MISSOURI
DEPARTMENT OF
NATURAL RESOURCES

Modeling Lake Water Quality

John Hoke, Water Protection Program

Missouri Department of Natural Resources

MISSOURI
DEPARTMENT OF
NATURAL RESOURCES

Lakes in Missouri

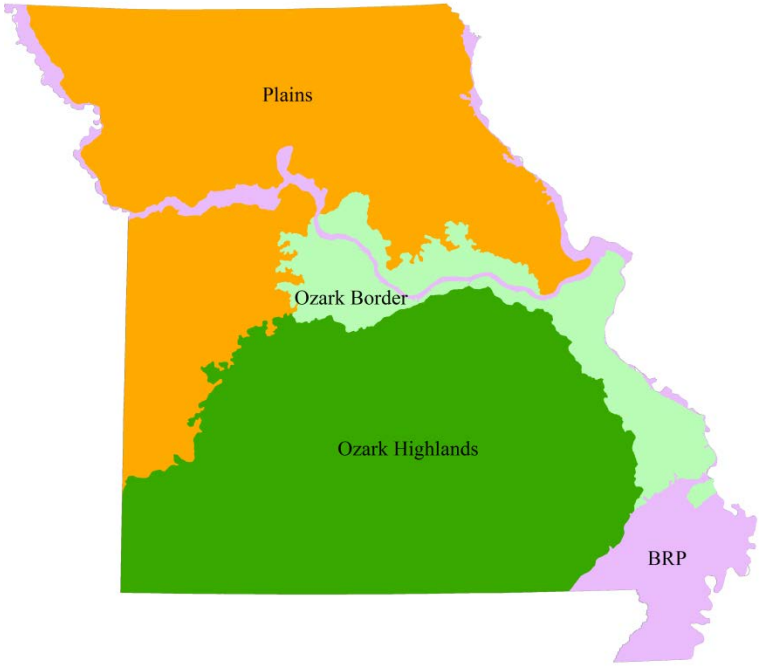
MISSOURI
DEPARTMENT OF
NATURAL RESOURCES

Lakes in Missouri

MISSOURI DEPARTMENT OF NATURAL RESOURCES

Nutrient Criteria for Lakes

- Framework that integrates nutrient parameters (Total P, Total N) and their response in lakes (algae/chlorophyll-a)
- Missouri Ecoregion specific
- The rule provides a weight of evidence approach where impairment status is unclear

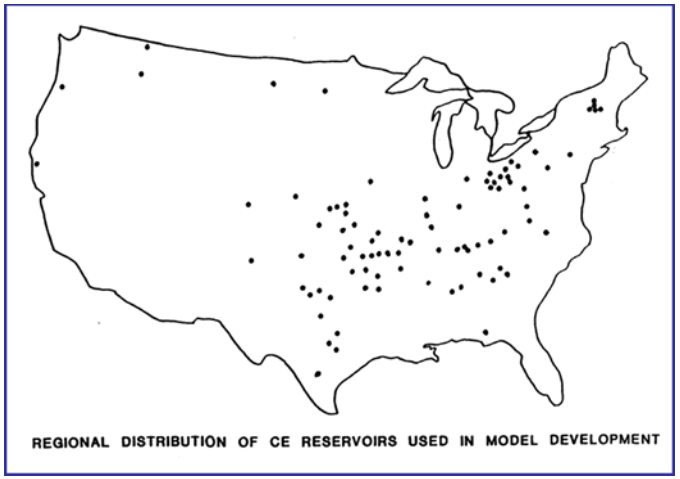


Lake Ecoregion	Chl-a Criterion (µg/L)	Screening Values (µg/L)		
		Total Phosphorous (TP)	Total Nitrogen (TN)	Chl-a
Plains	30	49	843	18
Ozark Border	22	40	733	13
Ozark Highland	15	16	401	6

MISSOURI DEPARTMENT OF NATURAL RESOURCES

Lake Water Quality Model (BATHTUB)

