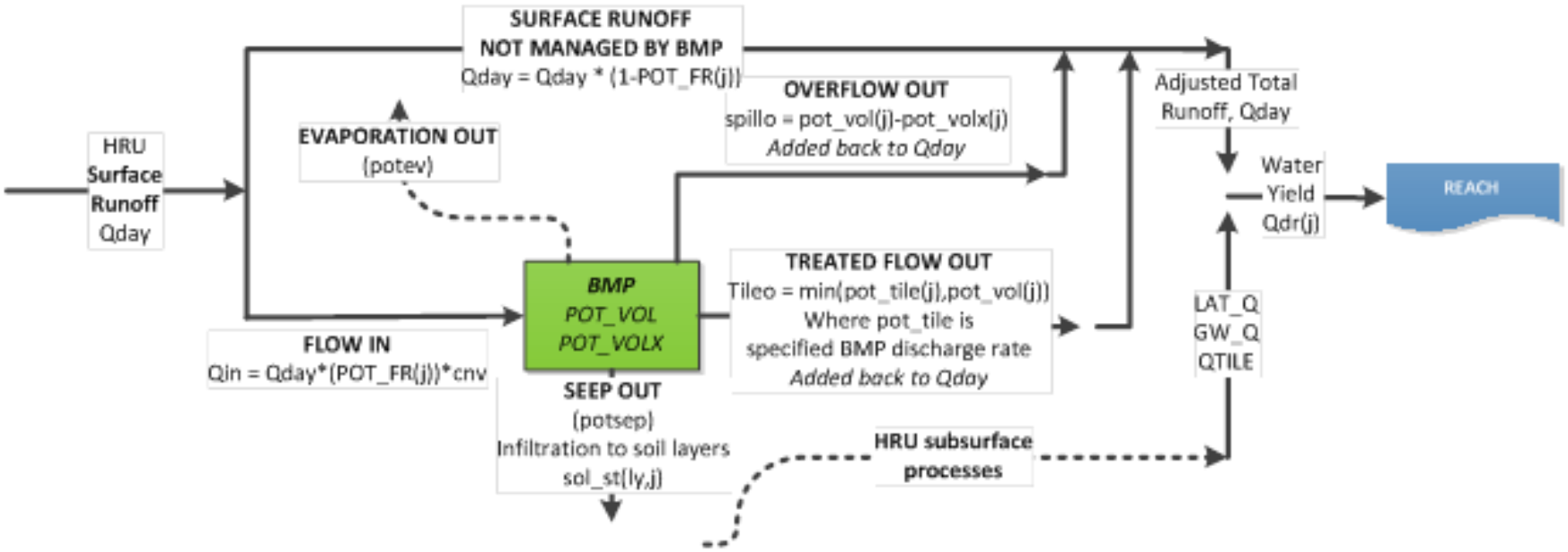
.hru file Watershed HRU:8 Subbasin:1 HRU:8 Luse:URMD Soil: TX042 Slope 0-10 2/11/2011 12:00:00 AM ArcSWAT 2009.93.5
0.0057474 | HRU_FR : Fraction of subbasin area contained in HRU
121.951 | SLSUBBSN : Average slope length [m]
0.003 | HRU_SLP : Average slope stepness [m/m]
0.100 | OV_N : Manning's "n" value for overland flow
0.000 | LAT_TTIME : Lateral flow travel time [days]
0.000 | LAT_SED : Sediment concentration in lateral flow and groundwater flow [mg/l]
0.000 | SLSOIL : Slope length for lateral subsurface flow [m]
0.000 | CANMX : Maximum canopy storage [mm]
0.000 | ESCO : Soil evaporation compensation factor
0.000 | EPCO : Plant uptake compensation factor
0.000 | RSDIN : Initial residue cover [kg/ha]
0.000 | ERORGN : Organic N enrichment ratio
0.000 | ERORGP : Organic P enrichment ratio
0.268 | POT_FR : Fraction of HRU are that drains into pothole -- Modified
0.000 | FLD_FR : Fraction of HRU that drains into floodplain
0.000 | RIP_FR : Fraction of HRU that drains into riparian zone
Special HRU: Pothole
8.357 | POT_TILE : Average daily outflow to main channel [mm/d] -- Modified
13.842 | POT_VOLX : Maximum volume of water stored in the pothole [mm] -- Modified
0.000 | POT_VOL : Initial volume of water stored in the pothole [mm] -- Modified
0.000 | POT_NSED : Normal sediment concentration in pothole [mg/l]
0.000 | POT_NO3L : Nitrate decay rate in pothole [1/day]
0 | DEP_IMP : Depth to impervious layer in soil profile [mm]
0.5 | EVPOT: Pothole evaporation coefficient
0.0 | DIS_STREAM: Average distance to stream [m]
0.0 | CF - septic parameter
0.0 | CFH - septic parameter
0.0 | CFDEC - septic parameter
27.107 | SED_CON : Sediment effluent concentration from pothole [mg/L]-- Modified
1.403 | ORGN_CON : Organic nitrogen effluent concentration from pothole [mg/L]-- Modified
0.007 | ORGP_CON : Organic phosphorous effluent concentration from pothole [mg/L]-- Modified
0.768 | SOLN_CON : Soluble nitrogen effluent concentration from pothole [mg/L]-- Modified
0.117 | SOLP_CON : Soluble phosphorous effluent concentration from pothole[mg/L]-- Modified



