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Protocol for Calibration of River Basins using SWAT

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The Context

- Insufficient guidelines for calibration of river basins
- Challenges-Lack of data, poor data quality
- General guidelines
- Ongoing national assessment study using SWAT-CEAP
- Lessons learned from calibration
- Applicable for other models, other countries

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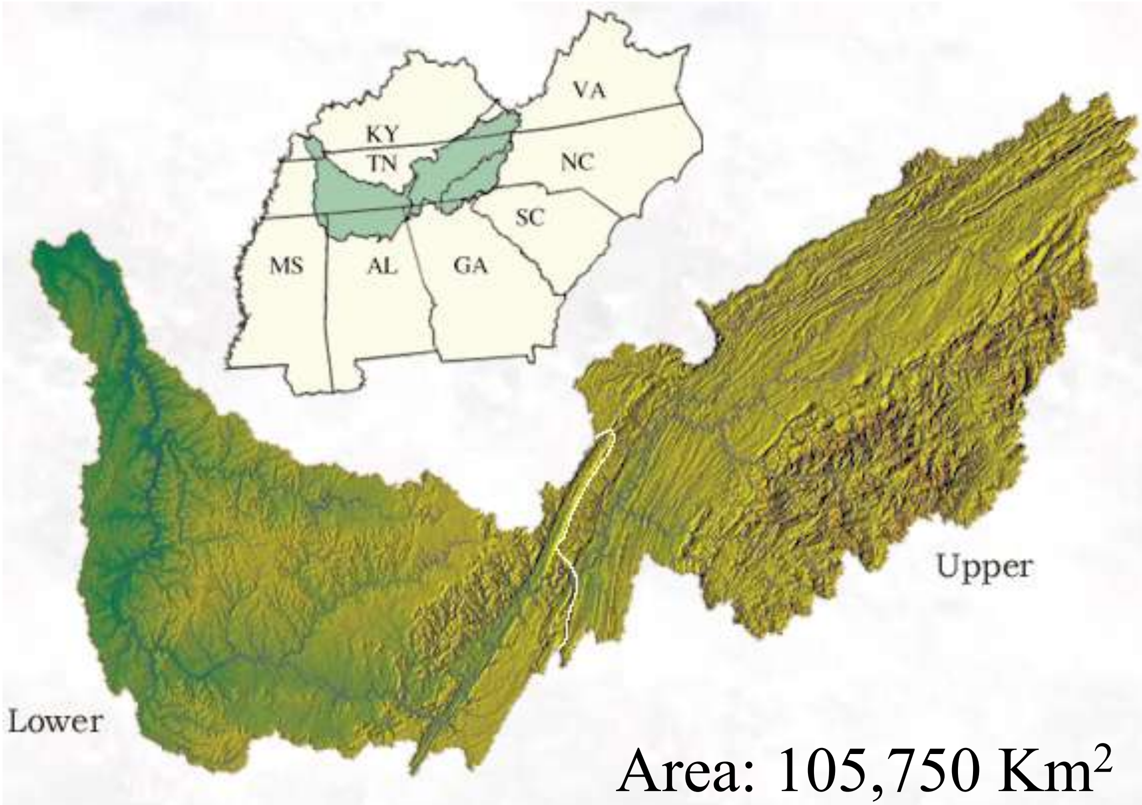
1. Study the river basin



Upper Tennessee

Land Cover

Forest 67 %
Pasture 26 %
Cultivated 2.5 %
Developed 4.5 %
(2.5 million people)

Elevation

621-6,684 feet

Precipitation: 1300 mm

Lower Tennessee

Land Cover

Forest 55 %
Pasture+row crops 41 %
Urban 1 %

Elevation

300-2900 ft

Precipitation: 1380 mm

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2. Identify key drivers of flow and pollutant transport

- Very High slope
- High precipitation
- Dams
- Dominant Land cover-Forest
- High surface runoff
- High water yield
- High Soil Erosion
- Deposition of pollutants in dams

3. Select adequate number of suitable monitoring stations

Selection based on

1. Drainage pattern
2. Data availability
3. Number of observations
4. Area covered
5. Nearness to reach outlets
6. Location: major/minor river
7. Continued availability of data