- Reservoir/Lake water quality model developed by the U.S. Army Corps of Engineers
- Uses empirical relationships to predict eutrophication-related water quality conditions (i.e., trophic conditions)
- Expressed as total phosphorous (TP), total nitrogen (TN), chlorophyll-a (Chl-a), and transparency (Secchi depth)



REGIONAL DISTRIBUTION OF CE RESERVOIRS USED IN MODEL DEVELOPMENT

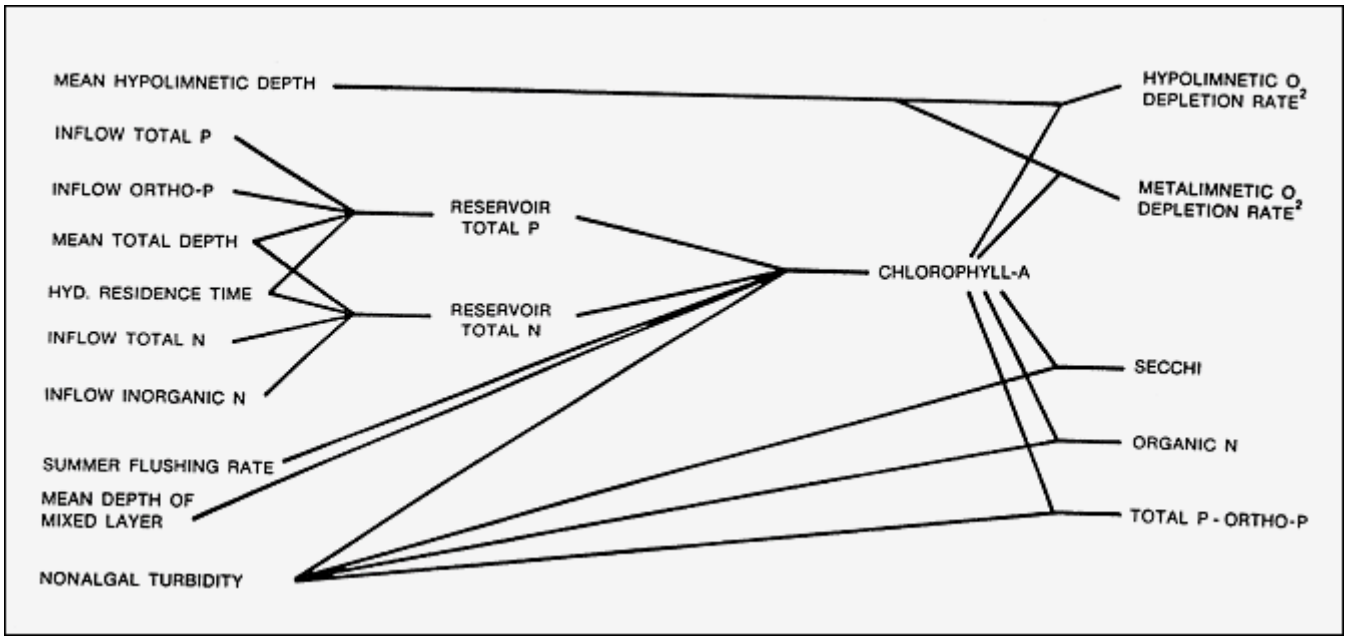
MISSOURI DEPARTMENT OF NATURAL RESOURCES

Lake Water Quality Model (BATHTUB)

- Can assess impacts of changes in mean pool elevation during the growing season
- Can assess impacts of changes in water and/or nutrient loadings
- Can estimate nutrient loadings consistent with given water quality management objectives
- Can estimate aggregate impact of point sources on the lake and determine reasonable potential

MISSOURI
DEPARTMENT OF
NATURAL RESOURCES

Lake Water Quality Model (BATHTUB)