2. Implementation


Precipitation
Rain
Snow
Snow cover
Snow melt
Irrigation
Land surface
Infiltration
Surface runoff
% HRU Managed
%HRU Not Managed
Transmission losses
Soil profile
Soil storage & soil water routing
Soil evaporation
Plant uptake and transpiration
Lateral flow
Percolation
BMP
Stormwater BMP storage & routing
BMP evaporation
BMP bypass
BMP outflow
BMP seepage
Main channel
Stream flow
Irrigation diversion
Transmission losses
Route to next reach or reservoir
Groundwater
Shallow aquifer
Irrigation
Revap
Seepage
Return flow
Deep aquifer
Irrigation

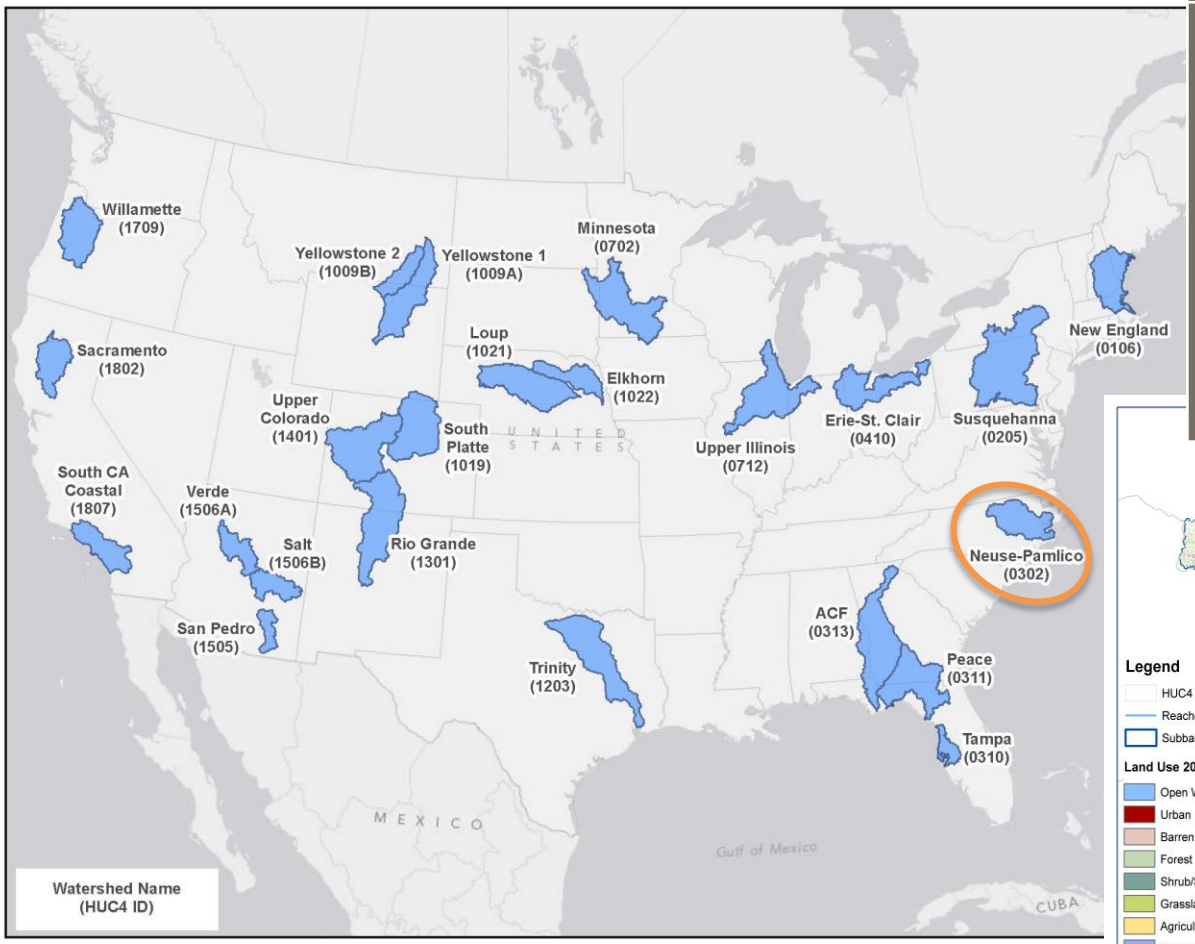
Aggregate Urban Stormwater BMP

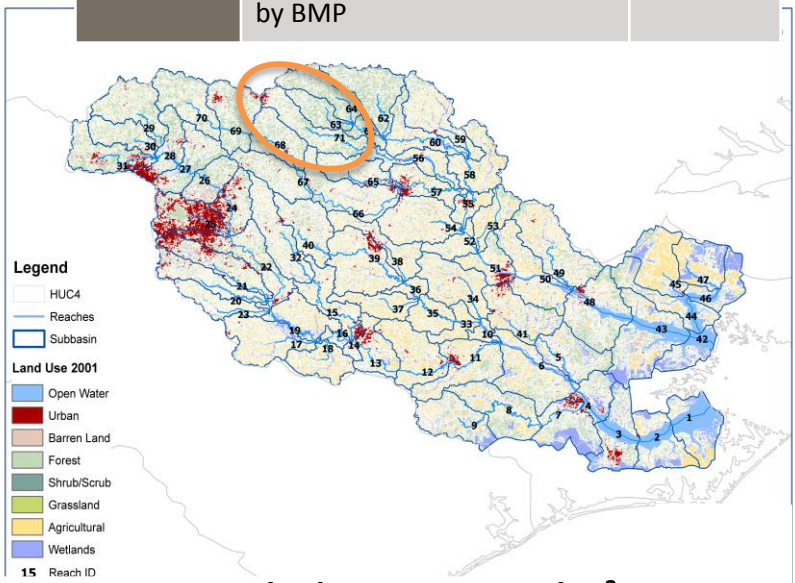


- Needed inputs are written outside ArcSWAT interface by modifying *.hru files
  - R used to aggregate site-level BMP parameters to HRU level.
  - VBA code used to rewrite *.hru files

Study Area

Level	Item	Value
Subbasin	Subbasin ID	71
	Percent of subbasin developed in 2001	8.0%
	Percent of subbasin developed in 2040	54.0%
HRU	HRU ID within subbasin	31
	HRU ID within watershed	2174
	HRU soil type (HSG)	NC075 (B)
	HRU land use	UFRL
	HRU impervious surface cover (based on land use definition)	7.2%
	HRU area in 2040	3,381 ha
	HRU share of subbasin in 2040	8.1%
	Share of HRU area managed by BMP	100.0%



