MODELING SHOWCASE

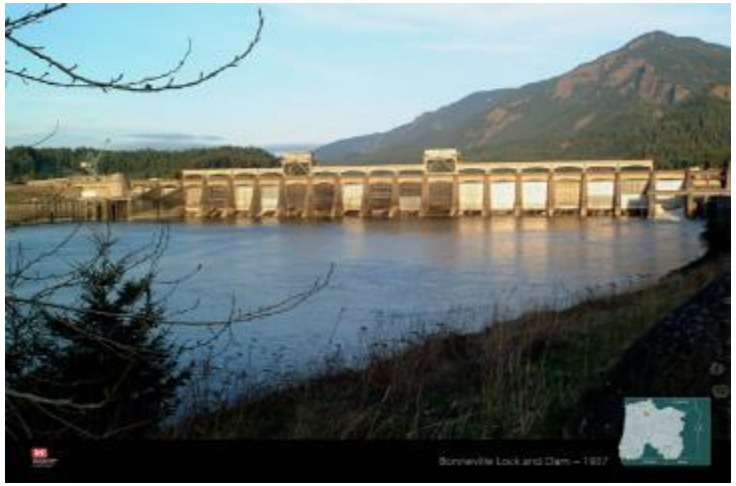
2020 NATIONAL
CWA 303(d) TRAINING WORKSHOP

Thursday May 28, 2020

Session #6

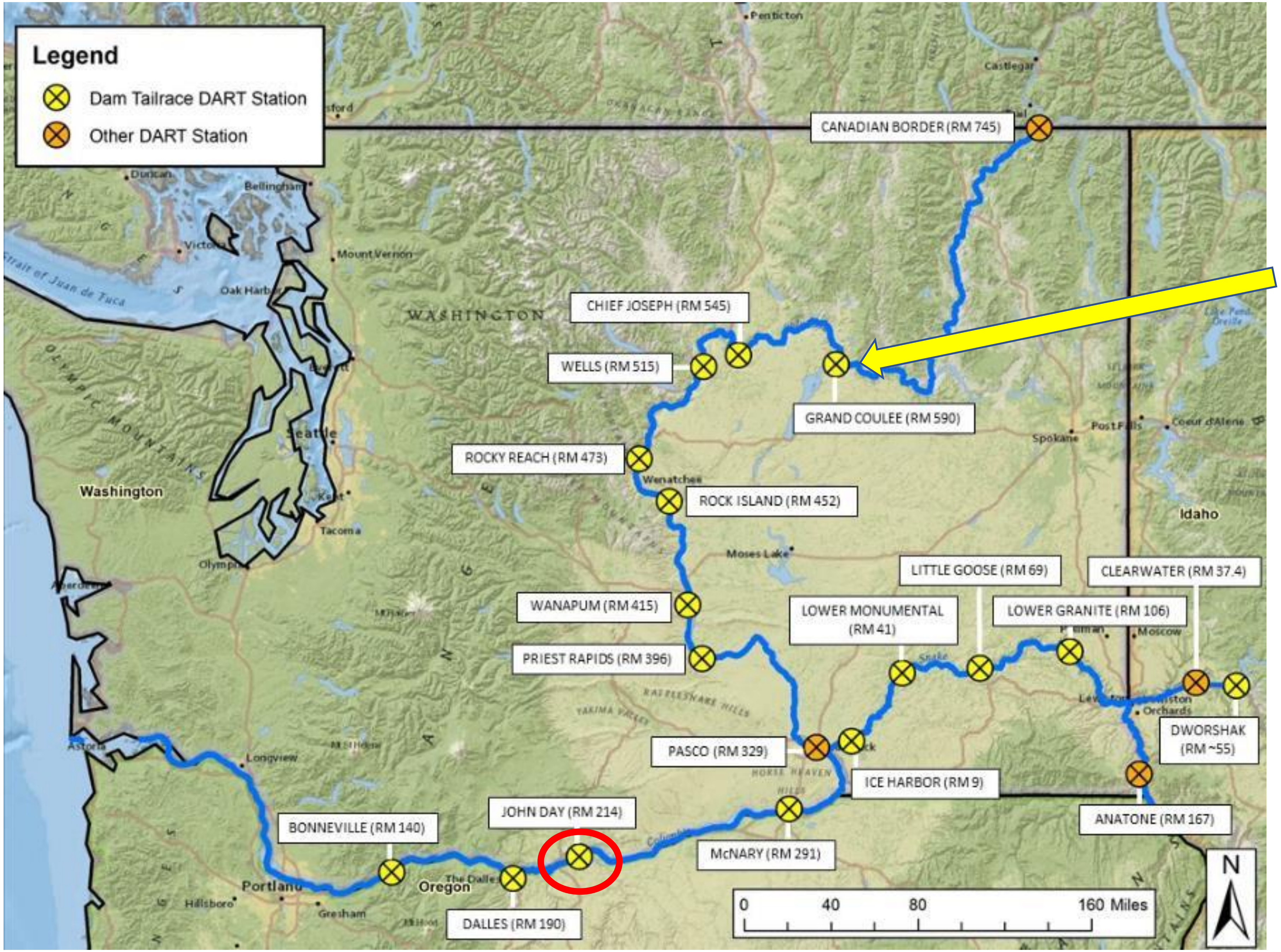
RBM10

Temperature Model of the Columbia and Snake Rivers

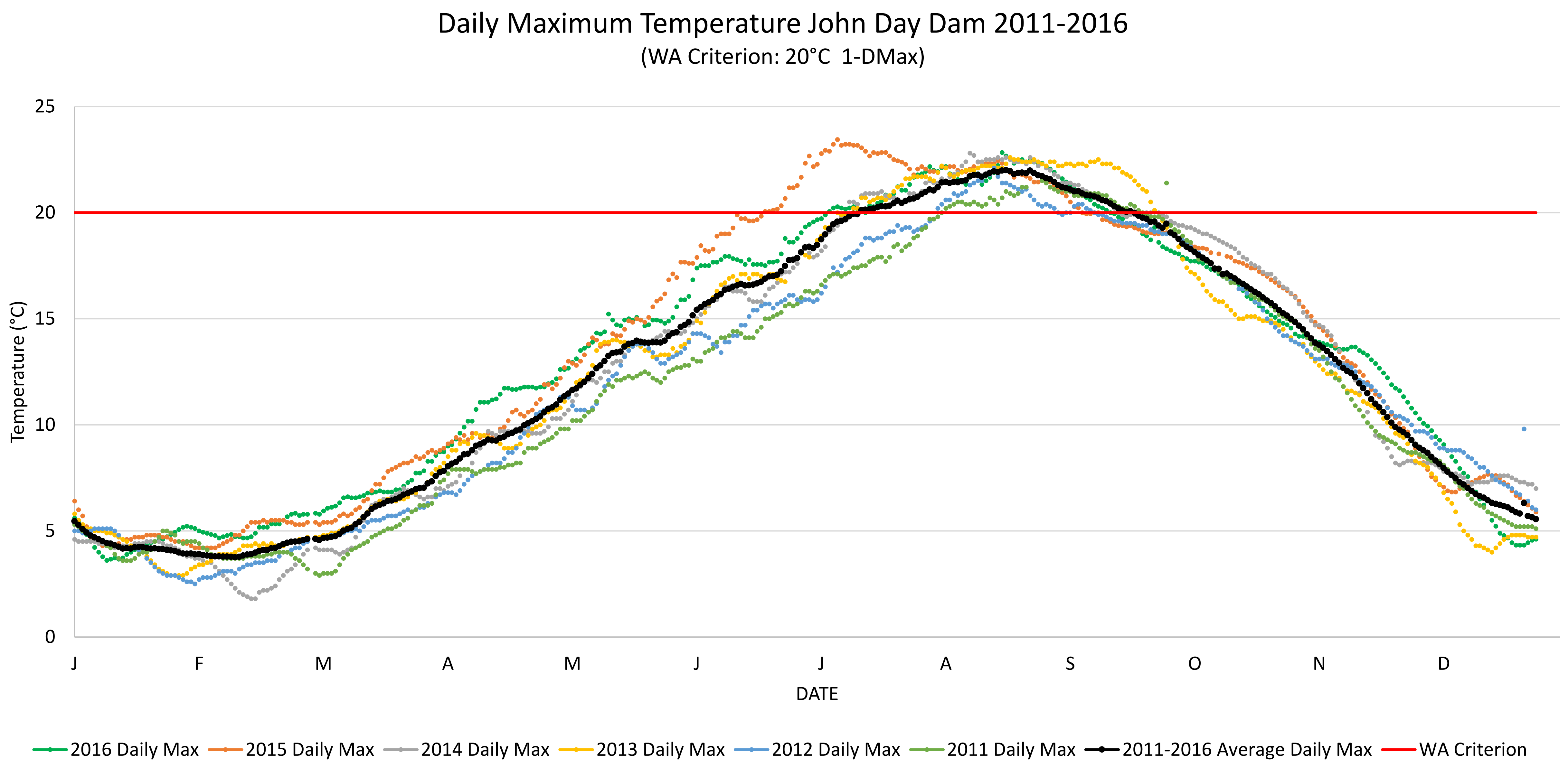


National 303d Meeting
Model Showcase

Ben Cope, EPA Region 10
Seattle, Washington
May 28, 2020



Fun Fact: Grand Coulee Dam contains enough concrete to build a highway from Seattle to Miami.