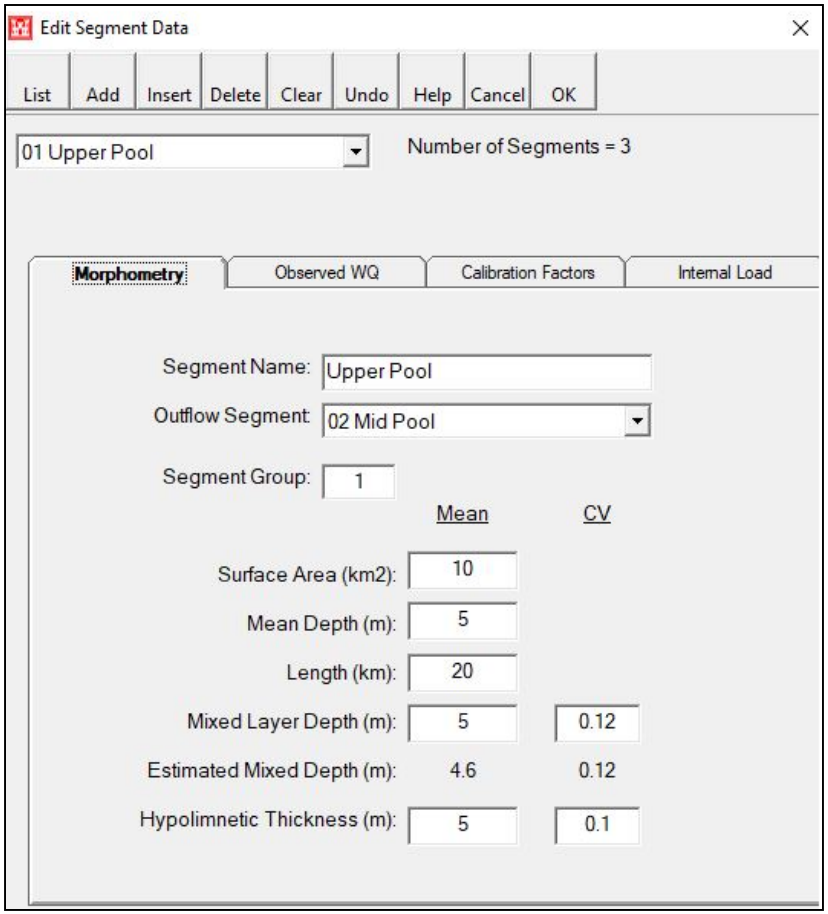


Model Control Pathways (Figure 2) – BATHTUB Overview

Model formulates steady-state water and nutrient mass balances in a spatially segmented hydraulic network that accounts for advective transport, diffusive transport, and nutrient sedimentation.

MISSOURI DEPARTMENT OF NATURAL RESOURCES

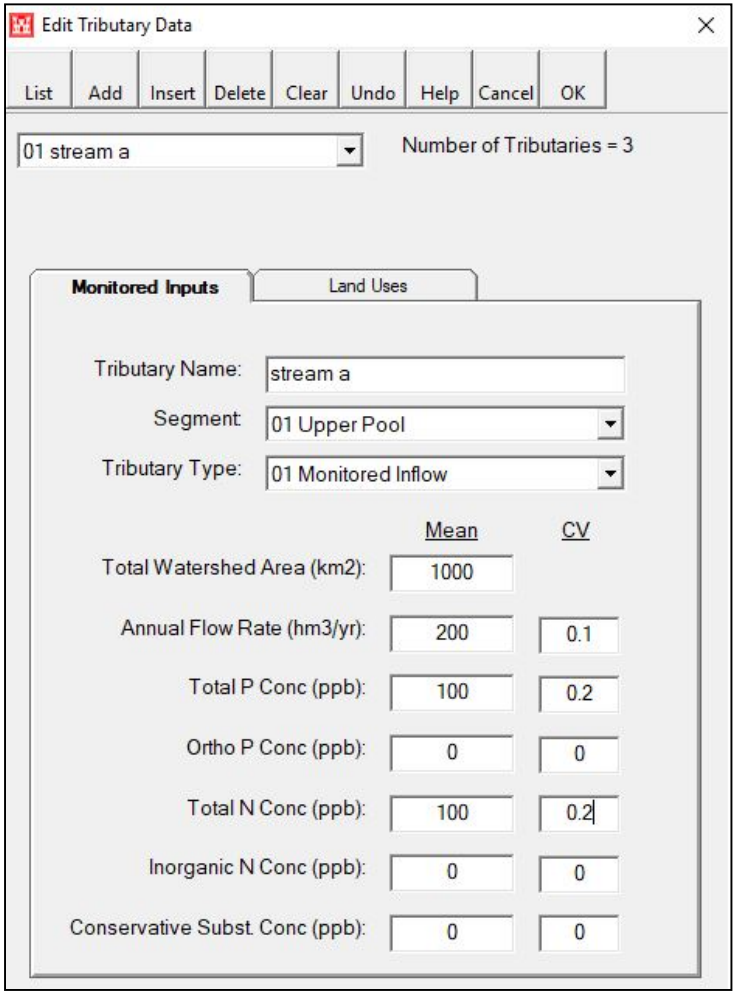
BATHTUB Setup
Lake Hydrologic Conditions



