April 12, 2019

Bear Creek Model Results

BUILDING A WORLD OF DIFFERENCE®

GEI Consultants

BLACK & VEATCH

Project Overview

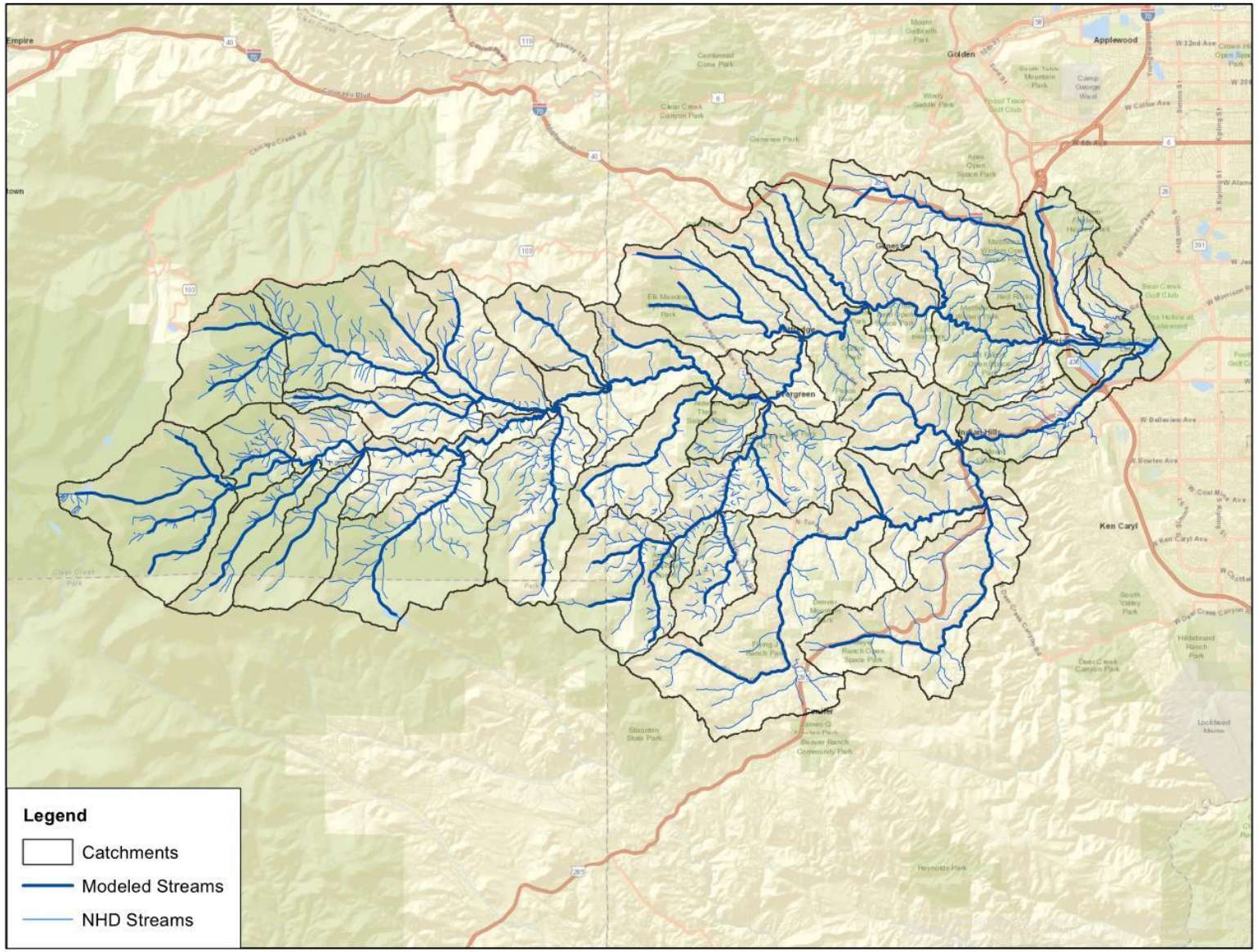
- Develop predictive models of Bear Creek watershed and reservoir
  - Total phosphorous and total nitrogen
  - Use models to identify sources, inputs to the reservoir and reservoir dynamics
- Define potential management scenarios to control nutrient inputs
- Incorporate management scenarios into models
- Technology transfer

Modeling Changes from Last Meeting

- Improved watershed hydrology, peak flows and seasonality
- Included lower watershed water quality for calibration
- Modified total nitrogen WWTP calculations
- Use longer reservoir simulation
- Clarified meteorological station
- More complete reservoir water quality calibration

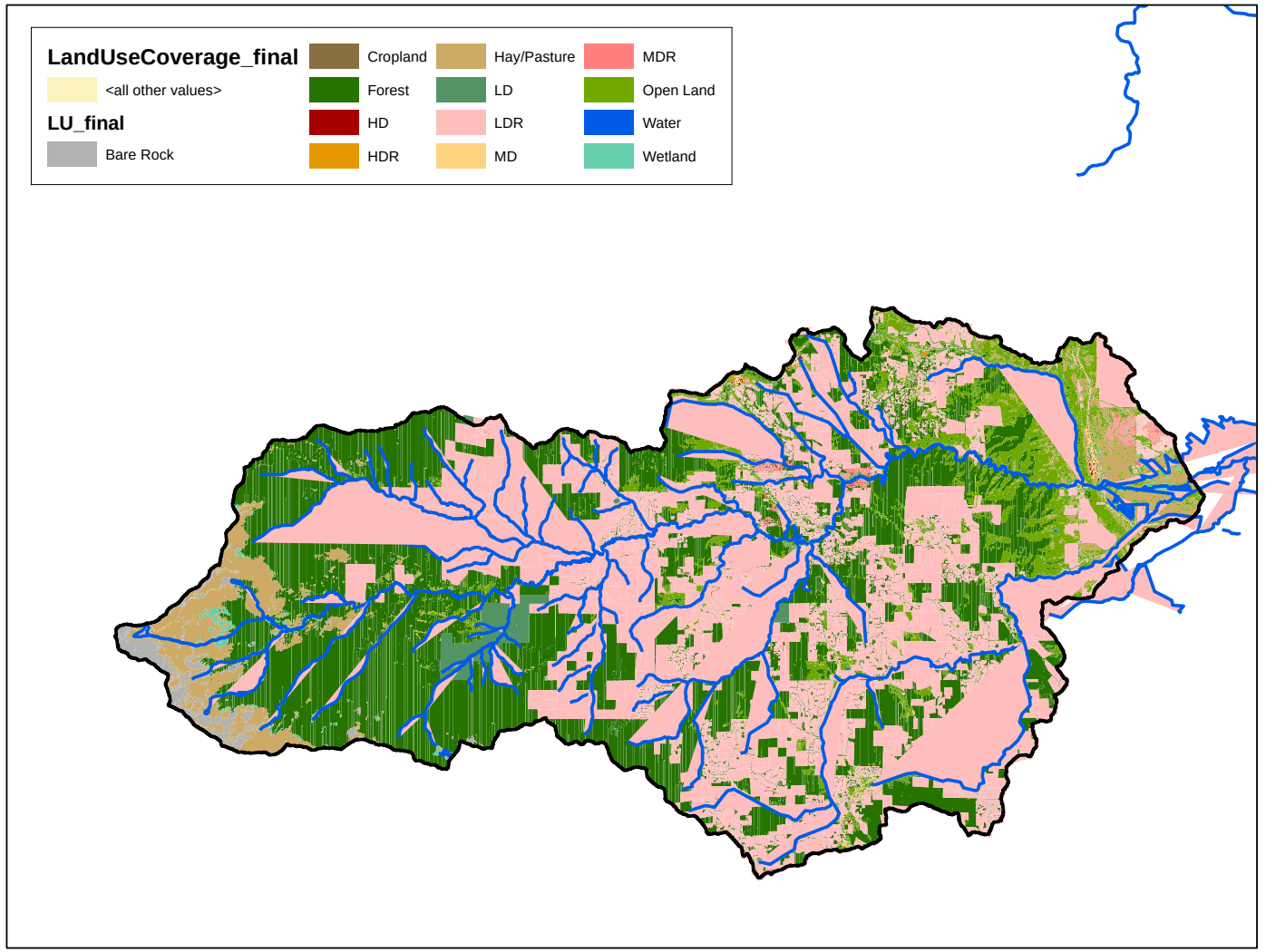
Watershed

- **Based on National Hydrography (NHD) catchments**
- **Higher resolution than HUC12s**



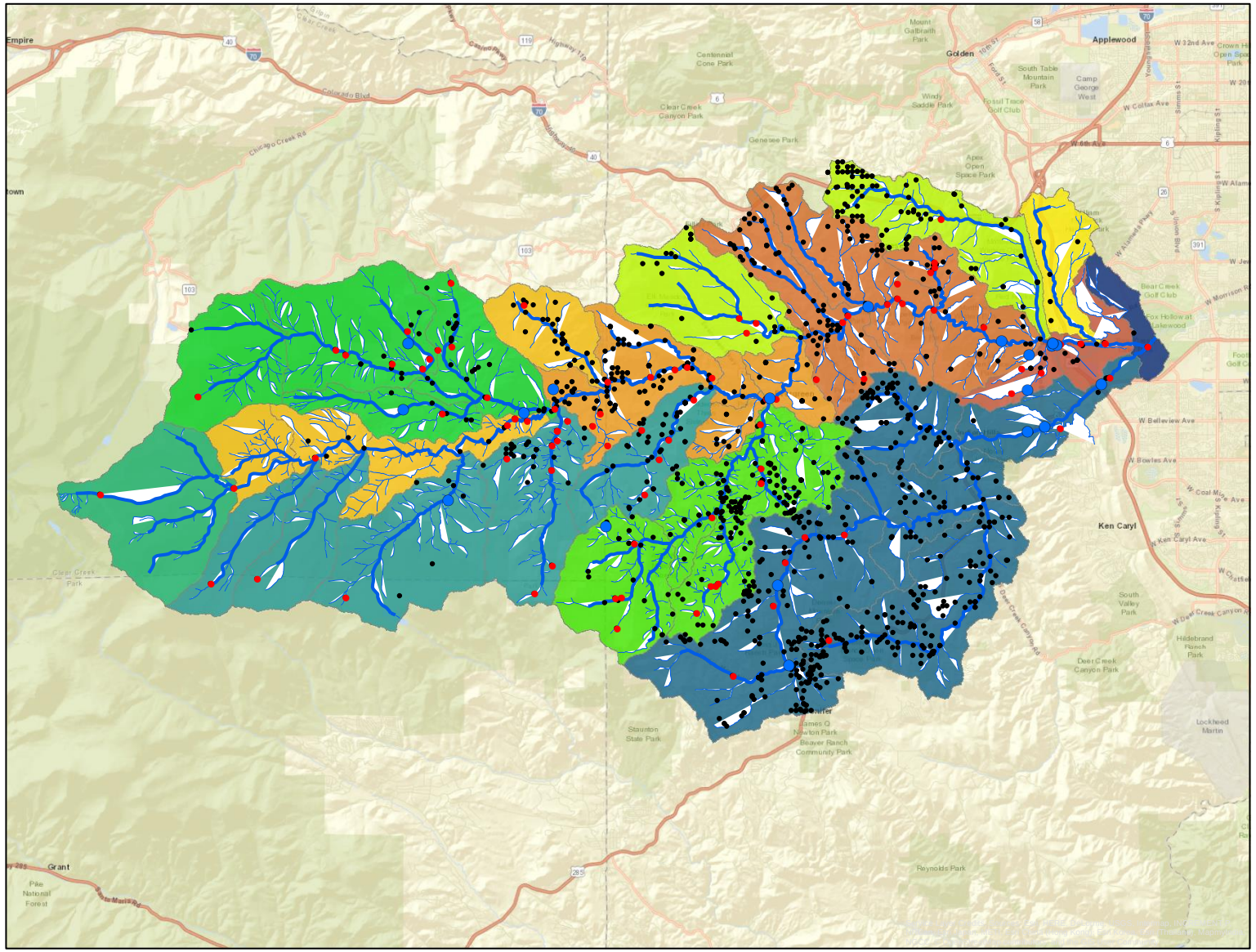
Land Use Data

- Combined different data sets to develop unified land use
  - USDA crop land use data
  - Use parcel data from Clear Creek and Jefferson Counties



Diversions

- Data from Colorado Division of Water Resources
  - 187 diversions
  - Divided to daily flow



Wastewater Treatment Plant Input

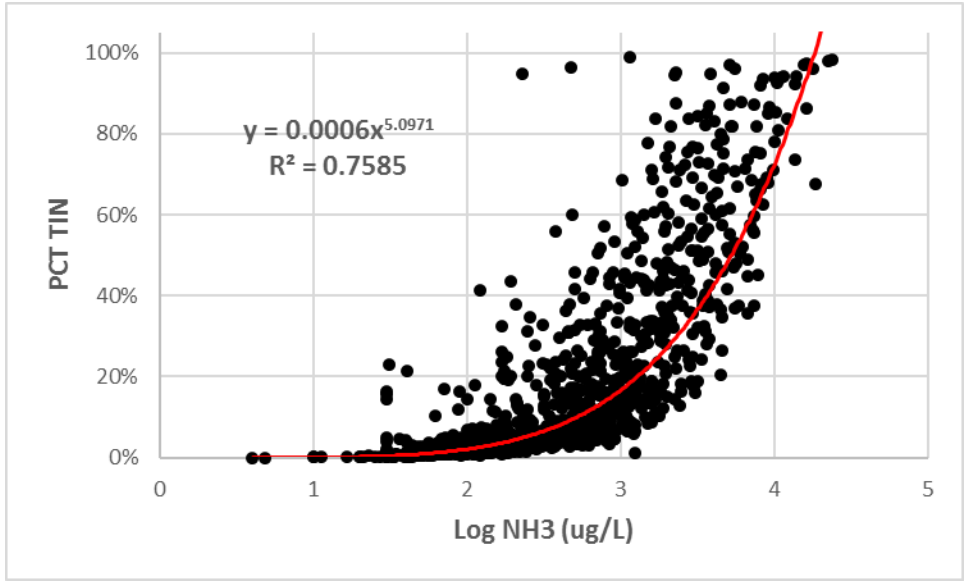
- 11 WWTP discharge and water quality data
  - Provided discharge data
  - Reg 85 data
  - DMR data
- Total phosphorous
  - Better, more complete data set
- Total nitrogen
  - Not complete time series for any input
  - Typically ammonia with some nitrate as well

Wastewater Treatment Plant Total Nitrogen

- **Mine additional data to complete TN time series**
- **USGS 1996: *Sources and Loads of Nutrients in the South Platte River, Colorado and Nebraska, 1994-95***
  - **38% NH_4, 36% NO_2+NO_3, and 26% organic nitrogen**
- **Applying linear rule over estimates TN concentrations**

WWTP TIN as a function of NH3

- Data from larger dischargers
  - Evergreen, West Jefferson, Kittredge, Genesee and Morrison
- Used measurements with paired TIN and NH3 measurements
- Percent NH3 of TIN vs log of NH3

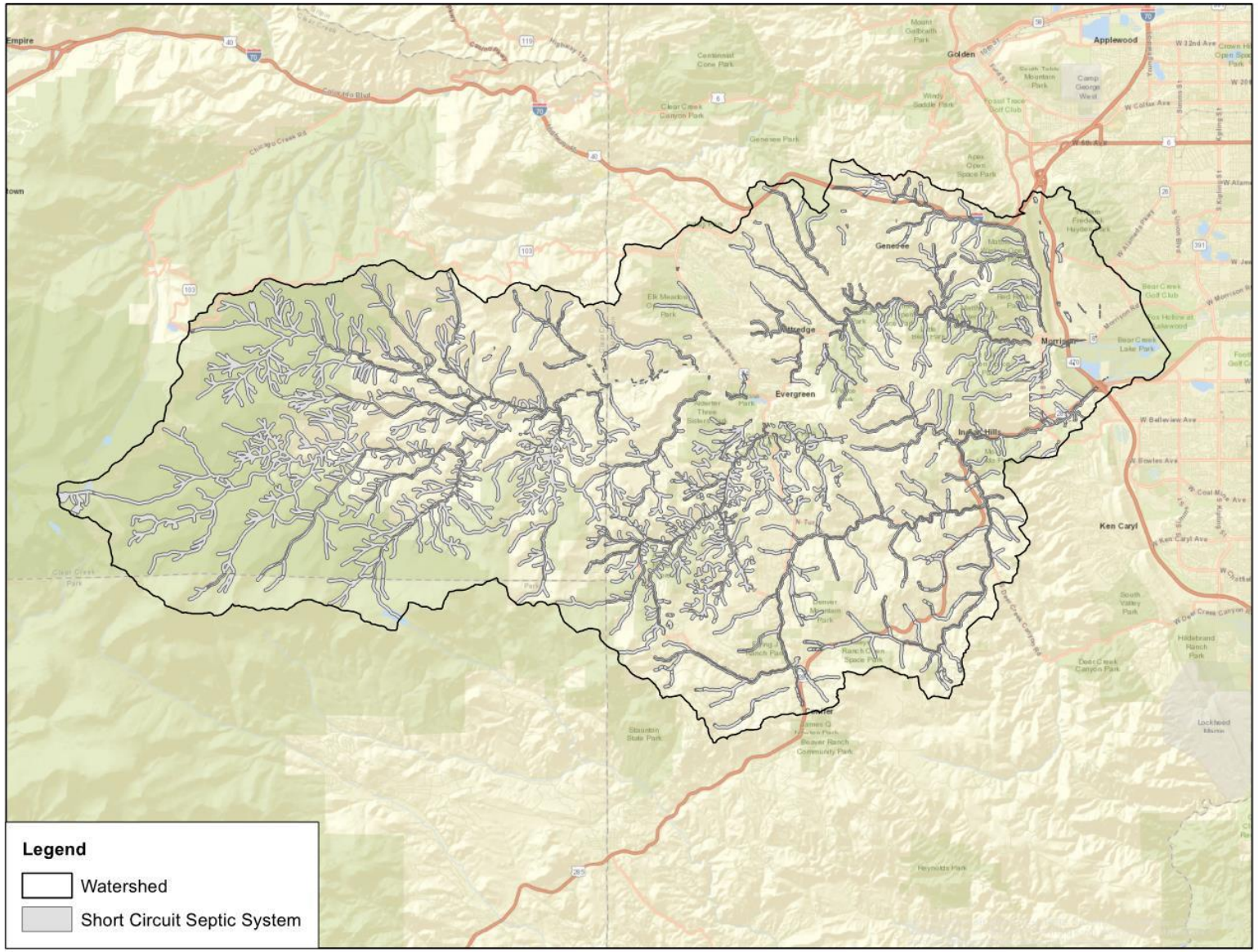


WWTP Organic Nitrogen

- USGS 1996
  - ON ~26% of TN
- Using Reg 85 data
  - ON ~22% of TN

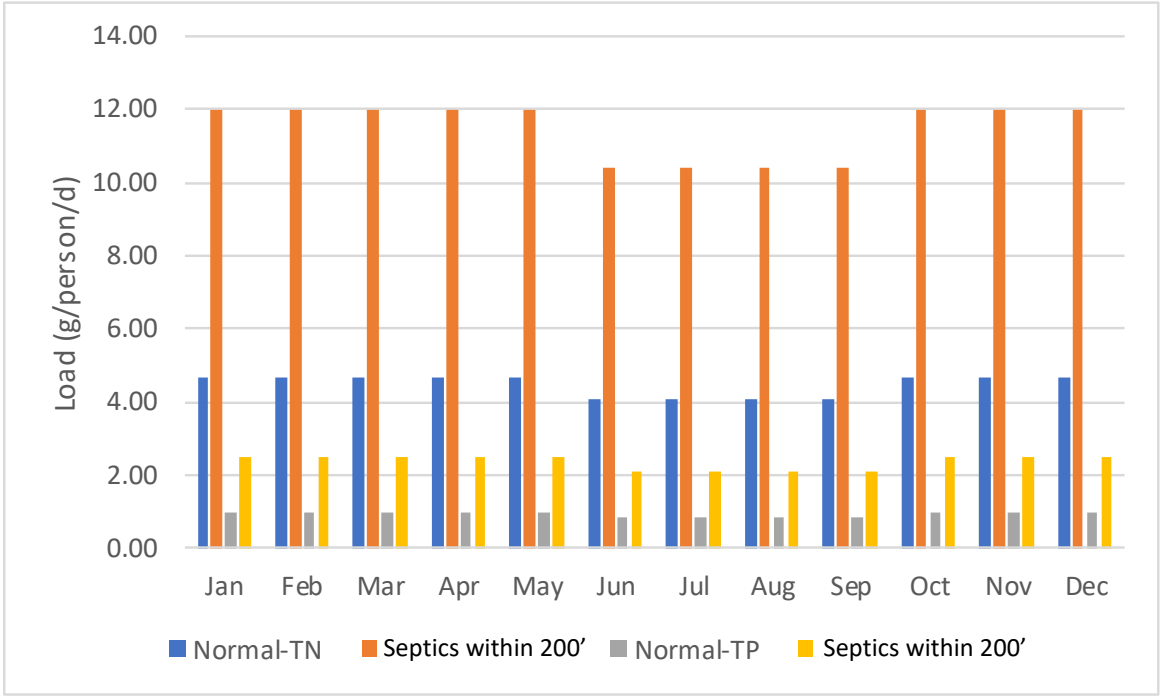
Septic Systems

- **NHD streams with 200 foot buffer as recommended by BCWA**
- **Erased buffered NHD streams from intersected Census Block data**
- **Intersected buffered NHD streams with intersected Census Block data**