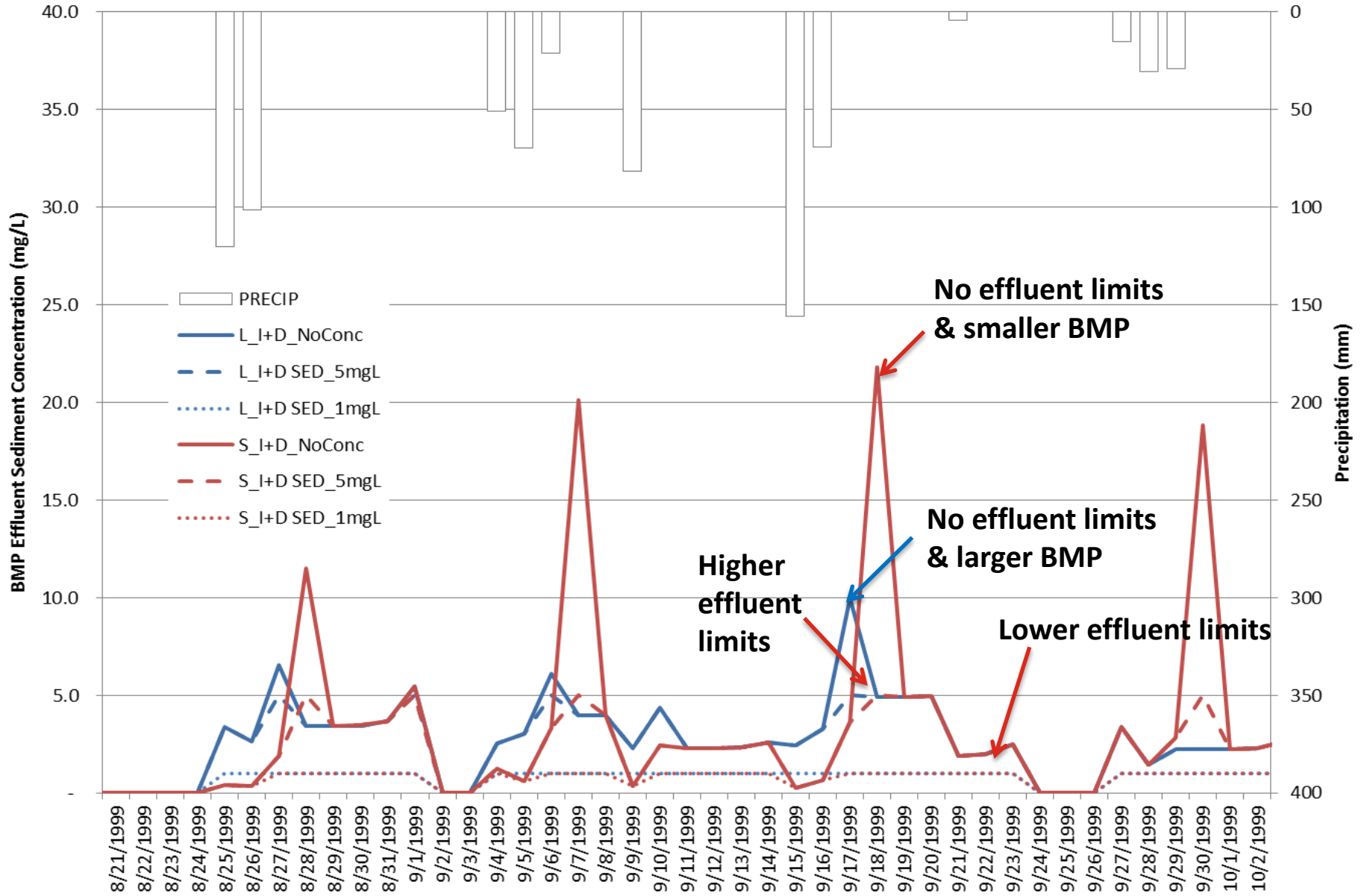


Watershed Area ~ 26,000 km²
Subbasin Areas ~ 300 km²

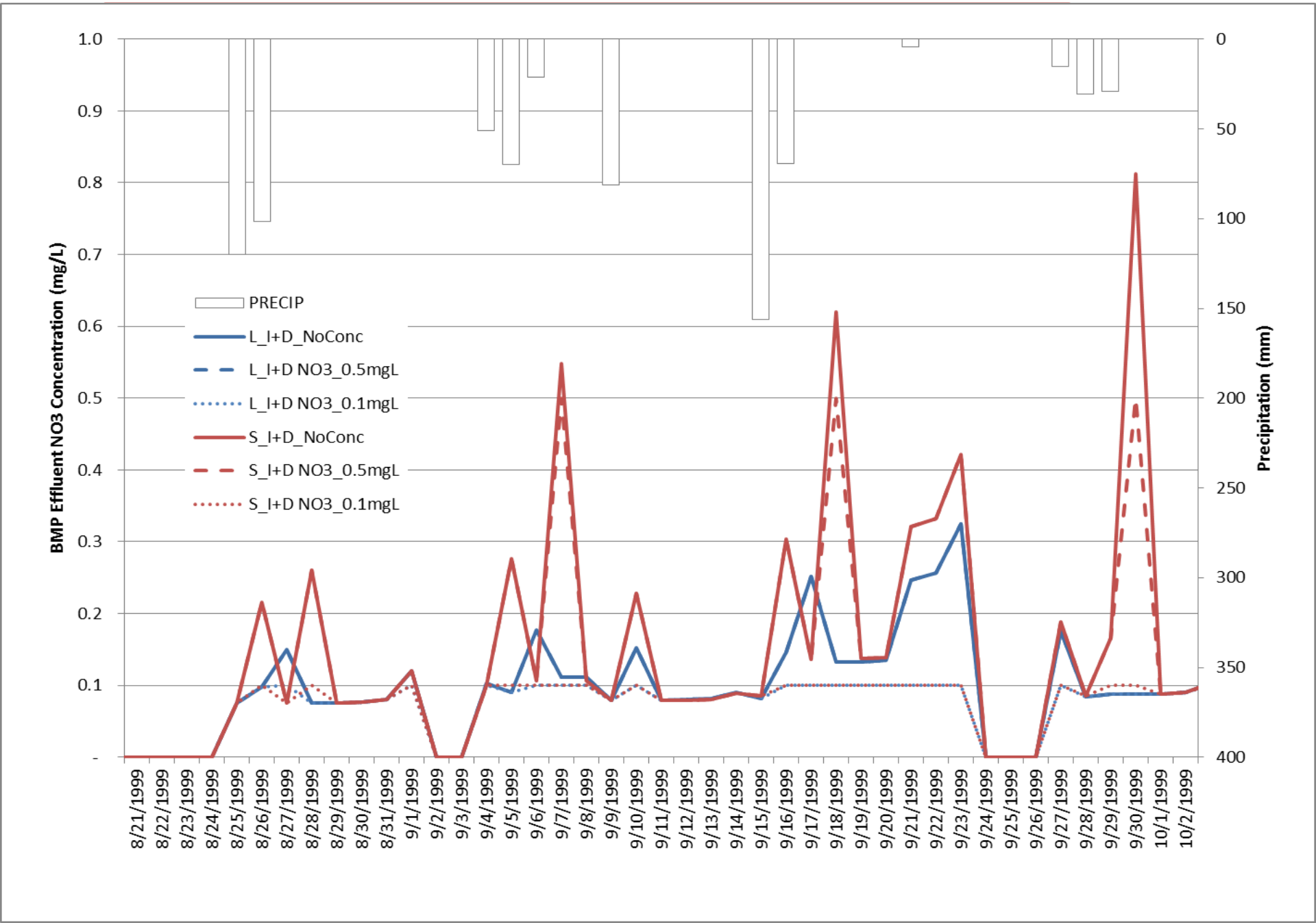
BMP Scenarios

Scenario	SWAT Run Label	BMP Specifications						
		POT_VOLX (mm)	POT_TILE (mm/day)	SED_CON (mg/L)	ORGN_CON (mg/L)	SOLN_CON (mg/L)	ORGP_CON (mg/L)	SOLP_CON (mg/L)