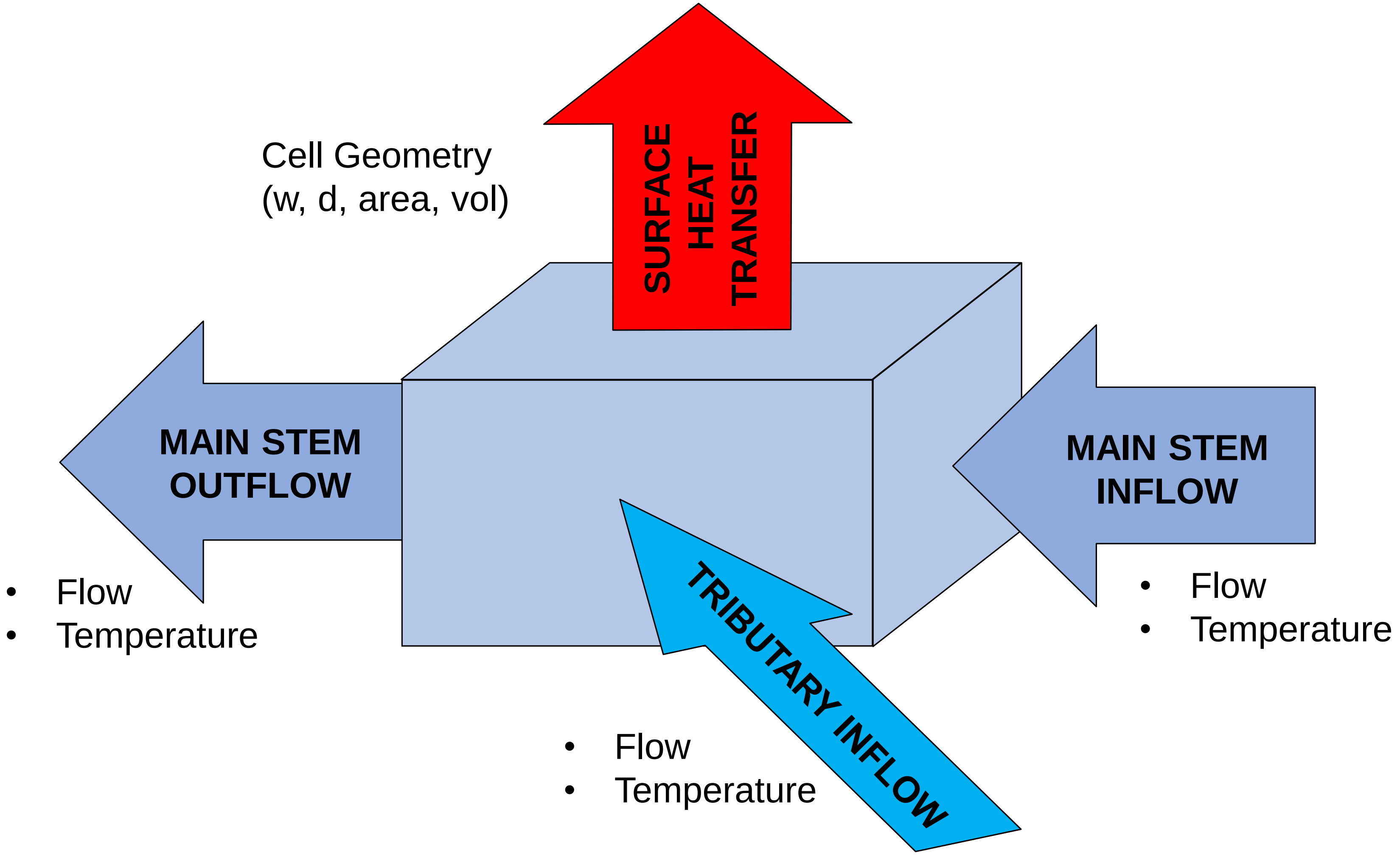


Daily Maximum Temperature John Day Dam 2011-2016
(WA Criterion: 20°C 1-DMax)
25
20
15
10
5
0
Temperature (°C)
J
F
M
A
M
J
J
A
S
O
N
D
DATE
2016 Daily Max
2015 Daily Max
2014 Daily Max
2013 Daily Max
2012 Daily Max
2011 Daily Max
2011-2016 Average Daily Max
WA Criterion

