Modeling of the Illinois River Watershed – Technical Update

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Illinois River Watershed Modeling
and TMDL Development Project
Public Information Meeting
The Jones Center for Families
Springdale, AR

November 8, 2012

Presentation Topics

- Watershed Model Setup/Overview
- Calibration and Validation Status
  - NEXRAD Issues
  - Current Hydrology Calibration Results
  - Initial Sediment and Water Temperature
- Phosphorus sources and Fate/Transport
- Planned Sensitivity and Uncertainty Analyses

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Models Used for the IRW TMDL

- Watershed Domain:
  - HSPF – Hydrologic Simulation Program FORTRAN
- Lake Tenkiller
  - EFDC – Environmental Fluid Dynamics Code

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THE MODELING PROCESS

Phase I

- Data collection
- Model input preparation
- Parameter evaluation

Phase II

- Calibration
- Validation
- (Post-audit)

Model Testing/ Performance Evaluation

Phase III

- Analysis of alternatives

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Constituents Modeled

- Flow/discharge
- Sediment/TSS
- Water temperature
- DO
- BOD ultimate or total BOD/Organics
- NO3/NO2, combined
- NH3/NH4
- Total N
- PO4
- Total P
- Phytoplankton as Chl a
- Benthic algae

IRW Gage Stations for Calibration/Validation

Location	Gage Station	Water Quality		Tributary Area (mi²)	Elevation (ft)
Illinois River near Tahlequah, OK	7196500	8/23/1955	12/15/2009	959	664.14
Baron Fork at Eldon, OK	7197000	5/7/1958	12/14/2009	307	701.14
Baron Fork at Dutch Mills, AR	7196900	3/17/1959	8/25/2009	40.6	986.47
Illinois River near Watts, OK	7195500	9/12/1955	10/26/2009	635	893.78
Illinois River near Viney Grove, AR	7194760	9/6/1978	7/19/2007	80.7	
Illinois River at Savoy, AR	7194800	9/11/1968	8/25/2009	167	
Osage Creek near Elm Springs, AR	7195000	9/10/1951	8/25/2009	130	1052
Illinois River at Hwy. 16 near Siloam Springs AR	7195400	9/8/1978	9/20/1994	509	
Illinois River South of Siloam Springs, AR	7195430	10/3/1972	8/25/2009	575	
Flint Creek at Springtown, AR	7195800	10/15/1975	7/1/1996	14.2	1173.47
Flint Creek near West Siloam Springs, OK	7195855	7/11/1979	8/28/1996	59.8	
Sager Creek near West Siloam Springs, OK	7195865	5/24/1991	10/21/2009	18.9	960
Flint Creek near Kansas, OK	7196000	9/7/1955	10/26/2009	110	854.59
Peacheater Creek at Christie, OK	7196973	8/6/1991	5/16/1995	25	801.72
Caney Creek near Barber, OK	7197360	8/25/1997	10/27/2009	89.6	
Illinois River at Chewey, OK	7196090	7/16/1996	10/27/2009		
Illinois River near Gore, OK	7198000	4/12/1940	8/16/1995	1626	468

Key: Pink – Border sites; Yellow – OK; Green - AR

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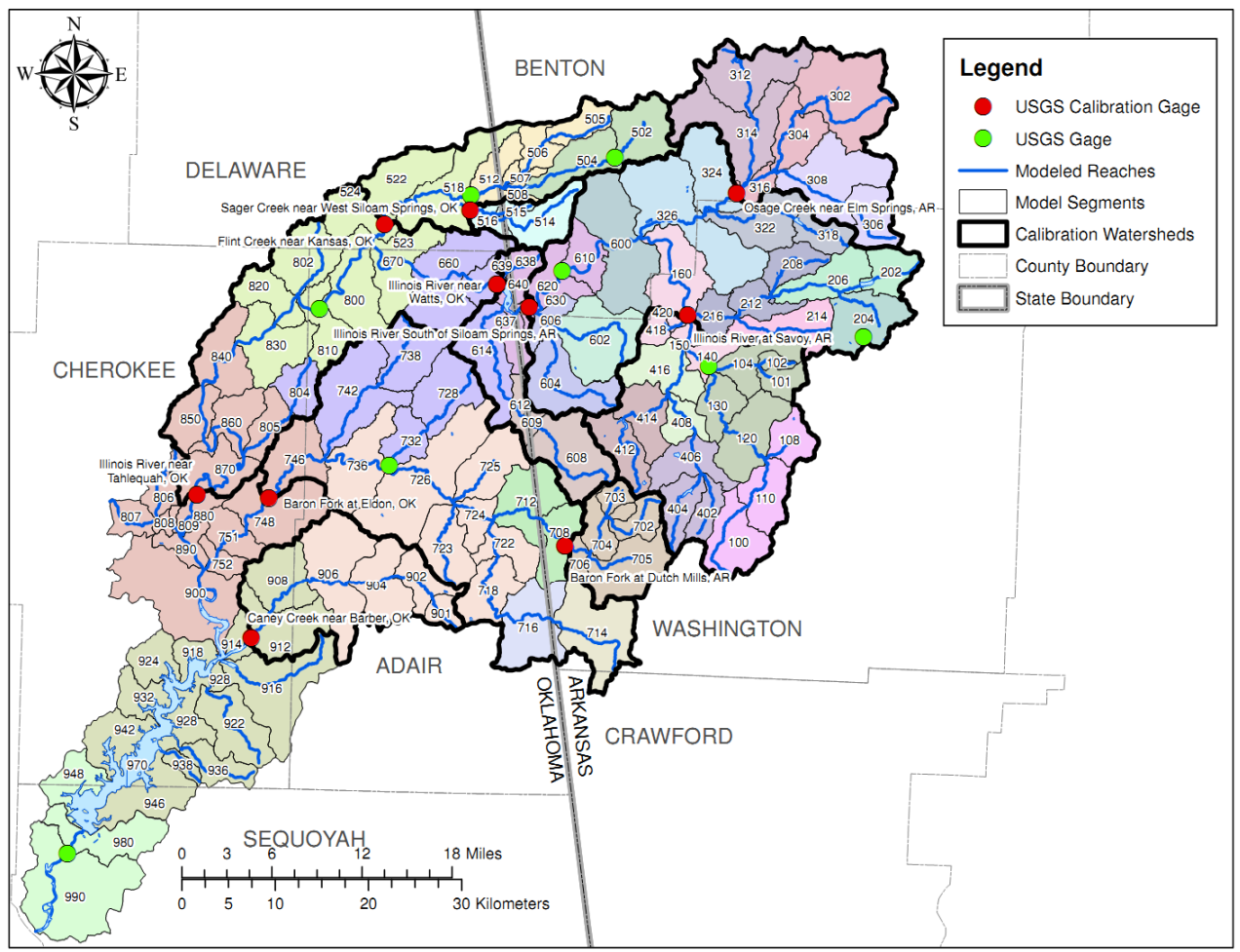
Final Watershed Segmentation

- Final Segmentation
- HUC12 starting point
- Adjusted for:
  - Gage locations
  - Stateline
  - Impaired segments
- Current detail:
  - 133 subbasins
  - 126 reachs



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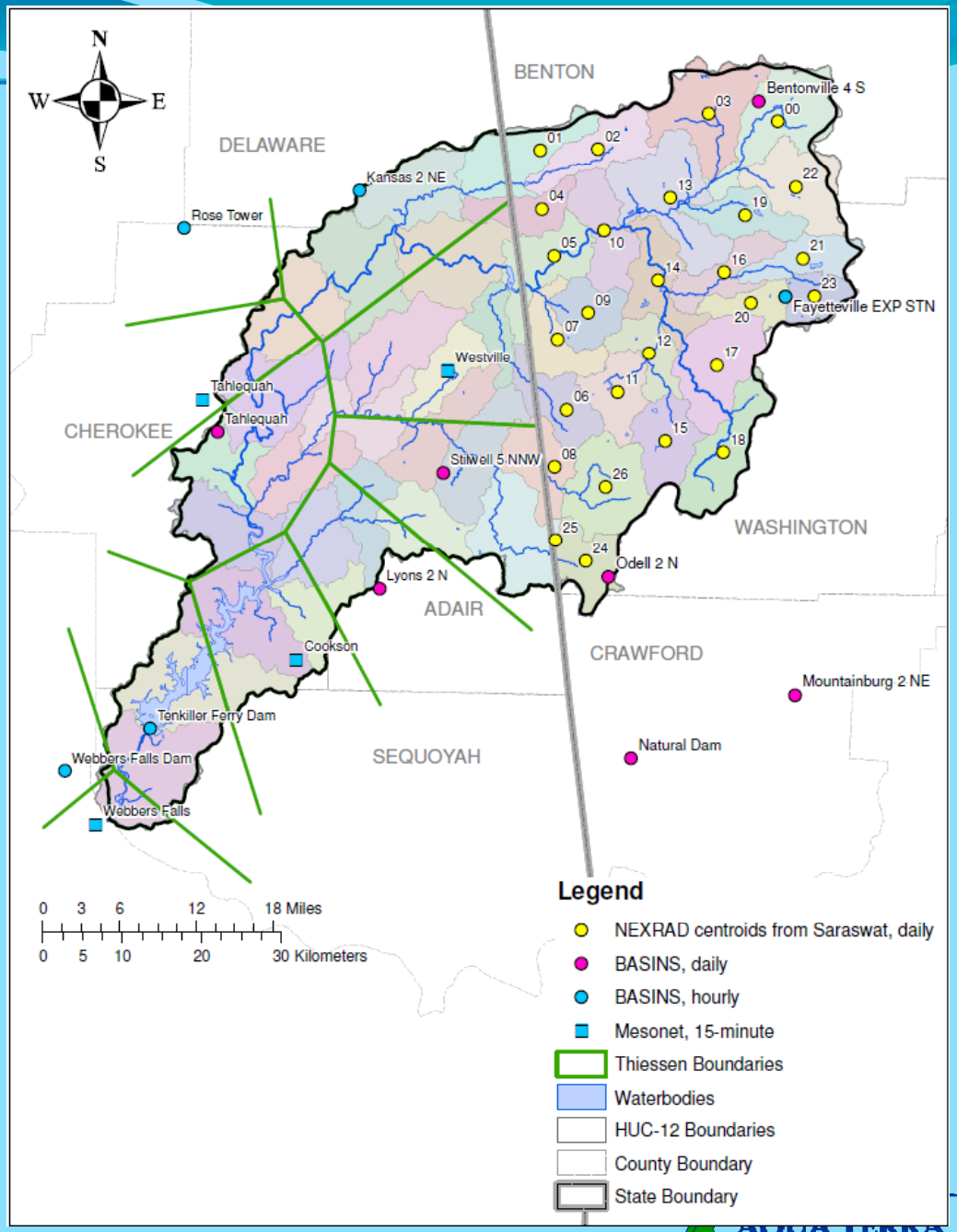
Calibration and Validation Sites

- AR –
  - Barren Fork at Dutch Mills
  - Osage Cr near Elm Springs
  - IR at Savoy
  - Sager Cr, nr West Siloam Springs
- Border sites:
  - IR south of Siloam Springs (HY 59)
  - IR near Watts
- OK –
  - Barren Fork at Eldon
  - Flint Creek near Kansas
  - Caney Creek near Barber
  - IR at Tahlequah

Calibration and Validation Modeling Inputs: Rainfall

- For OK – 11 gages using NWS/BASINS and Mesonet data
- For AR – NEXRAD data from Saraswat for 27 subwatersheds
- Daily data to be disaggregated to hourly values



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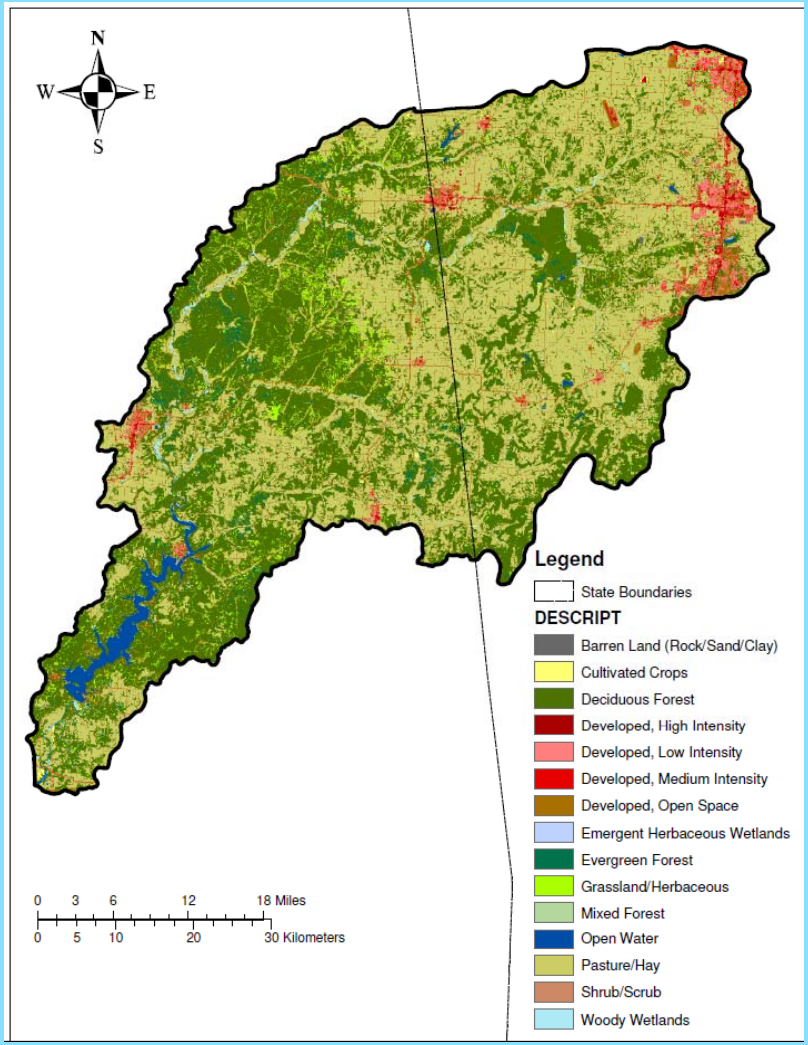
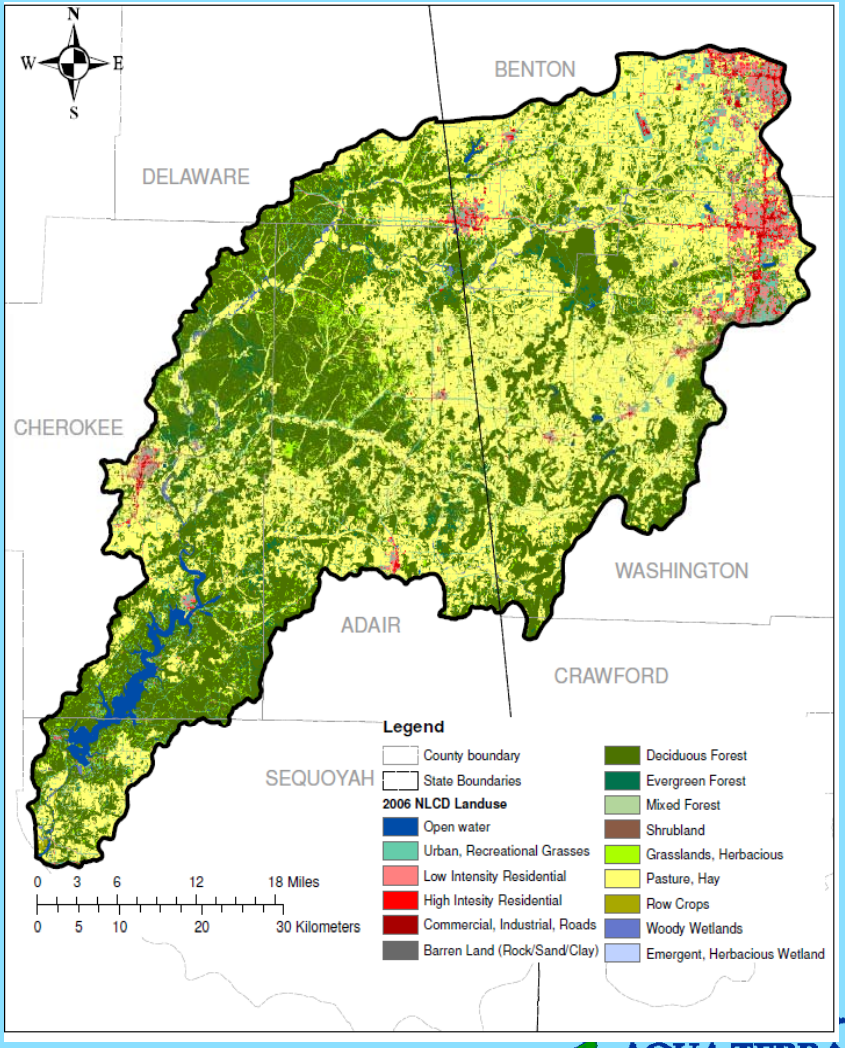
NLCD Land Use – 2001 and 2006

2001



2006



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NLCD Aggregation to Model Categories

NLCD Class (2001, 2006)	2001 Percent	2006 Percent	Aggregated Model Categories	2001 Percent	2006 Percent
Deciduous Forest	41.40%	41.11%	Forest	43.09%	42.78%
Evergreen Forest	1.20%	1.19%			
Mixed Forest	0.49%	0.49%			
Pasture/Hay	41.92%	41.08%	Pasture/Hay	41.92%	41.08%
Grassland/Herbaceous	3.41%	3.63%	Grass/Shrub/Barren	3.99%	4.33%
Shrub/Scrub	0.47%	0.50%			
Barren Land (Rock/Sand/Clay)	0.11%	0.19%			
Developed, Open Space	5.61%	5.93%	Developed, Open Space	5.61%	5.93%
Developed, Low Intensity	2.16%	2.42%	Developed, Open/Low Intensity	2.16%	2.42%
Developed, Medium Intensity	0.74%	0.92%	Developed, Medium/High Intensity (includes Commercial/Industrial)	1.03%	1.27%
Developed, High Intensity	0.29%	0.35%			
Woody Wetlands	0.59%	0.59%	Wetlands	0.60%	0.60%
Emergent Herbacious Wetlands	0.01%	0.01%			
Cultivated Crops	0.15%	0.15%	Cultivated Crops	0.15%	0.15%
Open Water	1.46%	1.46%	Open Water	1.46%	1.46%
Totals	100%	100%	Totals	100%	100%

Note: Open Water modeled as a water surface (stream/lake), not as a land component.