No BMP	NoBMP	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Large BMP with Untreated Discharge	L_I+D	50	20	N/A	N/A	N/A	N/A	N/A
Small BMP with Untreated Discharge	S_I+D	5	2	N/A	N/A	N/A	N/A	N/A
Large infiltration-only BMP	L_IOnly	50	0	N/A	N/A	N/A	N/A	N/A
Small infiltration-only BMP	S_IOnly	5	0	N/A	N/A	N/A	N/A	N/A
Large BMP with Treated Discharge	L_I+DConc	50	20	5.0	1.0	0.5	0.05	0.03
Small BMP with Treated Discharge	S_I+DConc	5	2	5.0	1.0	0.5	0.05	0.03
Large BMP with more Stringent Treated Discharge	L_I+DConc2	50	20	1.0	0.2	0.1	0.01	0.01
Small BMP with more Stringent Treated Discharge	S_I+DConc2	5	2	1.0	0.2	0.1	0.01	0.01

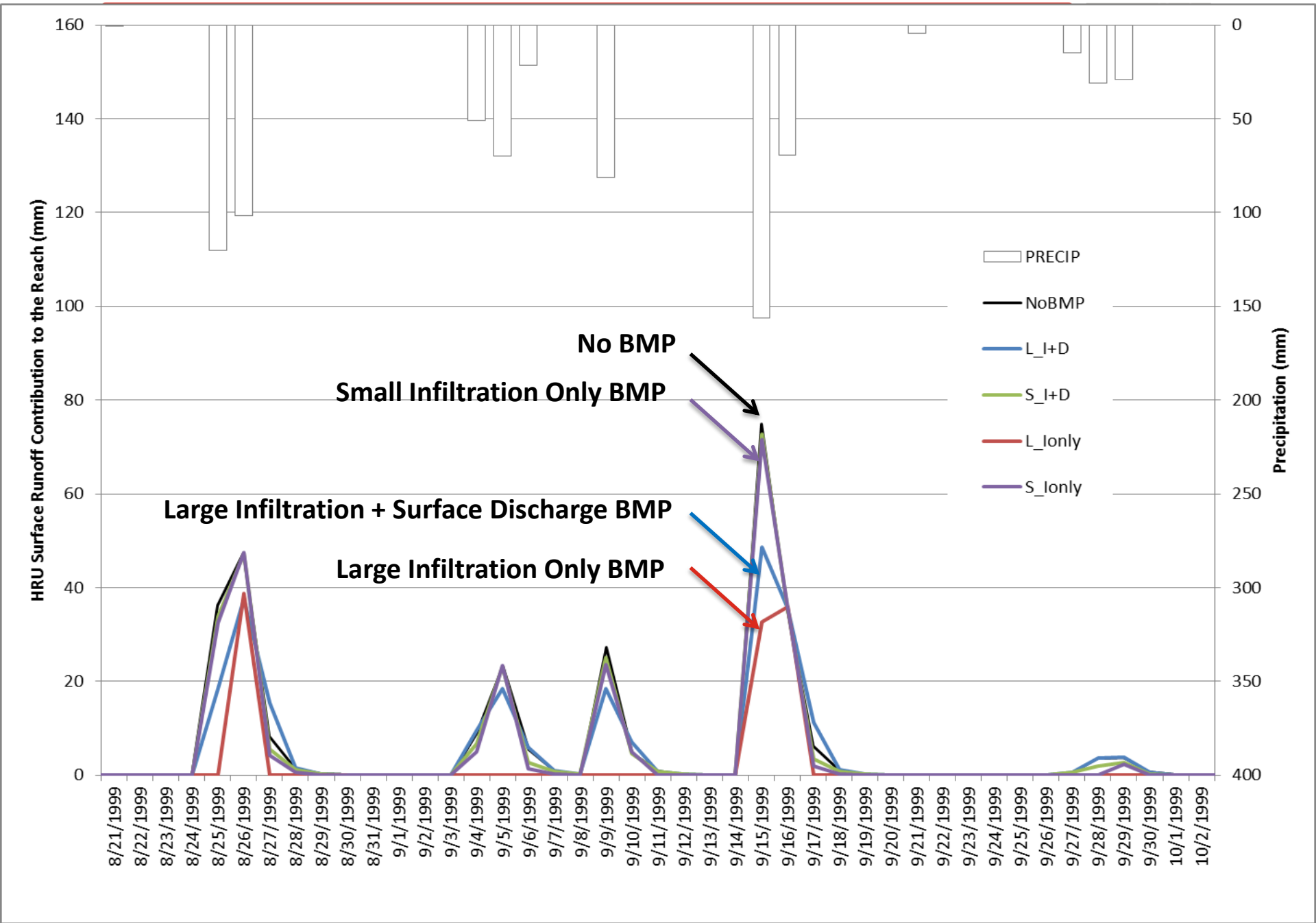
Suspended sediment concentration in surface discharge from simulated BMP