Imagery – Google Maps (2019)

MISSOURI DEPARTMENT OF NATURAL RESOURCES

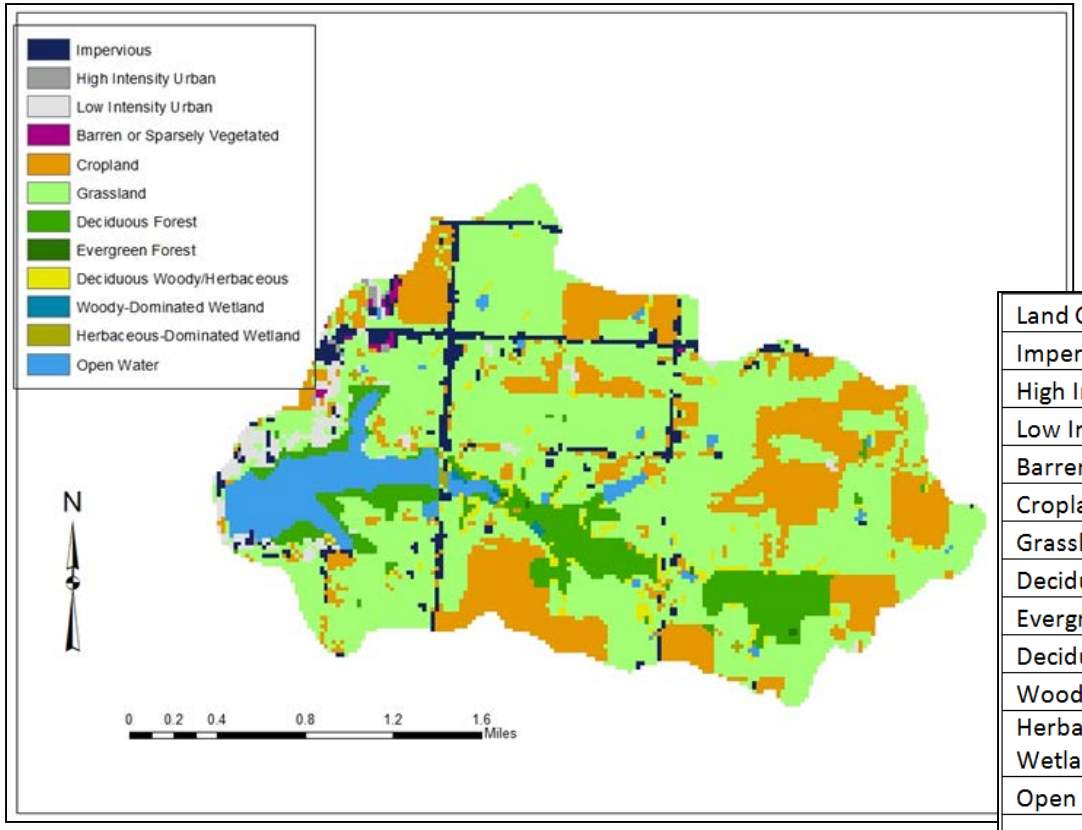
BATHTUB Setup
Water Quality Conditions