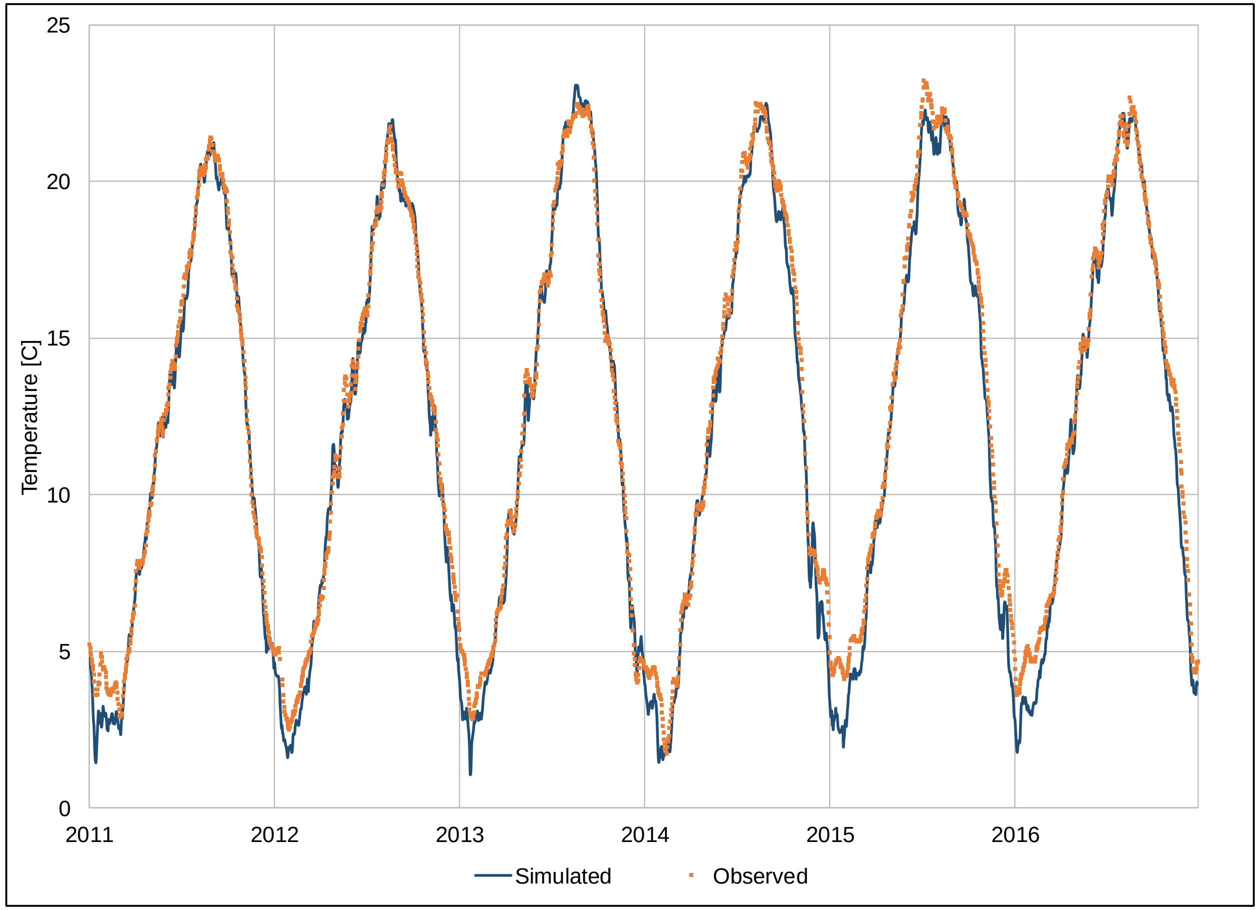
RBM10 Temperature Model

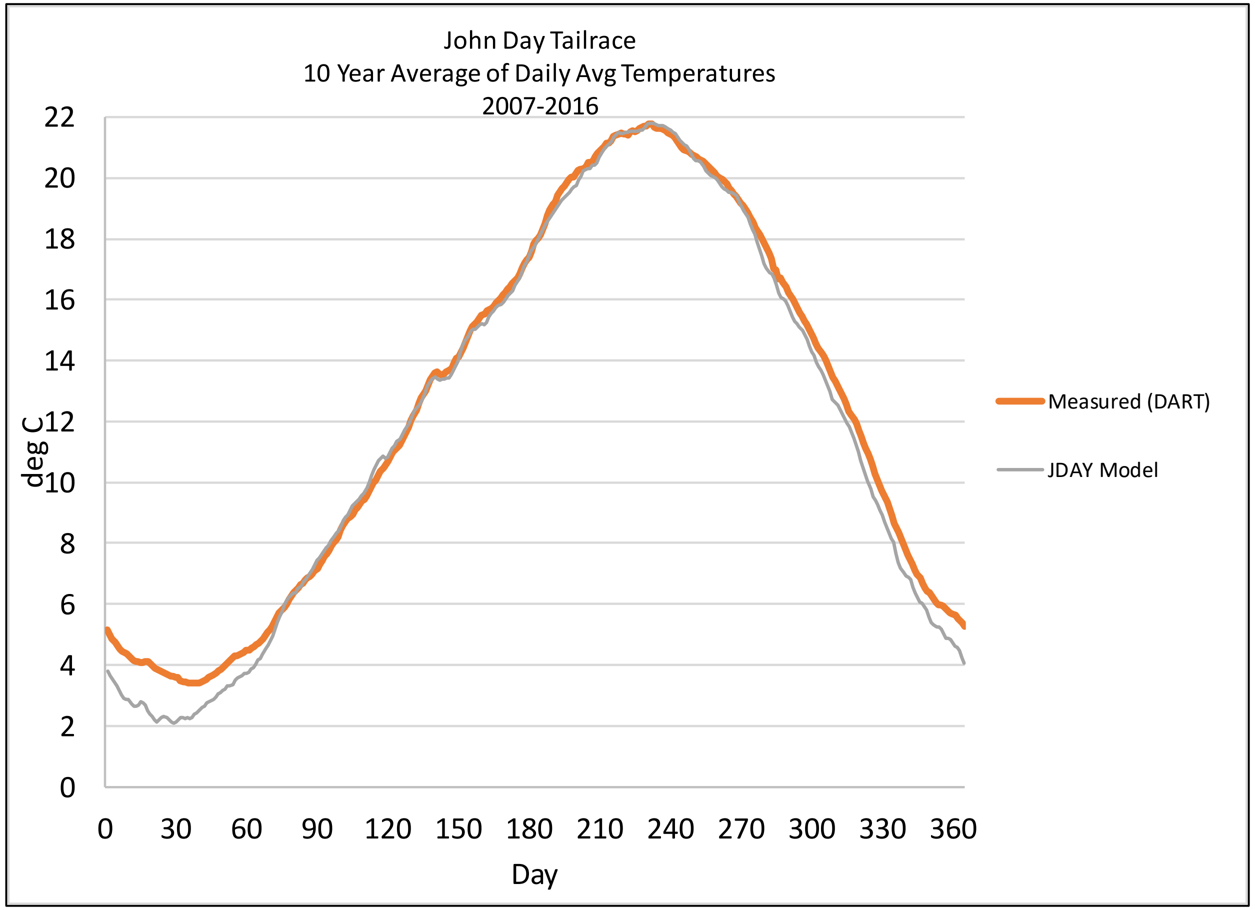
- 1-Dimensional
  - Cross-sectional average temperature simulated
- Daily time step (daily average temperature)
- Simulation years - 47 year simulation (1970-2016)