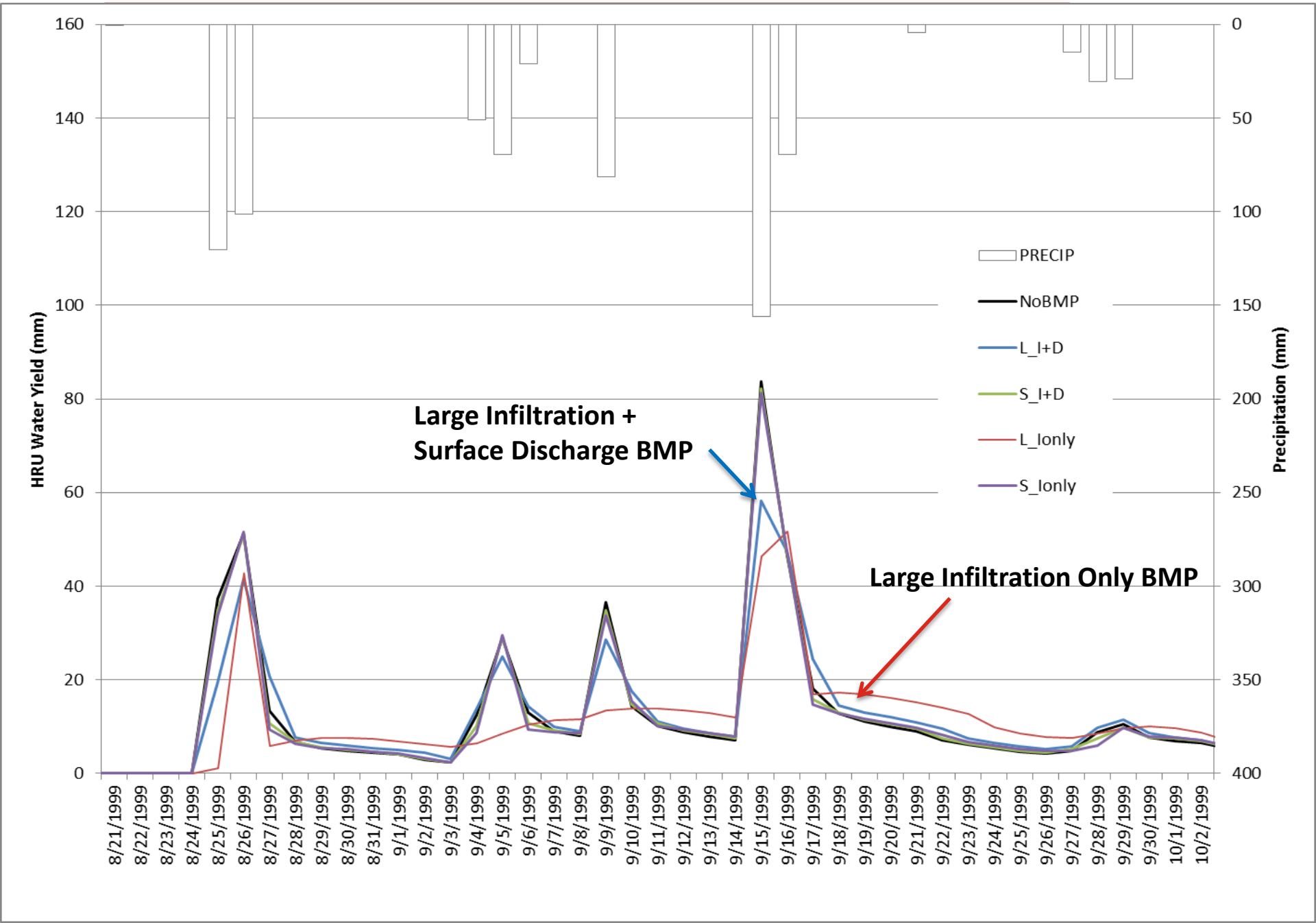
Nitrate concentration in surface discharge from simulated BMP