Septic Systems

- Assumed loads
  - 2.5 g TP/person/d
  - 12 g TN/person/d
- Plant uptake during the growing season
  - 0.59 TP g/person/day
  - 1.6 TN g/person/d
- Soils attenuated the loads
  - 59% for soil loss
  - 66% subsurface loss



HSPF Model

- Simulates runoff and nutrients (TP and TN)
  - Uses buildup/washoff dynamics
  - First order stream decay of TP/TN
- Point sources
  - Septic loads and point source discharge data time series input
- Uses hourly time steps

HSPF Model

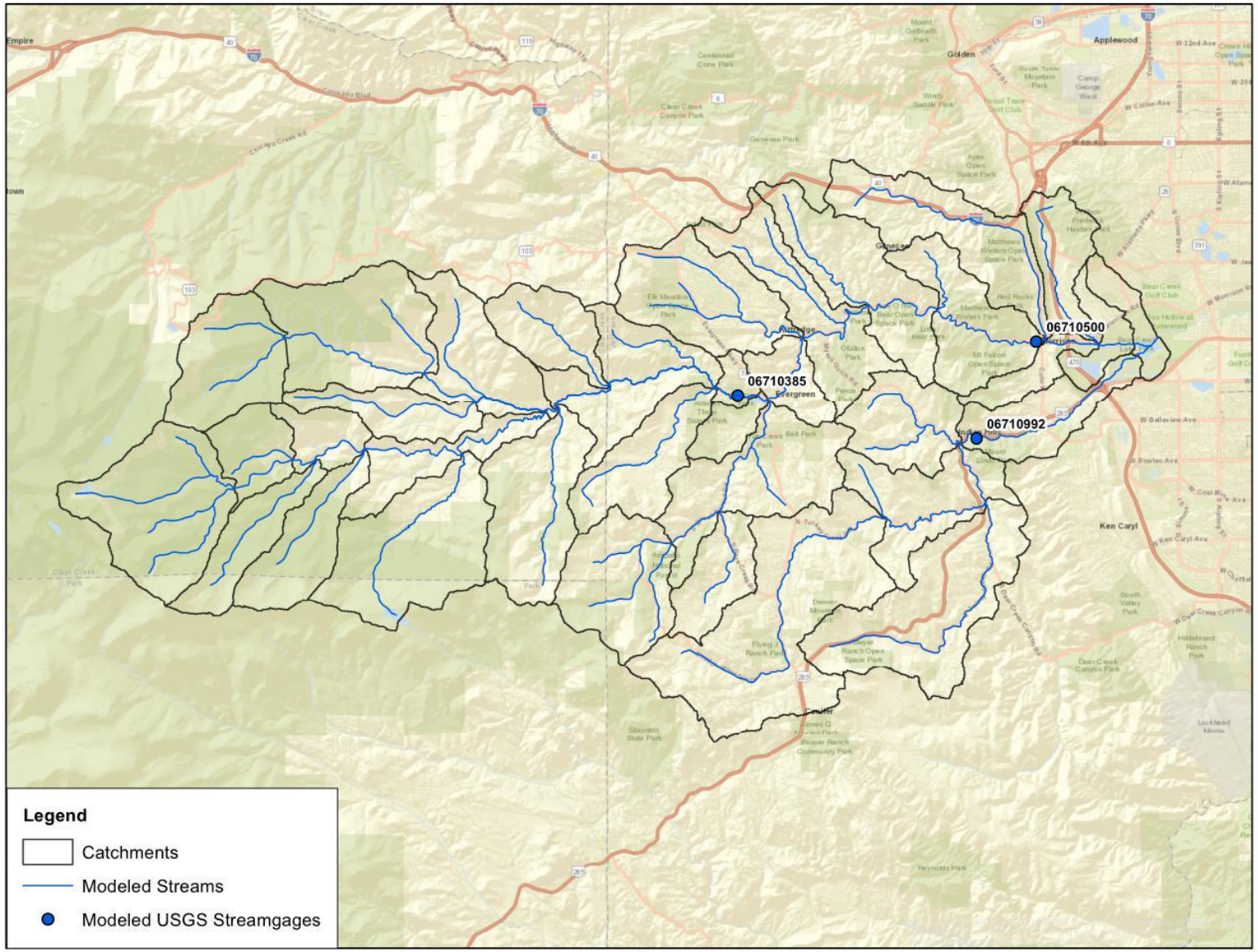
- Used BASINS interface to set up application
  - Stream cross sections, Manning's n
- Divides land into pervious and impervious
  - Connected impervious
- Model routes flows and TP/TN downstream

Hydrology Calibration

- **Adjust model parameters to match with the observed conditions**
  - **Volumes**
  - **Seasonal volume**
  - **Peak and base flows**
  - **Distribution of flows**

Flow Stations

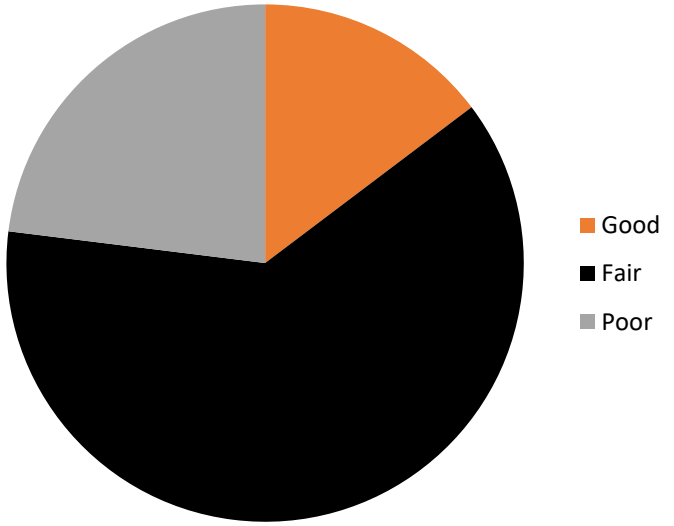
- USGS Stream gages
  - Calibration of watershed model
- USACoE inputs for reservoir inputs



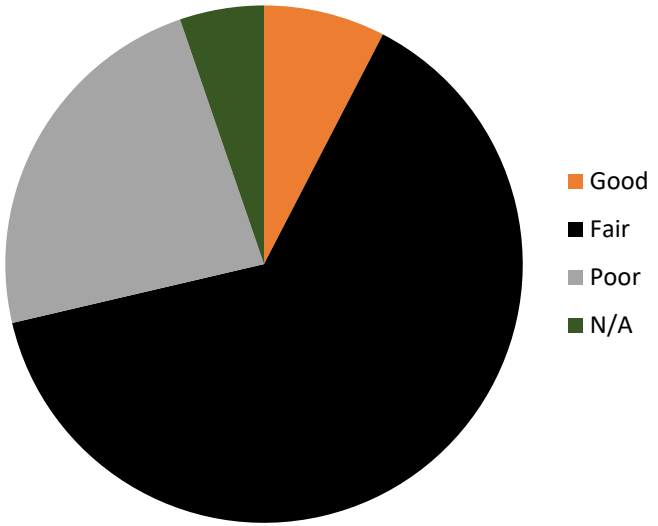
Flow Data Quality

- **Gage stations evaluated by USGS and accuracy determined**
  - **Good within 10% of measured**
  - **Fair within 15%**
  - **Poor >15%**