One-Dimensional Energy Budget Model



Model Is Checked Against All Available Data

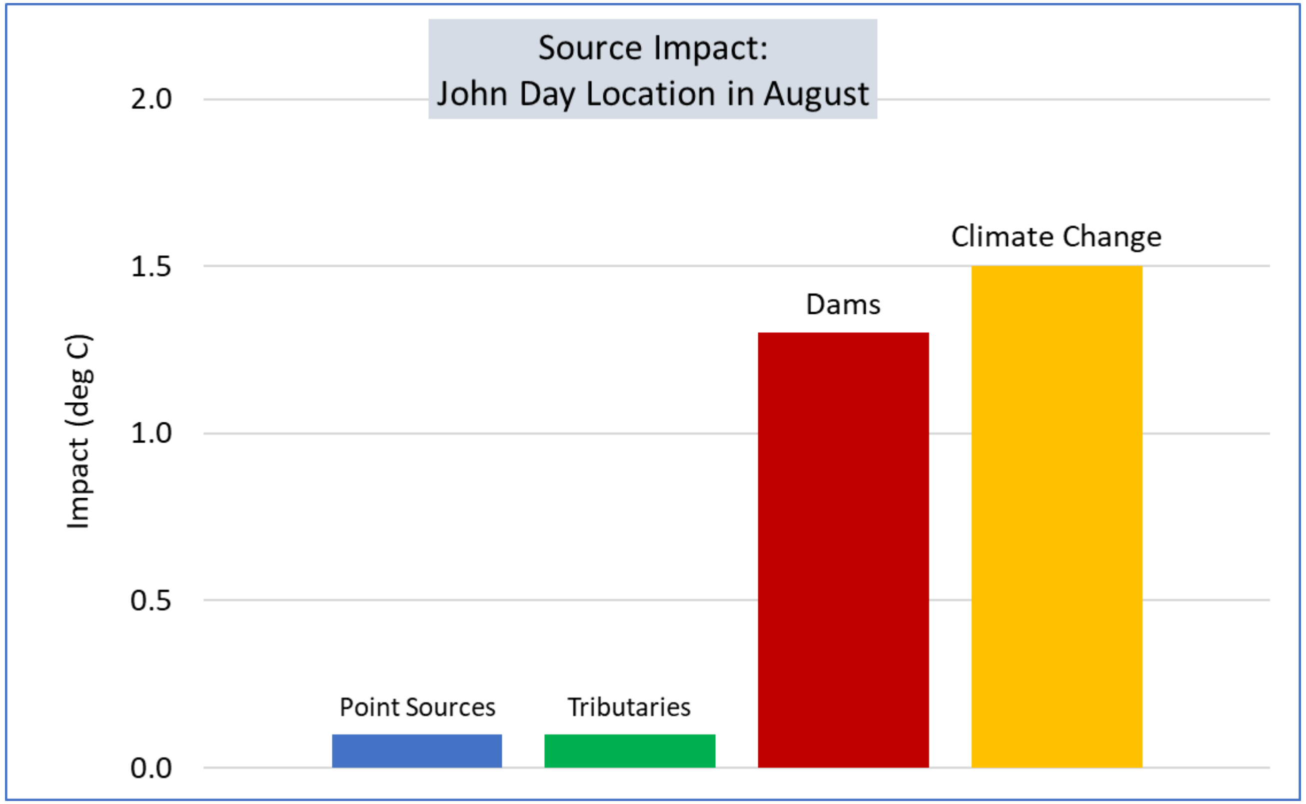


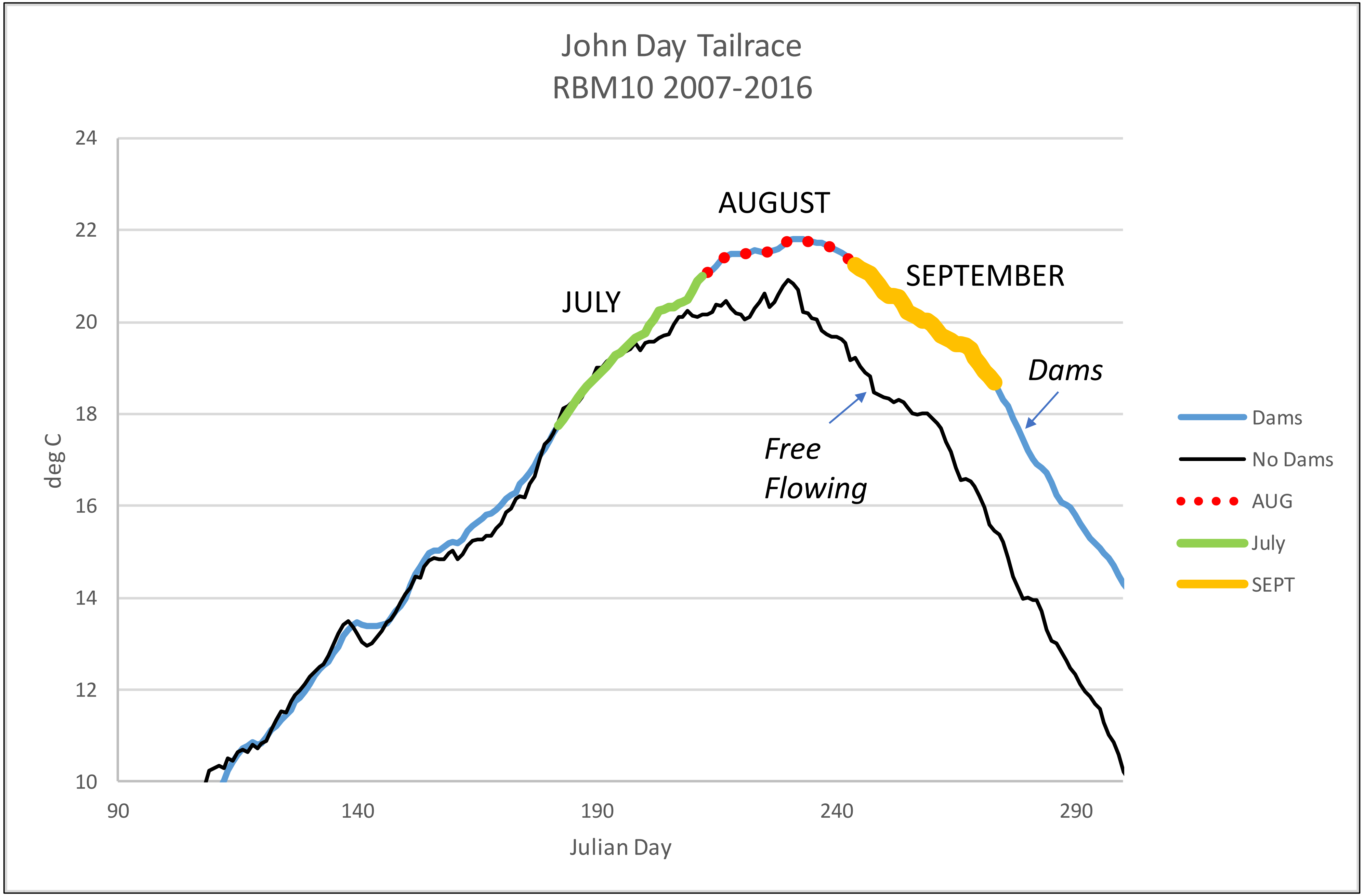


Source Assessment Scenarios

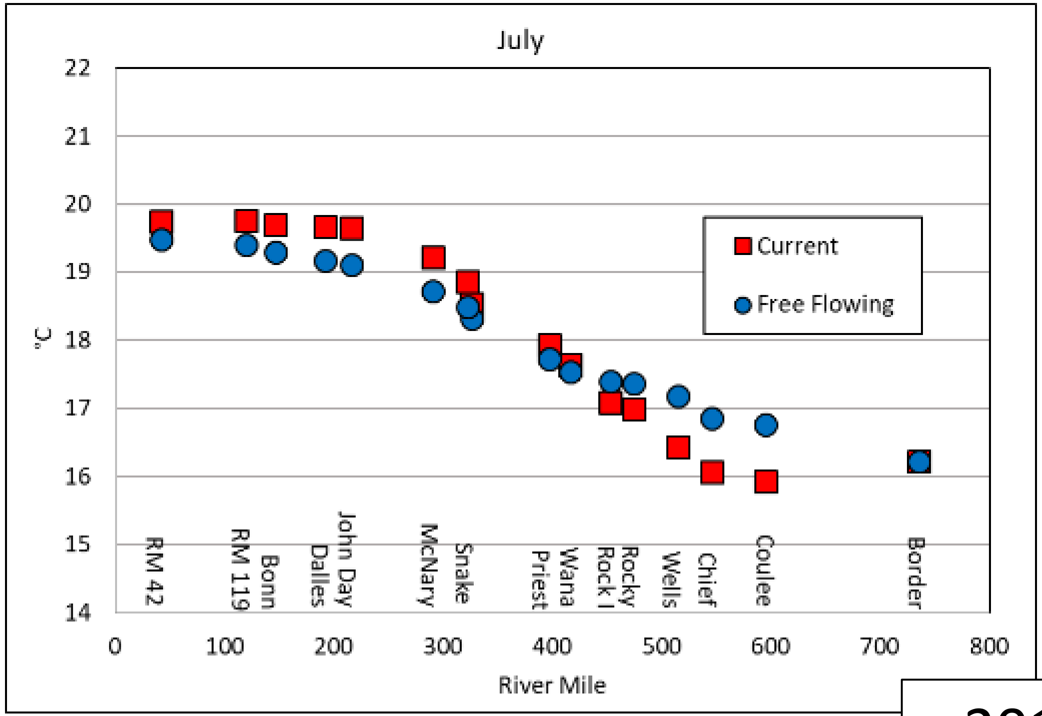
Source Assessment Scenarios

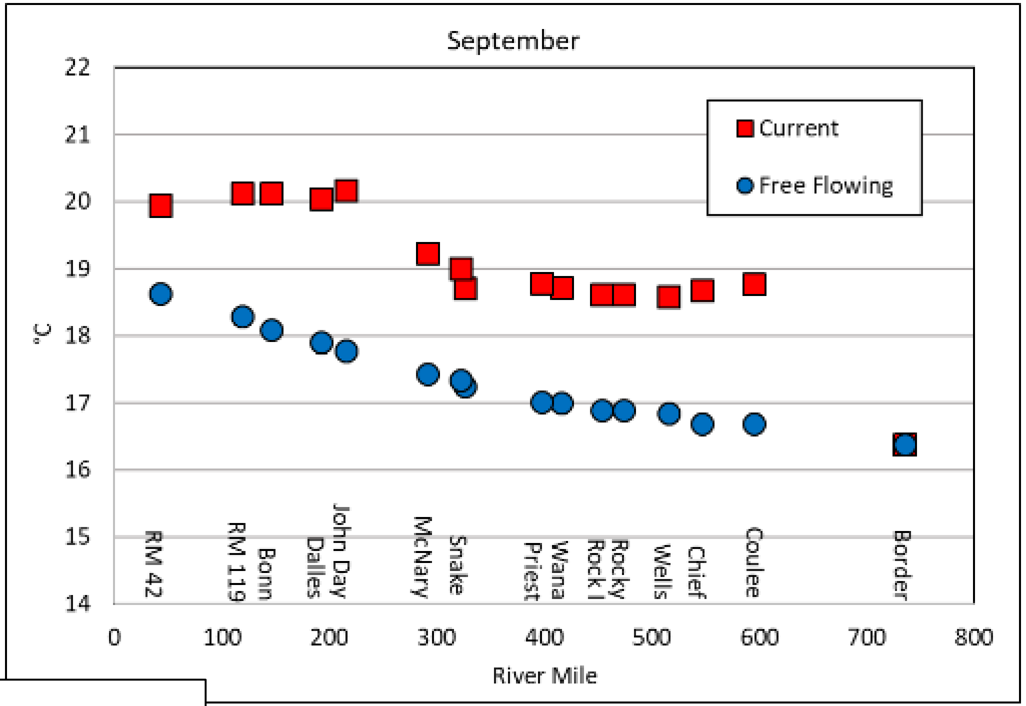
- Point source impact
  - with and without
- Tributary impact
  - altering trib temperature
- Dams
  - with and without
- Climate change
  - trend in long term simulation