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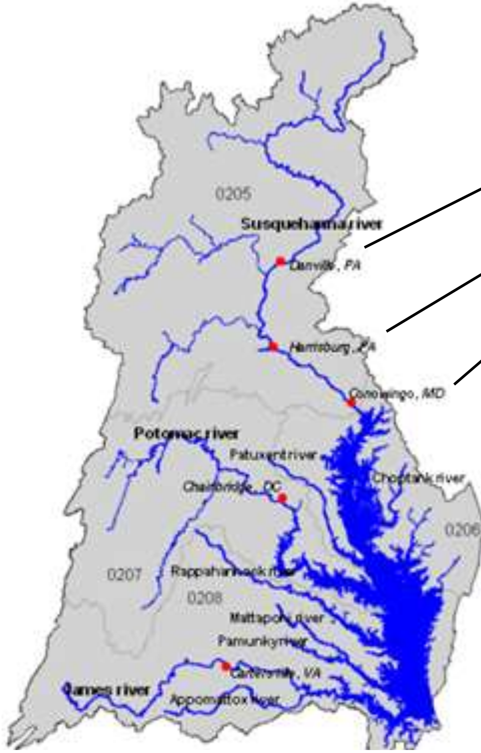
4. Identify anomalies in monitoring data

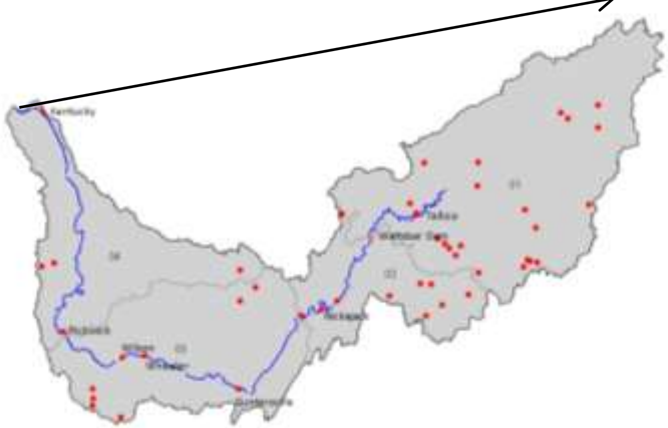


Average annual sediment loads (tons)

Place	Reach	Pred	95 % LCI	Obs	95 % UCI
Susquehanna river at Danville, PA	2050107			1,894,771	
Susquehanna river at Harrisburg, PA	2050305			3,467,593	
Susquehanna river at Conowingo, MD	2050306		823,183	1,237,925	1,817,343

Average annual total Phosphorus loads (tons)

Place	Reach	Pred	95 % LCI	Obs	95 % UCI
Susquehanna river at Danville, PA	2050107			1,707	
Susquehanna river at Harrisburg, PA	2050305			3,362	
Susquehanna river at Conowingo, MD	2050306		1,646	2,256	3,031



	A	B
1	DATE_OBSRV	SS_MGL
142	1/19/2000	7.0
143	2/8/2000	7.0
144	3/23/2000	8.0
	4/27/2000	15.0
	5/12/2000	11.0
	5/25/2000	11.0
	6/12/2000	7.0
	7/13/2000	7.0
	8/14/2000	8.0
	9/11/2000	12.0
	11/29/2000	4.0
	12/19/2000	11.0
	1/30/2001	28.0
	2/22/2001	40.0
	3/29/2001	5.0
	4/19/2001	9.0
	5/24/2001	7.0
	6/28/2001	8.0
	7/12/2001	7.0
	11/21/2001	4.0

	A	B
1	DATE_OBSER	TP_MGL
152	2/8/2000	0.07
153	3/23/2000	0.06
154	4/27/2000	0.09
155	5/12/2000	0.02
156	5/25/2000	0.05
157	6/12/2000	0.04
158	7/13/2000	0.05
159	8/14/2000	0.06
160	9/11/2000	0.08
161	11/29/2000	0.07
162	12/19/2000	0.07
163	1/30/2001	0.10
164	2/22/2001	0.19
165	3/29/2001	0.05
166	4/19/2001	0.04
167	5/24/2001	0.04
168	6/28/2001	0.05
169	7/12/2001	0.04
170	9/6/2001	0.07
171	11/21/2001	0.07