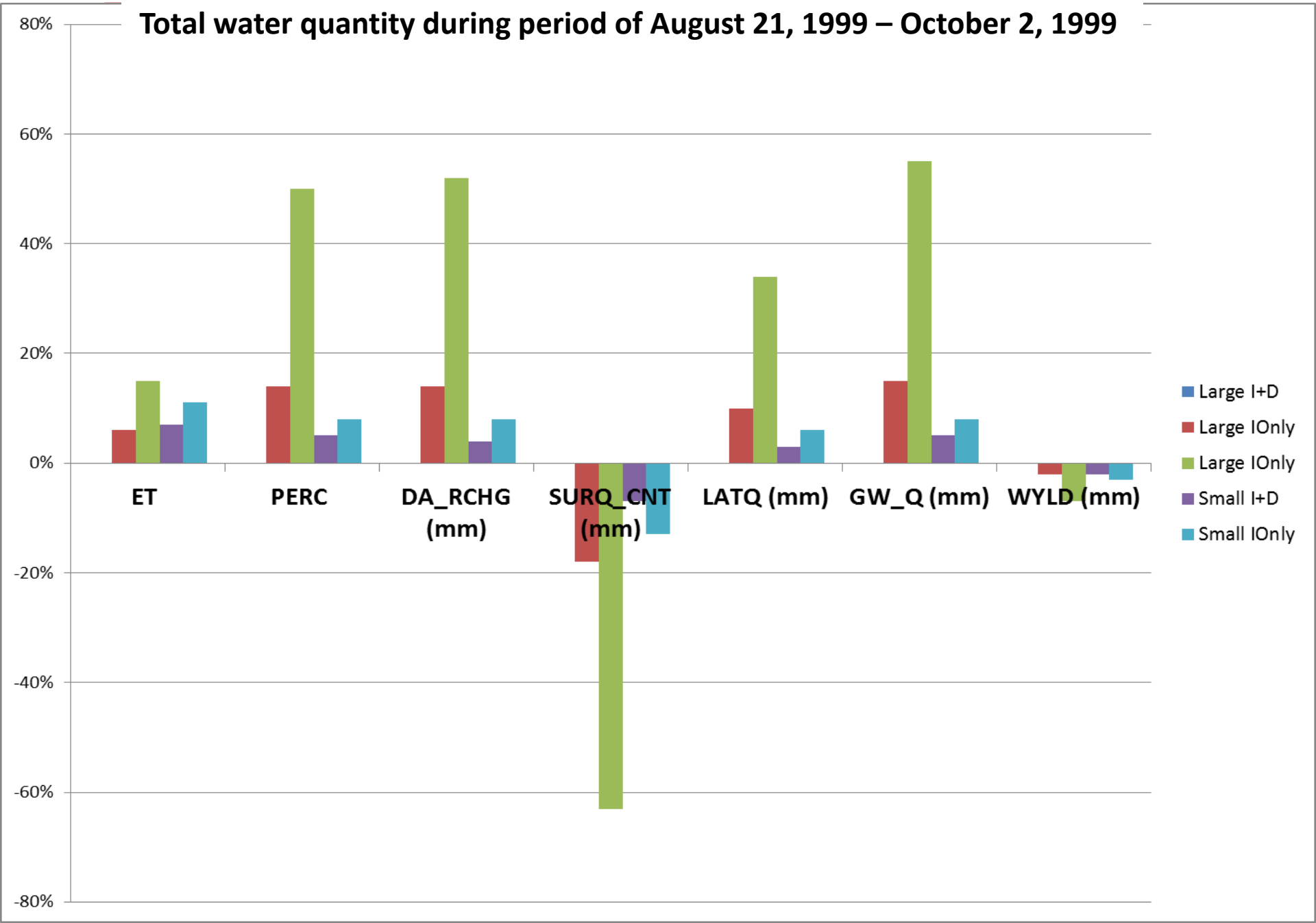
HRU Surface Runoff Contributed to the Reach (Qday)