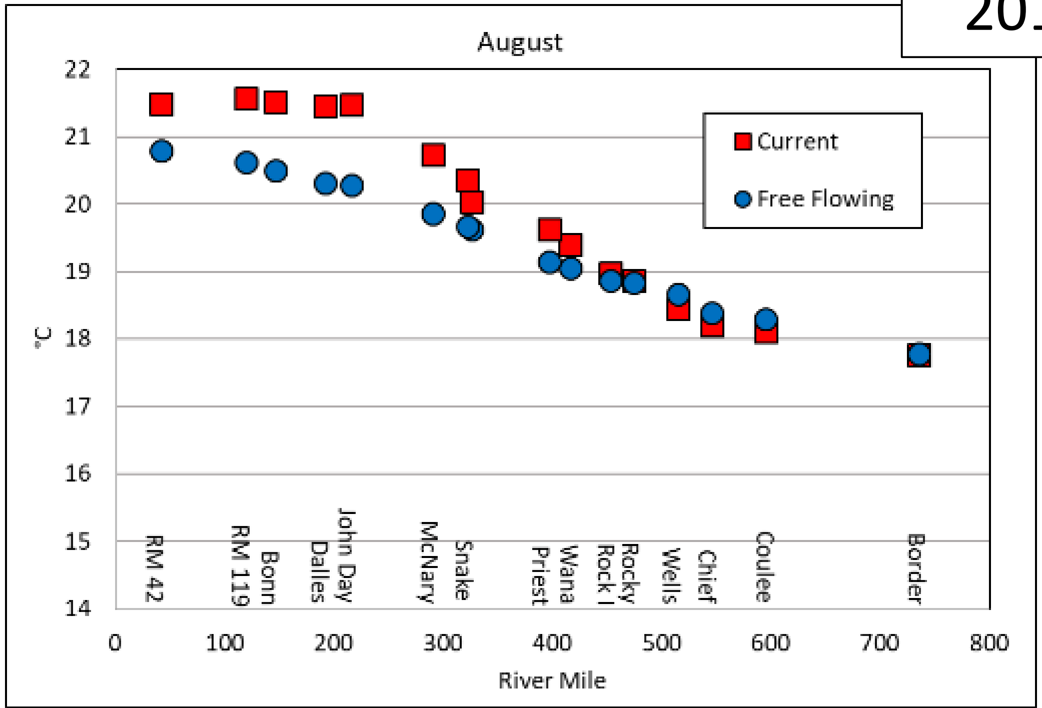


John Day Tailrace
RBM10 2007-2016
24
22
20
18
16
14
12
10
deg C
90
140
190
240
290
Julian Day
AUGUST
JULY
SEPTEMBER
Dams
Free
Flowing
Dams
No Dams
AUG
July
SEPT


July
°C
River Mile
Current
Free Flowing
RM 42
RM 119
Bonn
Dalles
John Day
McNary
Snake
Priest
Wana
Rock I
Rocky
Wells
Chief
Coulee
Border


September
°C
River Mile
Current
Free Flowing
RM 42
RM 119
Bonn
Dalles
John Day
McNary
Snake
Priest
Wana
Rock I
Rocky
Wells
Chief
Coulee
Border

2011-2016


August
°C
River Mile
Current
Free Flowing
RM 42
RM 119
Bonn
Dalles
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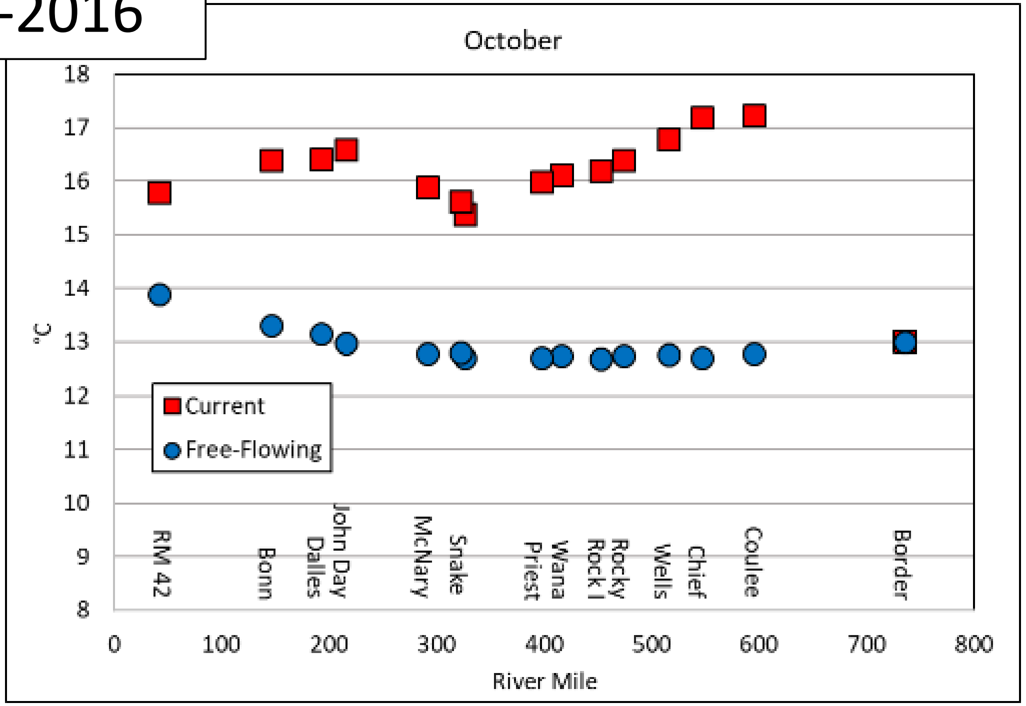
October
°C
River Mile
Current
Free-Flowing
RM 42
Bonn
Dalles
John Day
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Snake
Priest
Wana
Rock I
Rocky
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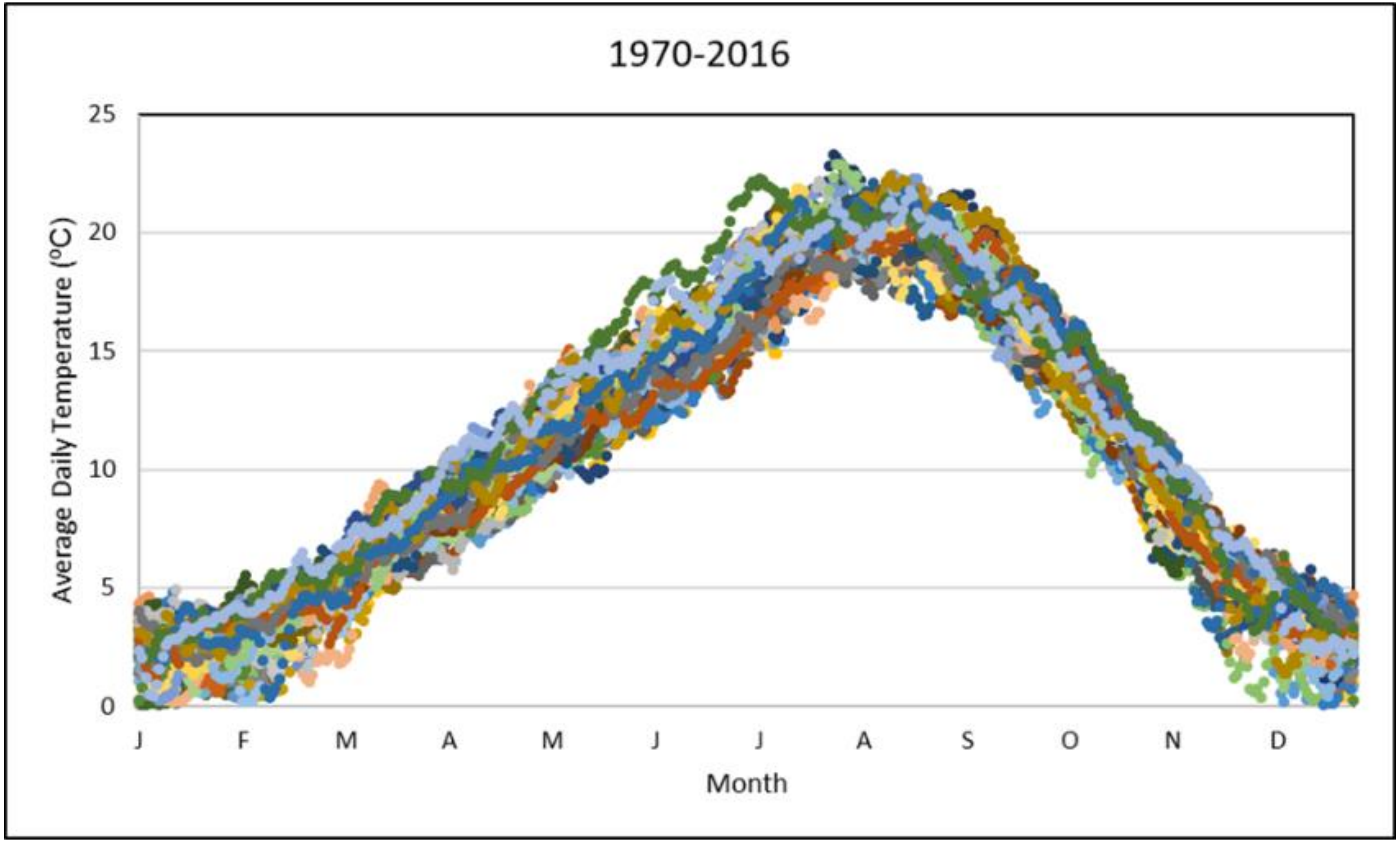
Chief
Coulee
Border