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5. Estimate uncertainties in observations

Average annual NO3+NO2 loads (tons)

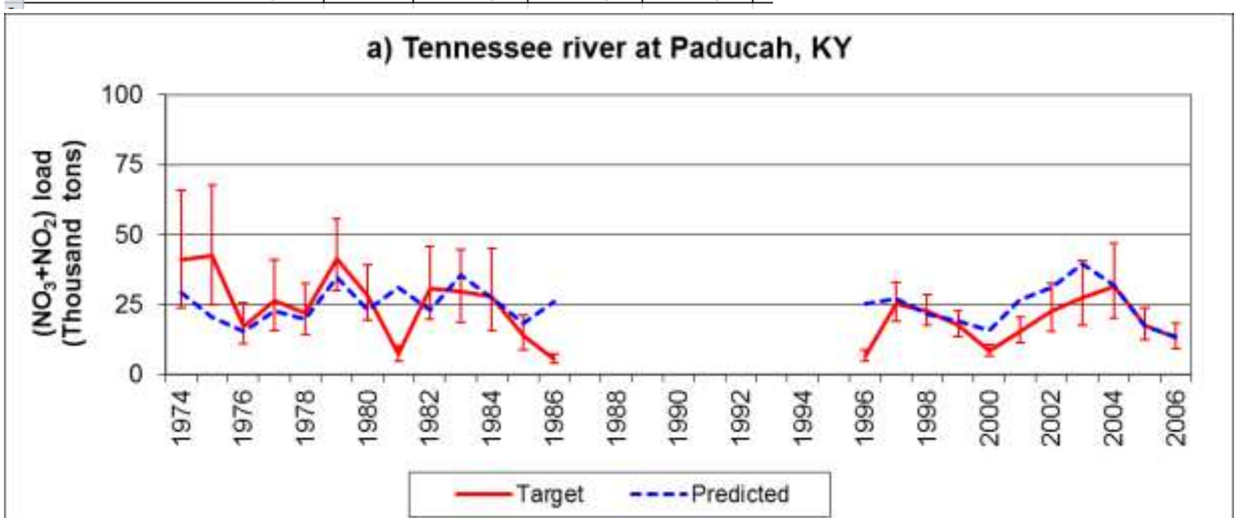
		Observations		
Place	Reach	Observed	Low Conf	Upper Conf
Tennessee river-near Paducah, KY	6040006	22,572	15,004	32,872

Average annual TKN loads (tons)

		Observations		
Place	Reach	Observed	Low Conf	Upper Conf
Tennessee river-near Paducah, KY	6040006	19,331	14,852	24,868

Average annual NH3 loads (tons)

		Observations		
Place	Reach	Observed	Low Conf	Upper Conf
Tennessee river-near Paducah, KY	6040006	2,625	1,521	4,353



Load Runner

- Estimate load as a function of discharge
- Input: Water quality data, daily flow
- Daily, monthly and annual fluxes
- Estimates uncertainty

More details:
http://environment.yale.edu/loadrunner/
http://water.usgs.gov/software/loadest/

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6. Prepare model setup and check input