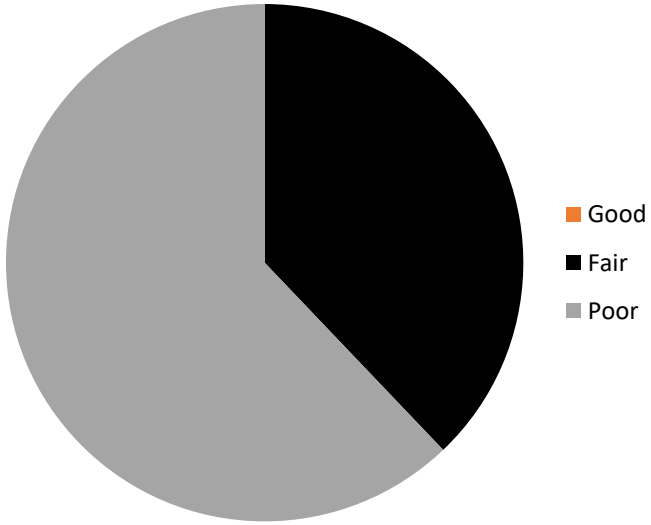
Bear Cr above Evergreen



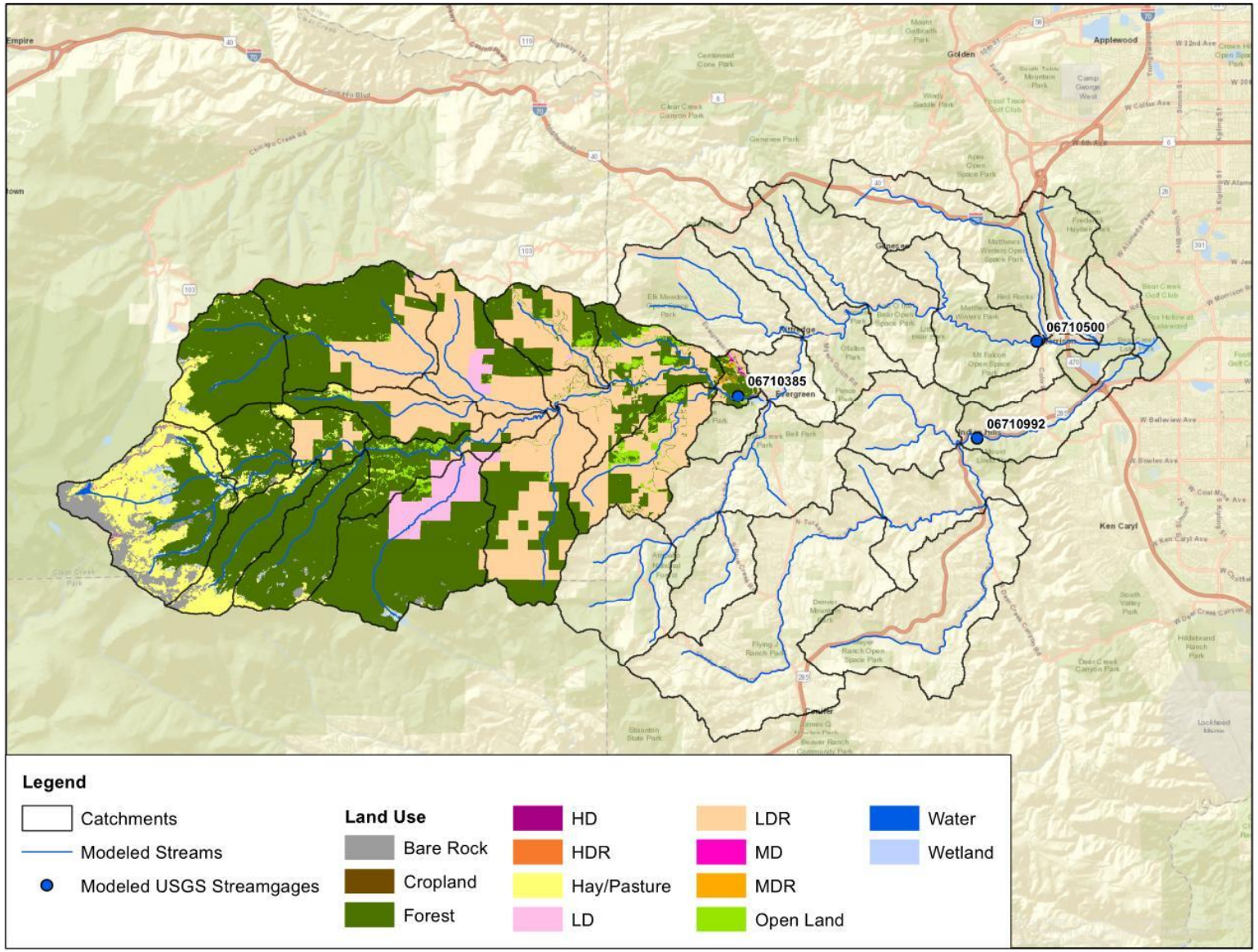
Bear Cr near Morrison



Turkey Cr near Indian Hills

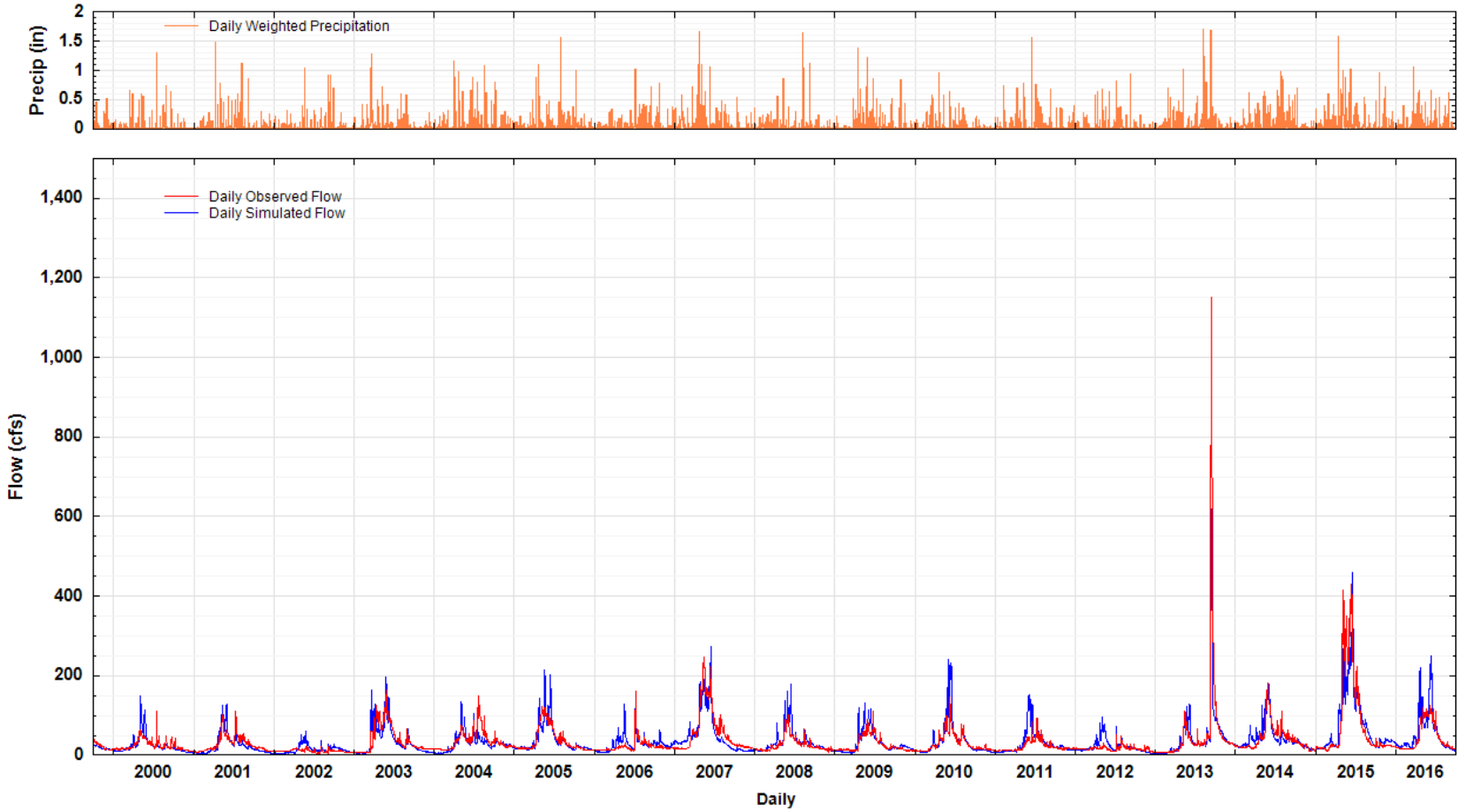


Bear Creek above Evergreen



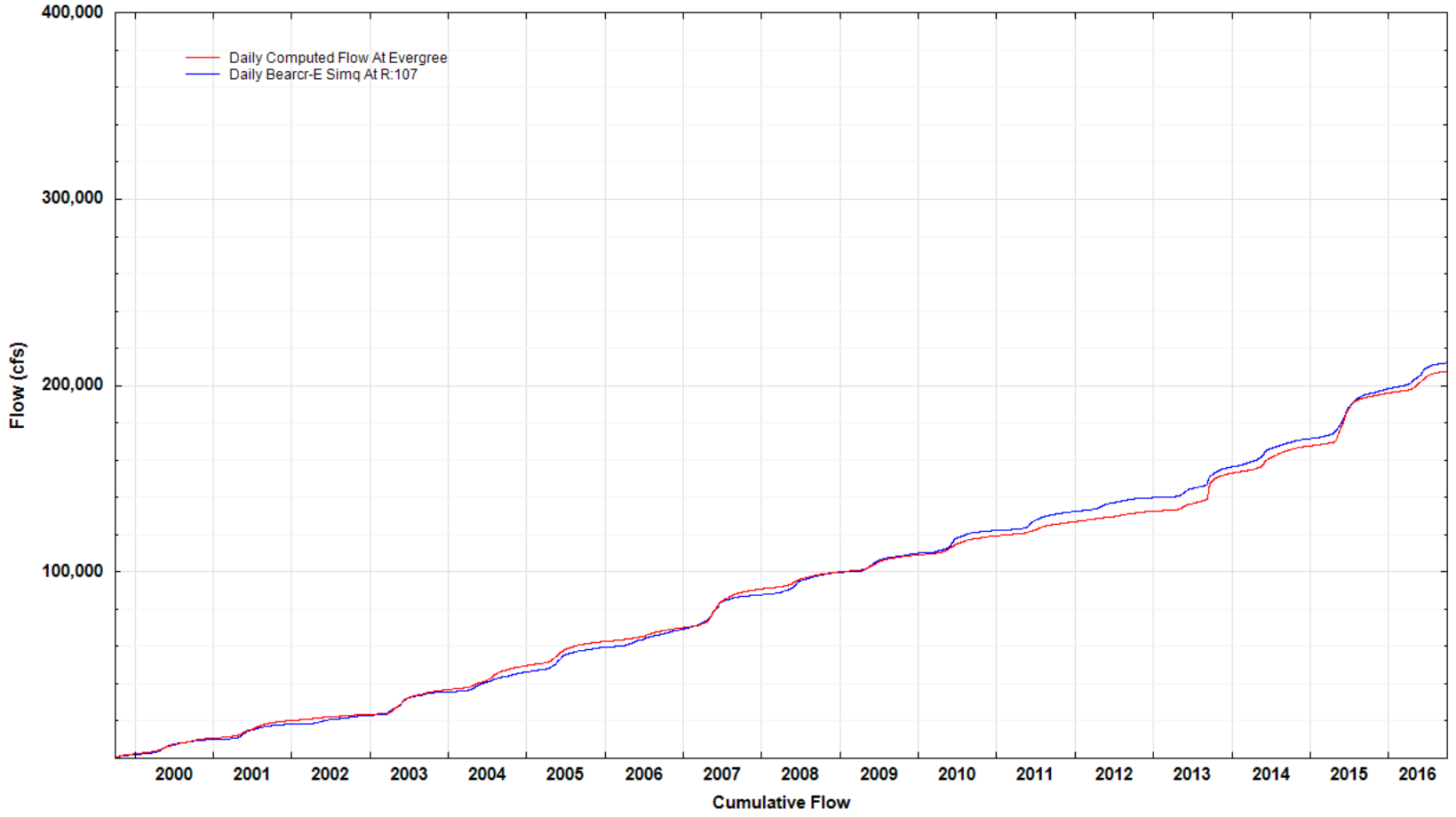
Bear Creek above Evergreen

- **Daily flow comparison**



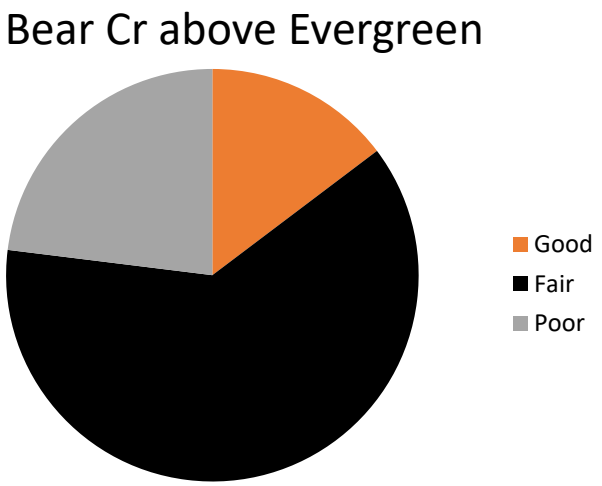
Bear Creek above Evergreen

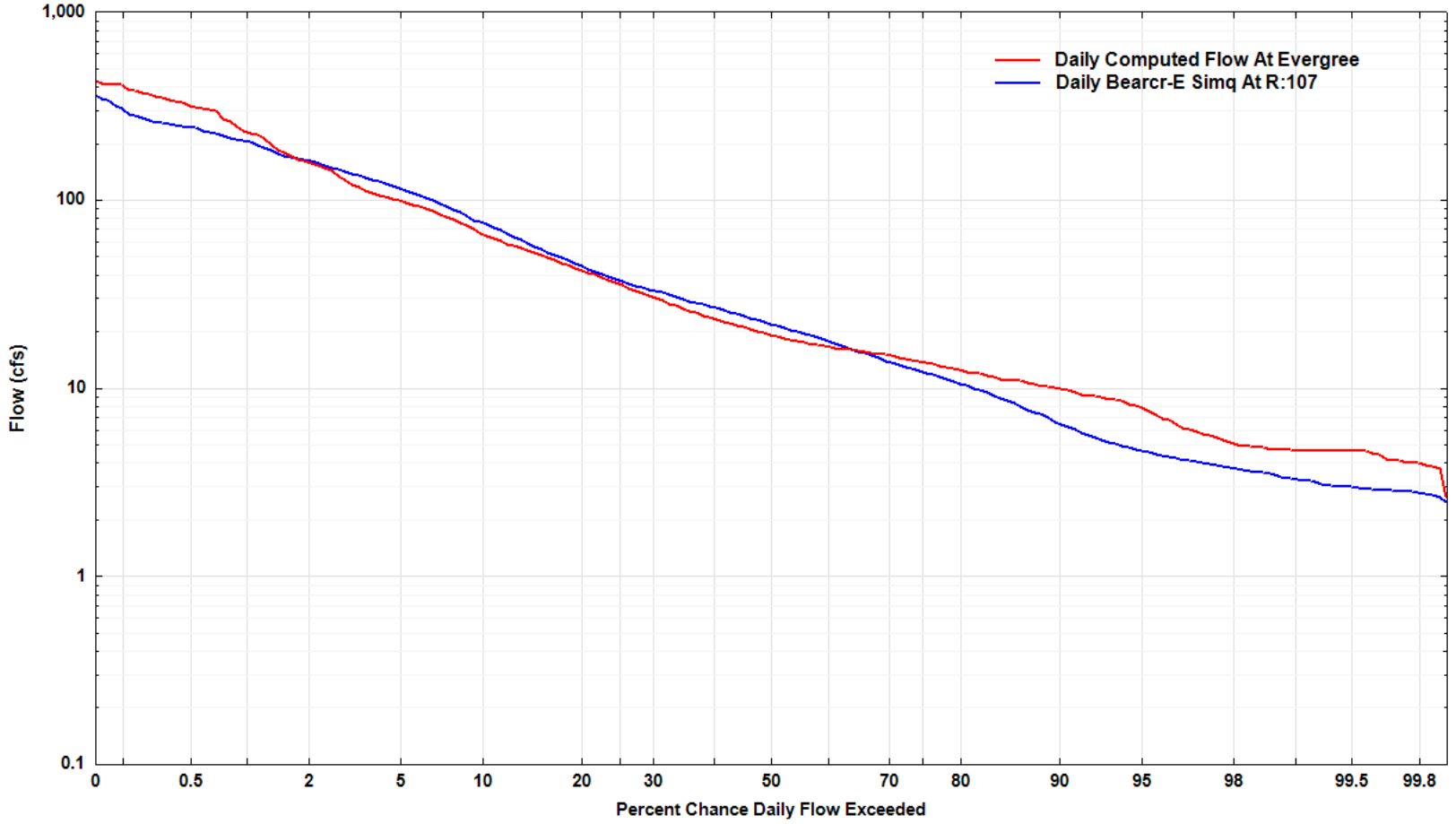
- **Cumulative flow comparison**



Bear Creek above Evergreen

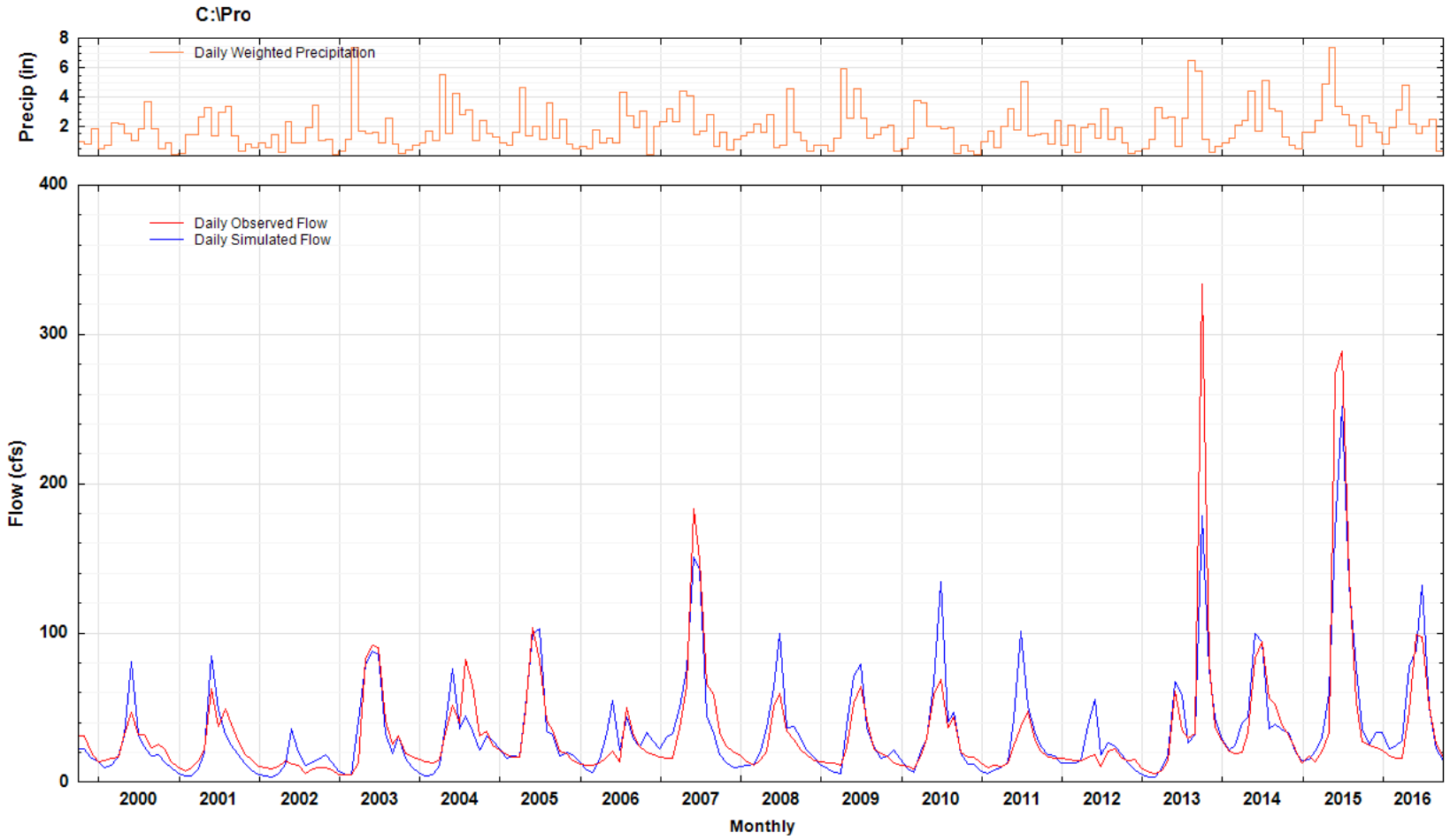
- **Flow distribution**





Bear Creek above Evergreen

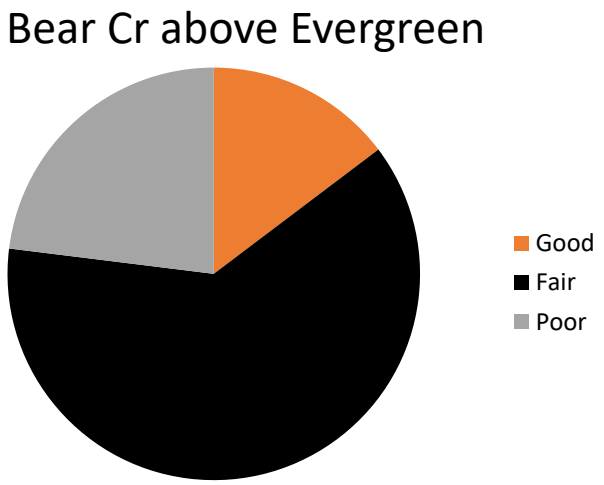
- **Monthly flow comparison**



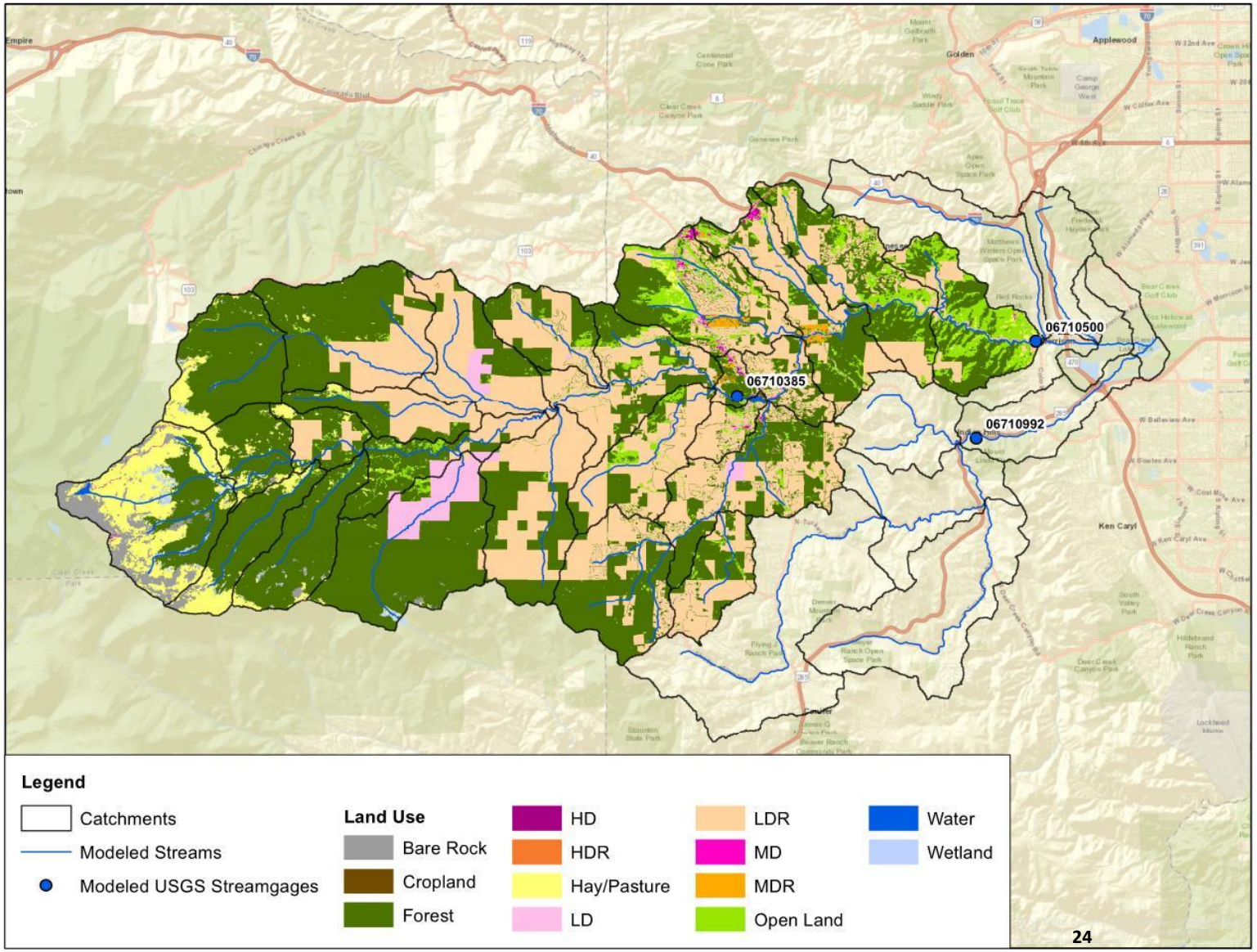
Bear Creek above Evergreen

- **HSPF expert stats results**

Error in total volume	(%)	2.17	10	OK
Error in 10% highest flows	(%)	-1.05	15	OK
Error in 25% highest flows	(%)	2.18	10	OK
Error in 50% highest flows	(%)	4.42	10	OK
Error in 50% lowest flows	(%)	-7.04	10	OK
Error in 25% lowest flows	(%)	-24.23	15	
Error in 10% lowest flows	(%)	-36.49	20	
Error in low-flow recession		0.02	0.03	OK
Error in storm volumes	(%)	-12.80	15	OK
Seasonal volume error	(%)	9.32	20	OK
Error in average storm peak	(%)	-11.03	15	OK
Summer volume error	(%)	2.48	20	OK
Winter volume error	(%)	-6.84	15	OK
Summer storm volume error	(%)	-5.54	15	OK
Winter storm volume error	(%)			