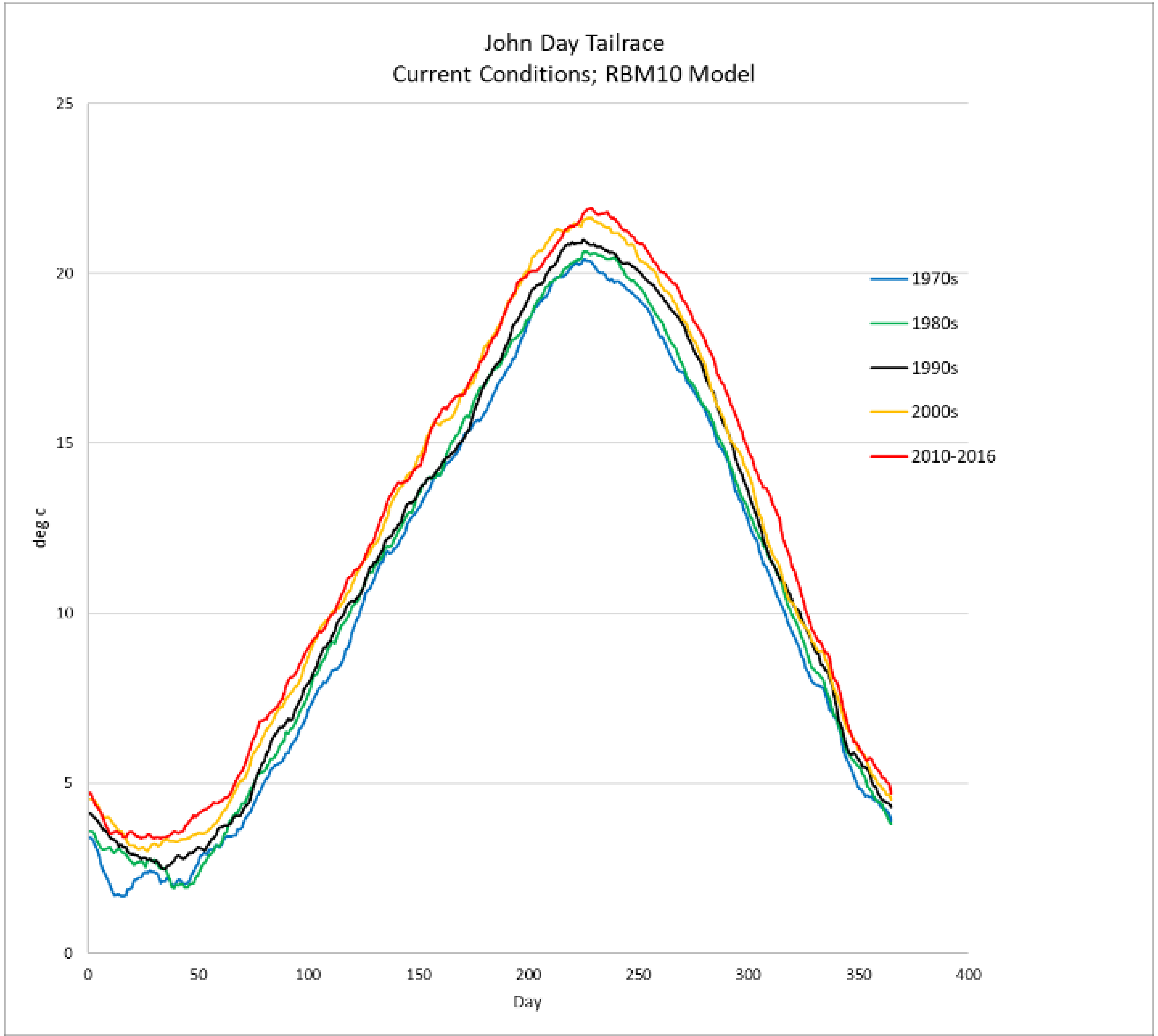
47 Year Simulation

RBM10
Free-Flowing; Bonneville Dam location



Average daily temperature by decade

Trend is 0.4°C increase per decade



The End

Acknowledgements

Rene Camacho, Tetra Tech

Erin Lincoln, Tetra Tech

Laurie Mann, TMDL Project Lead, EPA

Contact

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Connecticut Department of Energy and Environmental Protection