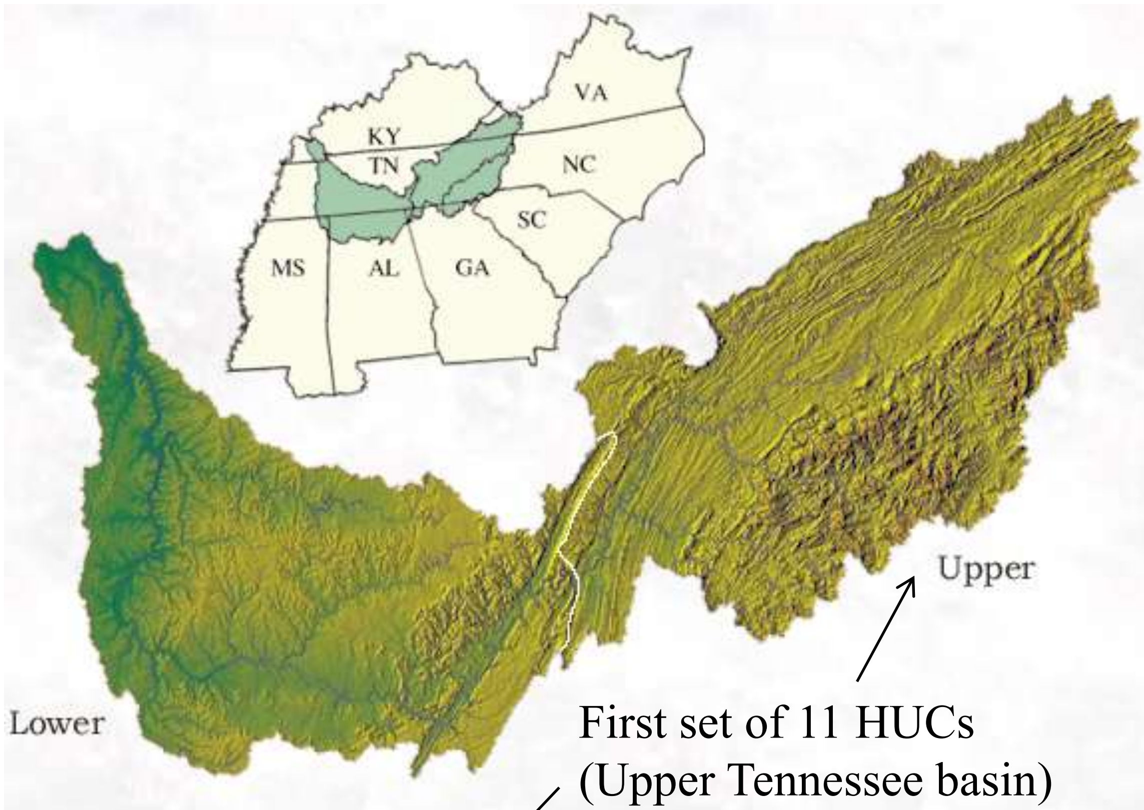
- As many years of data for warm-up
- Many years of data for calibration (including wet, dry average rainfall periods)
- Some years of data for validation
- Recent changes in code/model set up are working
- Copy of model setup (backup !!)

- Precipitation–compare literature values with model input (e.g. annual total)
- Temperature–compare literature values with model input (e.g. monthly mean)
- Crop rotation
- Mean rates and timing of fertilizer, manure application
- Quantity, frequency and timing of irrigation
- Land management operations
- Point source discharges
- Atmospheric nitrogen deposition
- Dams

7. Check overall water balance and pollutant budget

- Average annual water balance (Relate ET, surface runoff, base flow, and water yield to precipitation)
- Check reservoir water balance is meaningful (especially ET and seepage)
- Make sure irrigation applied is accounted in water balance
- Make sure soil erosion rates are reasonable
- Check nutrient budget

8. Check relative contribution from sub-basins



First set of 11 HUCs (Upper Tennessee basin)

No of sub-basins	Precip (mm)	ET (mm)	SurQ (mm)	GWQ (mm)	wyld (mm)	syld (t/ha)
11	1,323	741	287	322	610	10.0
10	1,386	844	352	209	561	3.3

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9. Check relative contribution from different land parcels

	PREC mm	SURQ mm	GWQ mm	ET mm	WYLD **mm**
FRST	1,372.8	319.3	265.3	815.0	584.6
ORCD	1,372.3	344.5	132.8	937.9	477.3
URBN	1,372.8	394.5	302.8	676.4	697.3

	PCP **mm**	ET **mm**	wyld **mm**	Sed t/ha
BARN	1,104.2	487.5	576.6	4.4
URBN	1,112.4	632.8	646.7	1.0
WETN	1,104.1	630.7	442.3	0.1