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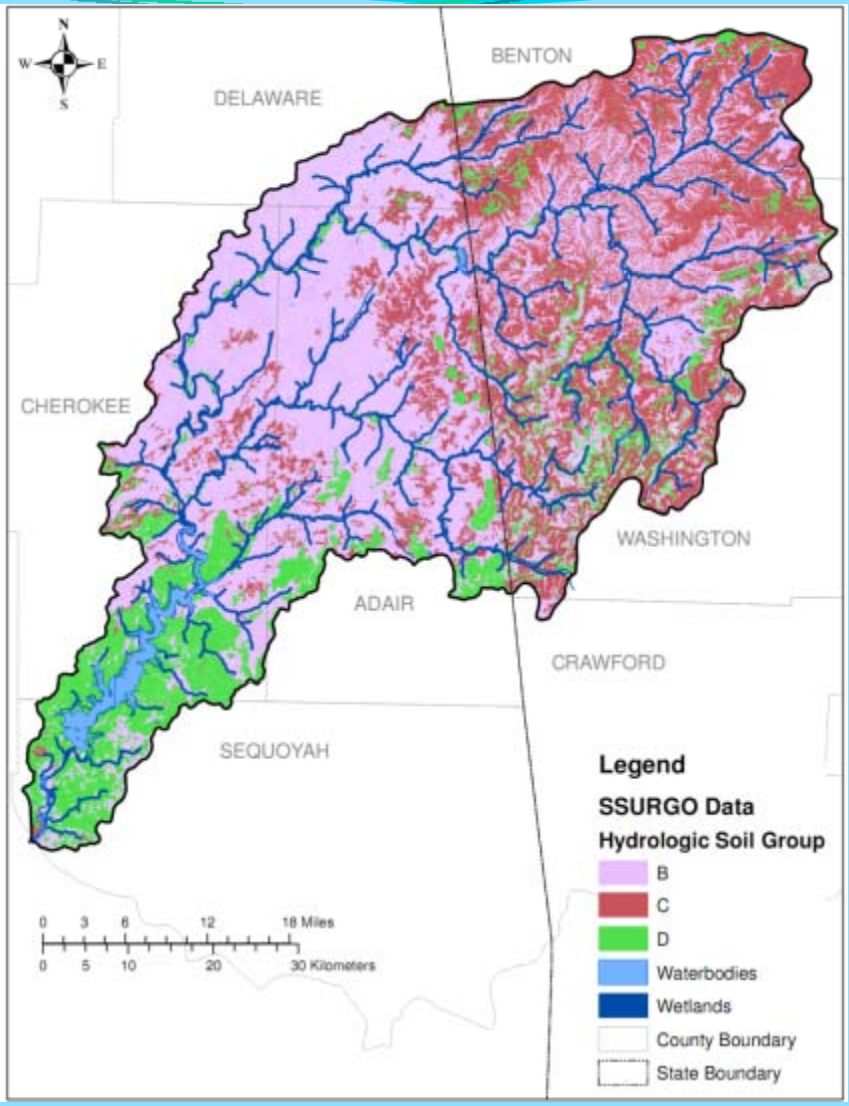
Calibration and Validation Modeling Inputs:

Hydrologic Soil Groups



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WWTP Point Sources Discharges

- Daily timeseries of loadings developed for all constituents
- Loadings developed from daily data when available, but often from weekly/monthly data
- Loadings developed from data obtained from the facilities, from previous studies, and DMR reports
- Missing data filled by interpolation and averaging, as needed, or estimated from other facilities

Facility	State	Typical Flow (MGD)	TP Load 1990-2000 (lb/year)	TP Load 2001-2009 (lb/year)	2009 TP Load (lb/year)
Springdale	AR	12	140,000	77,100	16,900
Rogers	AR	6.5	7,410	11,300	5,380
Fayetteville - Noland & Westside	AR	4.5/5.8	5,100	5,650	7,907**
Siloam Springs	AR	3	29,500	25,900	12,600
Gentry	AR	0.45	5,430	5,430	4,920
Lincoln	AR	0.45	2,390	1,950	1,540
Prairie Grove	AR	0.3	3,550	3,950	3,400
SWEPCO Flint Ck Power Plant	AR	5/400	n/a *	n/a *	n/a *
USDA FS - Lake Wedington	AR	0.0013	1.2	2.3	4.5
Tahlequah	OK	2.7	11,900	2,790	3,910
Stilwell	OK	0.85	2,040	2,370	1,920
Westville	OK	0.2	1,440	720	489

* SWEPCO- no significant TP discharges ** Fayetteville 2009 load corrected from value shown at the meeting

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Watershed Model Calibration and Validation

Modeled Periods:

Calibration: 2001 – 2009 (9 years)

Validation: 1992 – 2000 (9 years)

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MODEL/DATA COMPARISONS

"Weight-of-Evidence" Approach

- Annual and monthly runoff volume (inches)
- Mean runoff volume for simulation period (inches)
- Daily flow timeseries (cfs)
  - observed and simulated daily flow
  - scatter plots
- Flow frequency (flow duration) curves (cfs)
- Storm hydrographs, hourly or less, (cfs)

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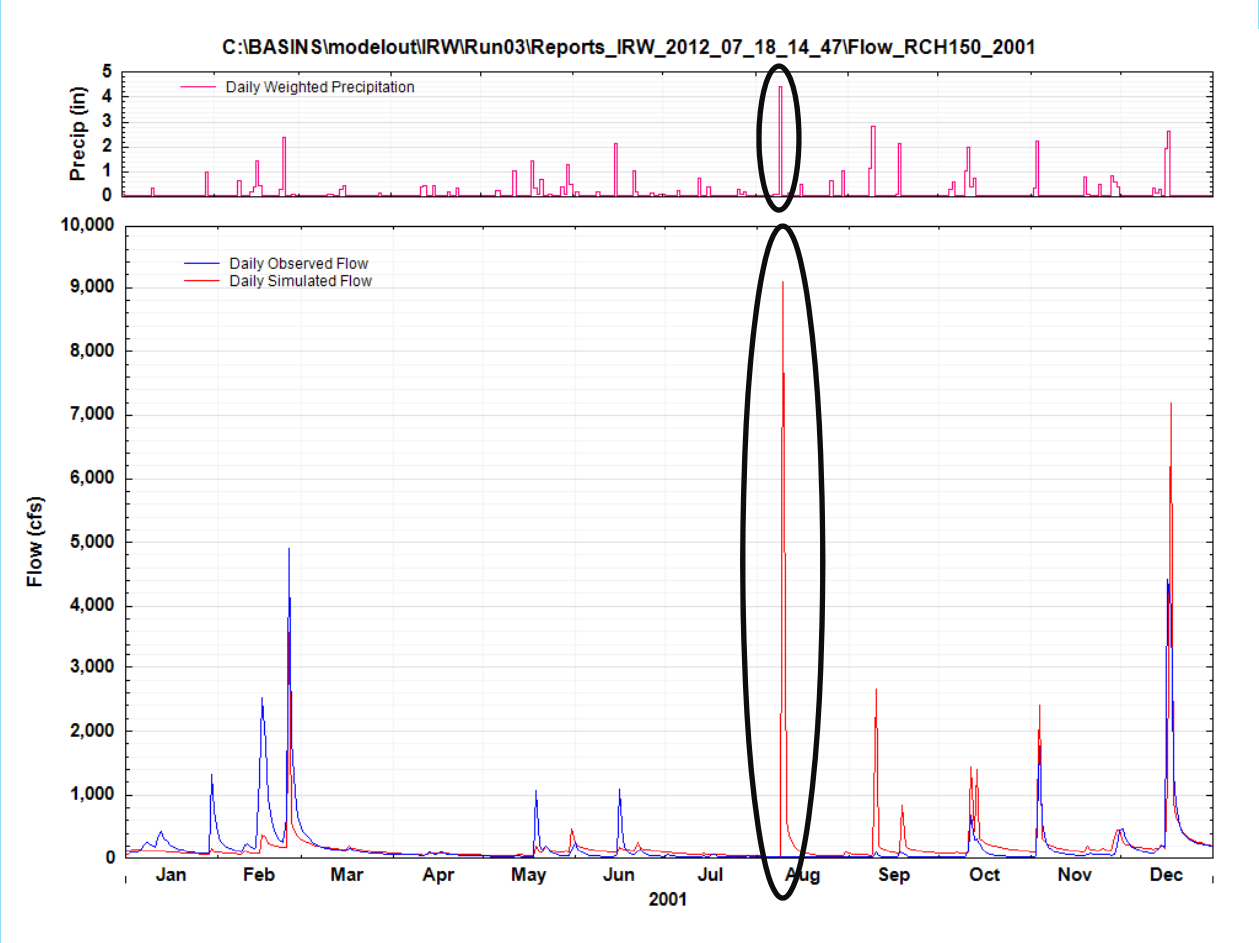
NEXRAD (Rainfall) Data Issues

- Provides much improved spatial resolution; daily values obtained from earlier SWAT model study
- Daily values distributed to hourly for use in HSPF, using closest NWS/Mesonet gages
- Initial model runs identified numerous 'extreme' daily values at selected subbasins, e.g. 10-22 inches in one day, for up to 10-15 events during the calibration period
- Some 'extreme' events were judged to be 'phantom' based on lack of noticeable response at closest flow gages
- Required adjustments to be consistent with nearby observed rainfall (both NEXRAD and NWS/Mesonet)

NEXRAD Issues

Illinois River at Savoy, AR (RCH 150, USGS 07194800)



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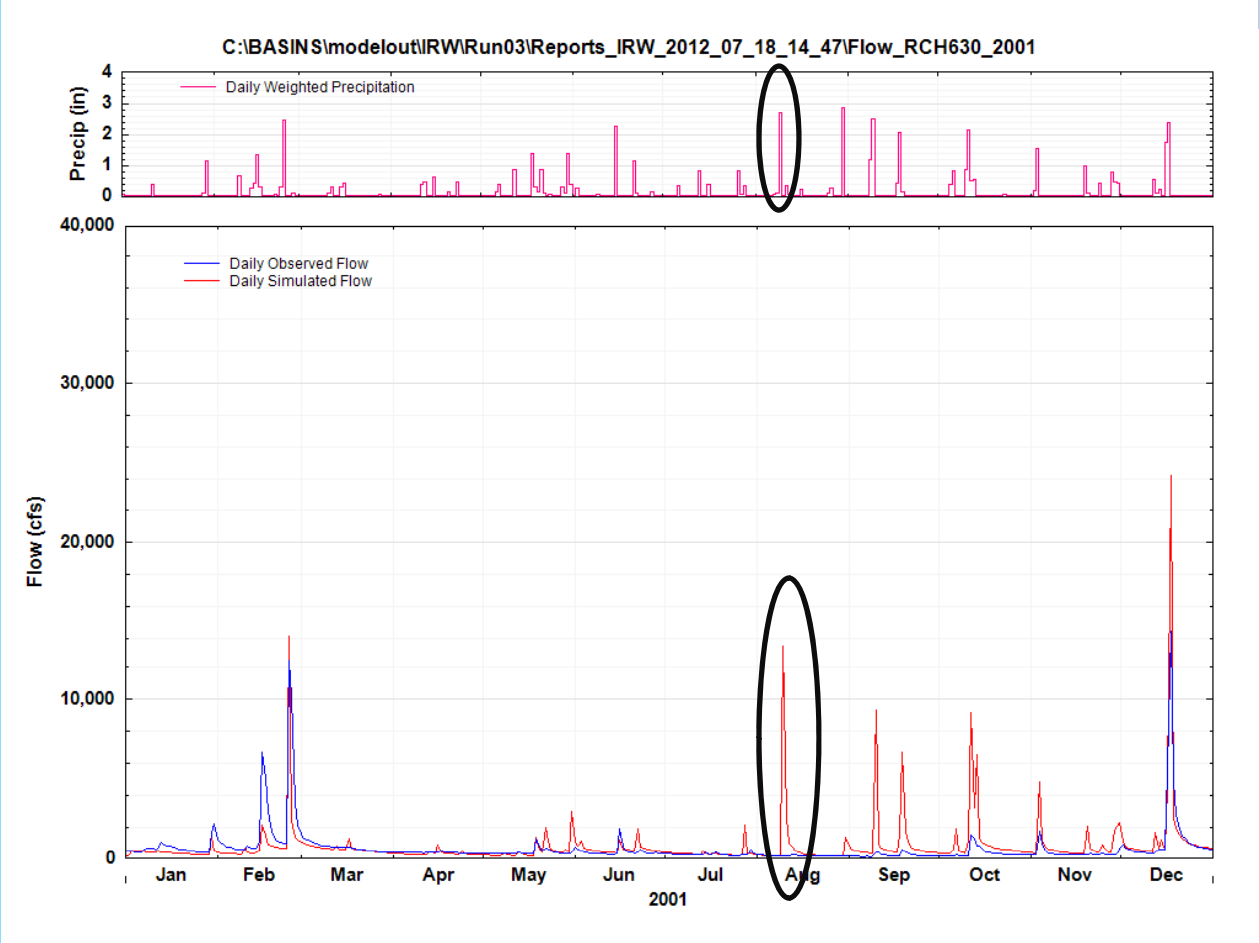
NEXRAD Issues

Illinois River South of Siloam Springs, AR (RCH 630, USGS



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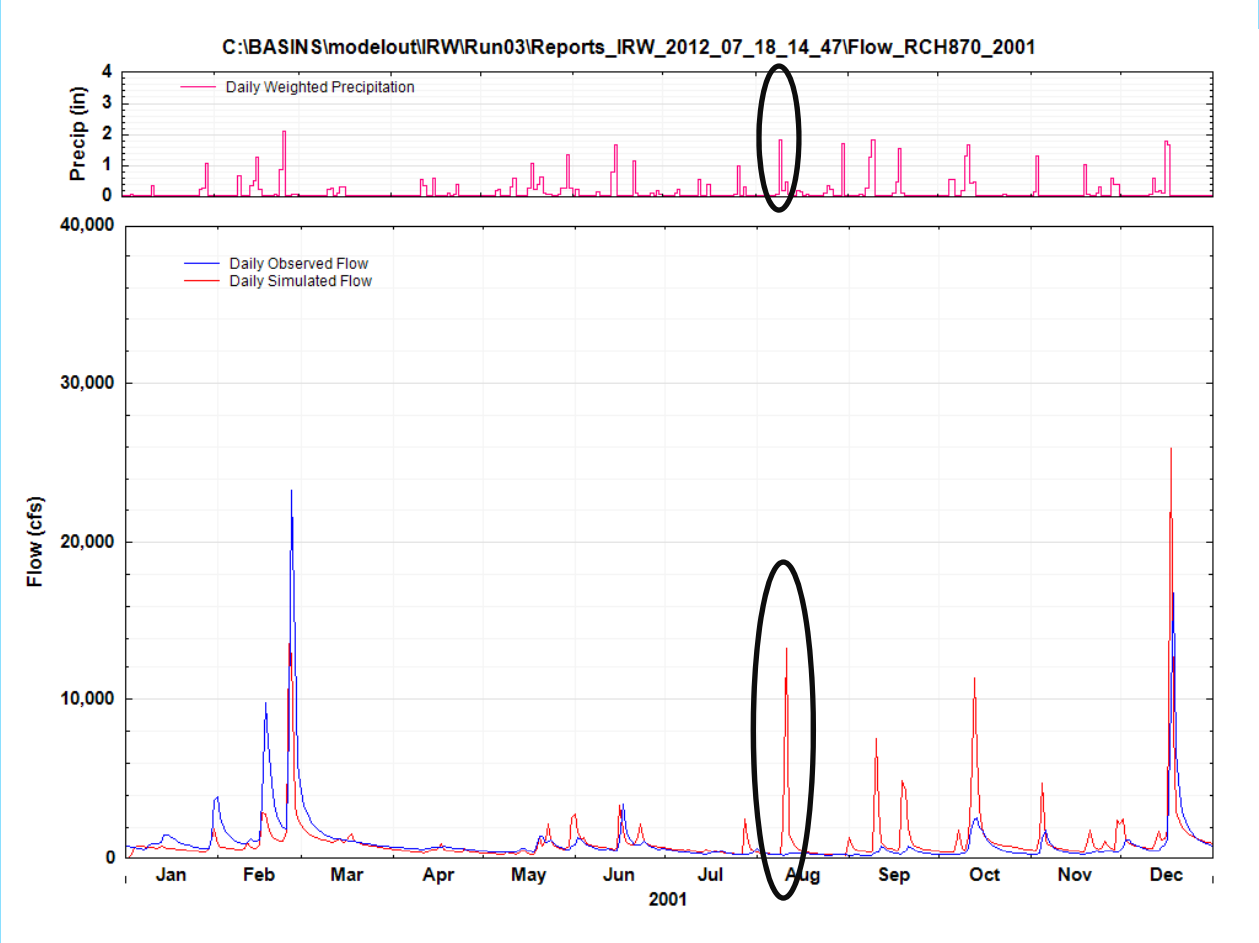
NEXRAD Issues