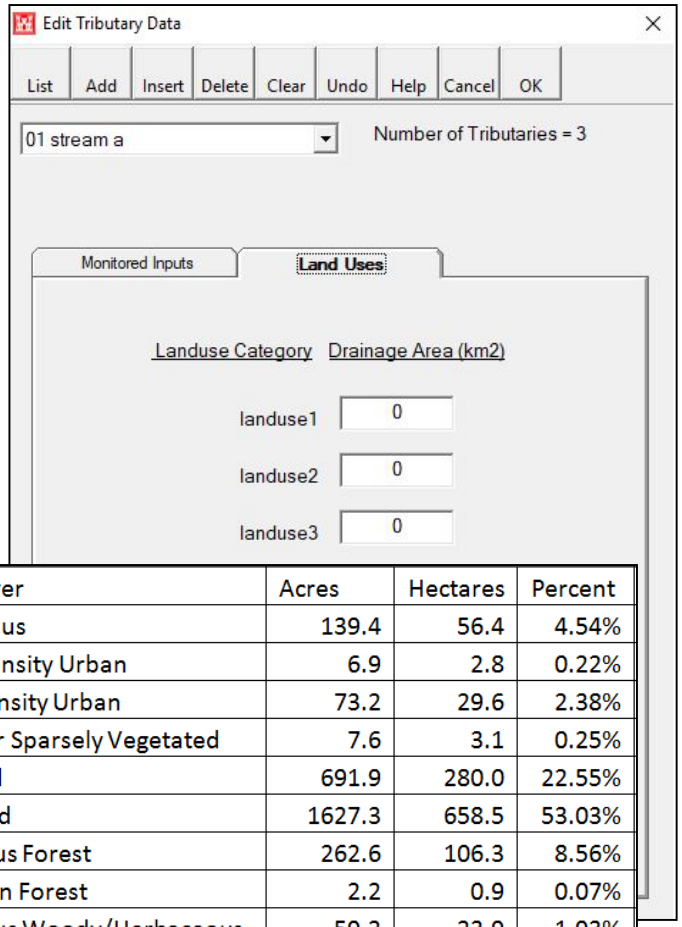


- Measured Tributary Loads
- Measured Point Source Loads
- Estimated Nonpoint Source Loads (e.g., STEPL)