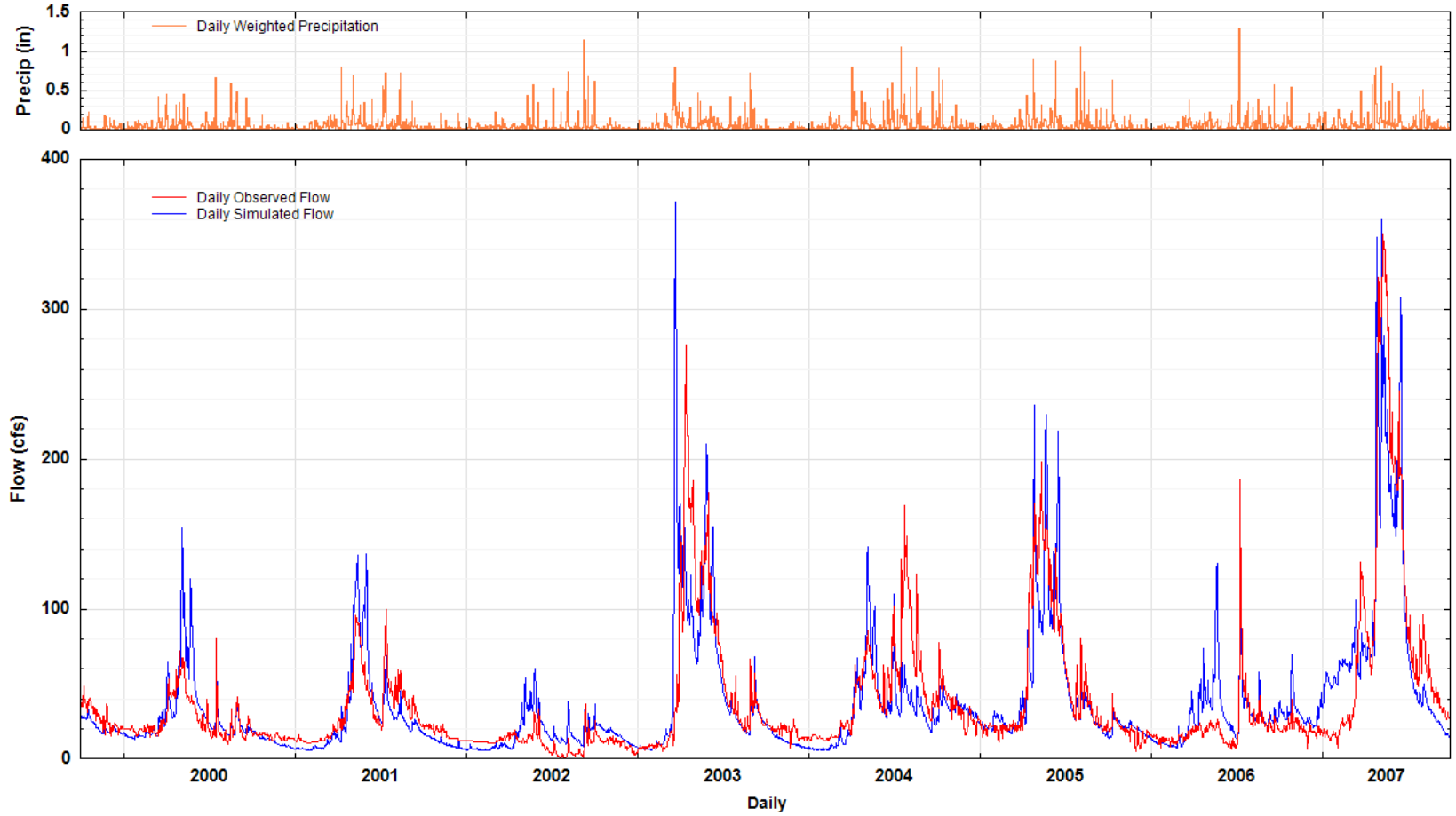


Bear Creek above Morrison



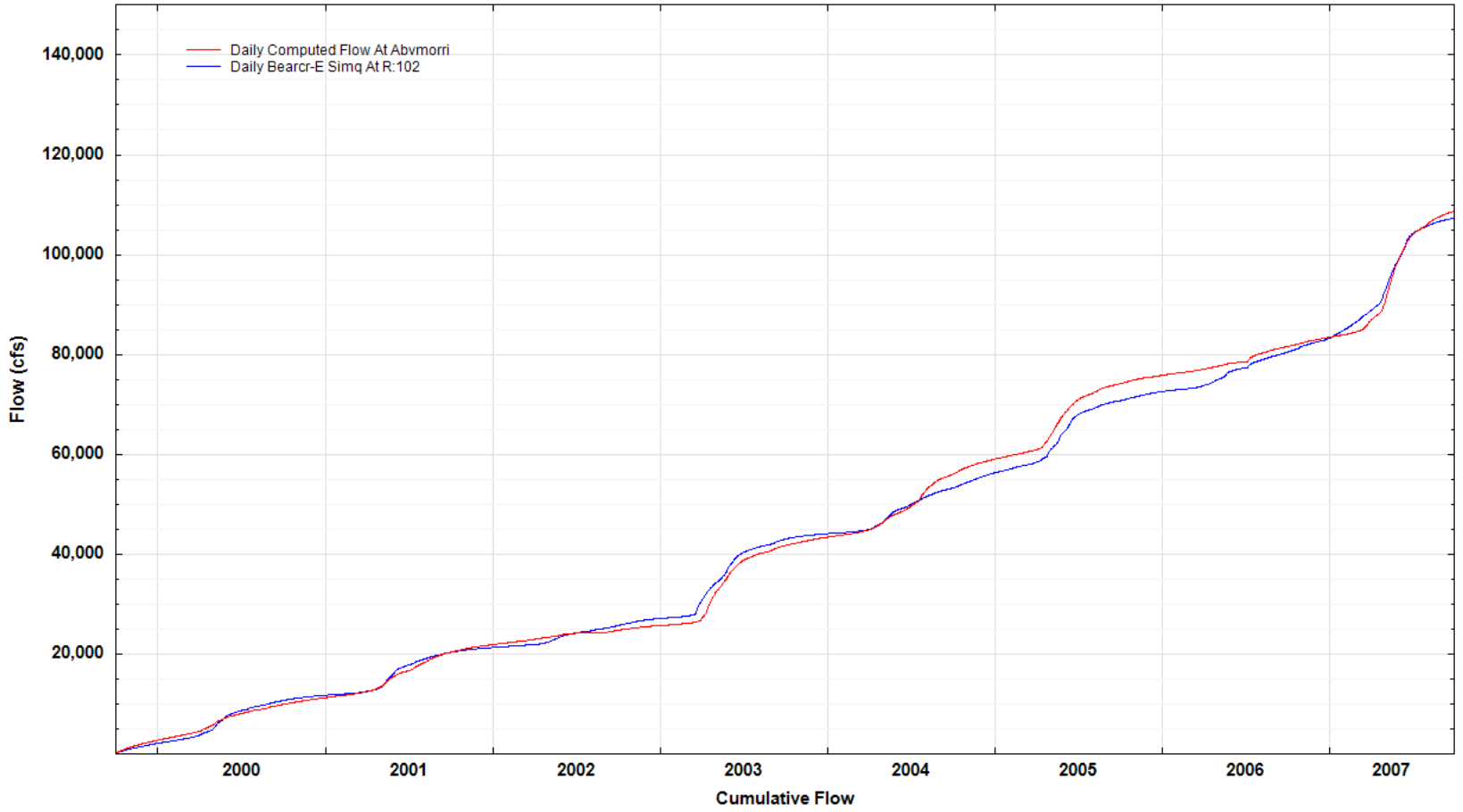
Bear Creek above Morrison

- **Daily flow comparison**



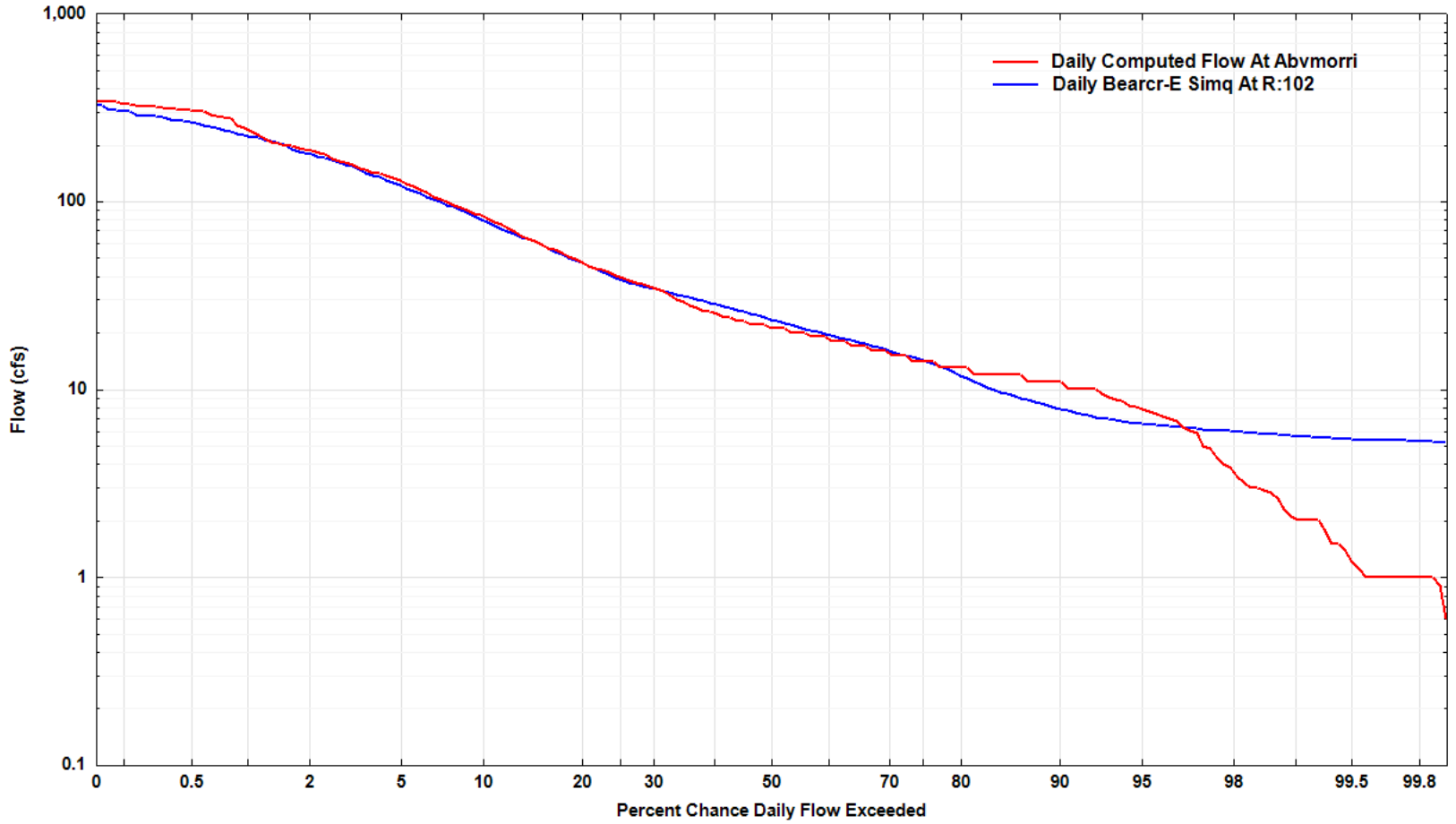
Bear Creek at Morrison

- **Cumulative flow comparison**



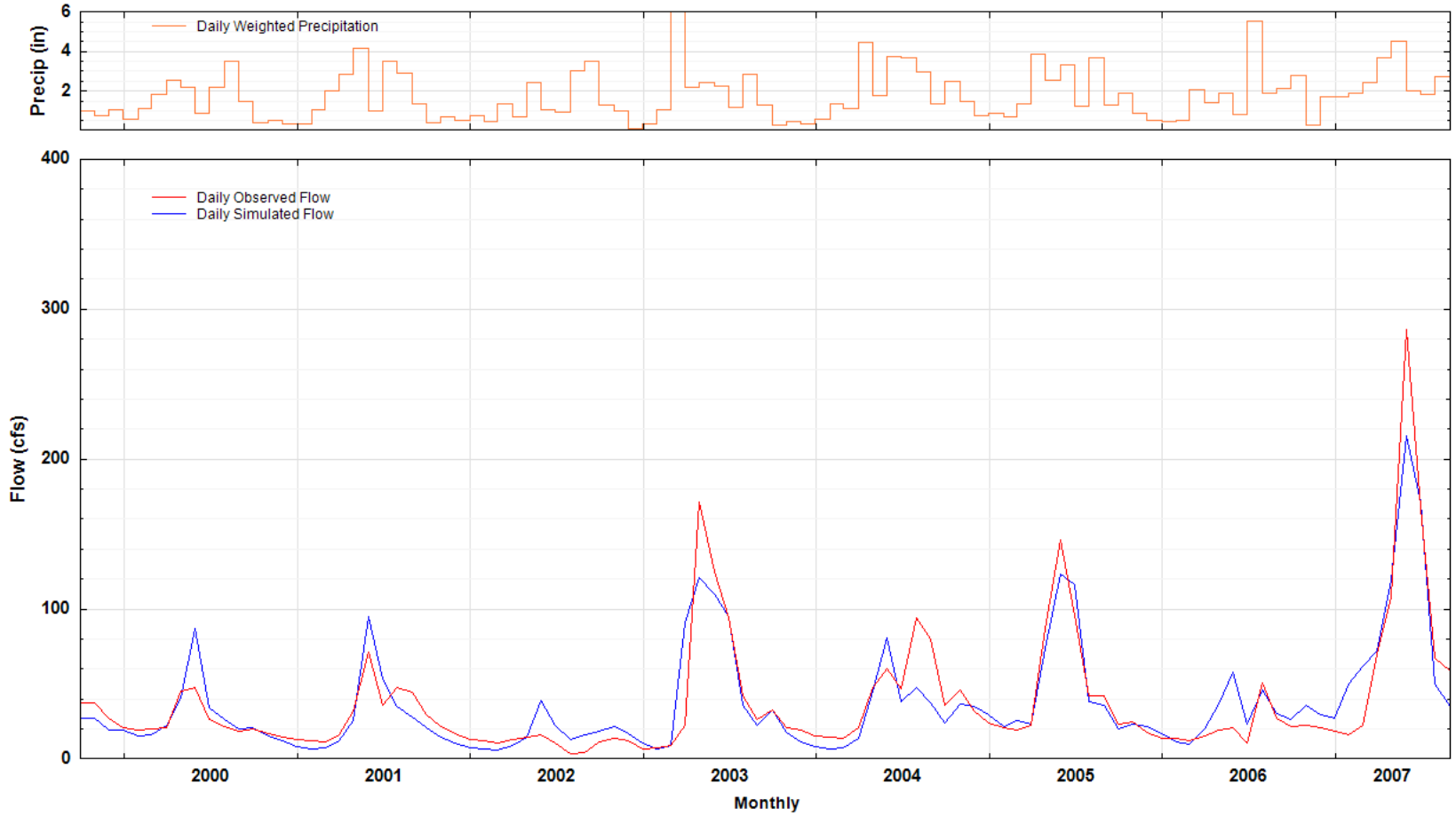
Bear Creek at Morrison

- **Flow distribution**



Bear Creek at Morrison

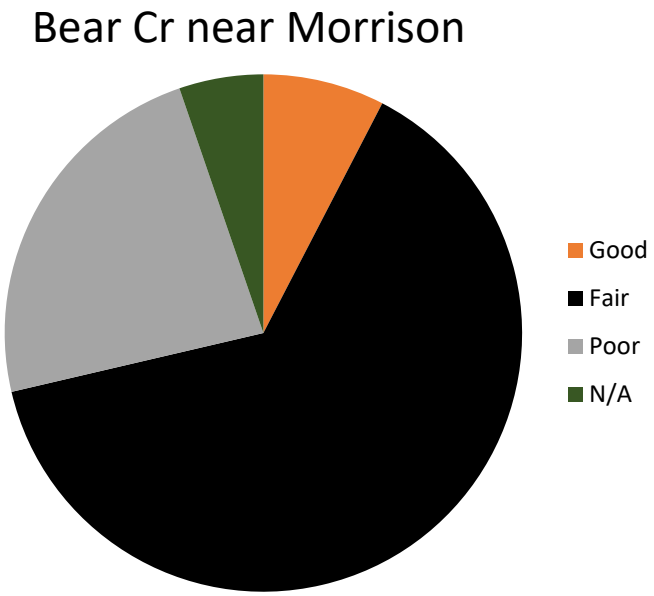
- **Monthly flow comparison**



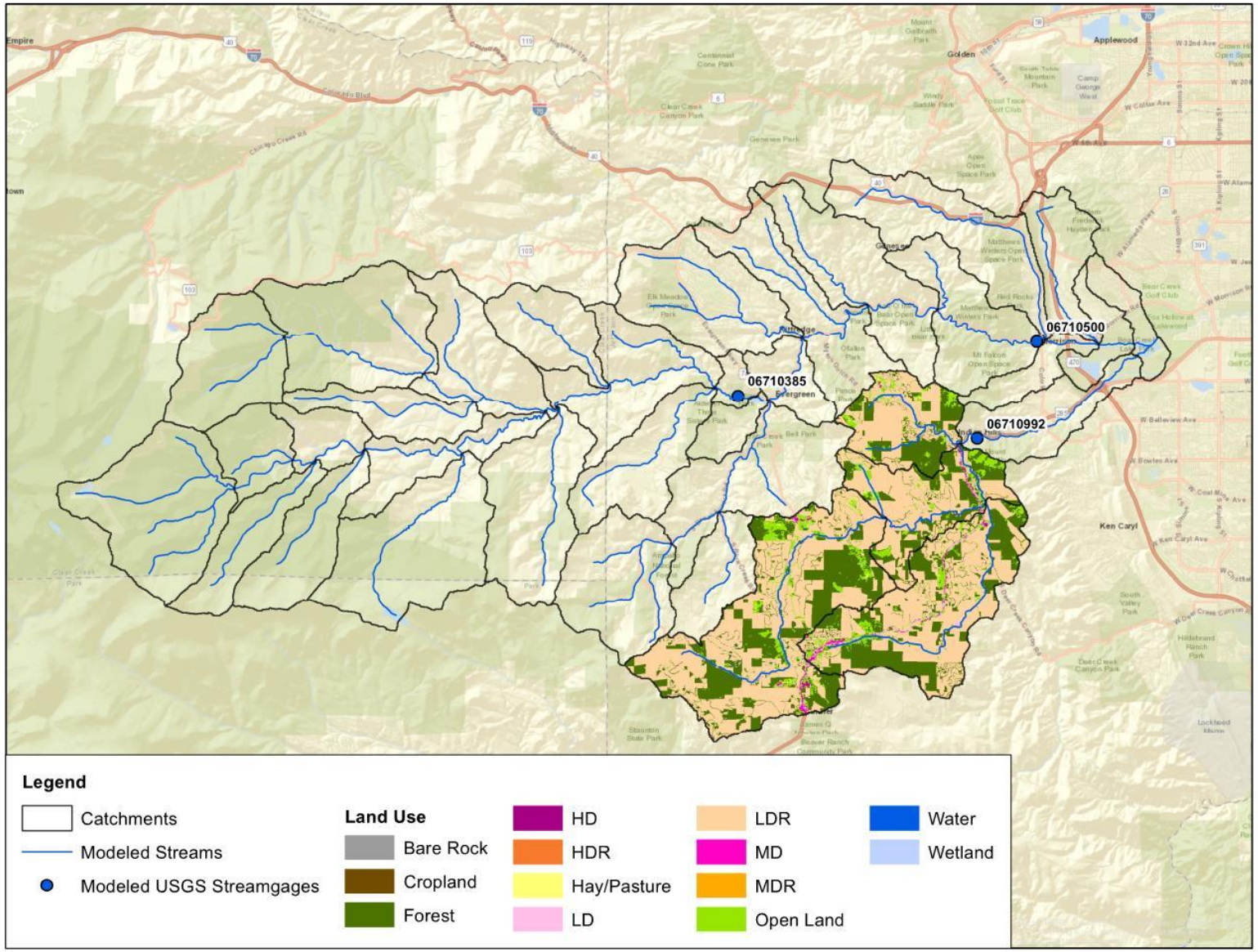
Bear Creek at Morrison

- **HSPF expert stats results**

Error in total volume	(%)	-1.27	10	OK
Error in 10% highest flows	(%)	-4.83	15	OK
Error in 25% highest flows	(%)	-3.80	10	OK
Error in 50% highest flows	(%)	-1.42	10	OK
Error in 50% lowest flows	(%)	-0.65	10	OK
Error in 25% lowest flows	(%)	-10.86	15	OK
Error in 10% lowest flows	(%)	-6.92	20	OK
Error in low-flow recession		0.02	0.03	OK
Error in storm volumes	(%)	-16.10	15	
Seasonal volume error	(%)	-17.52	20	OK
Error in average storm peak	(%)	-8.21	15	OK
Summer volume error	(%)	-7.78	20	OK
Winter volume error	(%)	9.74	15	OK
Summer storm volume error	(%)	-10.71	15	OK
Winter storm volume error	(%)			