Illinois River near Tahlequah, OK (RCH 870, USGS 07196500)



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‘Current’ Hydrology Calibration Results

Site	Flow (in)			Daily		Monthly			NSE	
	Sim	Obs	% Vol error	R	R^2	R	R^2	Daily Peaks % Diff	Daily	Monthly
316 (Osage Creek near Elm Springs, AR (USGS gage))	17.80	17.07	4.25	0.76	0.57	0.87	0.75	14.00	0.37	0.74
150 (Illinois River at Savoy, AR)	14.98	13.77	8.79	0.80	0.63	0.90	0.82	-11.21	0.62	0.81
630 (Illinois River South of Siloam Springs, AR (USGS *)	16.52	14.07	17.43	0.80	0.64	0.88	0.78	9.52	0.52	0.75
640 (Illinois River near Watts, OK (USGS gage))	15.86	13.60	16.60	0.78	0.61	0.89	0.80	13.14	0.50	0.77
516 (Sager Creek near West Siloam Springs, OK (USGS ga*)	17.67	18.03	-2.01	0.71	0.50	0.81	0.65	-21.75	0.45	0.65
523 (Flint Creek near Kansas, OK)	13.30	12.28	8.24	0.78	0.61	0.89	0.79	2.57	0.55	0.78
870 (Illinois River near Tahlequah, OK (USGS gage))	15.17	13.74	10.43	0.73	0.53	0.92	0.85	-0.16	0.47	0.83
706 (Baron Fork at Dutch Mills, AR (USGS gage))	14.73	15.10	-2.42	0.75	0.56	0.83	0.70	-13.00	0.51	0.69
746 (Baron Fork at Eldon, OK (USGS gage))	15.08	13.69	10.13	0.88	0.77	0.93	0.87	-14.00	0.76	0.86
912 (Caney Creek near Barber, OK (USGS gage))	16.23	13.18	23.10	0.78	0.62	0.89	0.79	-2.64	0.58	0.74

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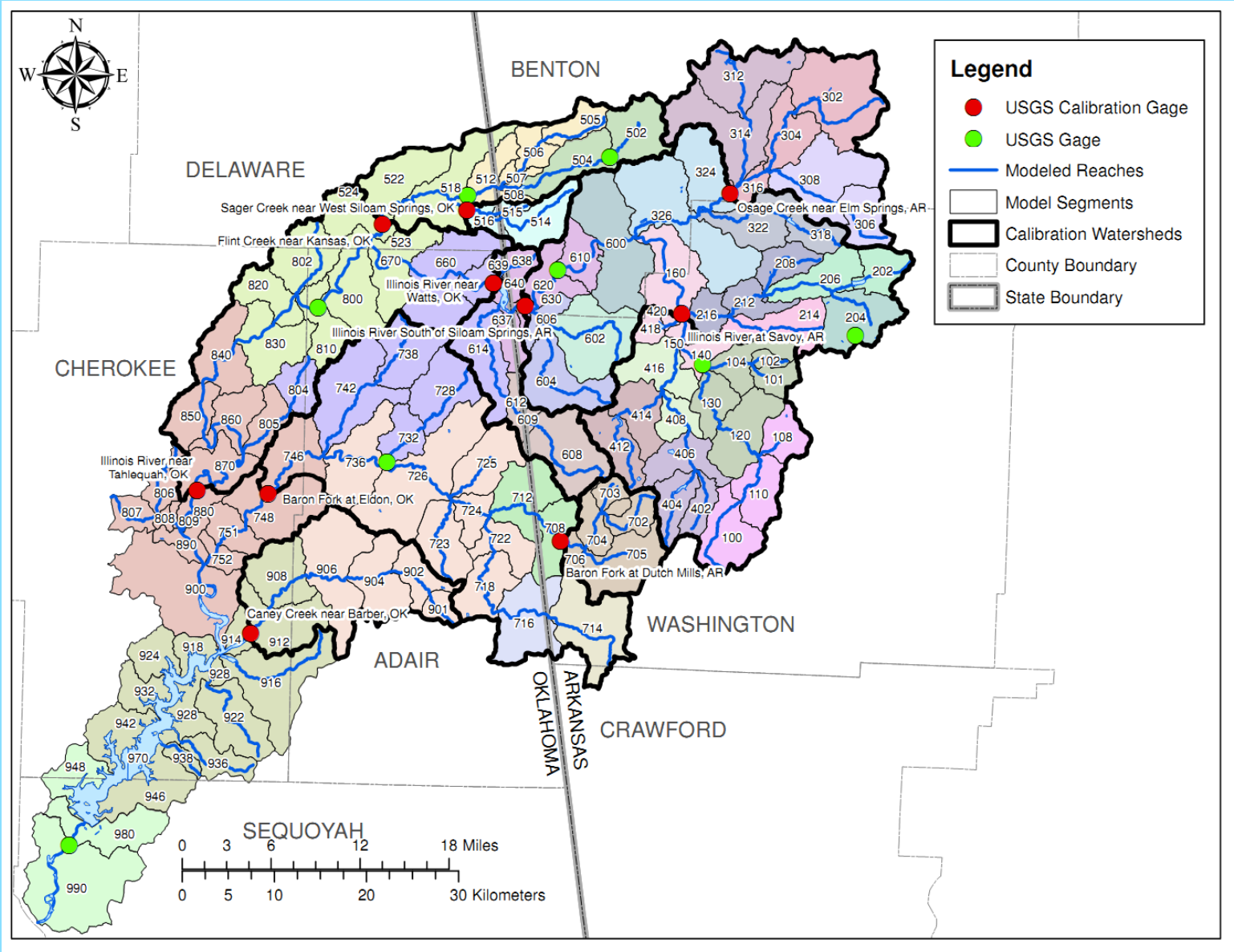
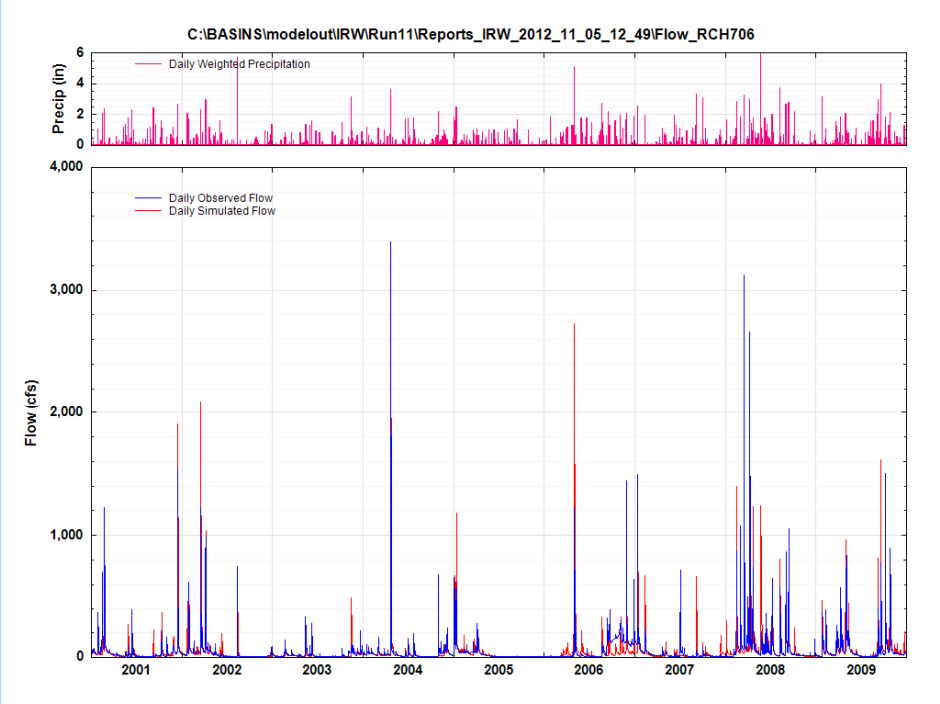
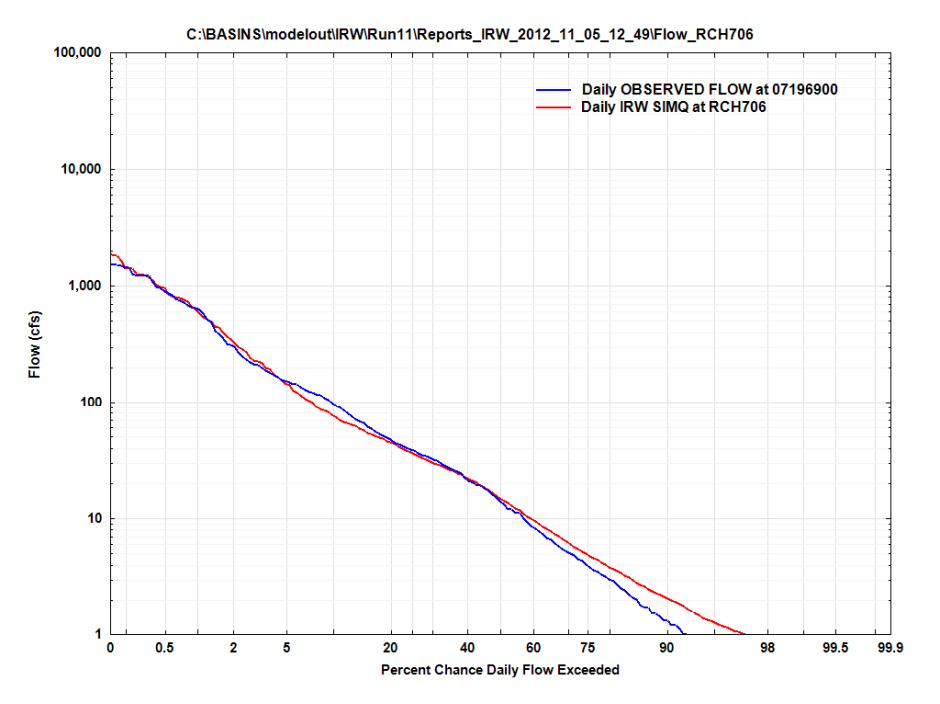
Final Watershed Segmentation



Hydrology Calibration Results

Baron Fork at Dutch Mills, AR (RCH 706, USGS 07196900)





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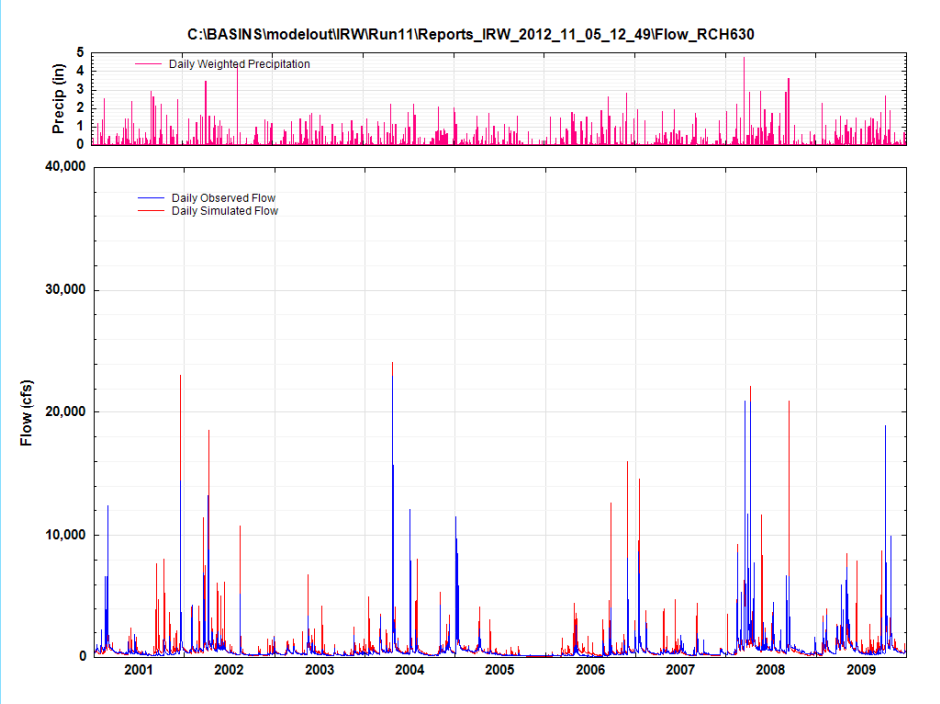
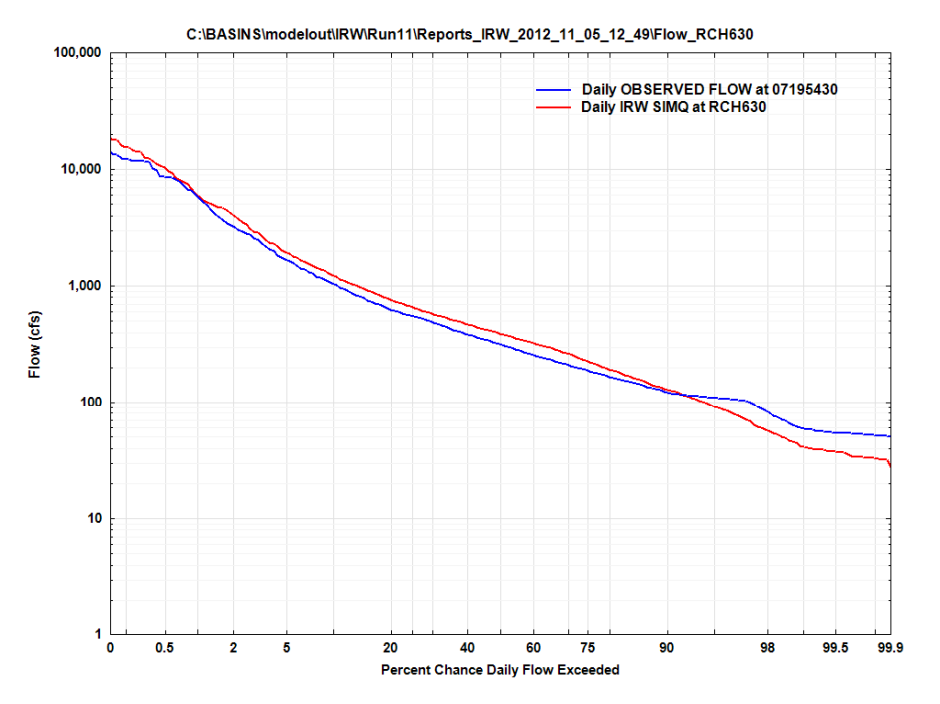
Hydrology Calibration Results

Illinois River South of Siloam Springs, AR (RCH 630, USGS 07195430)