MISSOURI DEPARTMENT OF NATURAL RESOURCES

BATHTUB Setup
Lake Watershed Conditions

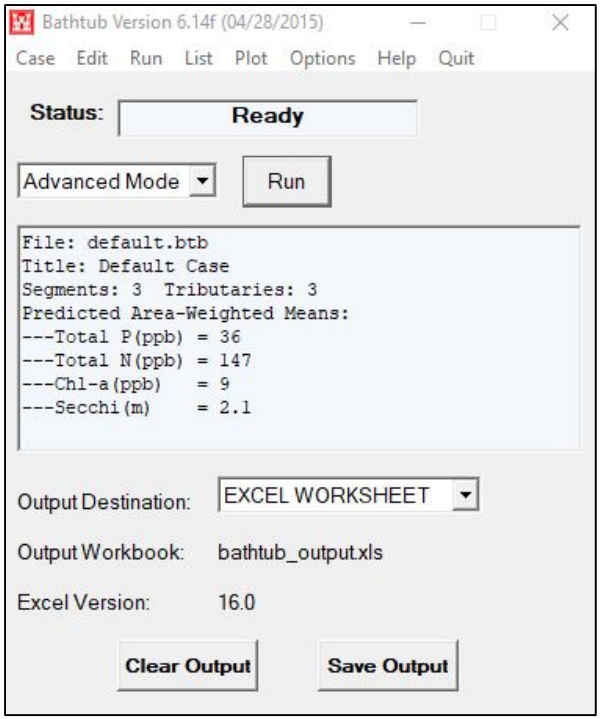


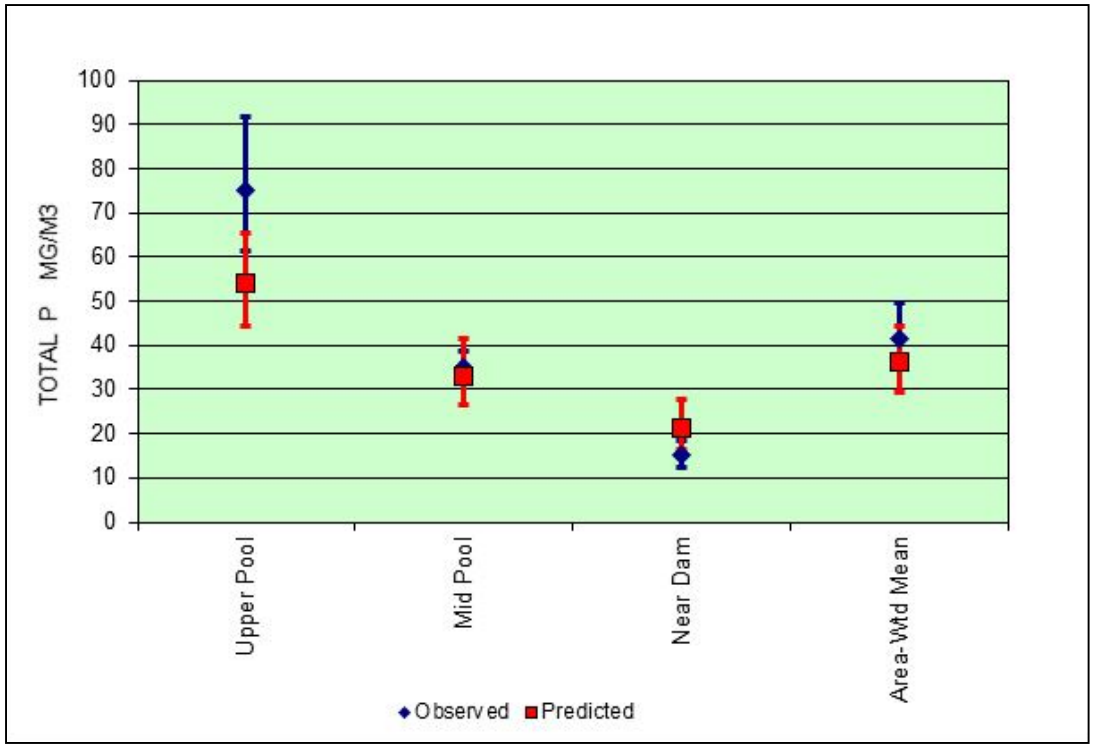


Land Cover	Acres	Hectares	Percent
Impervious	139.4	56.4	4.54%
High Intensity Urban	6.9	2.8	0.22%
Low Intensity Urban	73.2	29.6	2.38%
Barren or Sparsely Vegetated	7.6	3.1	0.25%
Cropland	691.9	280.0	22.55%
Grassland	1627.3	658.5	53.03%
Deciduous Forest	262.6	106.3	8.56%
Evergreen Forest	2.2	0.9	0.07%
Deciduous Woody/Herbaceous	59.2	23.9	1.93%
Woody-Dominated Wetland	4.9	2.0	0.16%
Herbaceous-Dominated Wetland	6.2	2.5	0.20%
Open Water	187.3	75.8	6.10%
Totals	**3068.604**	**1241.8**	

MISSOURI DEPARTMENT OF NATURAL RESOURCES

BATHTUB Output





Model calibration important to reduce uncertainty and increase confidence in the model and predictive scenarios to determine impacts