Connecticut Department of ENERGY & ENVIRONMENTAL PROTECTION

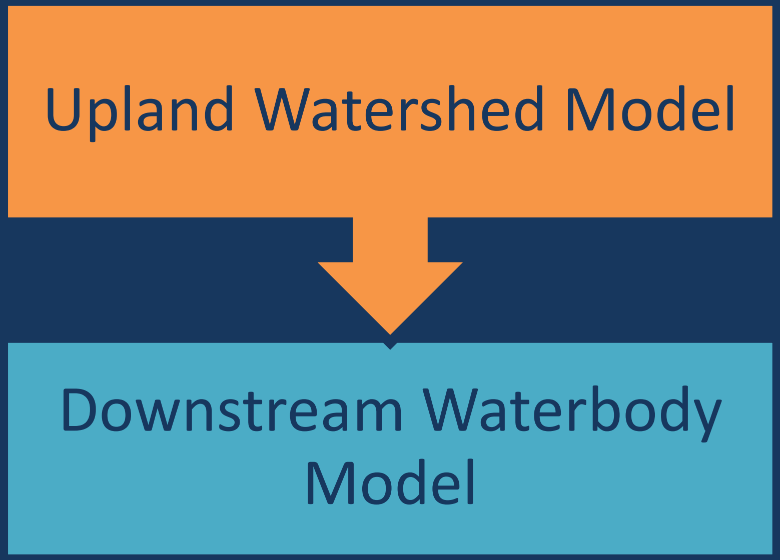
Modeling Projects in CT

May 13, 2020
CTDEEP Presentation
Teleconference with Local Stakeholders

Connecticut Department of Energy and Environmental Protection

Overview: Watershed Based Approach to Nutrients

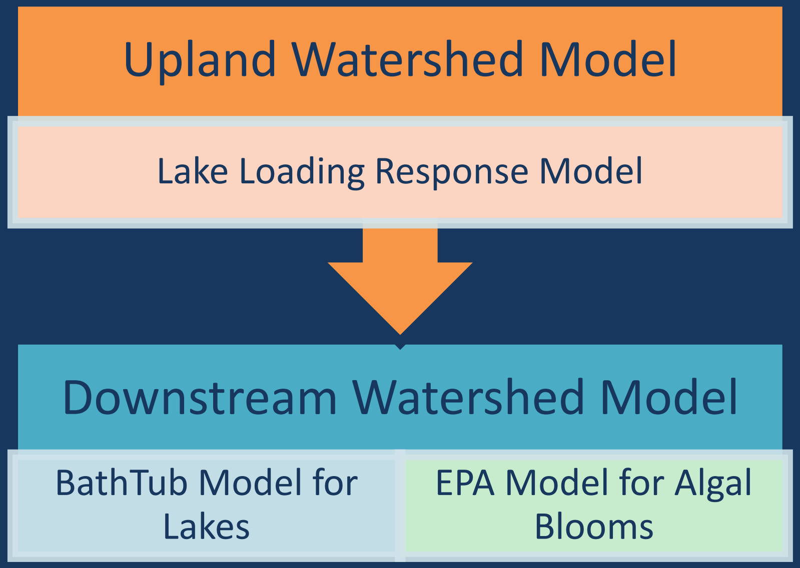
- Objective:
  - Develop a watershed scale approach
  - Evaluating nutrient related environmental conditions and sources
  - Nitrogen & Phosphorus
  - Point and Nonpoint Sources
  - Nutrient effects in
    - freshwater watersheds & associated embayments
    - Lakes
  - Restoration and Protection



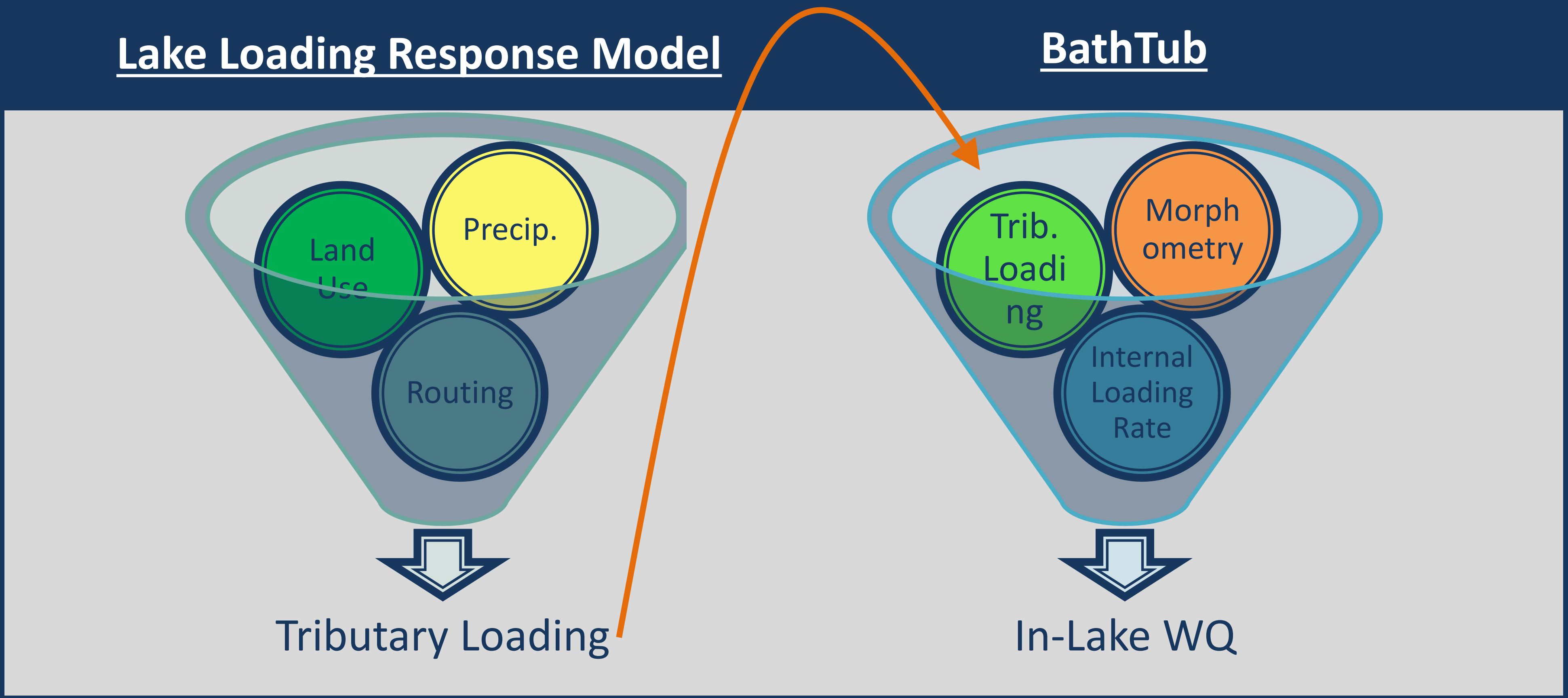
Nutrients Affecting CT Lakes

Overview: Watershed Based Approach to Nutrients

- Lakes and Associated Watersheds
- Modeling Objectives
  - Identify nutrient conditions associated with lake trophic status goals
  - Evaluate current and future frequency for harmful algal blooms
- Develop modeling capacity at CTDEEP for project models
- Coordinate with EPA HQ on application of EPA lake nutrient model in CT regarding nutrients and Harmful Algal Blooms



Modeling Overview



Nutrients in Coastal Embayments and Contributing Watershed

Overview: Watershed Based Approach to Nutrients

- Estuaries and Associated Freshwater Watersheds
- Build on existing WQ restoration activities
  - Bacteria TMDLs
  - WQ Based Permits
  - EPA Nitrogen Reduction Strategy
  - CT Second Generation Nitrogen Strat
  - Habitat improvements

Upland Watershed Model
- Hydrologic Simulation Program Fortran (HSPF)

Downstream Watershed Model
- Tiered Approach to Model Selection

Open Water Long Island Sound Model
- Update Under Development

SNEP Project Components

- HSPF Watershed Model
  - Hydrologic Simulation Program - Fortran
  - Comprehensive
  - Hydrology & WQ
  - Addresses soil, groundwater, surface water processes
  - Storm Events
  - Point & Non-point Sources
  - Used previously in CT, RI & other states
  - Developed for Fresh water portion of watershed
  - Supported by EPA and USGS

Objective: Create a tool to evaluate and predict and evaluate watershed responses based on current and future conditions

Pawcatuck Project Communication & Outreach

- Project web page
  - Updates
  - Reports
  - Data
- Interactive Story Map
- Meetings with Partners and Stakeholders to be planned

Pawcatuck Project Website

Click on the picture above to go to the Pawcatuck Project Story Map

Extending to Other CT Embayments

Support from LISS to develop HSPF Model for rest of CT

- Pawcatuck Project is demonstration project for this concept
- Working with USGS to develop associated monitoring program
- Contracted for statewide HSPF mod update
- Considering a tiered approach to embayment modeling
- Focus on initial priority embayments
- Coordination with future updated LIS model