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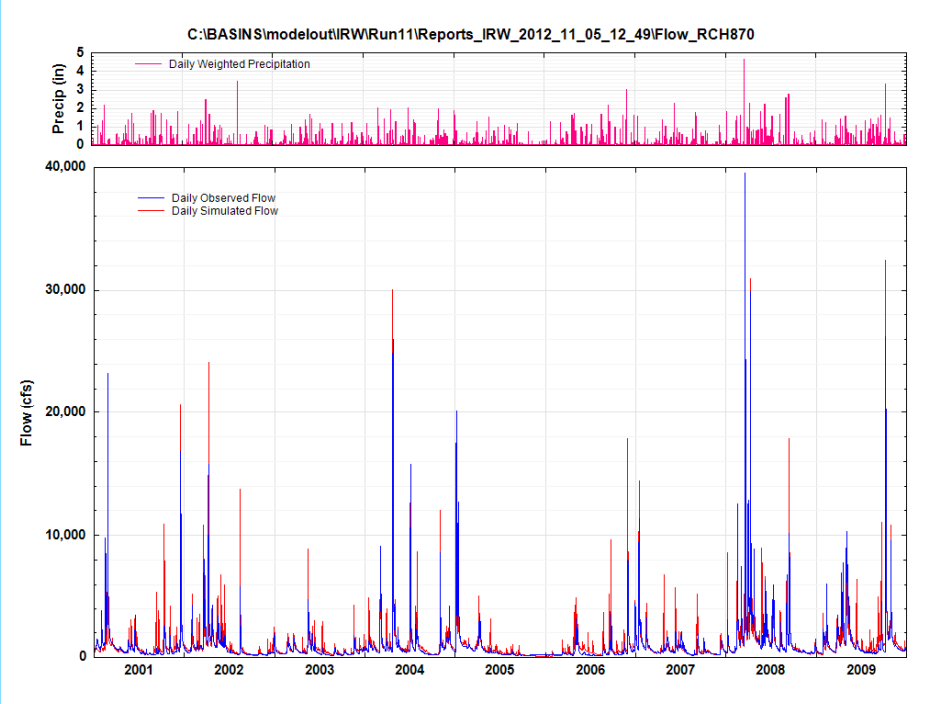
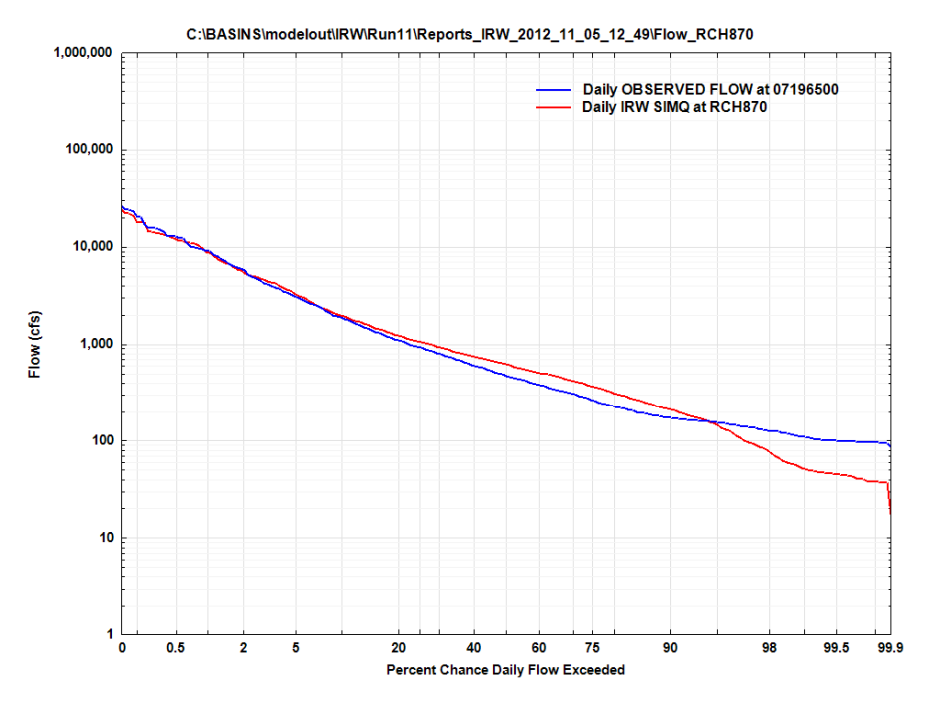
Hydrology Calibration Results

Illinois River near Tahlequah, OK (RCH 870, USGS 07196500)





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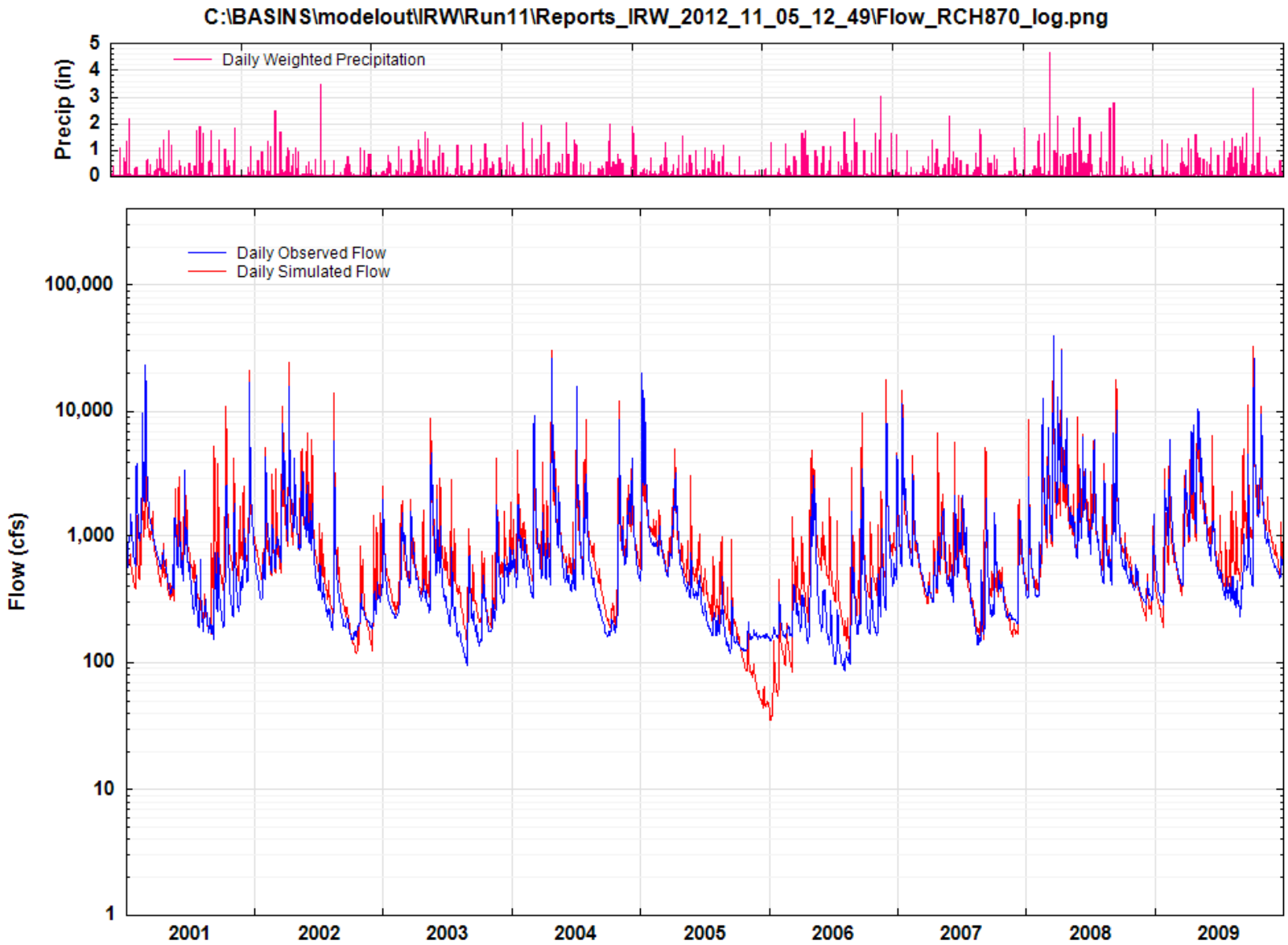
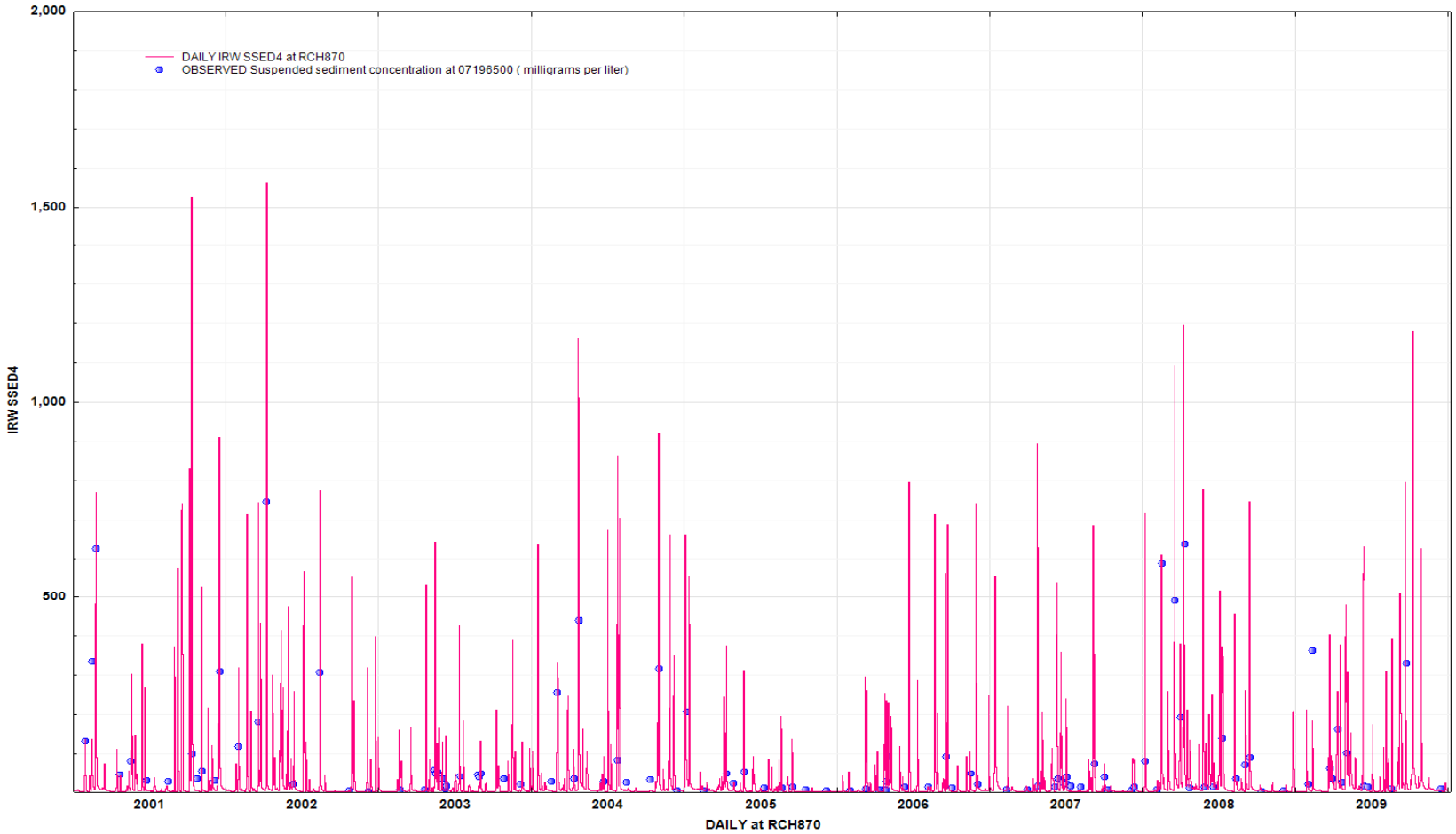
IR @ Tahlequah, Log Plot of Flow, 2001-2009



Preliminary Sediment Simulation Results

(Illinois River @ Tahlequah, OK: 2001-2008)



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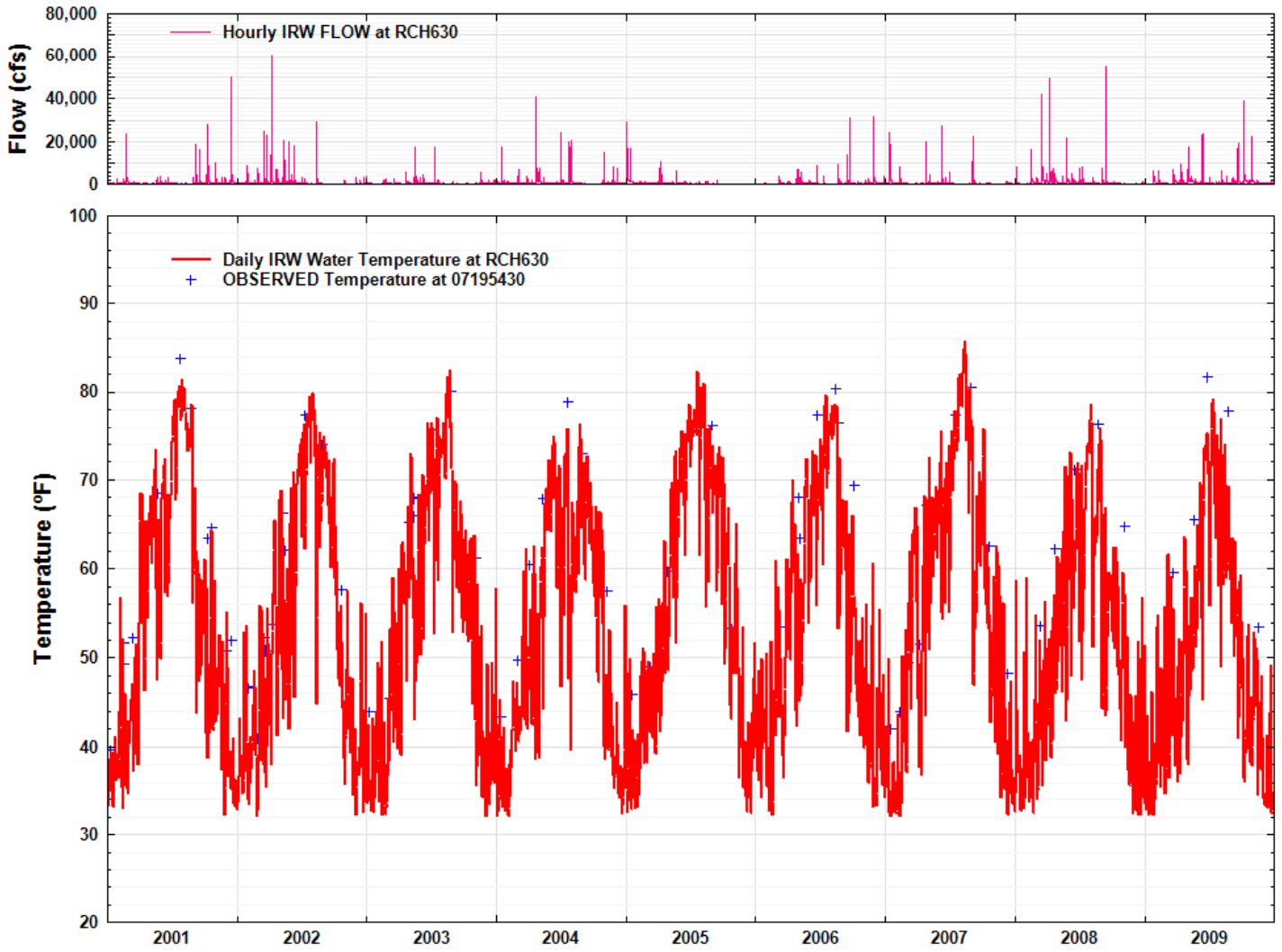
Preliminary Water Temperature Simulations

(IR South of Siloam Springs – Reach 630)



Phosphorus Sources Modeling Approaches and Issues (Ongoing)

- Goal – distinguish contributions from each source
- Animal Wastes –
  - Use AGCHEM on pasture lands receiving wastes
  - Define alternative categories of pasture, e.g. pasture, pasture-littered, pasture-comm.fert
  - For other land uses, apply simpler approaches (e.g. accumulation-wash off)
- For other sources, consider 'pseudo-point source' representation (e.g., AFO/CAFOs)