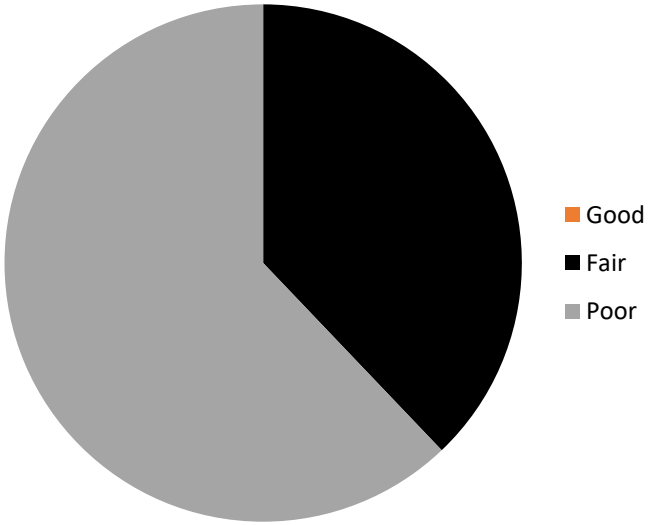


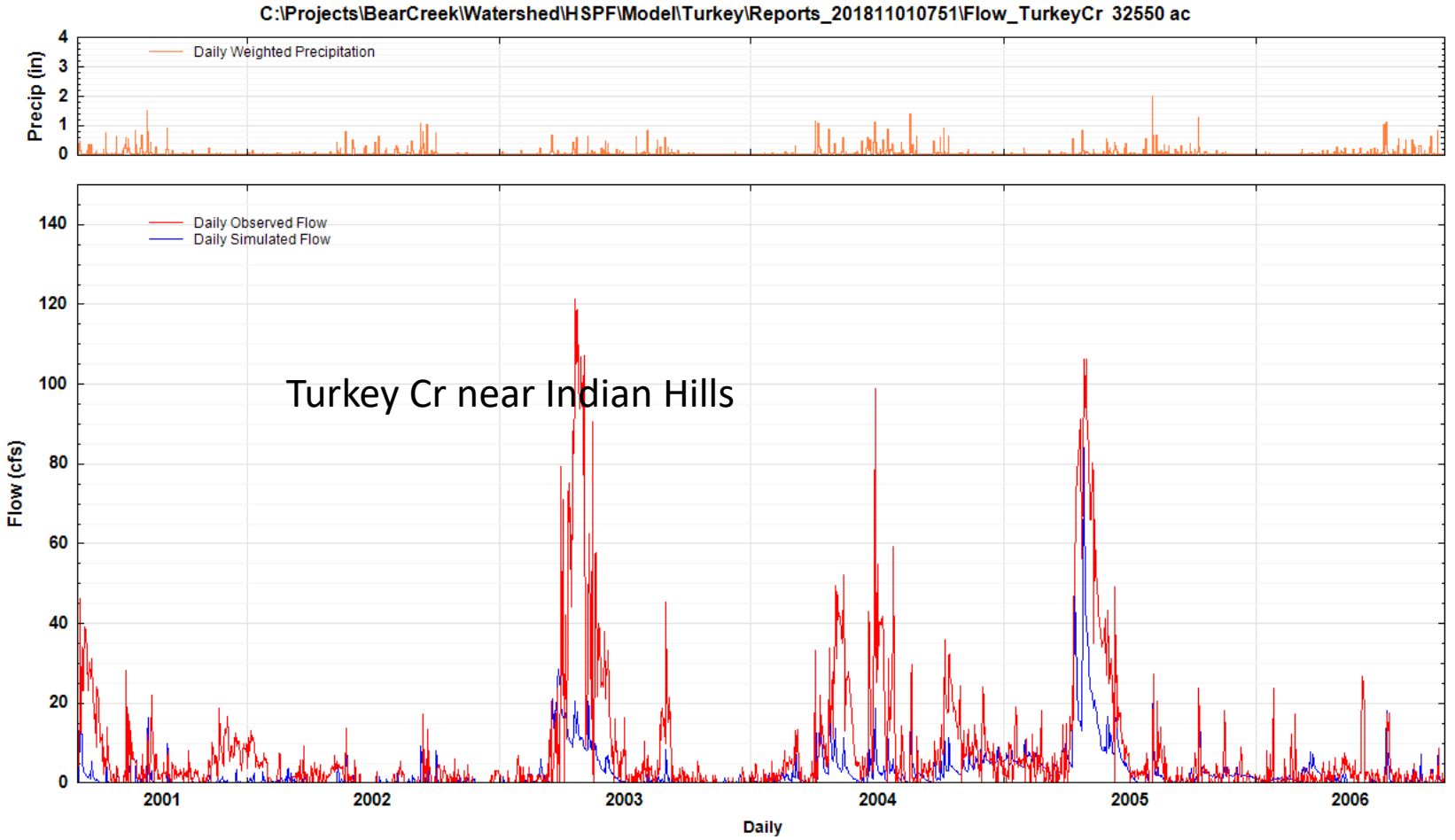
Turkey Creek



Turkey Creek

- **Daily flow comparison**



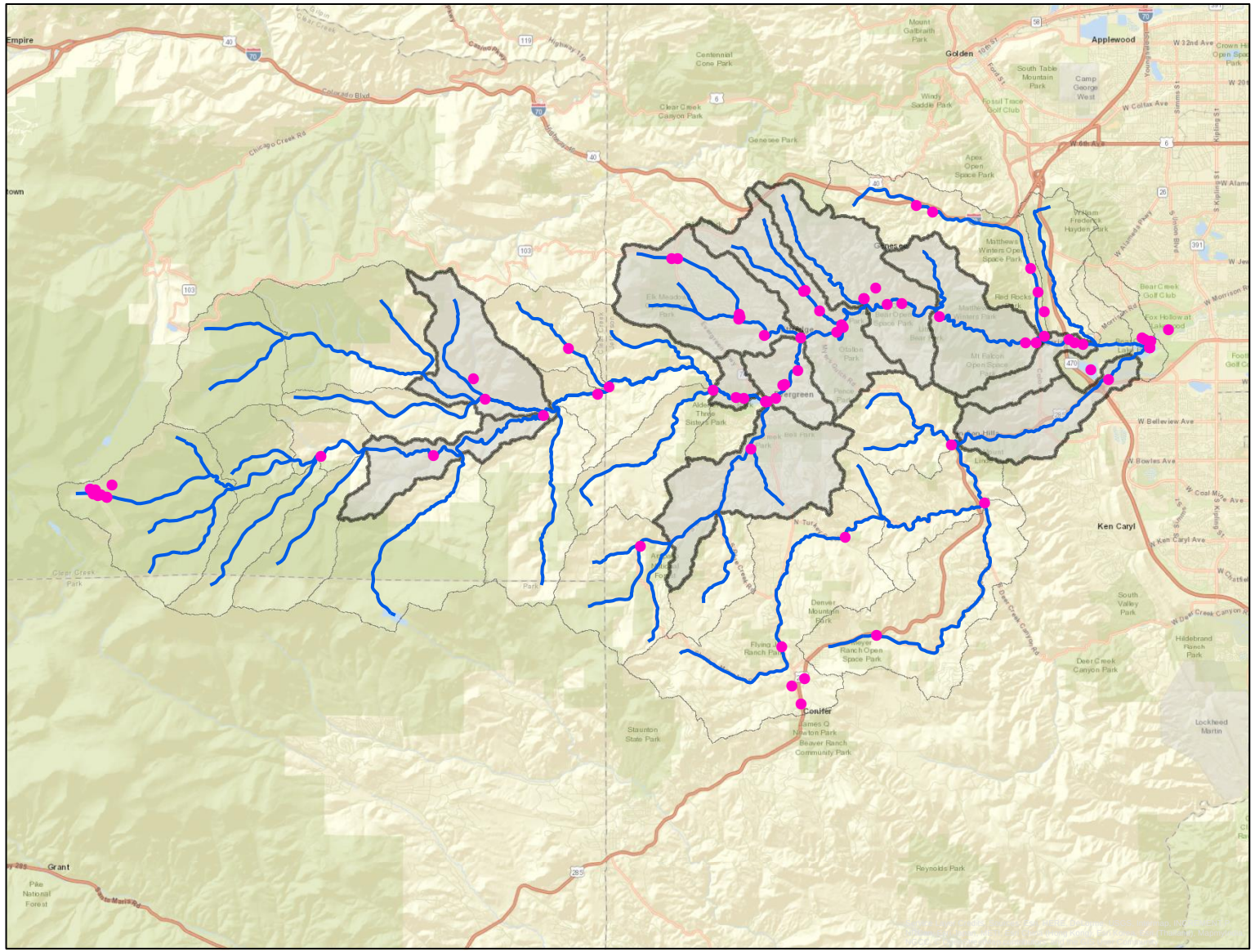


Watershed Water Quality Calibration

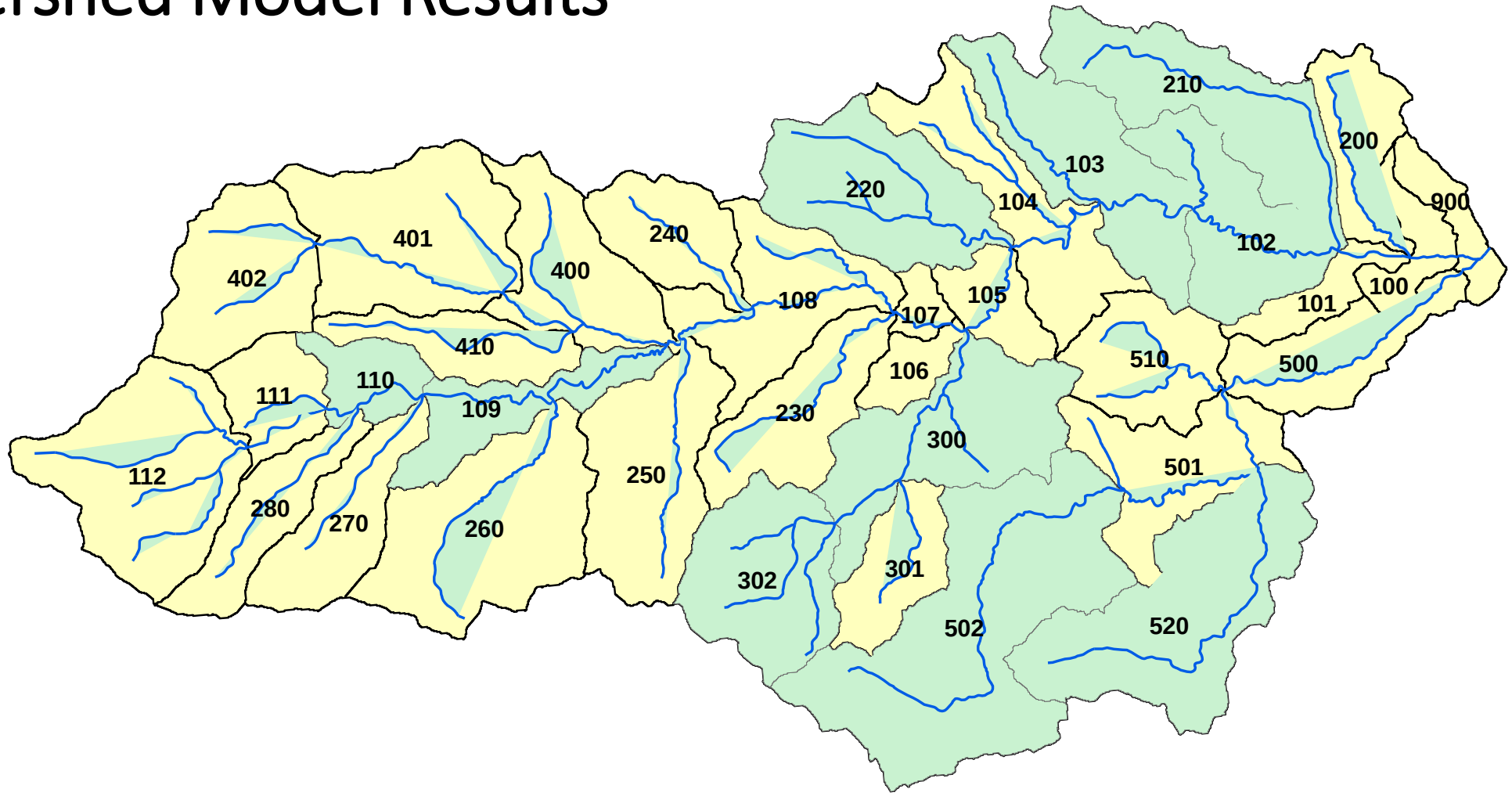
- **Land use calibration**
  - **Reg 85 Data Gap Report**
- **Watershed calibration**
  - **Use historic monitoring to confirm results**

Watershed Water Quality Calibration

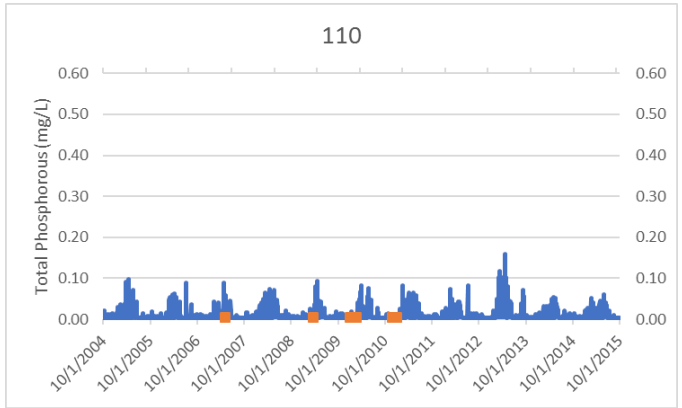
- Start upstream and calibrate as go downstream
  - Use data from sampling points lowest in the catchment
- Calibrate TP and TN
  - Compare with measured concentrations
  - Aggregate stations within a model catchment
- Subset of results in following slides