MISSOURI DEPARTMENT OF NATURAL RESOURCES

BATHTUB Output

					Load		Load Variance			Conc	Export
	Trb	Type	Seg	Name	kg/yr	%Total	$(kg/yr)^2$	%Total	CV	mg/m^3	$kg/km^2/yr$
20	Overall Mass Balance Based Upon				Predicted		Outflow & Reservoir Concentrations				
21	Component:				TOTAL P						
24	1	1	1	stream a	20000.0	77.2%	2.00E+07	95.7%	0.22	100.0	20.0
25	2										33.4
26	3										33.4
27	PRECI										30.0
28	TRIBU										21.7
29	***TO										22.0
30	ADVE										4.4
31	***TO										4.4
32	***RE										
33											
34		C									
35		H									
36		R									

4	Segment Mass Balance Based Upon Predicted Concentrations							
5								
6	Component: TOTAL P			Segment:	1	Upper Pool		
7				Flow	Flow	Load	Load	Conc
8	Trib	Type	Location	hm^3/yr	%Total	kg/yr	%Total	mg/m^3
9	1	1	stream a	200.0	94.8%	20000.0	98.5%	100
10	PRECIPITATION			11.0	5.2%	300.0	1.5%	27
11	TRIBUTARY INFLOW			200.0	94.8%	20000.0	98.5%	100
12	***TOTAL INFLOW			211.0	100.0%	20300.0	100.0%	96
13	ADVECTIVE OUTFLOW			204.0	96.7%	10988.7	54.1%	54
14	***TOTAL OUTFLOW			204.0	96.7%	10988.7	54.1%	54
15	***EVAPORATION			7.0	3.3%	0.0	0.0%	
16	***RETENTION			0.0	0.0%	9311.3	45.9%	
17								
18	Hyd. Residence Time =			0.2451	yrs			
19	Overflow Rate =			20.4	m/yr			
20	Mean Depth =			5.0	m			

MISSOURI DEPARTMENT OF NATURAL RESOURCES

BATHTUB Output

T Statistics Compare Observed and Predicted Means Using the Following Error Terms:
1 = Observed Water Quality Error Only
2 = Error Typical of Model Development Dataset
3 = Observed & Predicted Error

Segment: Area-Wtd Mean

	Observed		Predicted		Obs/Pred	T-Statistics ---->		
Variable	Mean	CV	Mean	CV	Ratio	T1	T2	T3
TOTAL P MG/M3	41.7	0.17	36.1	0.21	1.15	0.83	0.53	0.53
CHL-A MG/M3	10.0	0.20	9.4	0.36	1.06	0.29	0.17	0.14
SECCHI M	2.1	0.21	2.1	0.63	0.98	-0.08	-0.06	-0.03
HOD-V MG/M3-DAY	83.3	0.16	147.4	0.25	0.57	-3.56	-2.82	-1.90
ANTILOG PC-1	152.5	0.18	23.1	0.29	6.60	10.72	5.37	5.52
ANTILOG PC-2	11.5	0.13	19.9	0.52	0.58	-4.12	-1.78	-1.03

Segment: 1 Upper Pool

	Observed		Predicted		Obs/Pred	T-Statistics ---->		
Variable	Mean	CV	Mean	CV	Ratio	T1	T2	T3
TOTAL P MG/M3	75.0	0.20	53.9	0.19	1.39	1.65	1.23	1.19
CHL-A MG/M3	5.0	0.20	9.5	0.42	0.53	-3.19	-1.84	-1.36
SECCHI M	0.8	0.30	0.6	0.39	1.31	0.90	0.96	0.54
HOD-V MG/M3-DAY	50.0	0.20	147.4	0.25	0.34	-5.41	-5.35	-3.34
ANTILOG PC-1	168.9	0.33	36.1	0.26	4.68	4.65	4.39	3.68
ANTILOG PC-2	3.4	0.27	9.5	0.50	0.36	-3.85	-3.34	-1.82

MISSOURI DEPARTMENT OF NATURAL RESOURCES

BATHTUB – Point Source Impacts

- Consider aggregate impacts of point sources on lake criteria
- If point source contributions impact lake criteria, reasonable potential exists
- Conduct facility-specific scenarios to determine needed reductions and effluent limits
- Focus on achieving chl-a criteria at the dam, but may consider other values (TN, TP), if limiting