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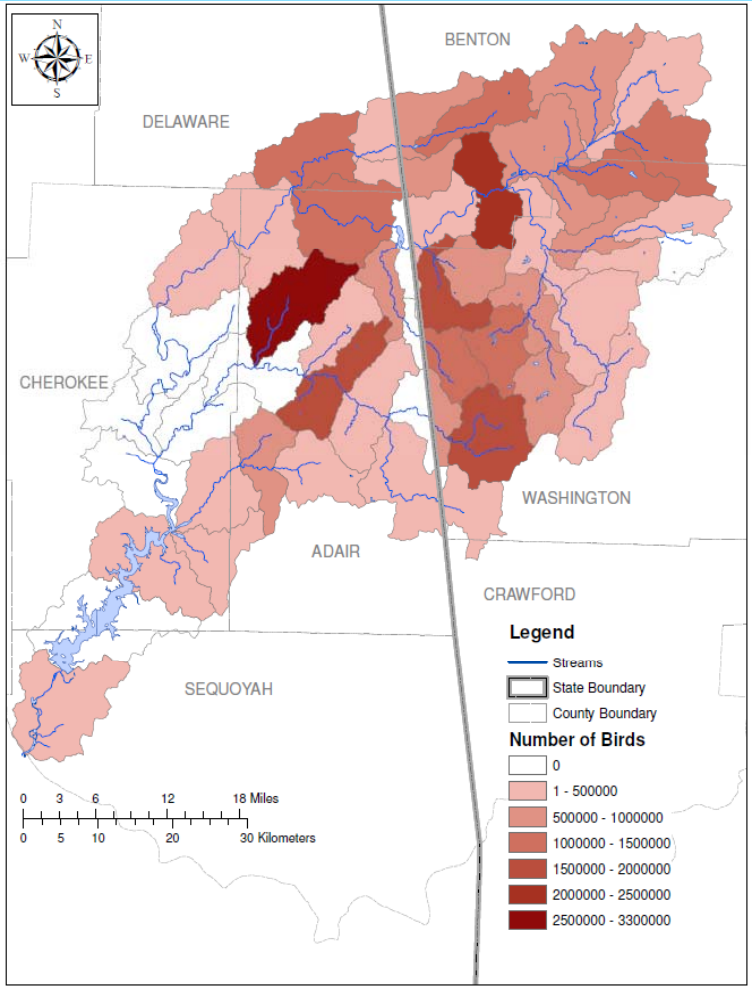
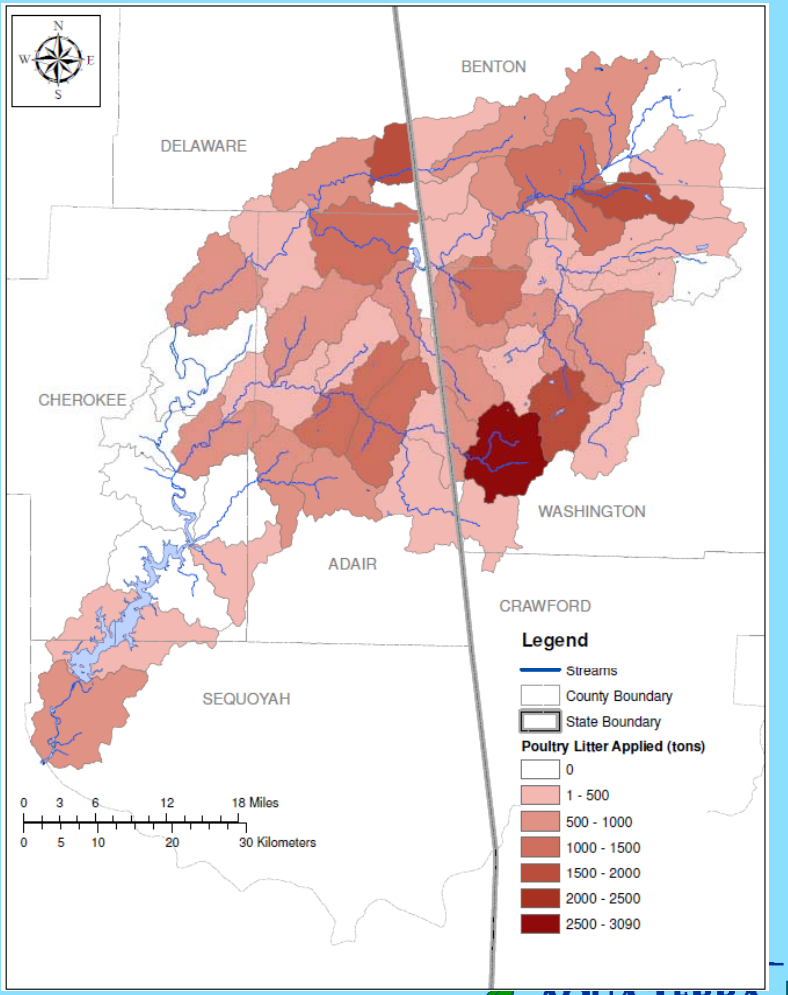
Sample data on Poultry Litter (Preliminary)

Bird Populations



Litter Applied, tons



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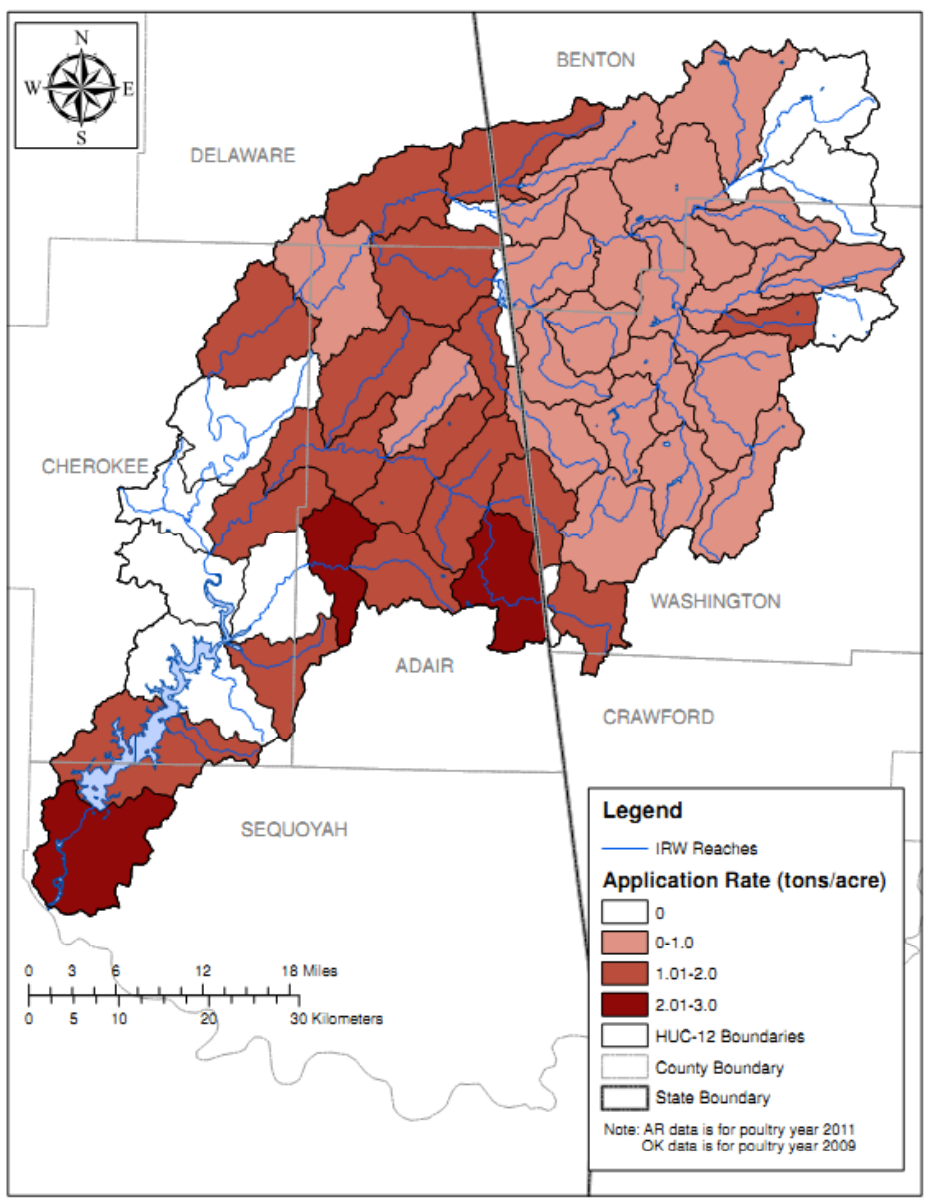
Sample Poultry Litter Application Rates



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Watershed Model Sensitivity Analyses

- Objective: Identify/quantify impacts of most sensitive model parameters
- Steps –
  - Select target inputs/parameters for analysis
  - Define reasonable perturbations from calibration values
  - Perform multi-year model runs with changes
  - QA and process model results
  - Rank input/parameters by sensitivity metrics

Watershed Model Uncertainty Analyses

- Monte Carlo approach used
- ~500-1000 HSPF multi-year runs performed
- Parameter values selected from assigned NO and LN distributions
- Model output analyzed for same quantities as the SA
- 5th and 95th percentile values generated to represent 90% confidence intervals

QUESTIONS/DISCUSSION

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ROUGH CALIBRATION/VALIDATION TARGETS

% Difference Between Simulated and Recorded Values

	VERY GOOD	GOOD	FAIR
Hydrology/Flow	< 10	10 - 15	15 - 25
Sediment	< 20	20 - 30	30 - 45
Water Temperature	< 7	8 - 12	13 - 18
Water Quality/Nutrients	< 15	15 - 25	25 - 35
Pesticides/Toxics	< 20	20 - 30	30 - 40

CAVEATS:
1.) Relevant to monthly and annual values; storm peaks may differ more.
2.) Quality and detail of input and calibration data.
3.) Purpose of model application.
4.) Availability of alternative assessment procedures.
5.) Resource availability (i.e. time, money, personnel).

Source: Donigian, 2000

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Scenarios for TMDL Development

- Objectives:
  - Use model as a tool for assessment of watershed impacts under alternative conditions, or scenarios, to meet water quality standards
  - Identify planned or projected changes in the watershed so TMDLs can be developed under realistic future conditions
  - Use existing Watershed Management Plans (e.g., OCC, IRWP) to identify and represent planned BMPs and mitigation measures for representation within the model (s)
  - Work with State agencies and other Stakeholders to identify scenarios of realistic watershed changes and management practices for evaluation of alternative means of attaining water quality standards and TMDLs

Scenarios for TMDL Development

- Proposed Procedures:
  - Define ‘Baseline’ conditions for scenario comparisons
  - Revise model (inputs/parameters) to represent ‘Baseline’ (e.g. current 2010/2011 land use, point source discharges)
  - Perform Baseline simulation to confirm impairments/sites. Runs will be long-term simulations of ~ 20-30 years
  - Quantify concentrations and load contributions at each impairment site, and confirm impairment conditions
  - Design scenarios to reduce loads and re-run the model to assess scenario impacts
  - Additional and alternative scenarios to be determined, and evaluated jointly with State agencies and other Stakeholders

Special Issues and Considerations

- Representation of Karst conditions in the model
- Comprehensive view of Phosphorus sources and mass balances
- Poultry litter representation, including export practices
- Consistency and interpretation of model outputs with respect to WQ standards
- Sensitivity and Uncertainty Analyses

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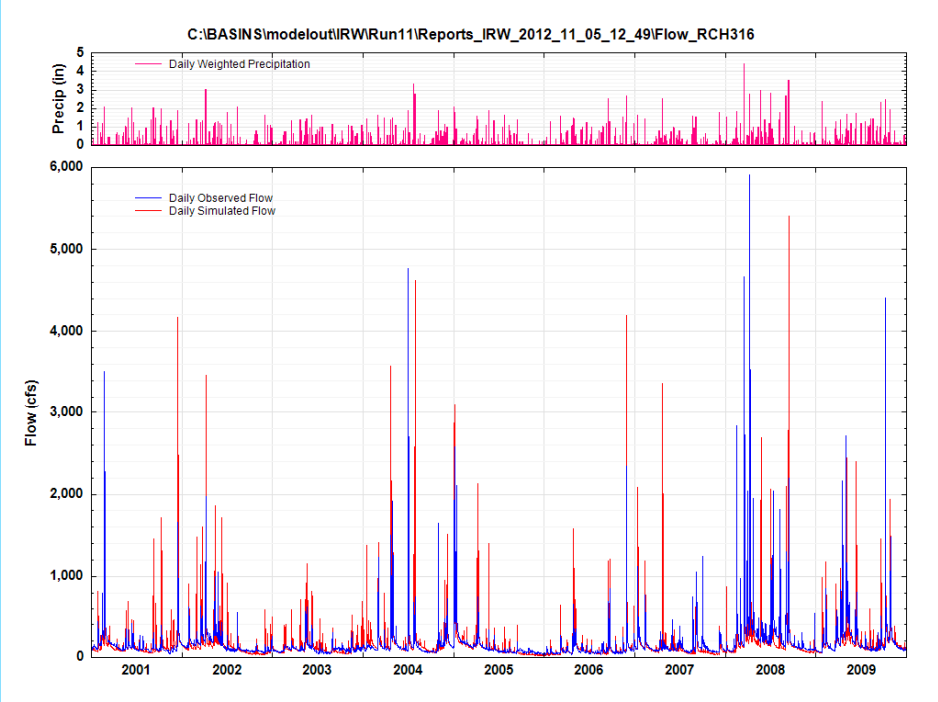
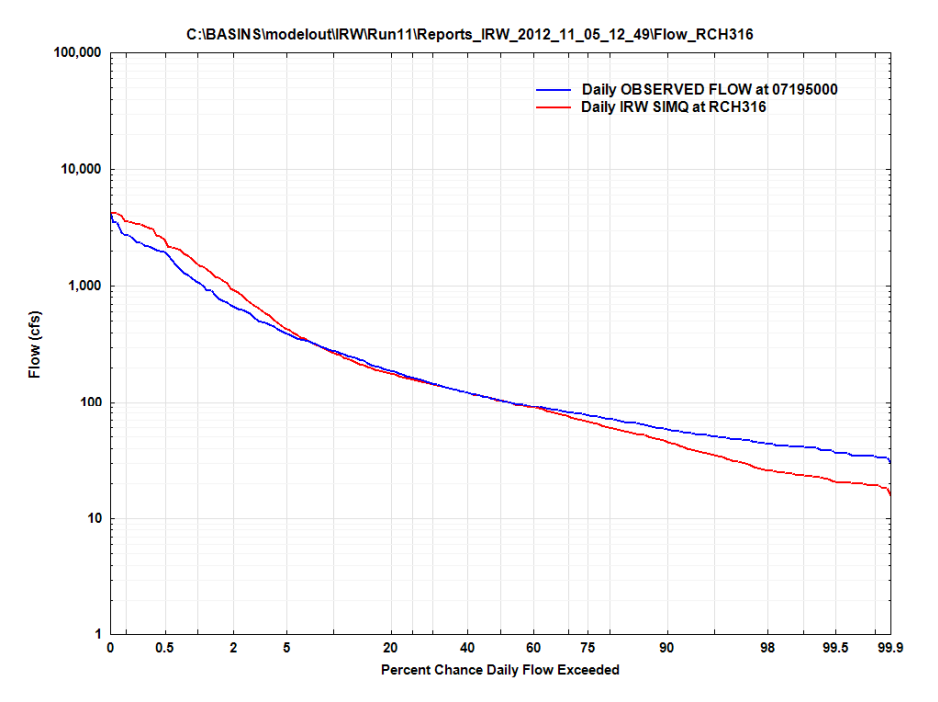
Hydrology Calibration Results

Osage Creek near Elm Springs, AR(RCH 316, USGS 07195000)





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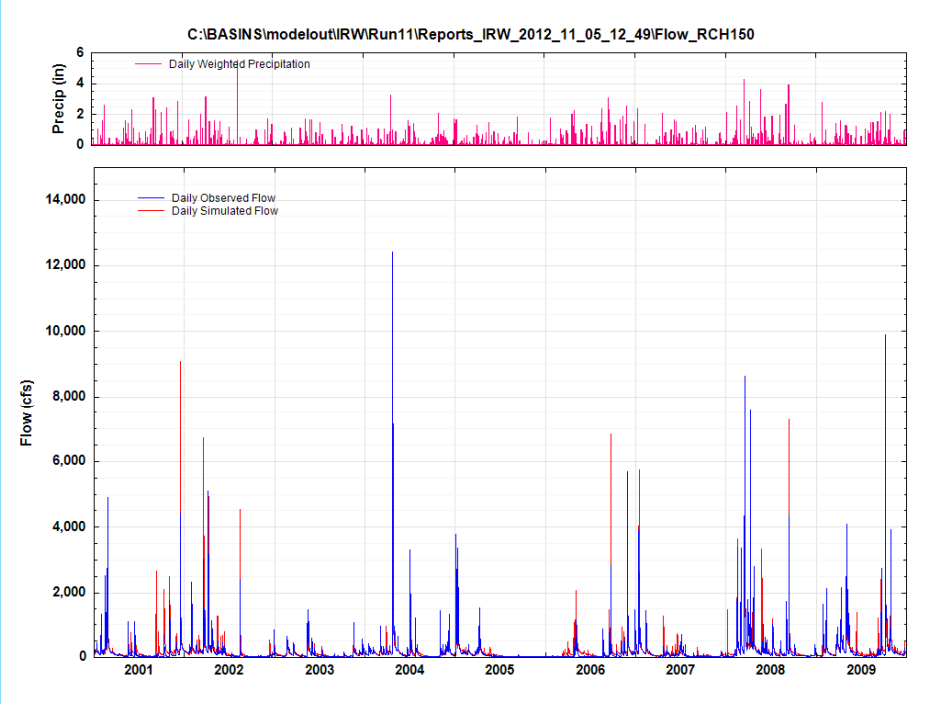
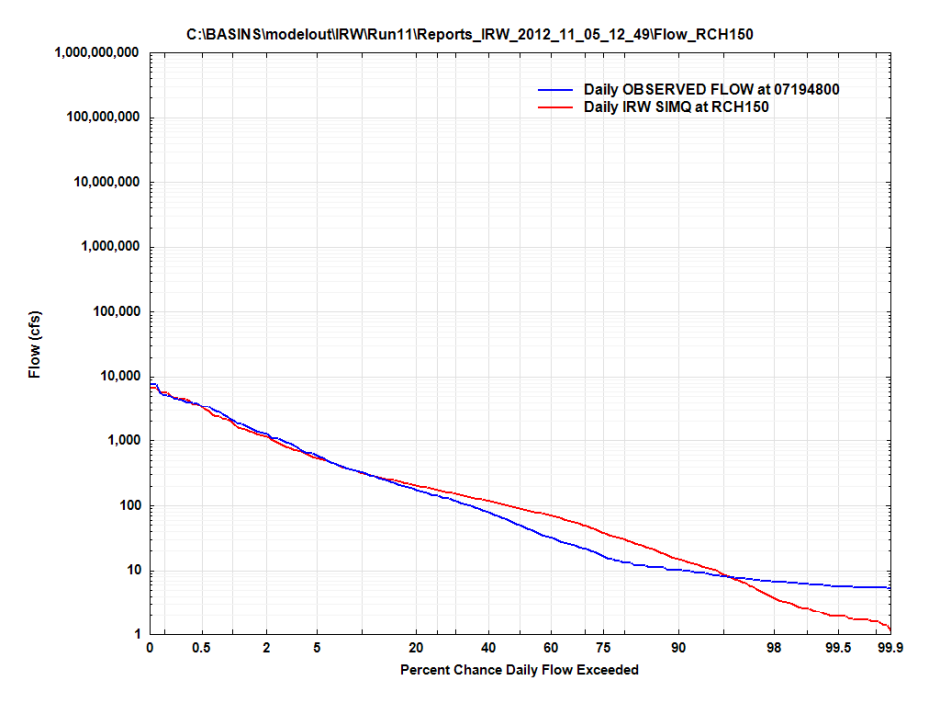
Hydrology Calibration Results