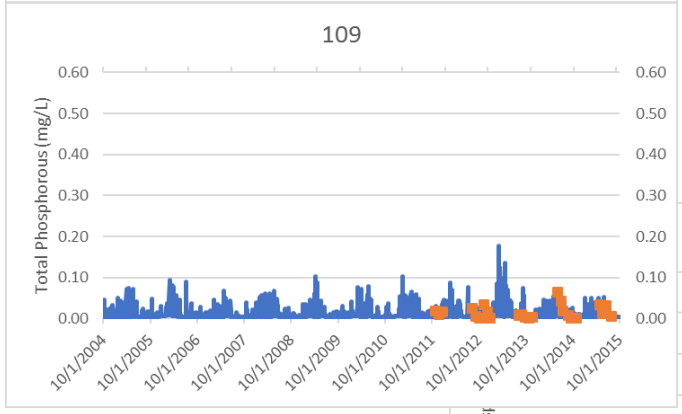


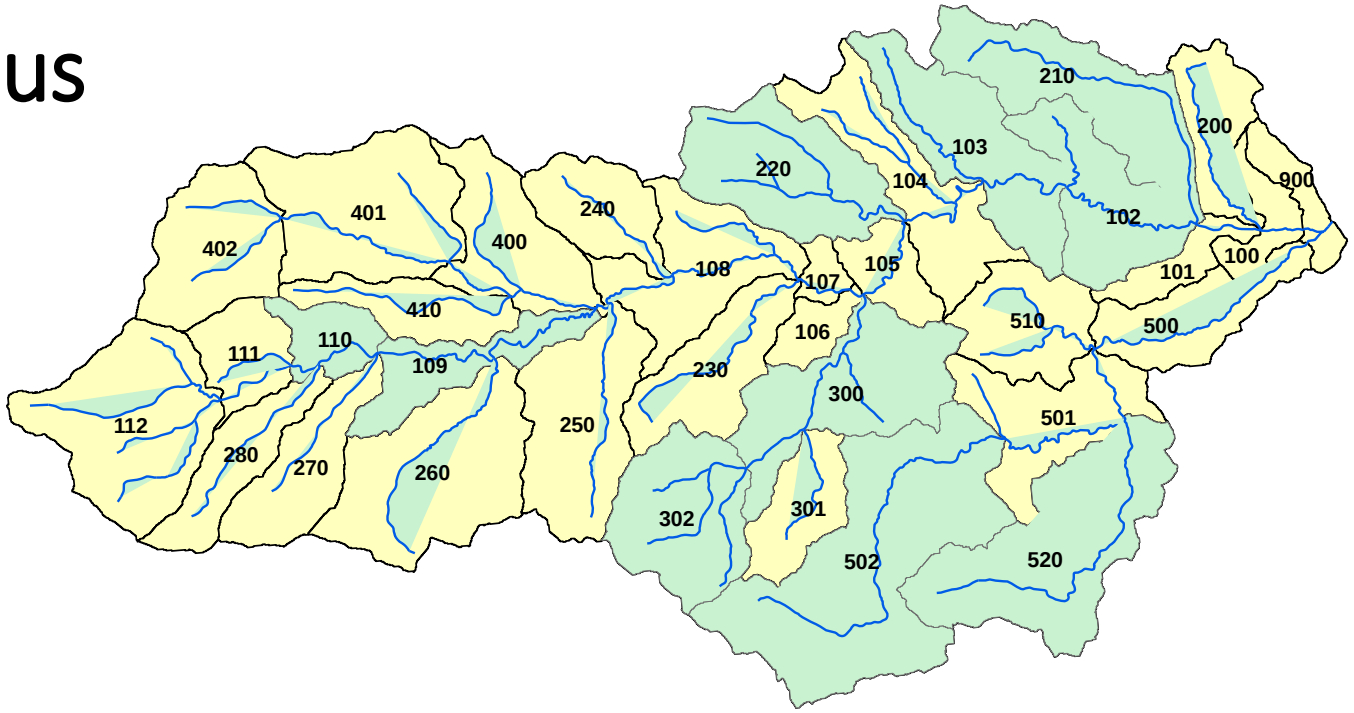
Watershed Model Results

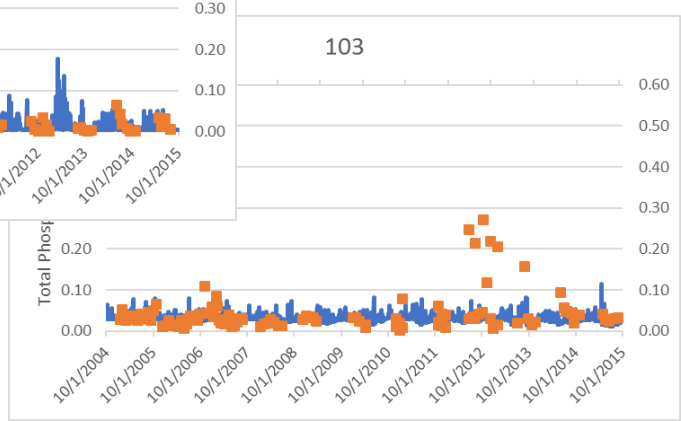


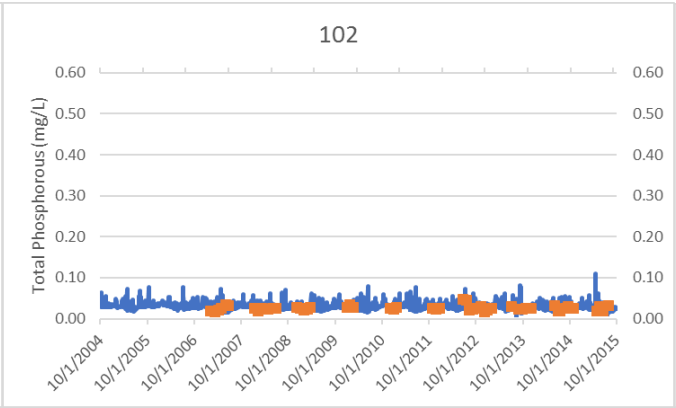
Bear Creek Total Phosphorous

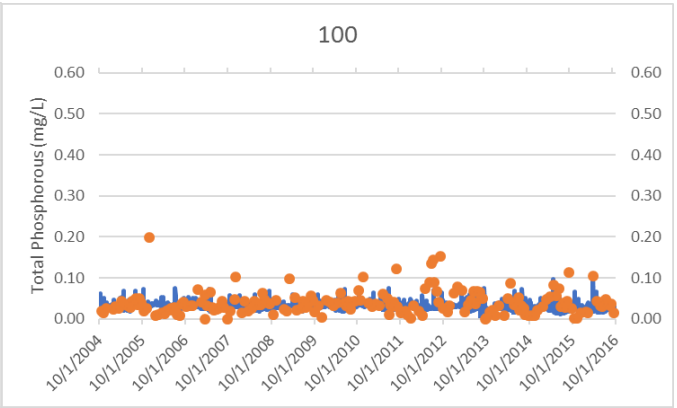




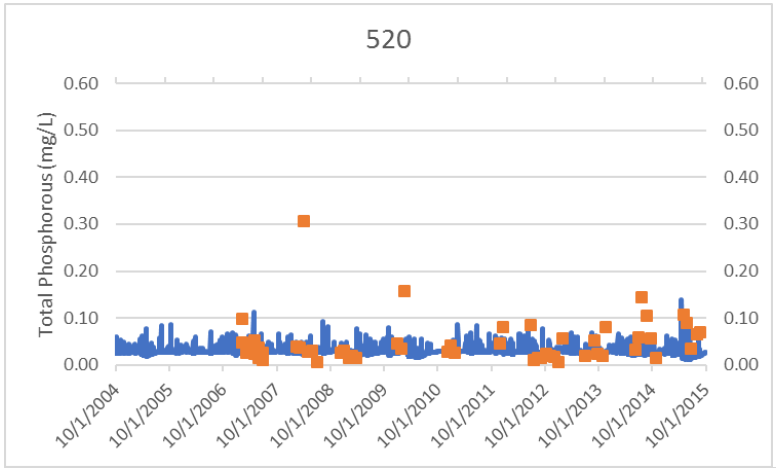


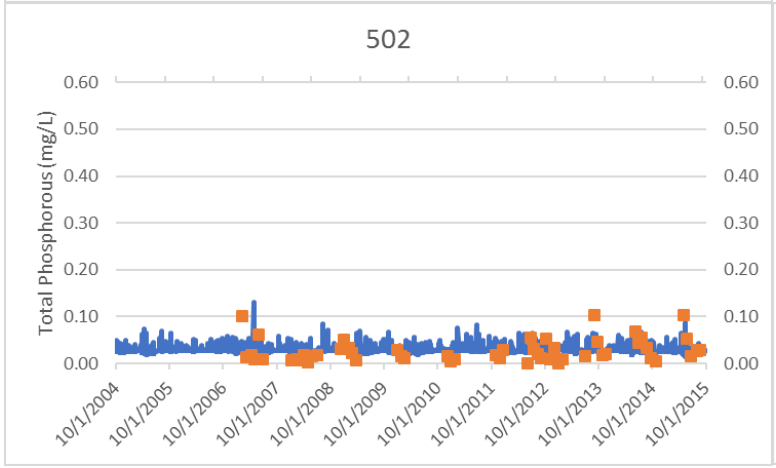


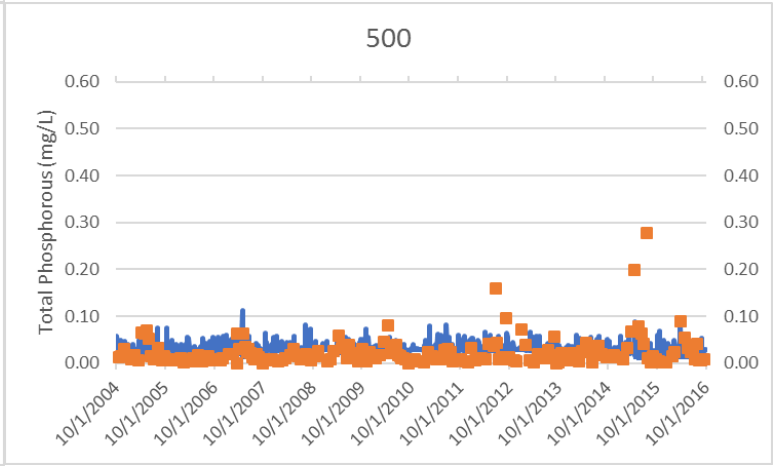


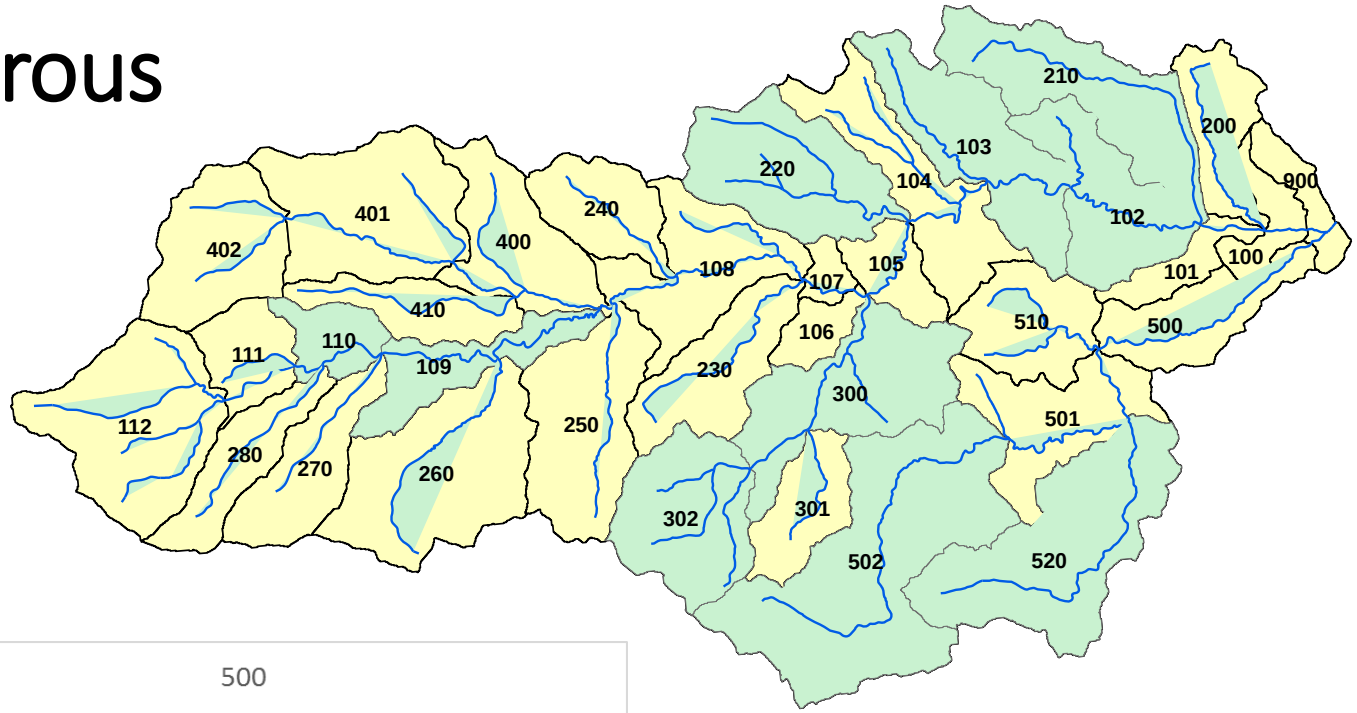


Turkey Creek Total Phosphorous









Watershed Water Quality Calibration

- **How good is good?**
- **Donigian 2000 guidance**

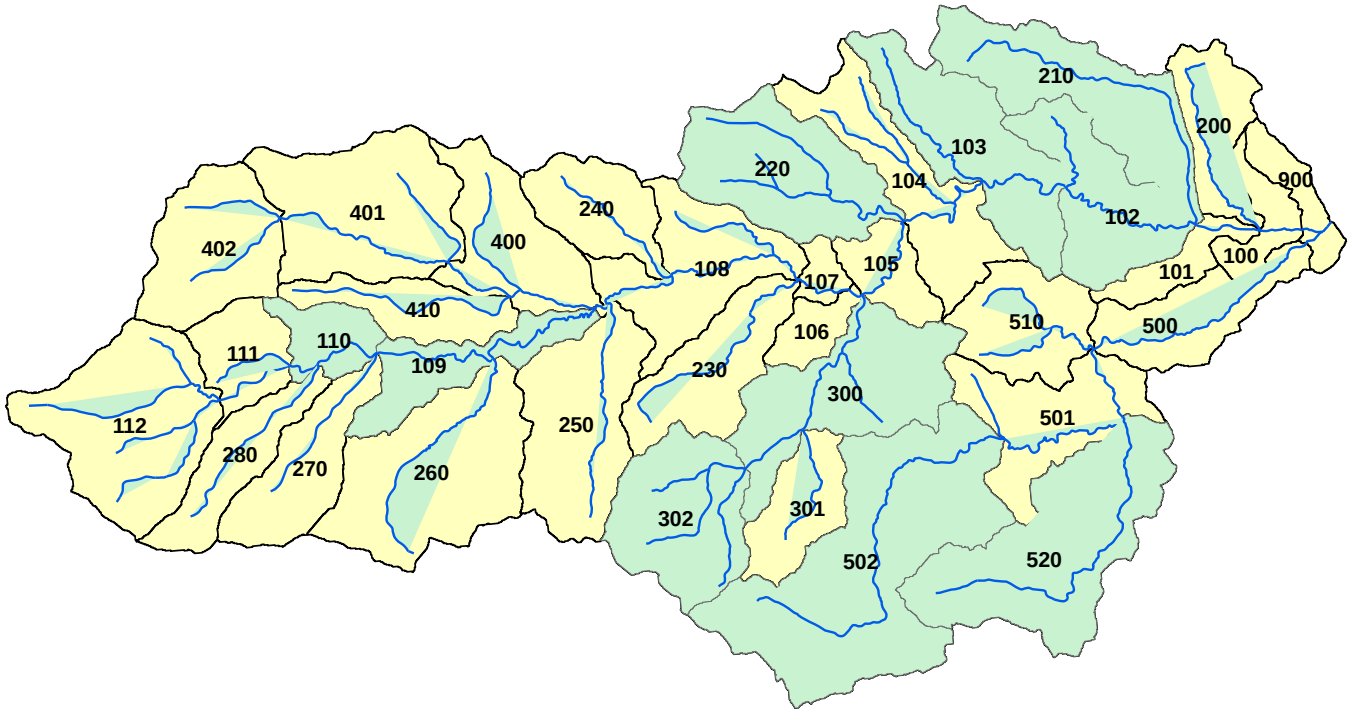
	% Difference Between Simulated and Recorded Values		
	Very Good	Good	Fair
Hydrology/Flow	< 10	10 - 15	15 - 25
Sediment	< 20	20 - 30	30 - 45
Water Temperature	< 7	8 - 12	13 - 18
Water Quality/Nutrients	< 15	15 - 25	25 - 35
Pesticides/Toxics	< 20	20 - 30	30 - 40

CAVEATS:

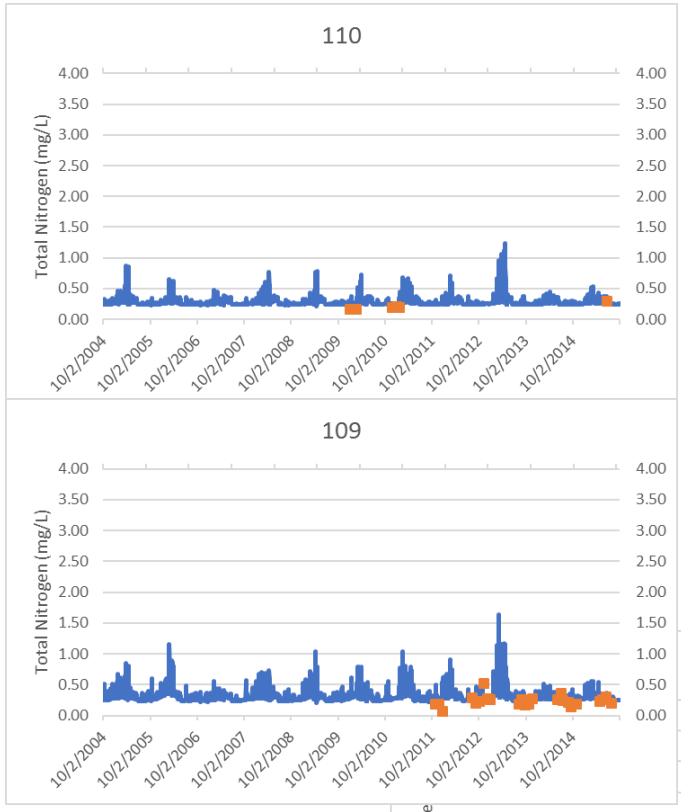
Relevant to monthly and annual values; storm peaks may differ more
Quality and detail of input and calibration data
Purpose of model application
Availability of alternative assessment procedures
Resource availability (i.e. time, money, personnel)

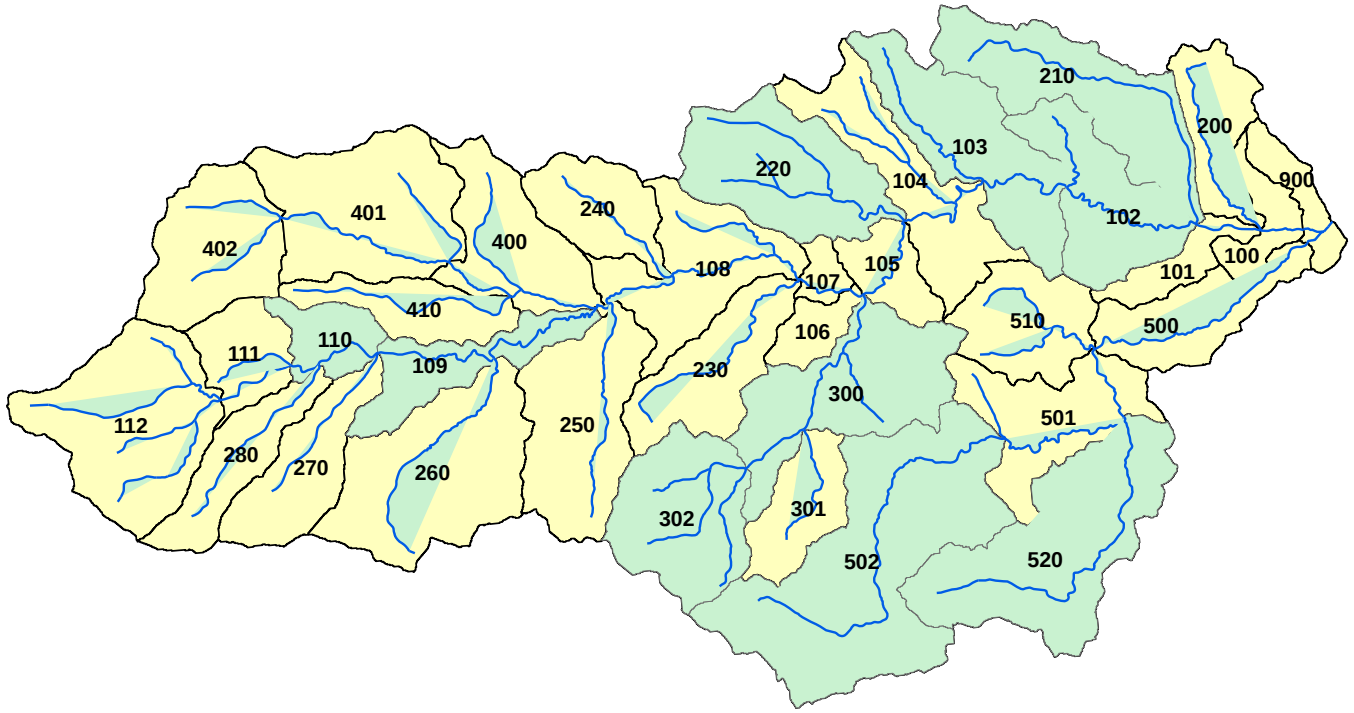
Total Phosphorous

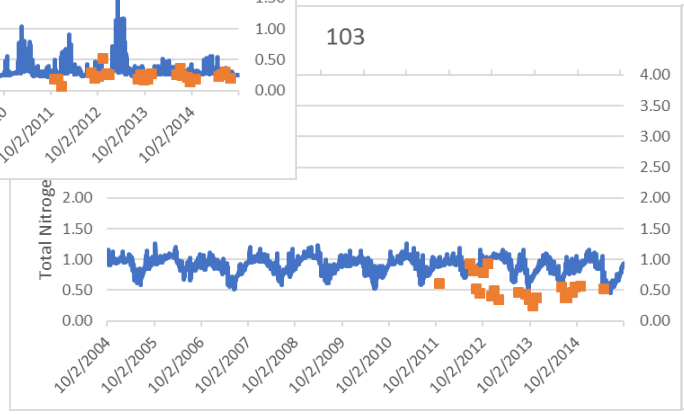
Catchment	Count	Avg error	Abs Error
110	6	-20%	33%
109	24	-15%	76%
103	125	7%	39%
102	103	-15%	48%
100	187	-1%	2%
210	26	64%	75%
220	48	-59%	60%
240	3	-77%	77%
300	29	1%	50%
302	29	49%	70%
400	40	-57%	66%
502	53	47%	61%
520	56	-22%	48%
500	187	0%	2%