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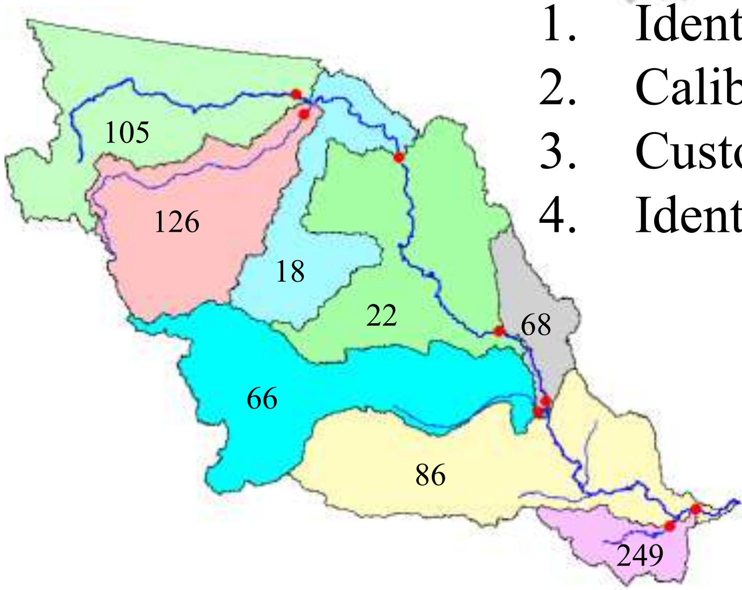
10. Check flow and pollutant transport pathways

MEAN	Sur Q mm	GWQ mm	Wyld mm
Observed	336	314	650
Predicted	332	199	530

11. Design a calibration strategy

1. Identify drainage area of validation gauges (excluding u/s)
2. Calibrate gauge by gauge starting from u/s
3. Customize parameters for each gauge
4. Identify the right set of results to validate



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12. Keep achievable goals for calibration

Annual Flow (Sub-basins)

- Match means within 20 % of observations (10 % for surface runoff and base flow)
- Minimize number of sub-basins not meeting above criteria

Annual and Monthly-Flow (River reaches)

- Match predicted means within 15 % of observations
- Match predicted and observed standard deviations as much as possible
- Try for Nash and Sutcliffe efficiency > 0.5 (> 0.6 preferred)
- Try for R^2 values > 0.6 (0.75 preferred)

Annual pollutant loads (River reaches)

- Bring predicted pollutant loads within the lower and upper confidence limits of observations
- If confidence limits are not available allow 30 % limit for sediment and 40 % limit for nutrients and 50 % for pesticide