Illinois River at Savoy, AR (RCH 150, USGS 07194800)





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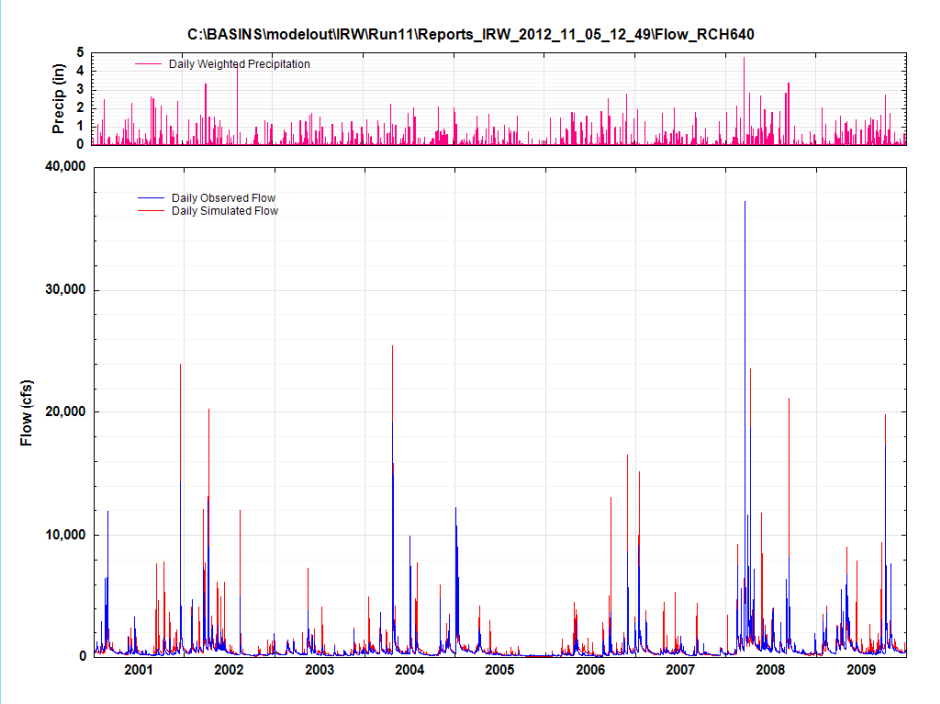
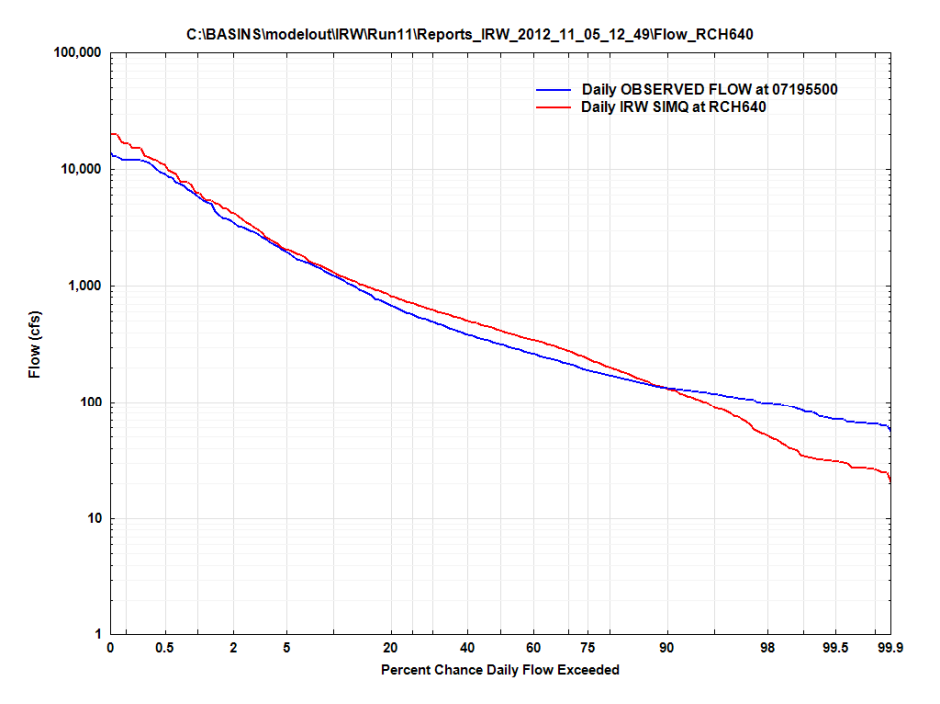
Hydrology Calibration Results

Illinois River near Watts, OK (RCH 640, USGS 07195500)





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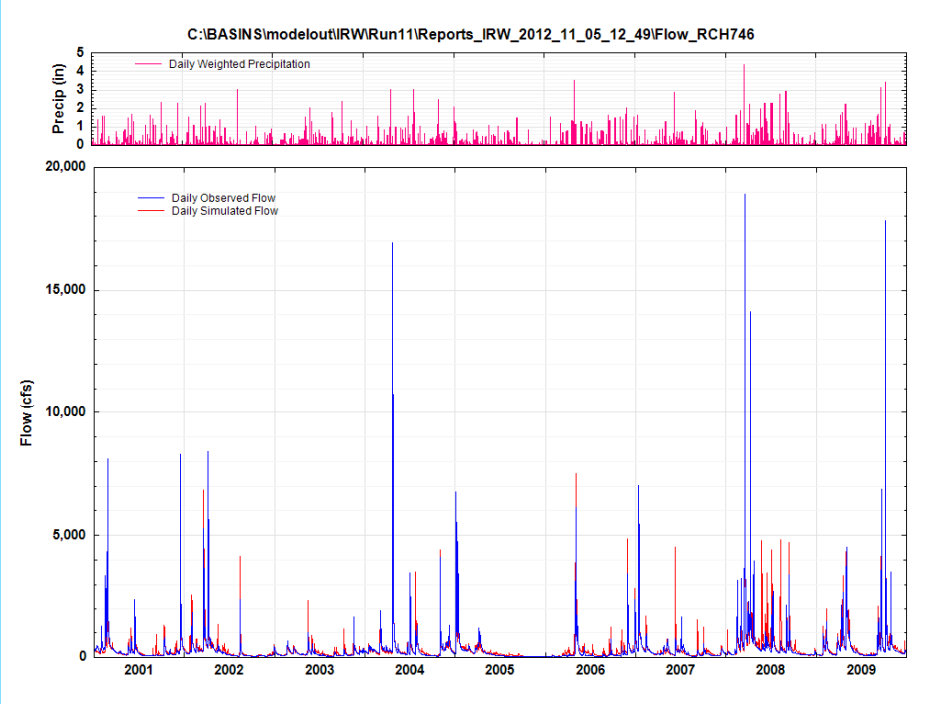
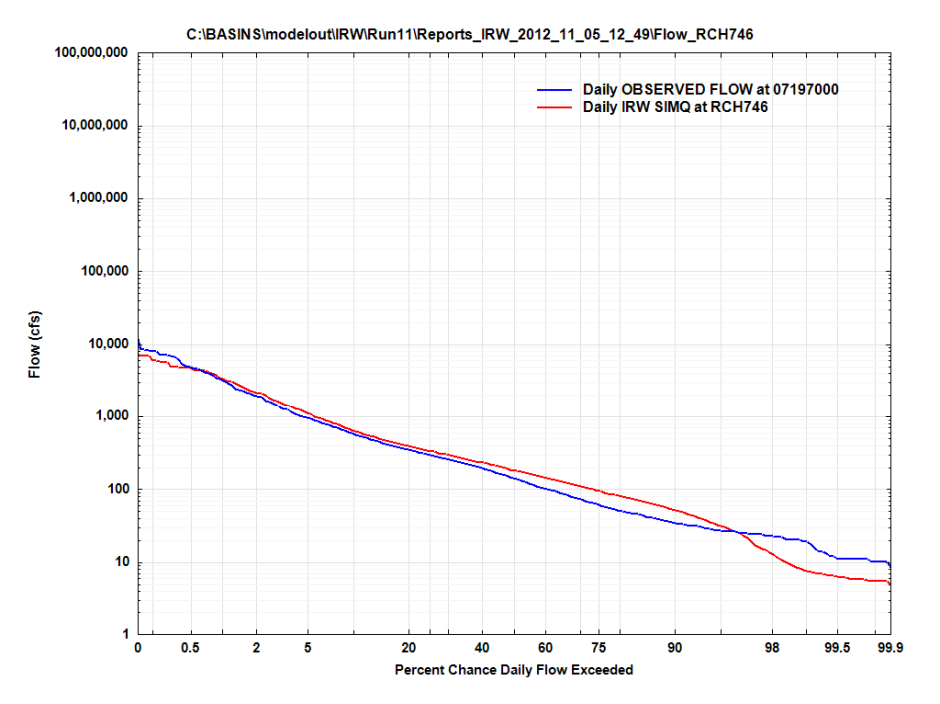
Hydrology Calibration Results

Baron Fork at Eldon, OK (RCH 746, USGS 07197000)





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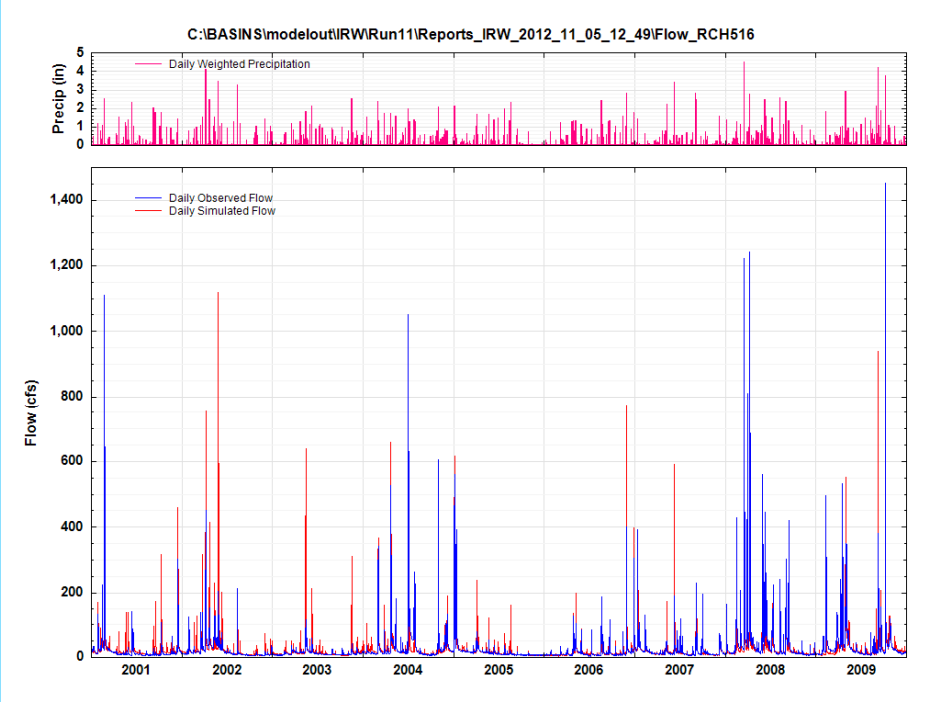
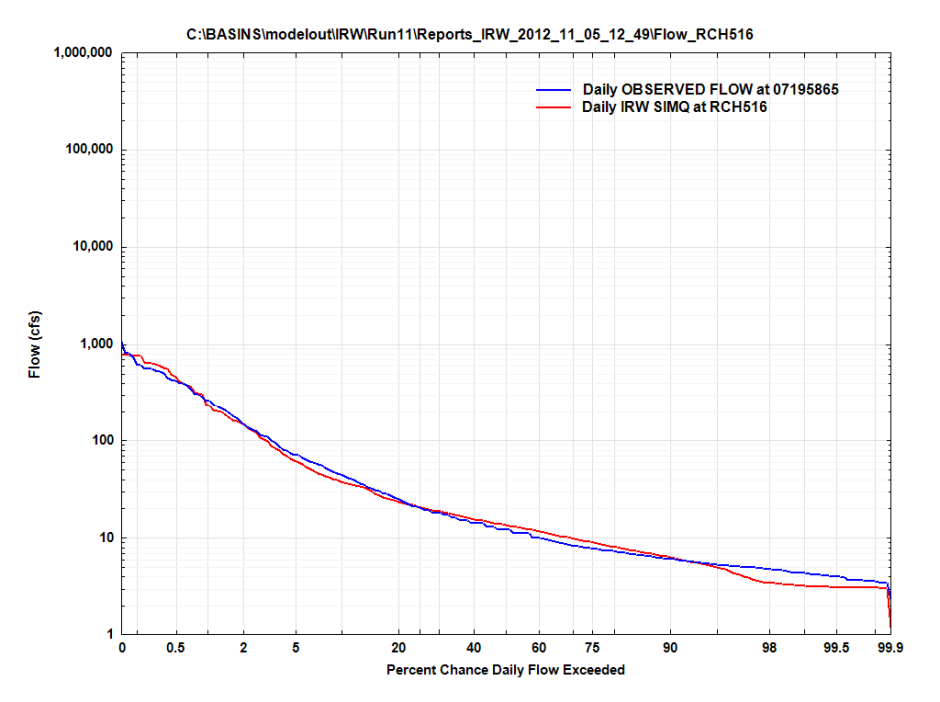
Hydrology Calibration Results

Sager Creek near West Siloam Springs, OK (RCH 516, USGS 07195865)





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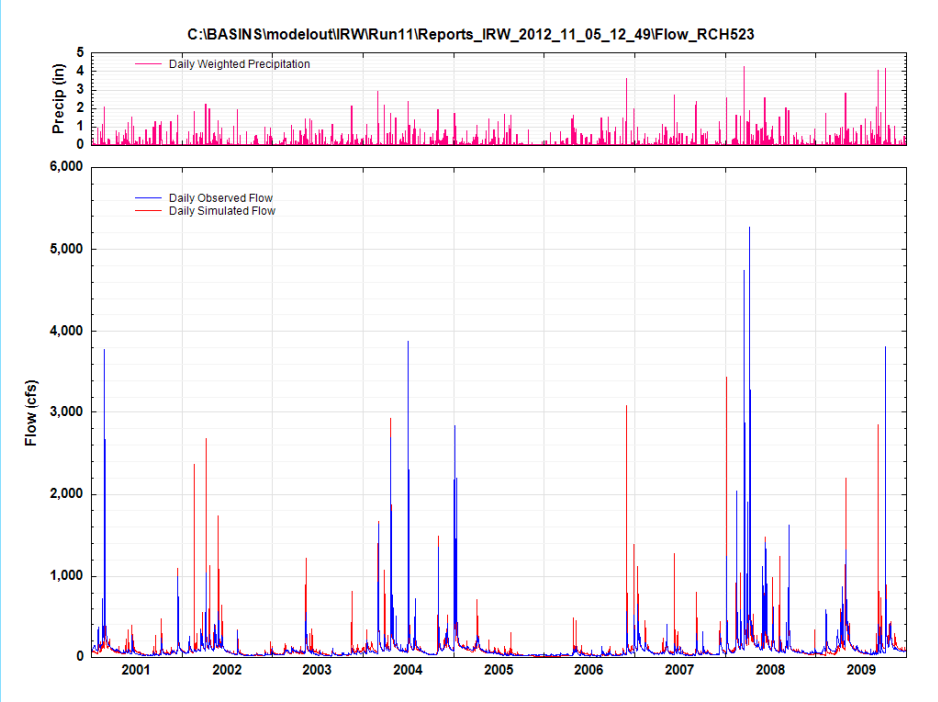
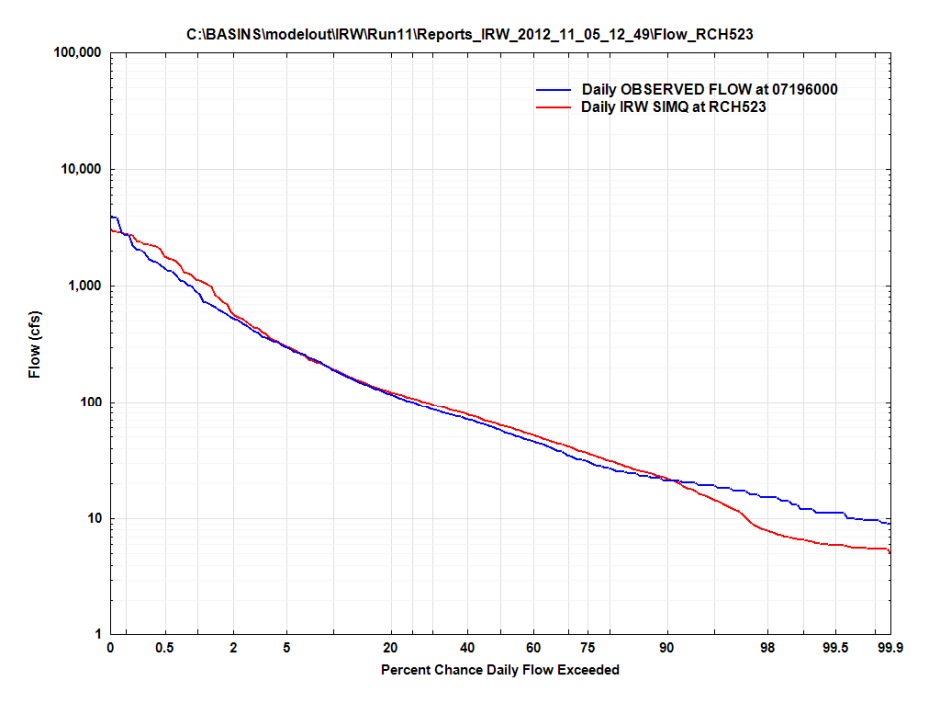
Hydrology Calibration Results