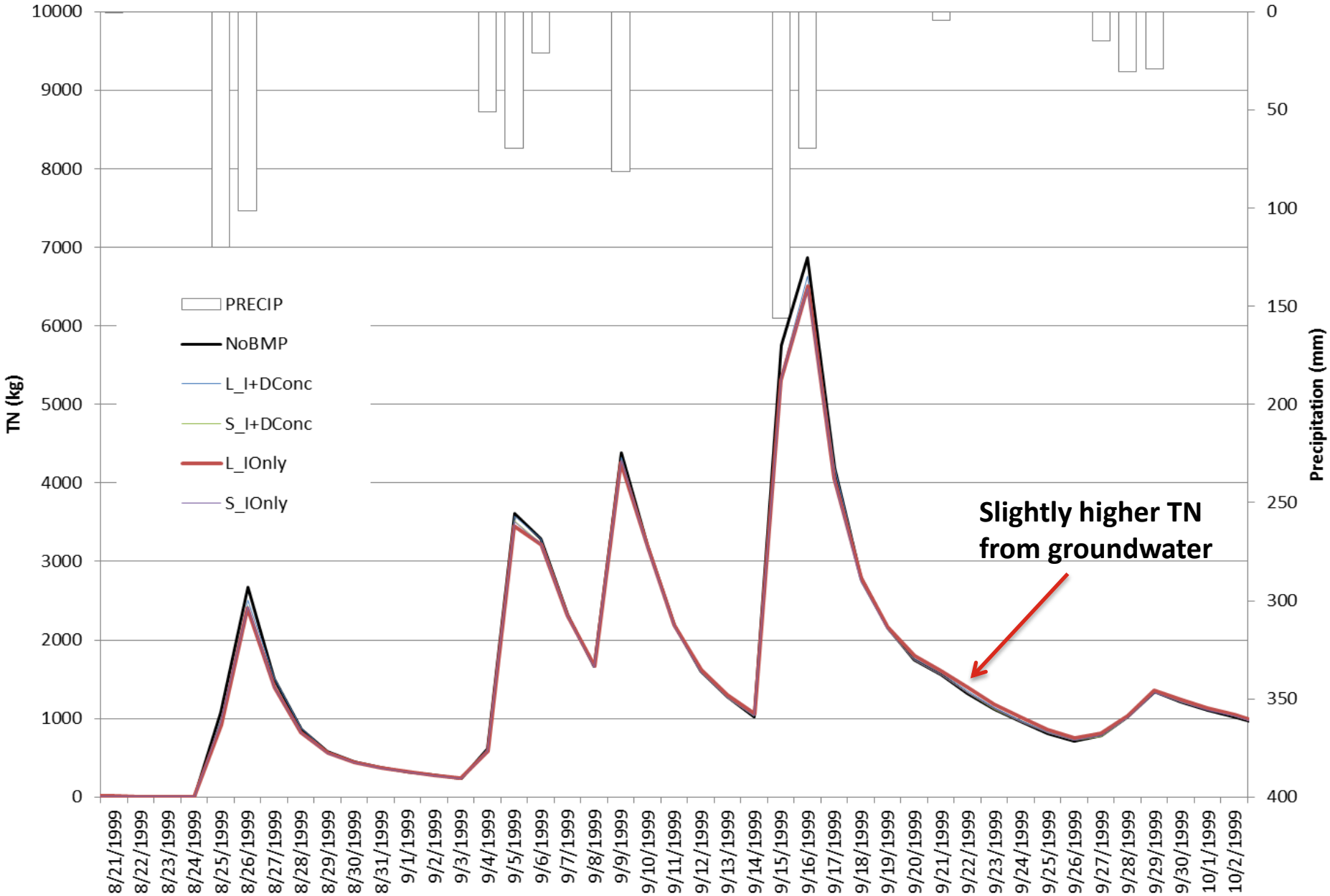
HRU Water Yield (i.e., Includes Lateral and Groundwater Flows)



% Change Relative to "No BMP" Baseline
Total water quantity during period of August 21, 1999 – October 2, 1999



TN Loads in Reach



Next Steps

- So far, conceptual validation
  - Would love to validate results against field data…
  - Confirm processes (e.g., denitrification)
- Enhance flexibility to model BMPs
  - HRU-specific adjustment to the infiltration rate applied to the BMP (including zero infiltration)
  - Differentiate HRUs (and BMPs) based on the development period relative to regulatory deadlines
- More informative and easier to use outputs
  - Annual/monthly average mass balance (e.g., water managed, retained, treated discharge)
  - Annual/monthly average pollutant loadings
- **[Your thoughts here?]**

Merci!

Questions?