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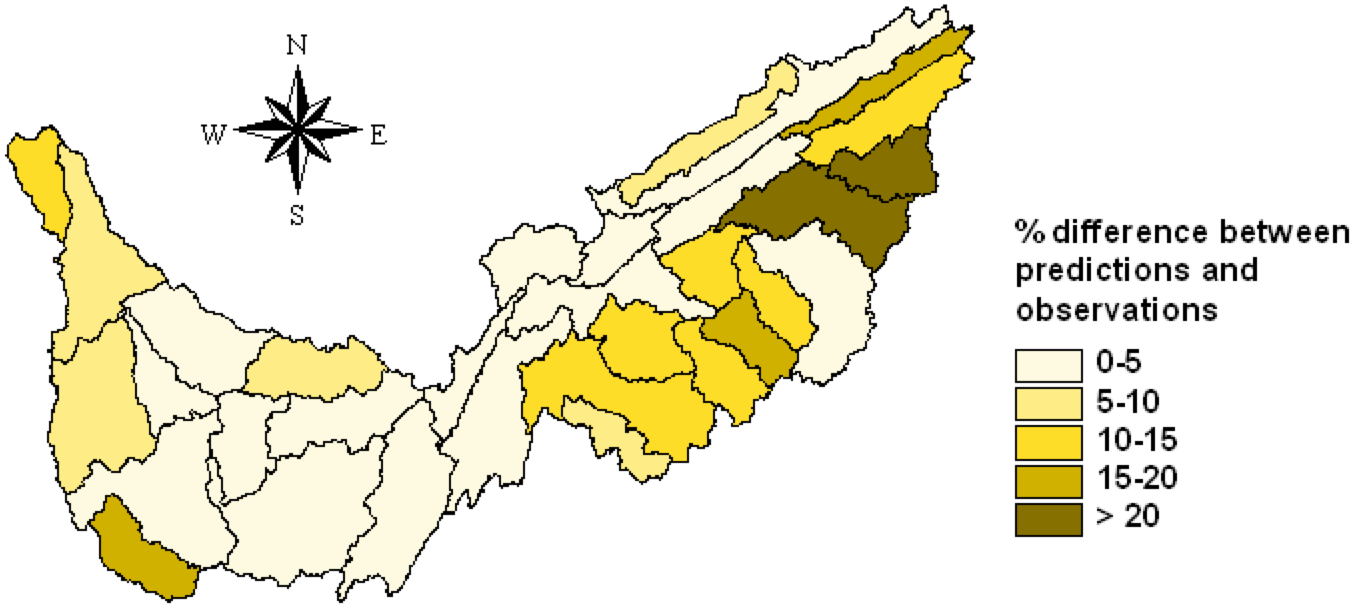
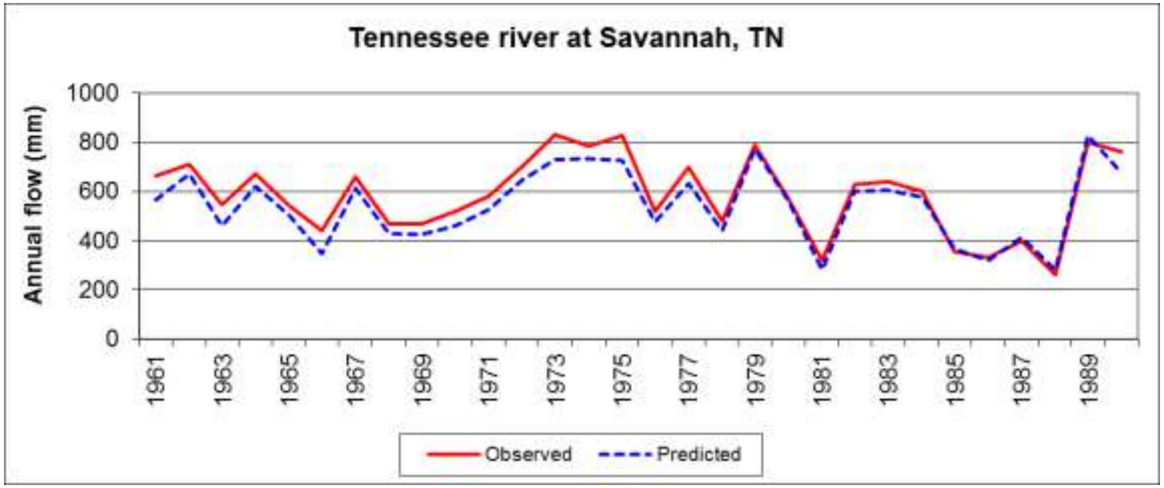
Mean annual water yield for sub-basins in Tennessee river basin