Flint Creek near Kansas, OK (RCH 523, USGS 07196000)





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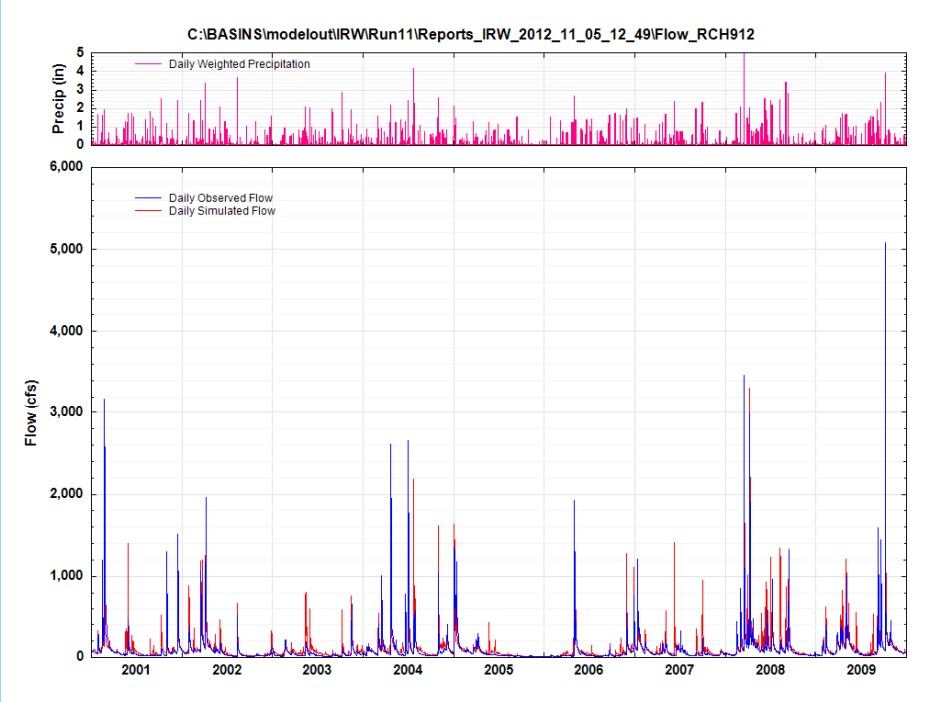
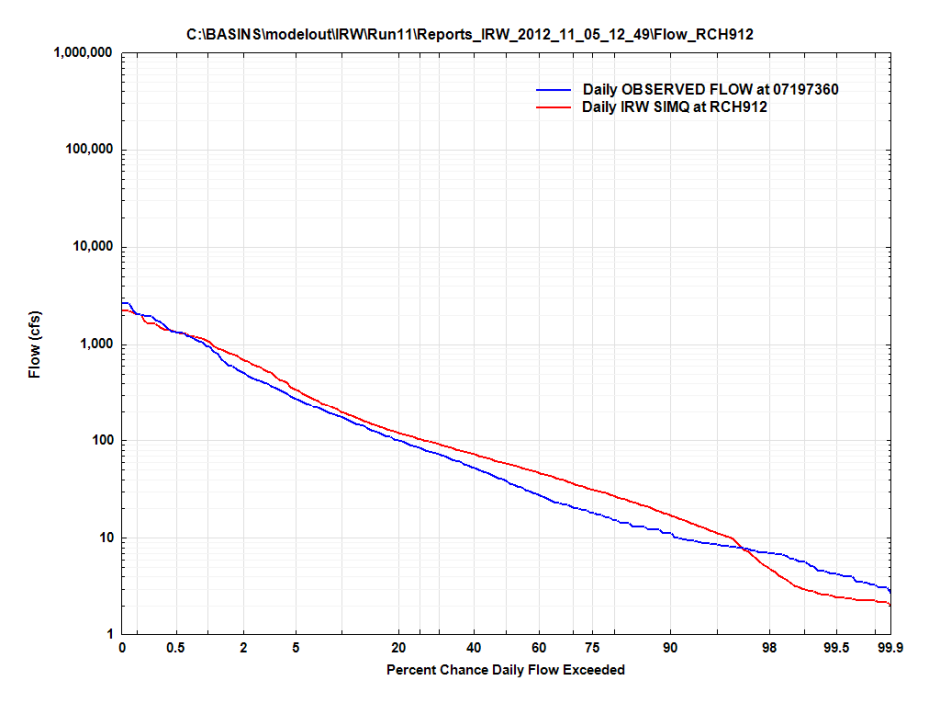
Hydrology Calibration Results

Caney Creek near Barber, OK (RCH 912, USGS 07197360)





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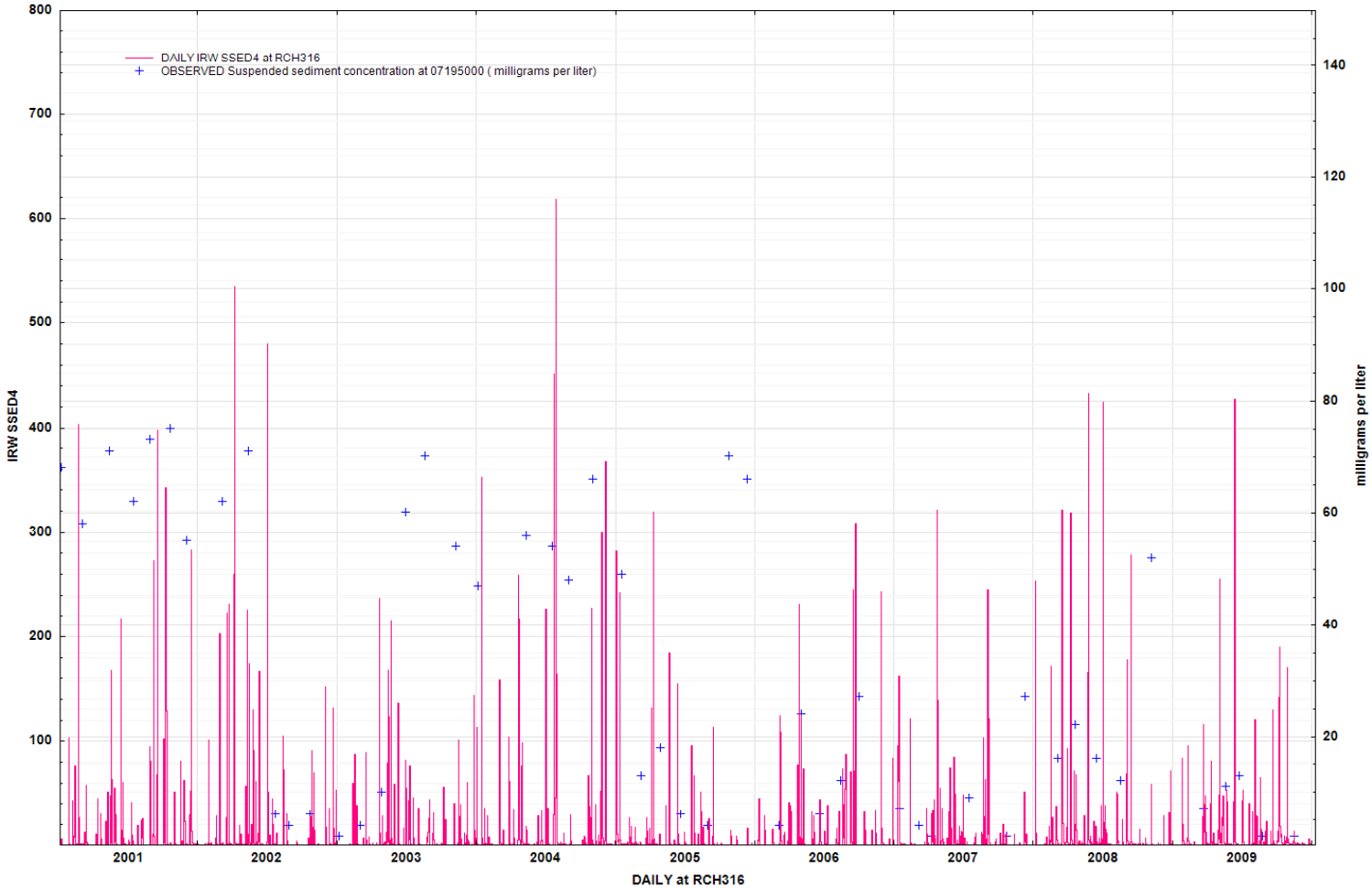
Preliminary Sediment Simulation Results

(Osage Creek nr Elm Springs AR: 2001-2009)



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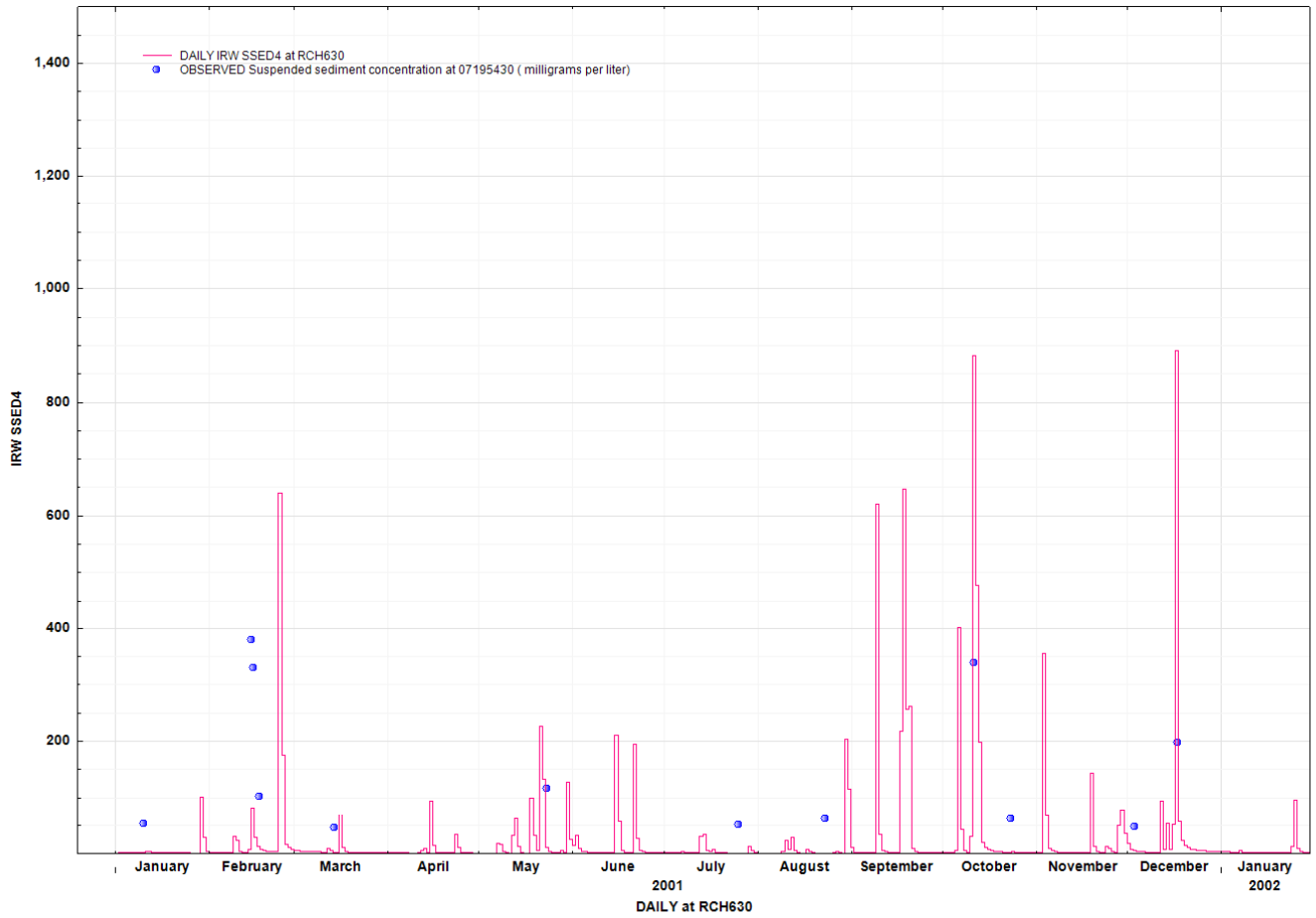
Preliminary Sediment Simulation Results

(Illinois River South of Siloam Springs, AR: 2001)



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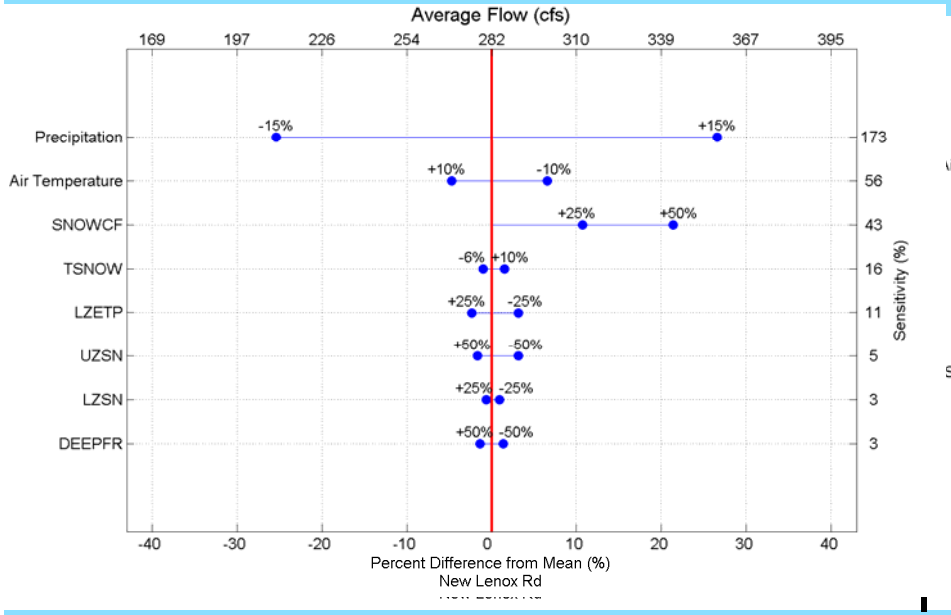
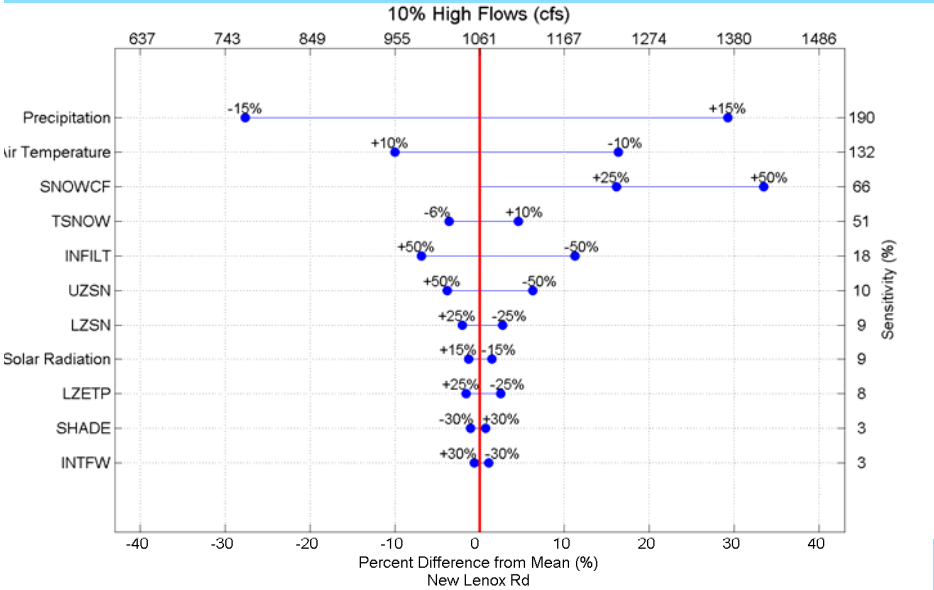
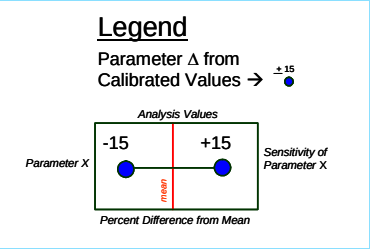
Tornado Diagrams for Flow Sensitivity