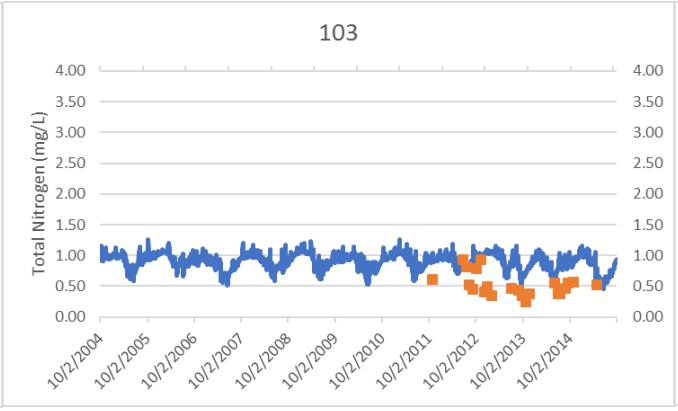


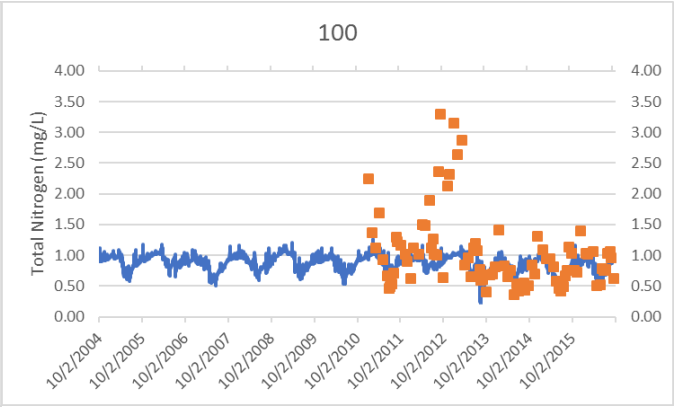
Bear Creek Total Nitrogen



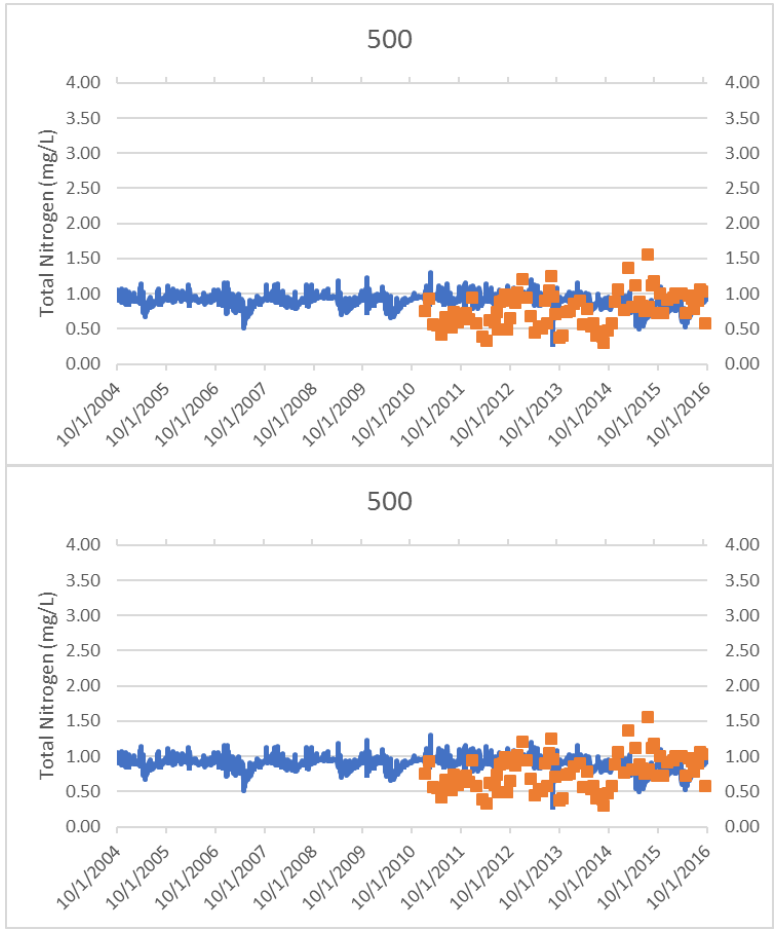


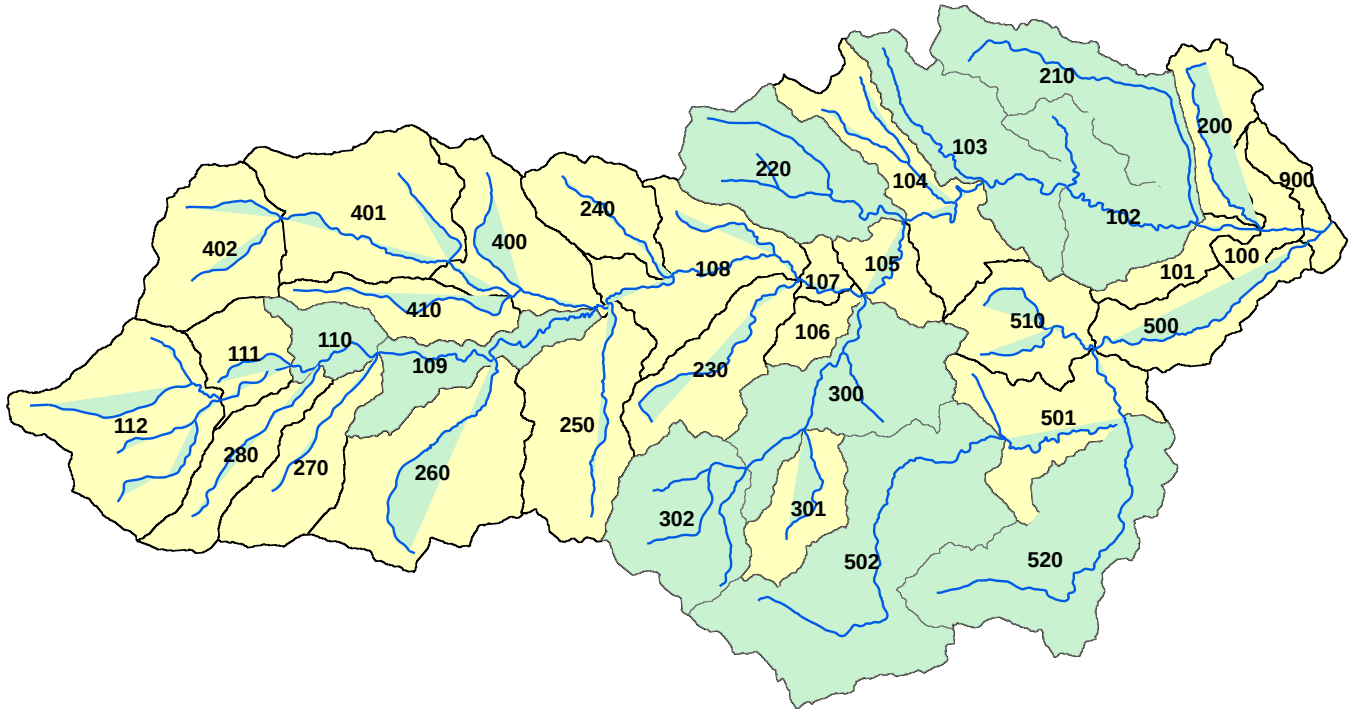






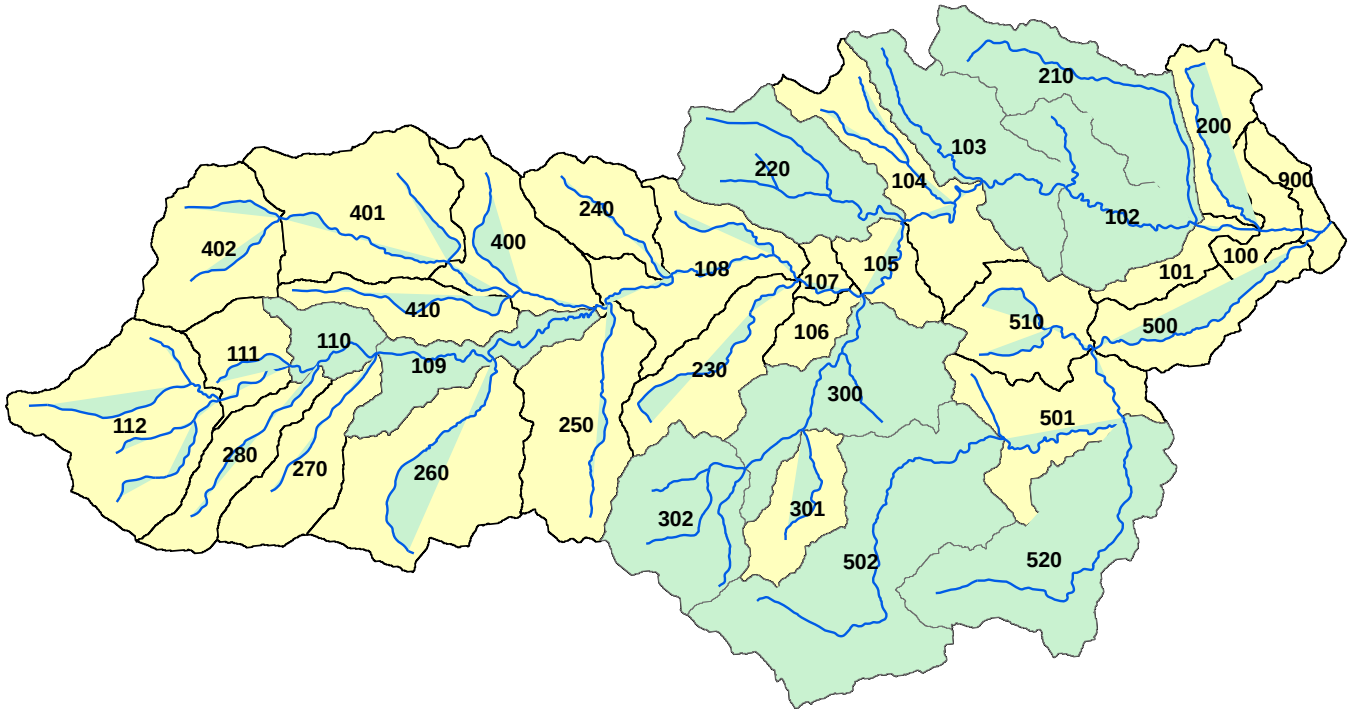
Turkey Creek Total Nitrogen





Total Nitrogen

Catchment	Count	Avg error	Abs Error
110	6	6%	6%
109	24	5%	5%
103	23	25%	26%
102	51	26%	26%
100	88	-18%	36%
210	19	-17%	17%
220	25	-30%	32%
240	n/a		
300	n/a		
302	19	40%	40%
400	21	13%	13%
502	27	36%	37%
520	n/a		
500	88	11%	25%
		9%	24%



Bear Creek Reservoir Modeling

Reservoir Modeling Approach

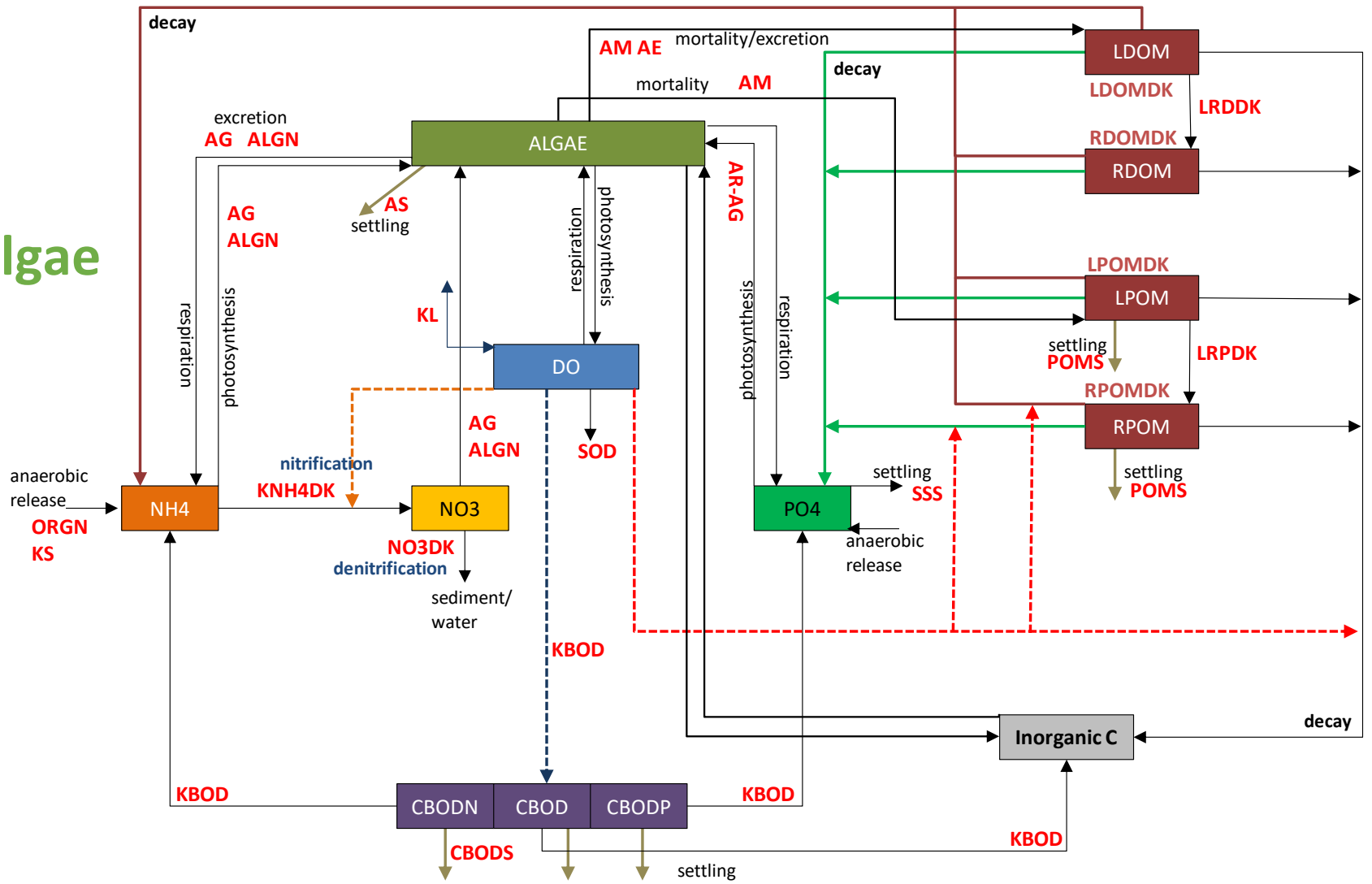
- **Use USACoE flows**
  - **Ensures that reservoir hydrodynamics are represented correctly**
- **Inflow nutrient water quality from HSPF model**

Model Selection

- Chose CE-QUAL-W2 model
  - Two-dimensional, time variable model
  - Coupled hydrodynamics and water quality
  - Used elsewhere in the region
    - Pueblo Reservoir, Cherry Creek, Chatfield

Water Quality

- Complex processes
- Can include multiple algae groups



Data Needs

- Bathymetry
- Meteorological data
- Flows in/out and reservoir elevation
- Aeration operation schedule
- Water quality
  - Vertical profiles of temperature and dissolved oxygen
  - Water quality chemistry data

Meteorology Data

- Rocky Mountain Regional Airport met station
  - Air temperature
  - Dew point
  - Wind speed
  - Cloud cover
- Compared with WeatherUnderground stations
  - Some difference
  - WU data poor quality, not controlled
- Compared with NREL data

Hydrology Calibration

- Used USACoE flows
  - Inflows of Turkey and Bear Creeks
  - Flows out
  - Measured elevation
- CE-QUAL-W2 water balance
  - Determined groundwater impacts on water balance

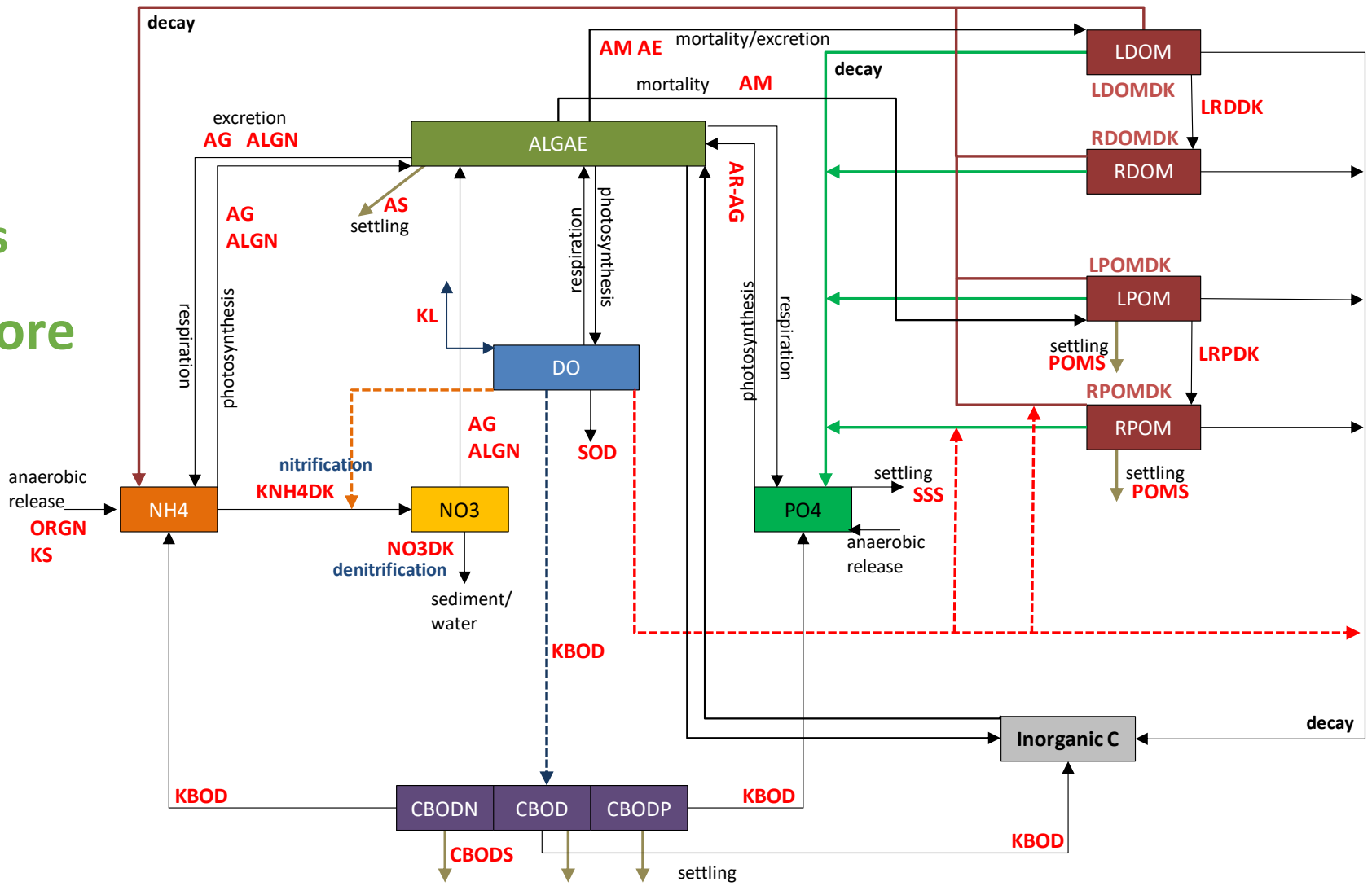
Aeration

- Obtained pumping periods from Lakewood
- Lakewood defined the pump flow rates
  - Calculated the oxygen flow rate
- Assumed equal oxygen delivery at each location
- Assumed oxygen delivery throughout the entire water column
- Extrapolated to unmonitored periods

On date	Off date	Pump Horsepower			
		7.5	15	40	75
5/24/2011	8/9/2011			•	
8/9/2011	10/13/2011	•			
5/16/2012	9/26/2012			•	
6/9/2013	7/9/2013			•	
7/9/2013	10/28/2013				•
5/5/2014	10/21/2014			•	
7/1/2015	11/9/2015			•	
6/1/2016	7/10/2016	•			
7/10/2016	9/9/2016			•	
6/13/2017	9/18/2017		•		

Water Quality

- HSPF
  - TP and TN calculations
- CE-QUAL-W2 needs more data



Water Quality Input Assumptions

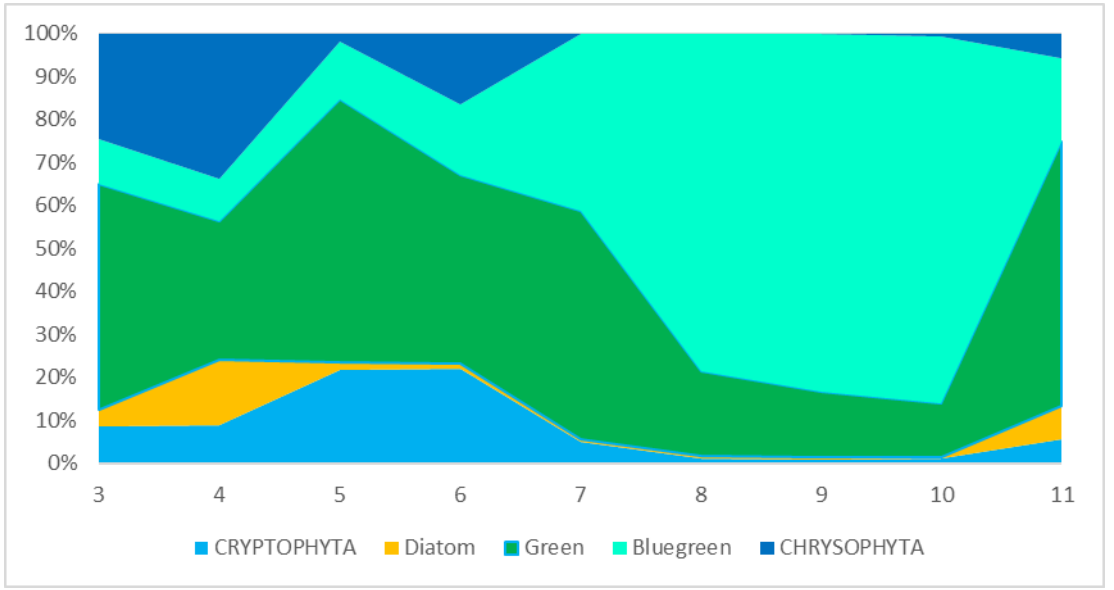
- Organic phosphorous as a percent of TP
  - From TP and SRP
  - Varies monthly based on monitoring data
- Nitrogen species
  - NH_3, NO_2+NO_3 and ON percentages based on TN monitoring data
    - Not as much TN data as TP
  - NH_3 1% of TN, NO_2+NO_3 67%, ON 32%
    - ANOVA analysis showed no significant monthly variation

Water Quality Input Assumptions

- **BOD**
  - **No direct measurements**
  - **Used historic regional measurements from USGS in early 1980s**
    - **Median 4.6 mg/L**

Algal Density

- Guide model calibration
  - Diatoms
  - Greens
  - Cyanobacteria
  - Cryptophytes
  - Chrysophytes

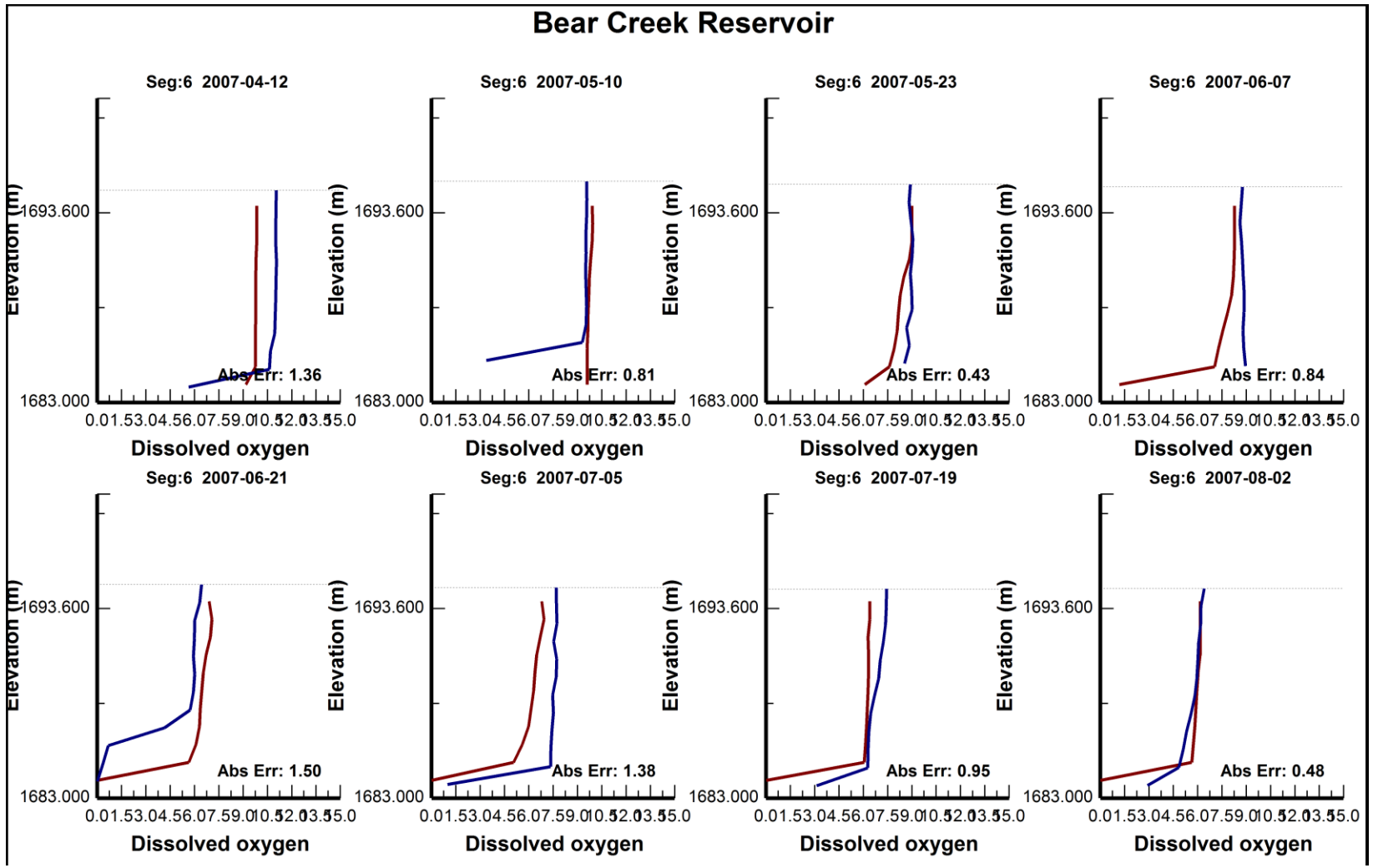


Model Water Quality Calibration

- Temperature
  - Include ice over
- Eutrophication
  - Dissolved oxygen
  - Nutrients
  - Chlorophyll a
  - Algal species
    - Diatoms, greens, cyanobacteria, cryptophytes, chrysophytes