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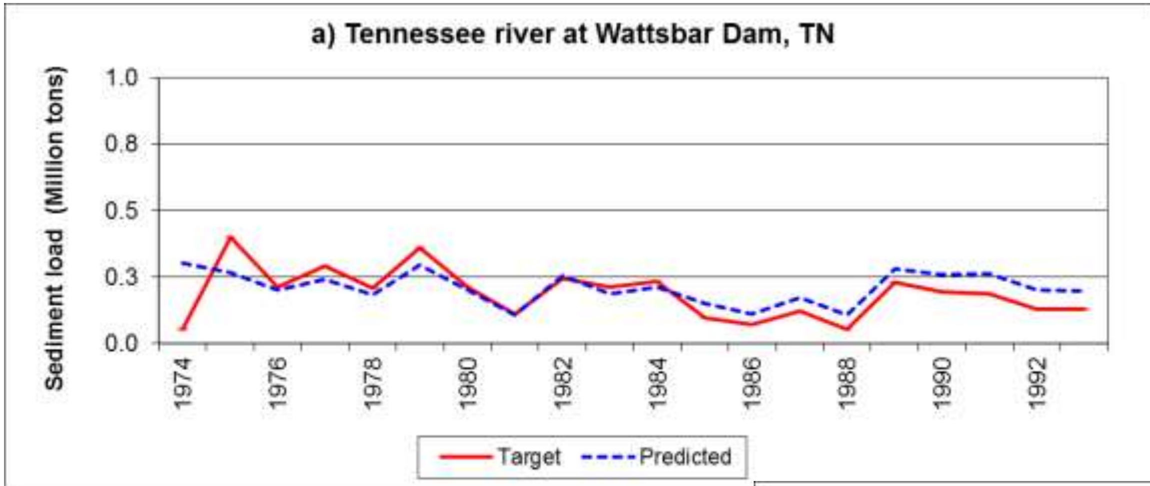
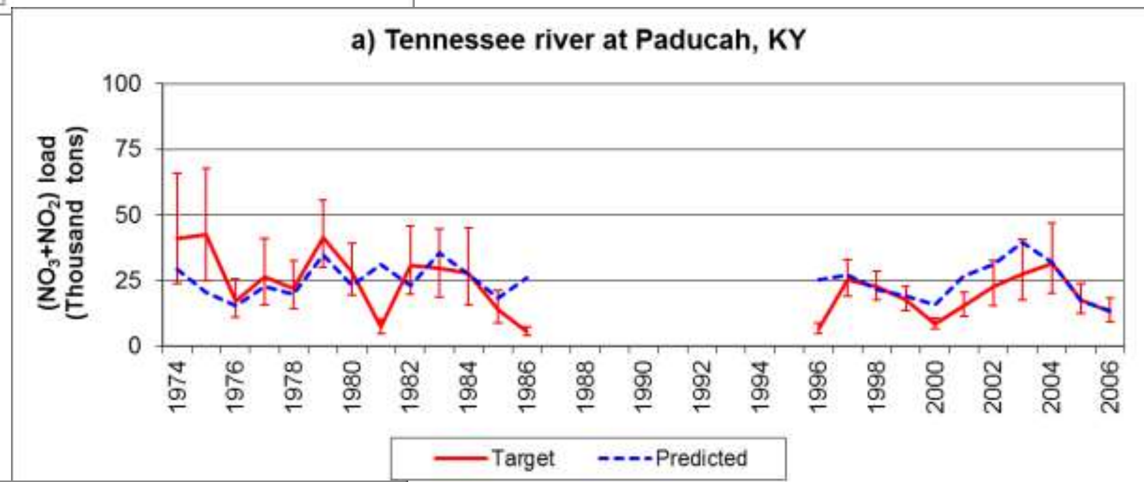
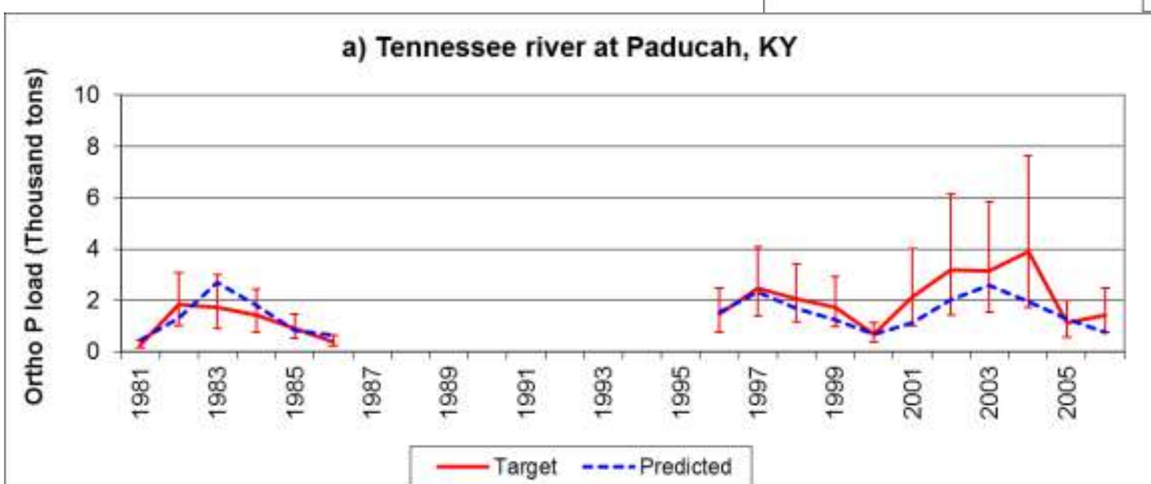


<u>Our publications on calibration</u>

Kannan et al., 2008 – Journal of Hydrology, 359, 1-15

Santhi et al., 2008 – JAWRA 44(4), 829-846.





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Concluding remarks

DO

- Understand the river basin-identify key drivers of flow and pollutant transport
- Customize a calibration plan for different regions of river basin

DO NOT

- calibrate without checking the quality of input and quality of un-calibrated model results
- Try to compensate for data problems by parameterization