Mean Annual Streamflow, cfs



10% Highest Flows, cfs





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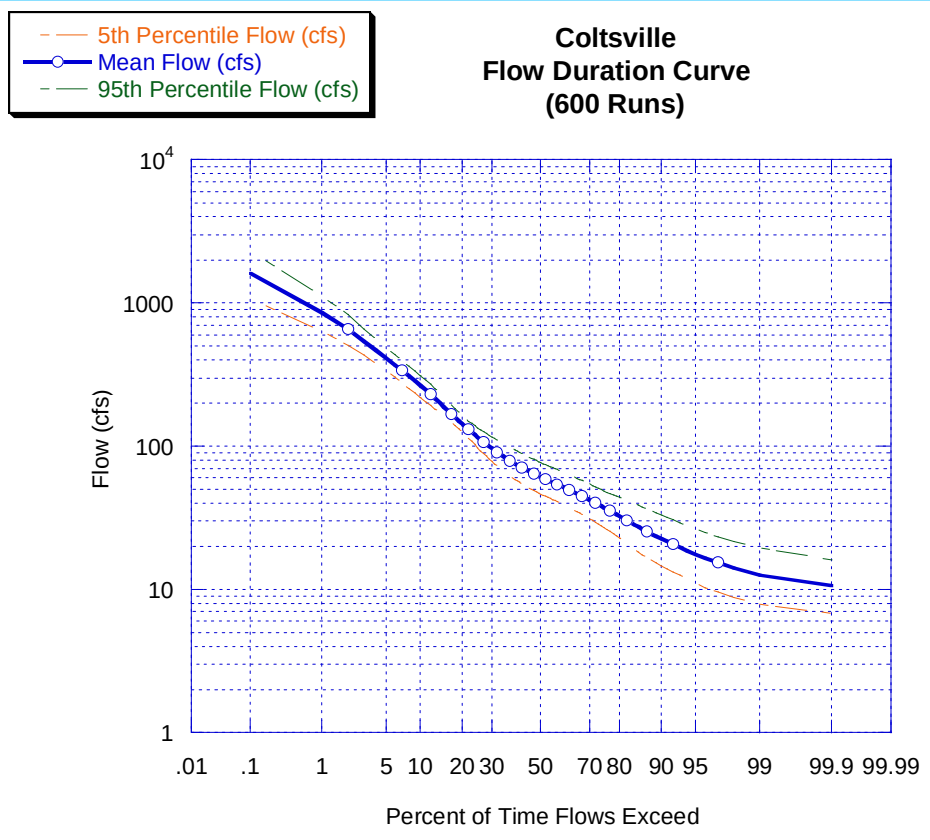
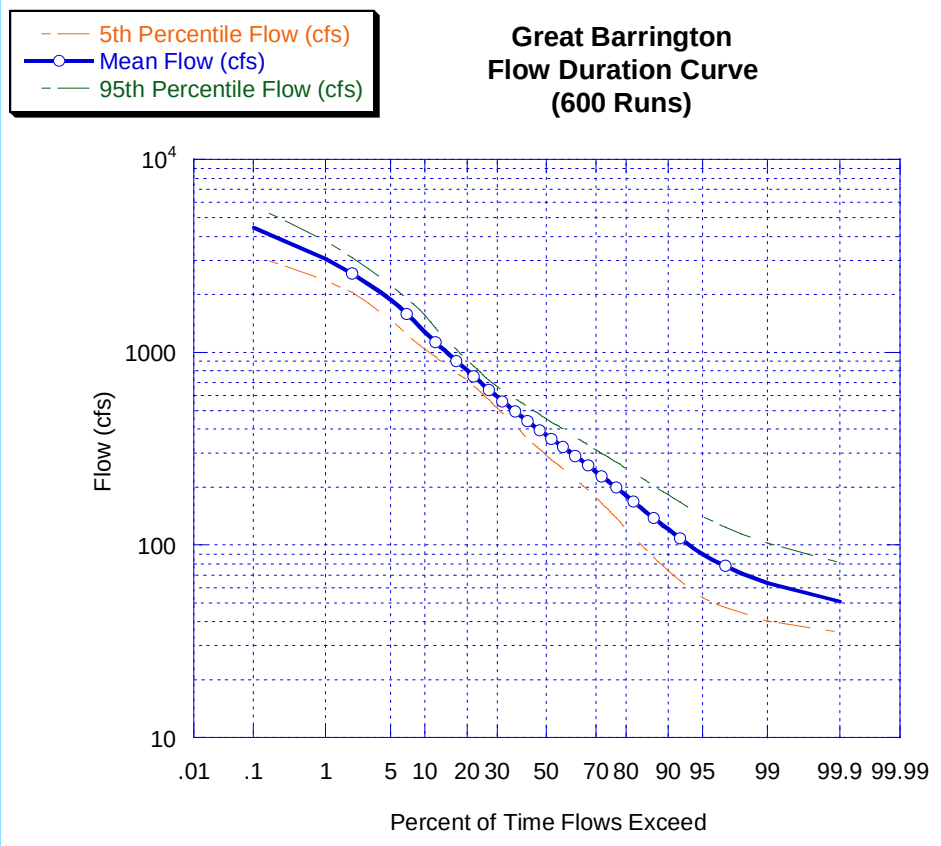
Flow Duration Curves with CIs





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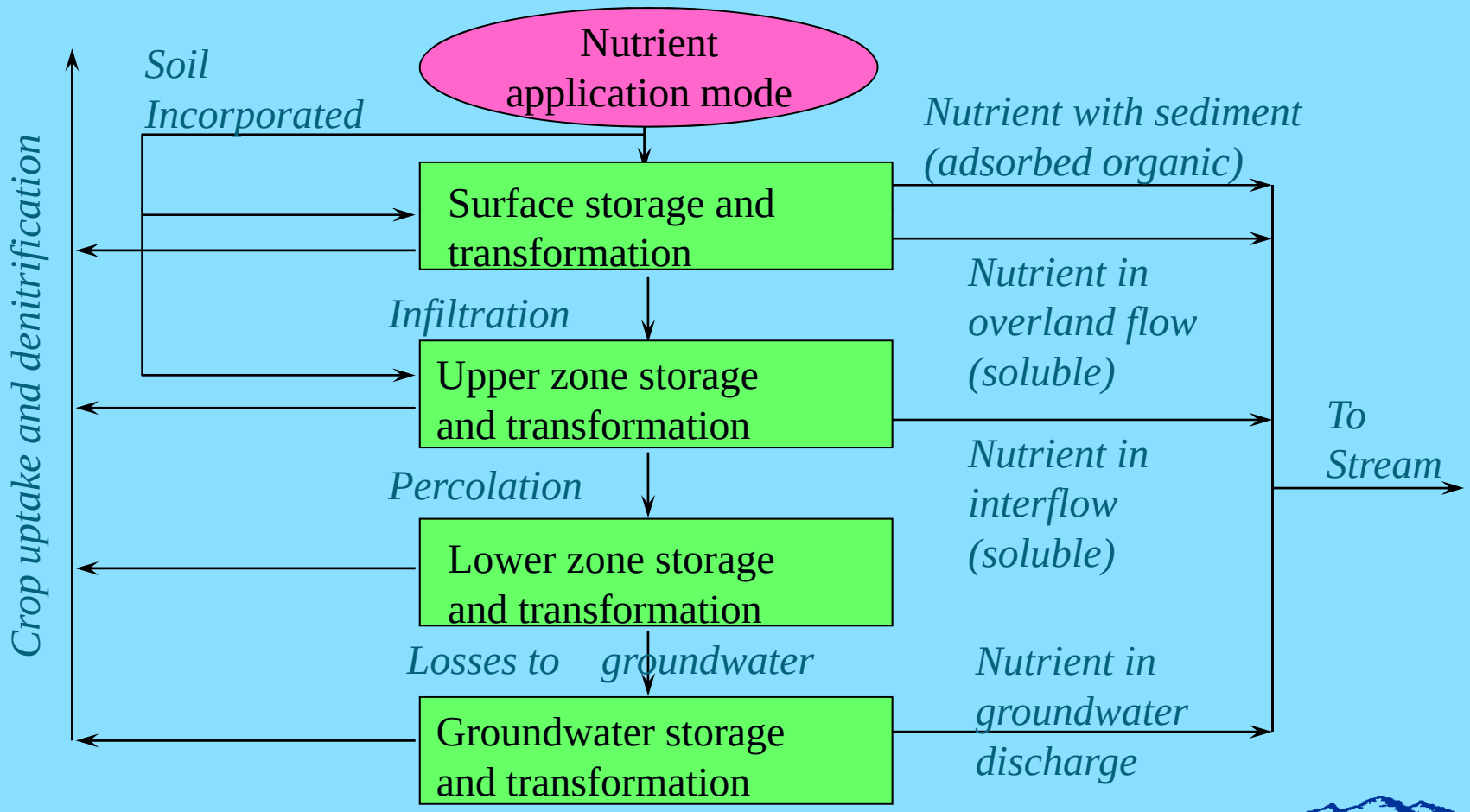
Nutrient Storages and Transport Modeled by HSPF AGCHEM



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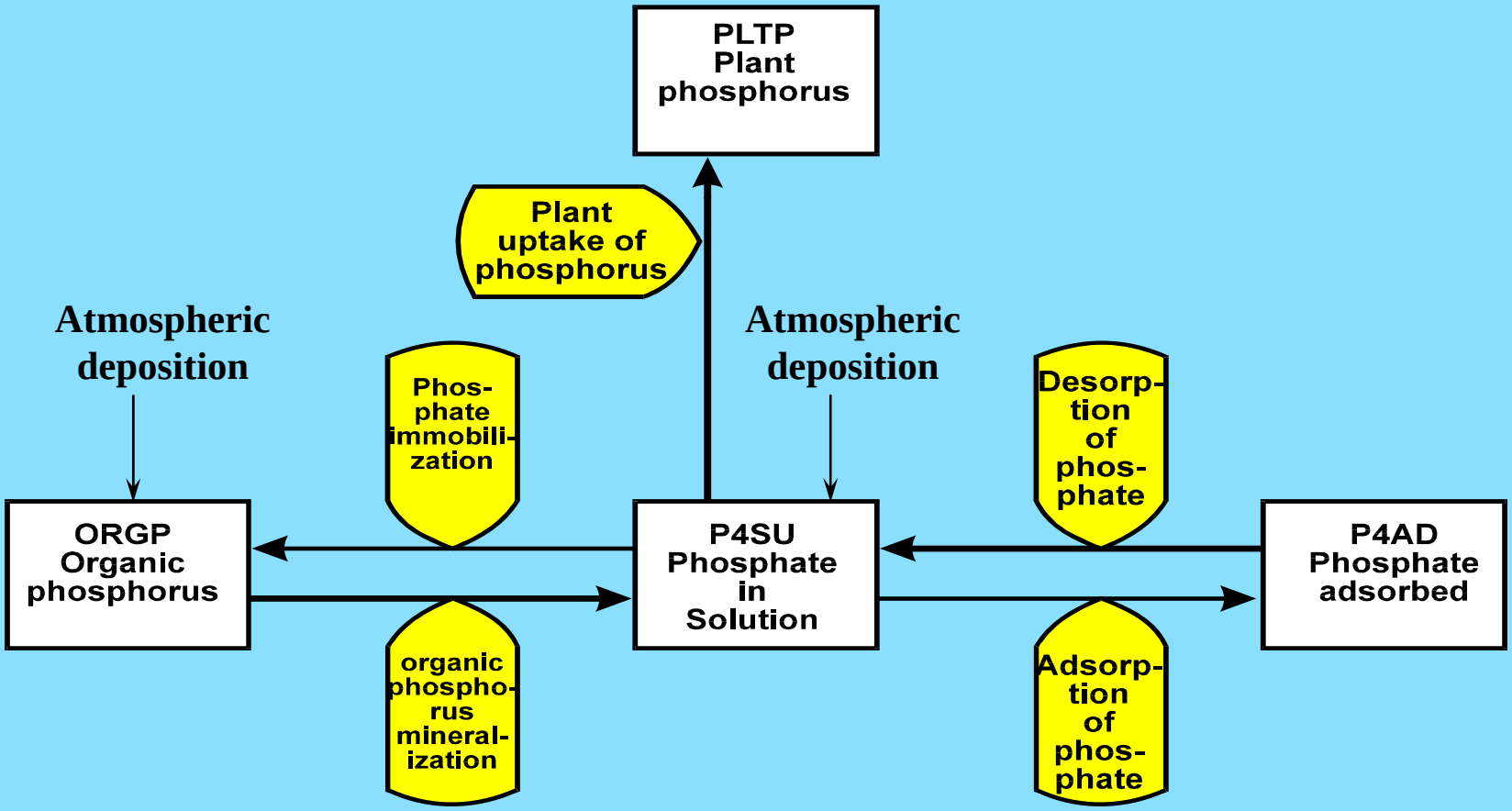
Phosphorus Transformations Simulated by HSPF/AGCHEM



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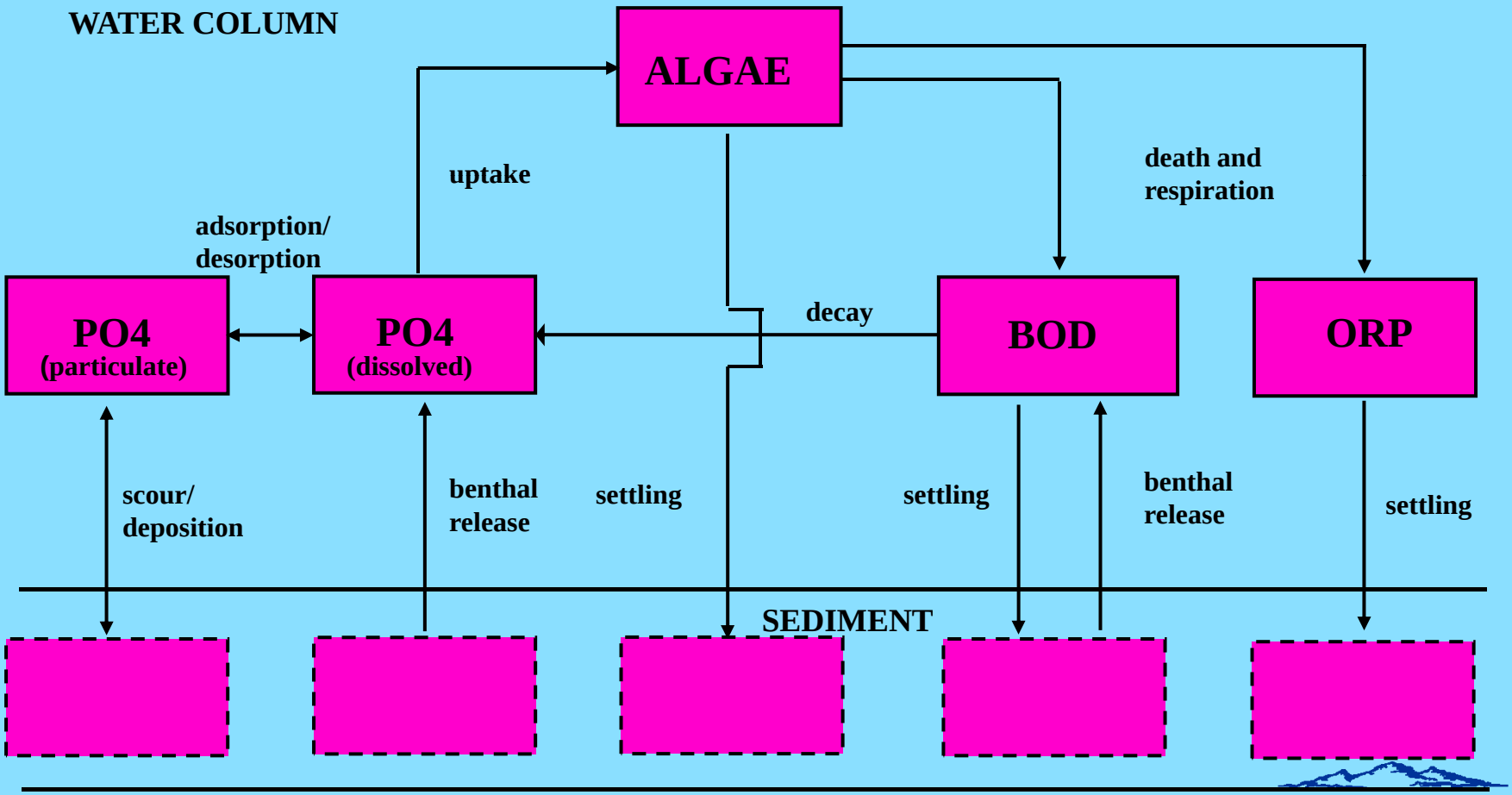
Summary of Instream Phosphorus Cycle in HSPF RCHRES



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