Temperature Profiles

- Overall error
  - Median 0.13 °C
  - Absolute median 0.8 °C

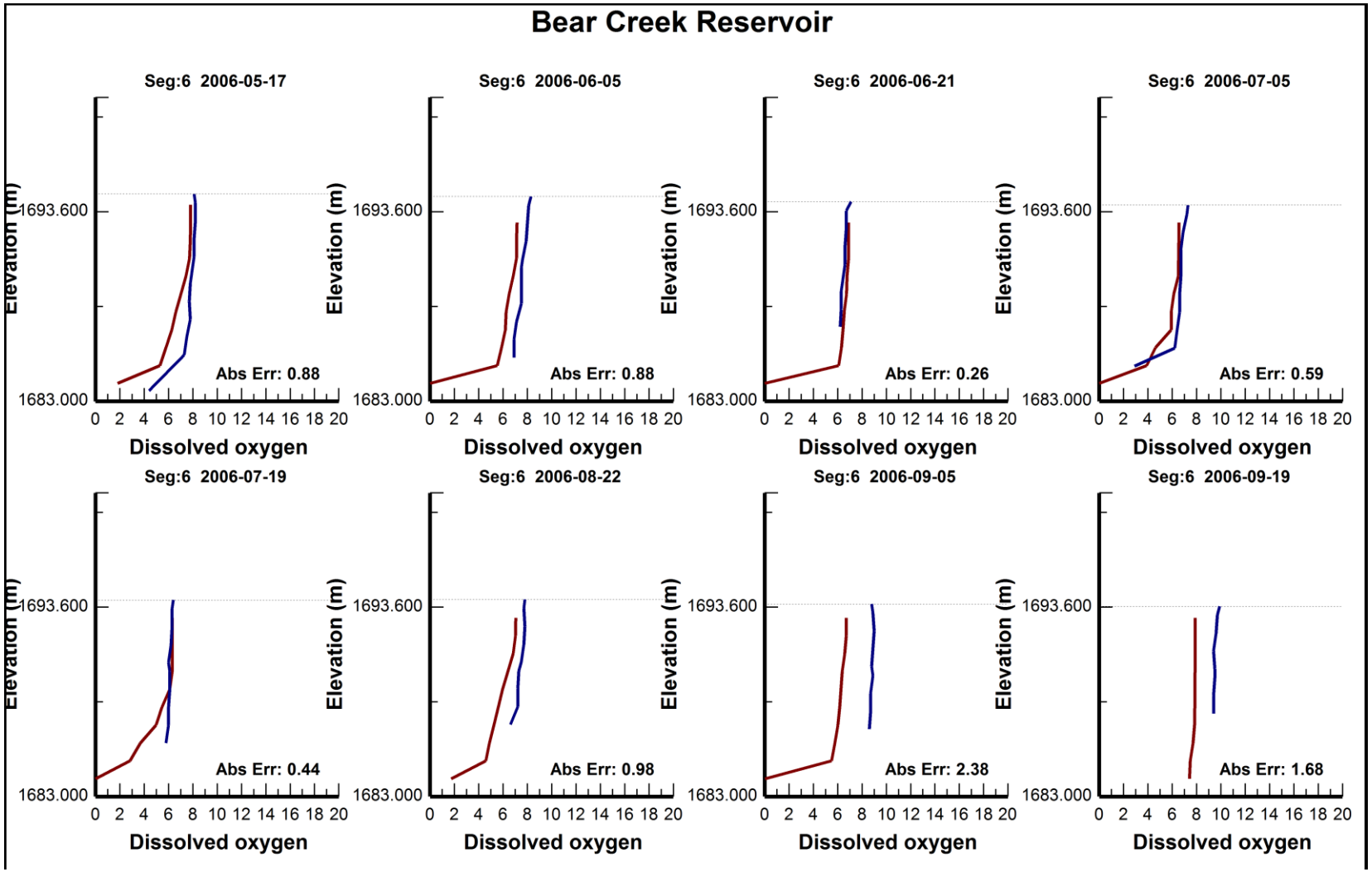


Blue line measured

Red line modeled

Dissolved Oxygen Profiles

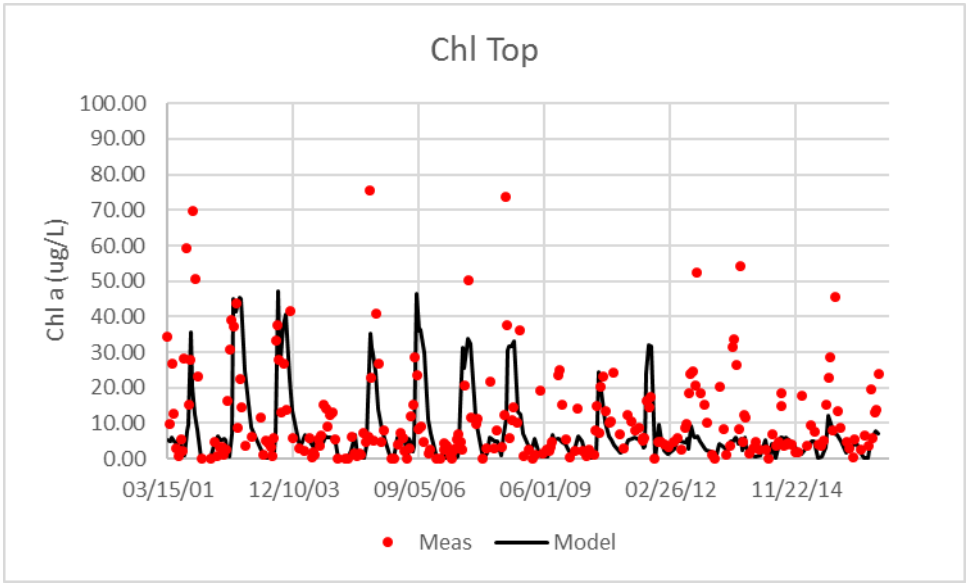
- Overall error
  - Median 0.01 mg/L
  - Absolute median 1.07 mg/L

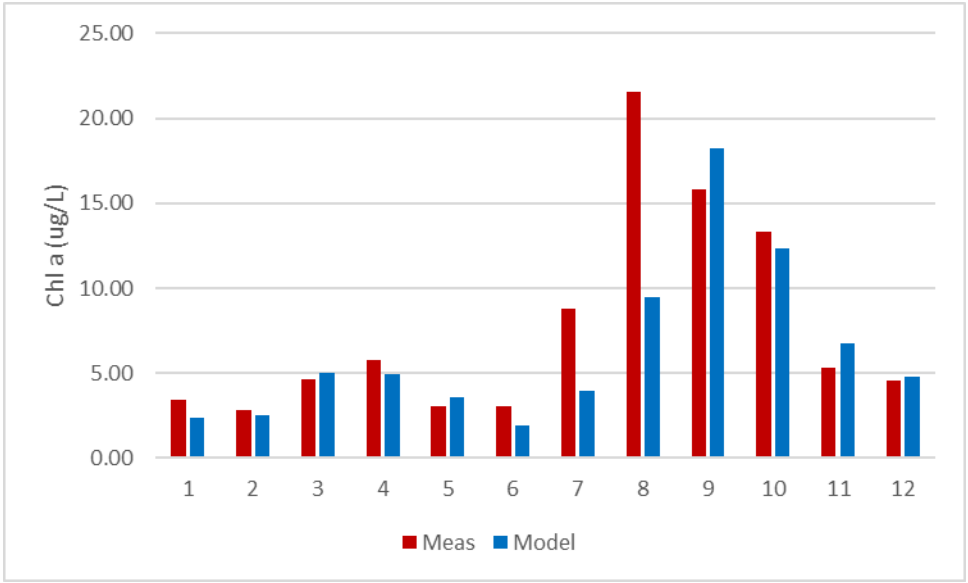


Blue line measured
Red line modeled

Monthly Surface Chlorophyll a Concentrations

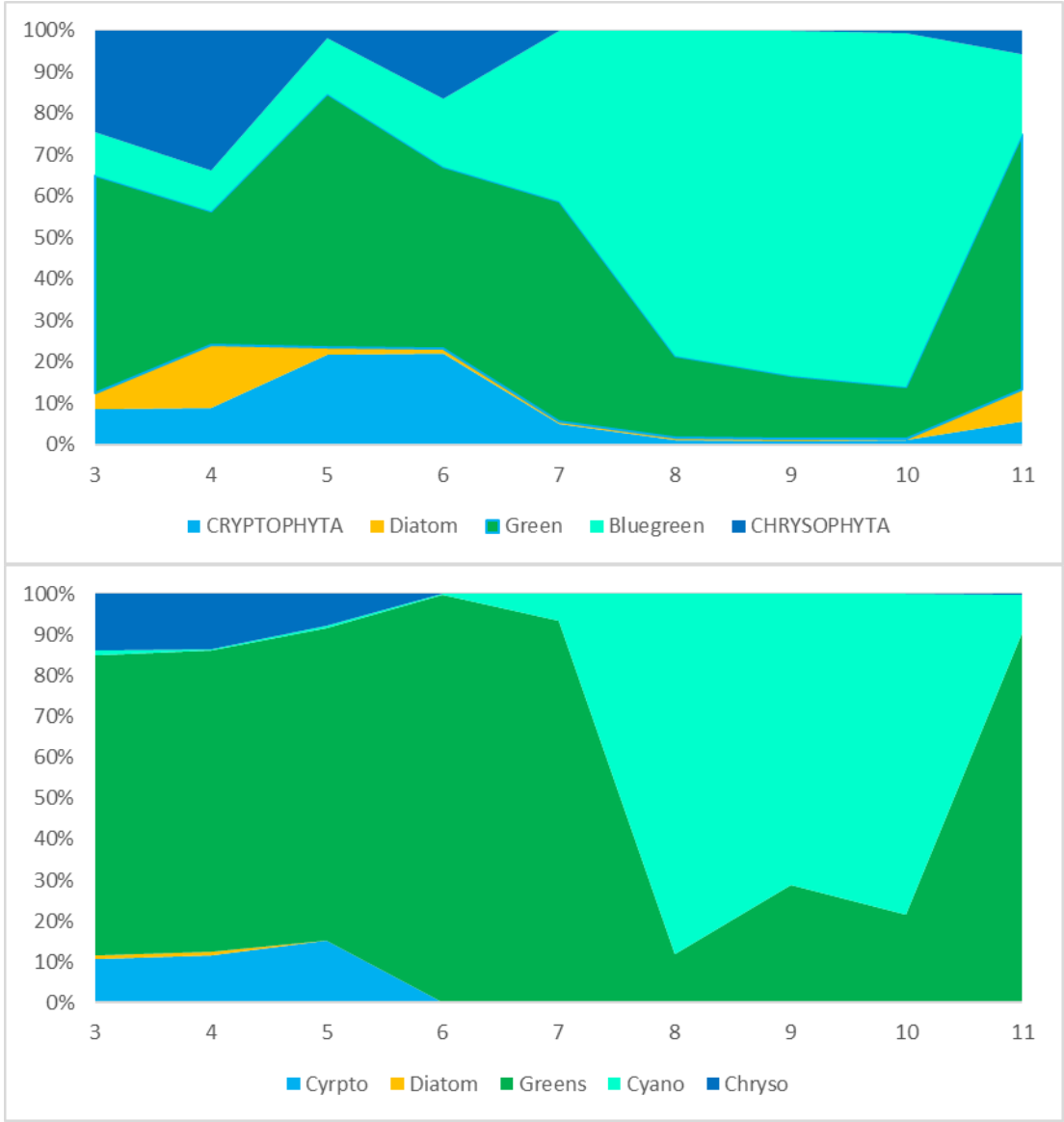
- **Overall error**
  - **Median error -33%**





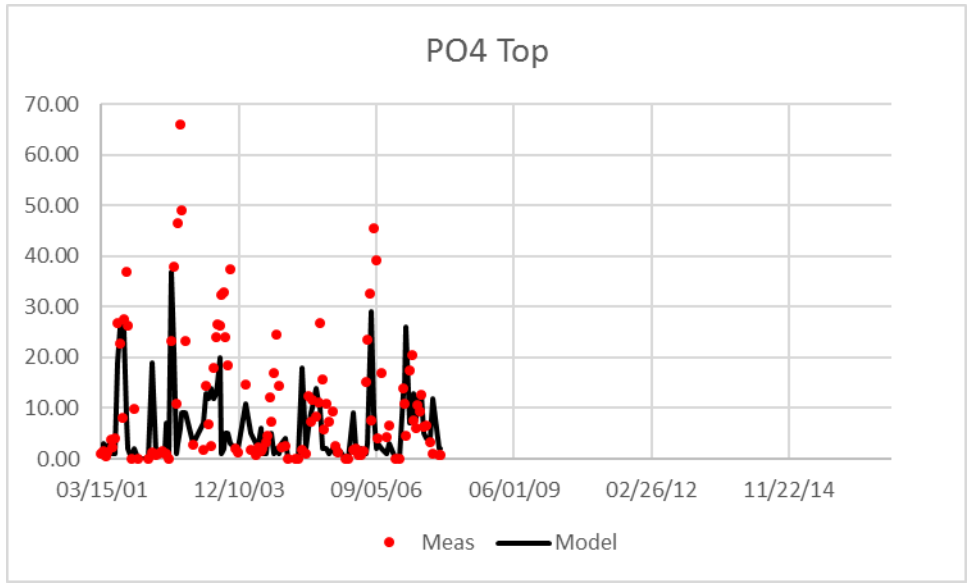
Monthly Algae Species

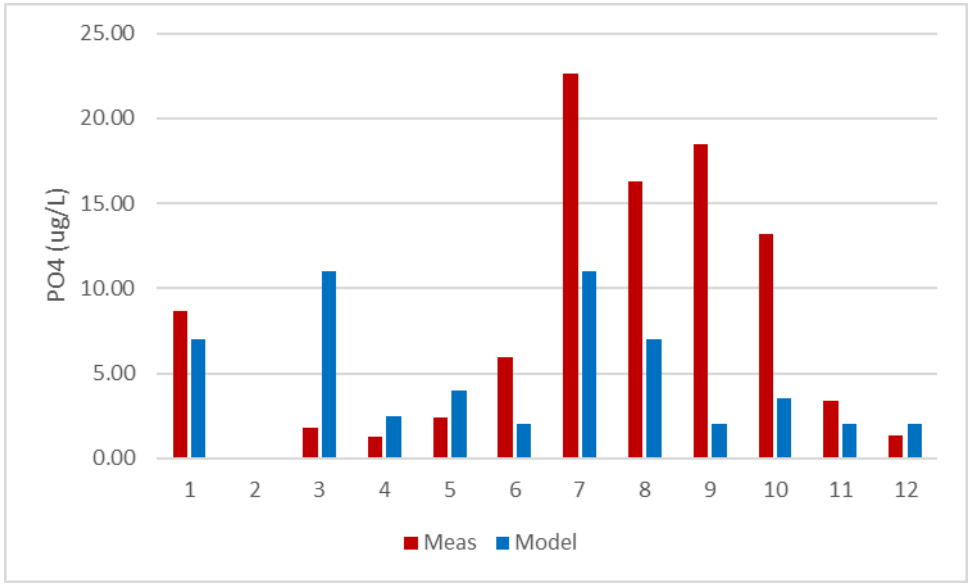
- **The model reproduced the observed algal patterns**



Monthly Surface Phosphate Concentrations

- **Overall error**
  - **Median error -20%**



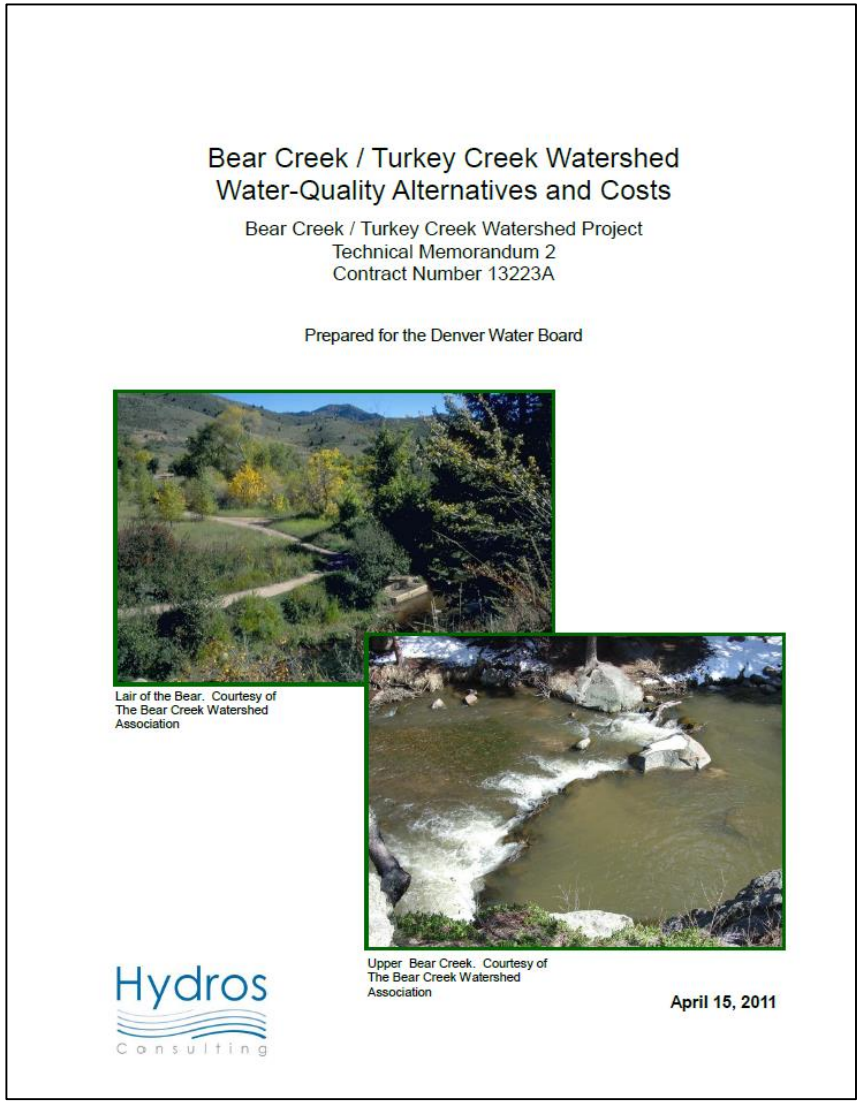


Summary

- **Both models perform well compared with the available data and model assumptions**
  - **Models based on provided and gathered information**
  - **Additional information could help**
- **Next steps**
  - **Model sensitivity simulations and finalize models**
  - **Develop scenarios to manage nutrients in the system**
  - **Additional meeting with BCWA to present final models and scenarios**
  - **Final report to CDPHE**

Scenarios

- **Use the models to quantify potential management implications**
  - **How are changes in the watershed management reflected in the reservoir?**
  - **Can changes in reservoir management improve water quality?**
  - **How would the two combined approaches impact water quality?**


Bear Creek / Turkey Creek Watershed
Water-Quality Alternatives and Costs

Bear Creek / Turkey Creek Watershed Project
Technical Memorandum 2
Contract Number 13223A

Prepared for the Denver Water Board

Lair of the Bear. Courtesy of The Bear Creek Watershed Association

Upper Bear Creek. Courtesy of The Bear Creek Watershed Association

Hydros Consulting

April 15, 2011

Watershed Management Scenarios

- Adapted from:

- ISDS modifications
  - Replace Existing ISDSs with a More Efficient Design
  - ISDS to Sewer Conversion / Connect to an Existing WWTP
  - ISDS to Sewer Conversion / Connect to a New WWTP
  - Providing Public Education on Proper ISDS Maintenance

- Rely on Evolving Nutrient Regulations
- Divert Bear Creek Water During Times of Suitable Water Quality
- Pretreatment via Constructed Wetlands
- Pretreatment via a Mechanical Pre-Treatment Plant

Reservoir Management Scenarios

- Change the operation schedule of the current aeration system
- Change the withdrawal to a bottom withdrawal
- Add a binding agent to reduce the PO4 mobility from the sediment
- Speece cone deployment

BUILDING A WORLD OF DIFFERENCE

8 April 2019

BUILDING A WORLD OF DIFFERENCE®

BLACK & VEATCH