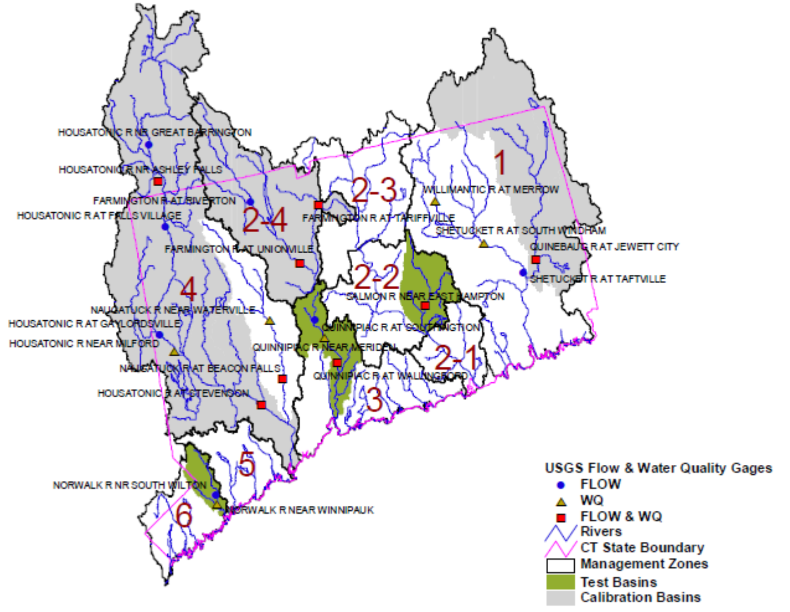


Figure 2.3 USGS Gages used in Connecticut Watershed Model

State Wide Beach Bacteria TMDL

Nine Eagles Lake

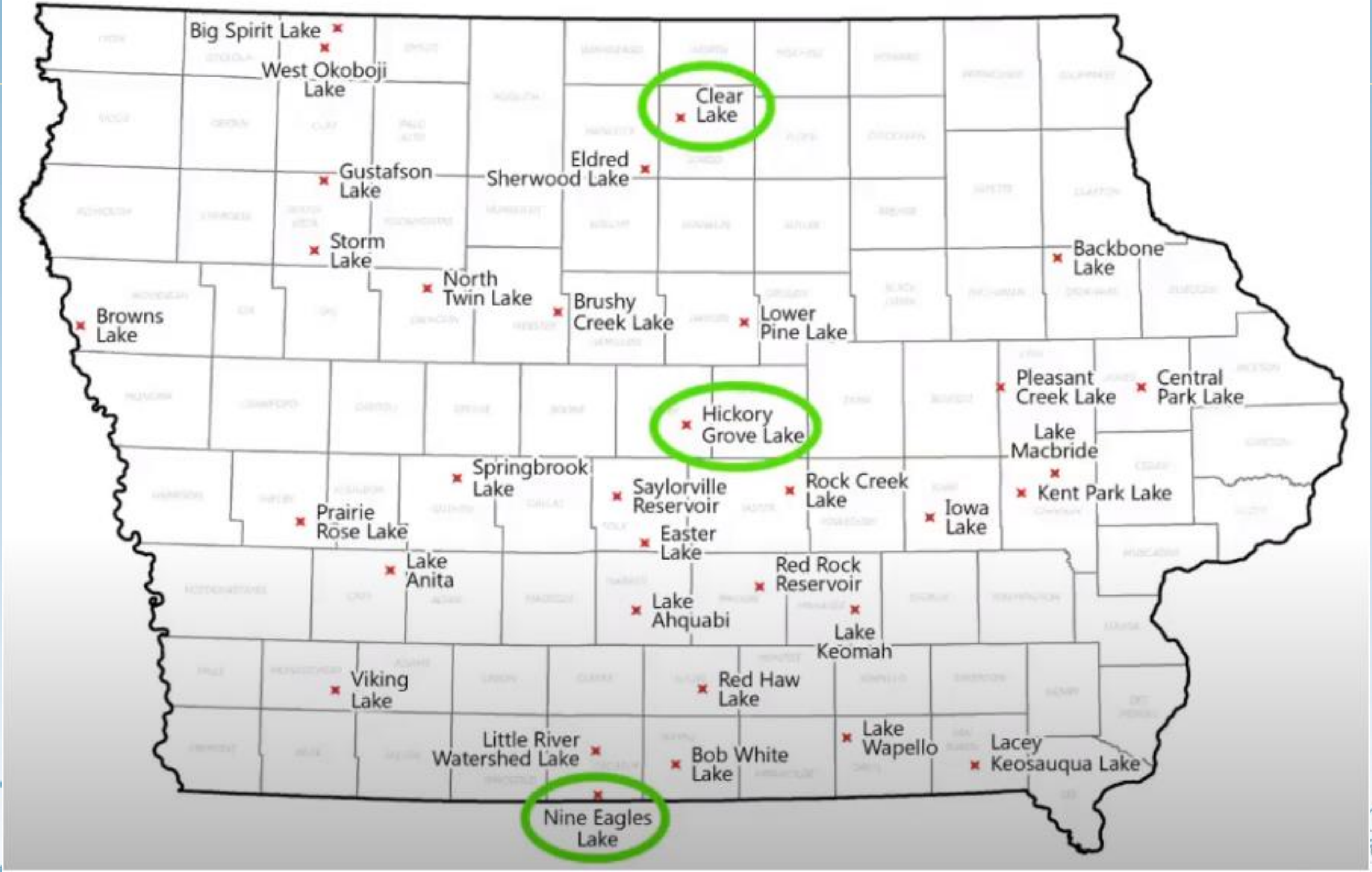
Moving Towards a Better Understanding of Bacterial Impairments at Public Beaches in Iowa

Jason Palmer, Jim Hallmark & Jeff Berckes Iowa Department of Natural Resources

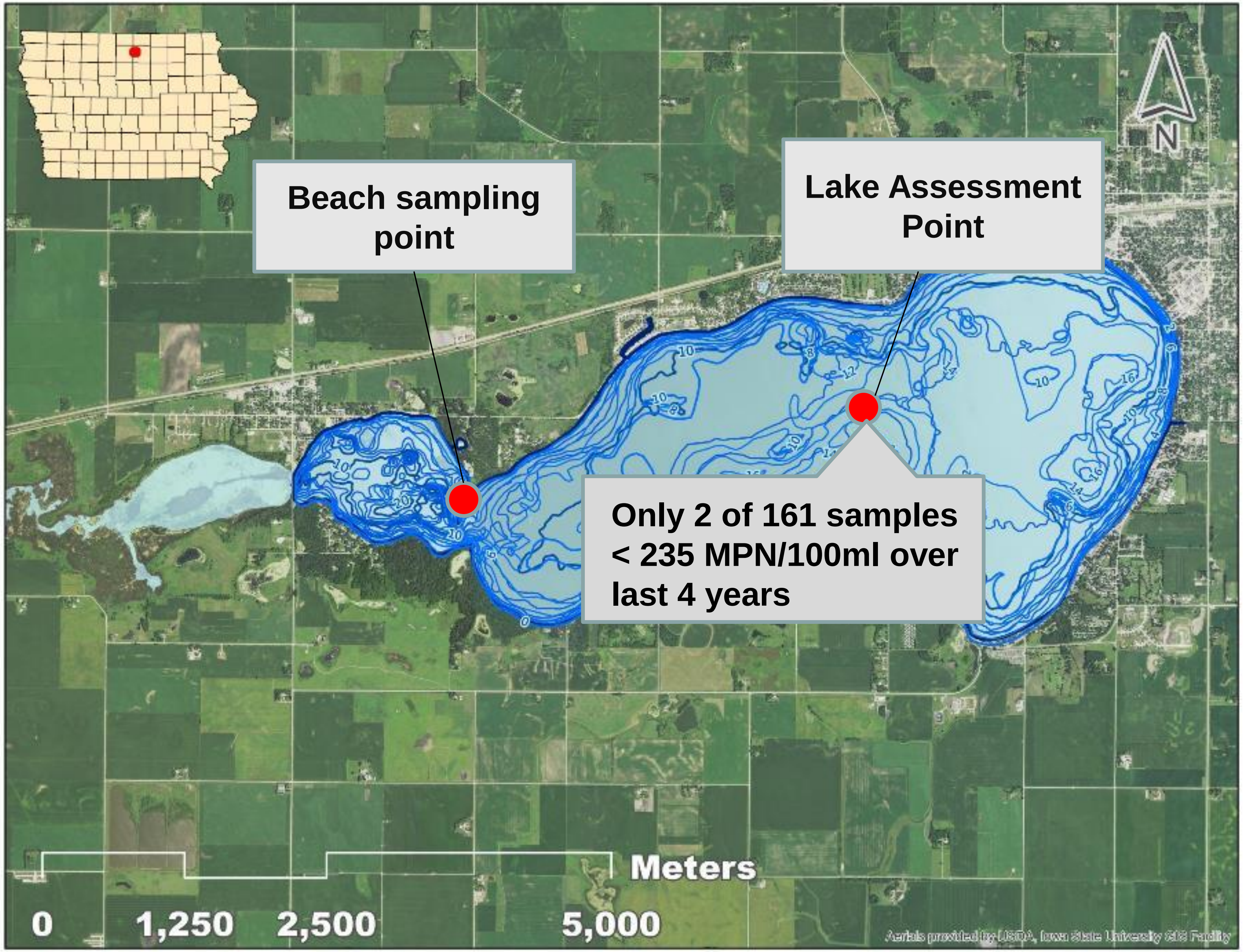
clean water starts with you.

IOWA DNR WATERSHED IMPROVEMENT

Beach Bacteria Impairments (Category 5a)

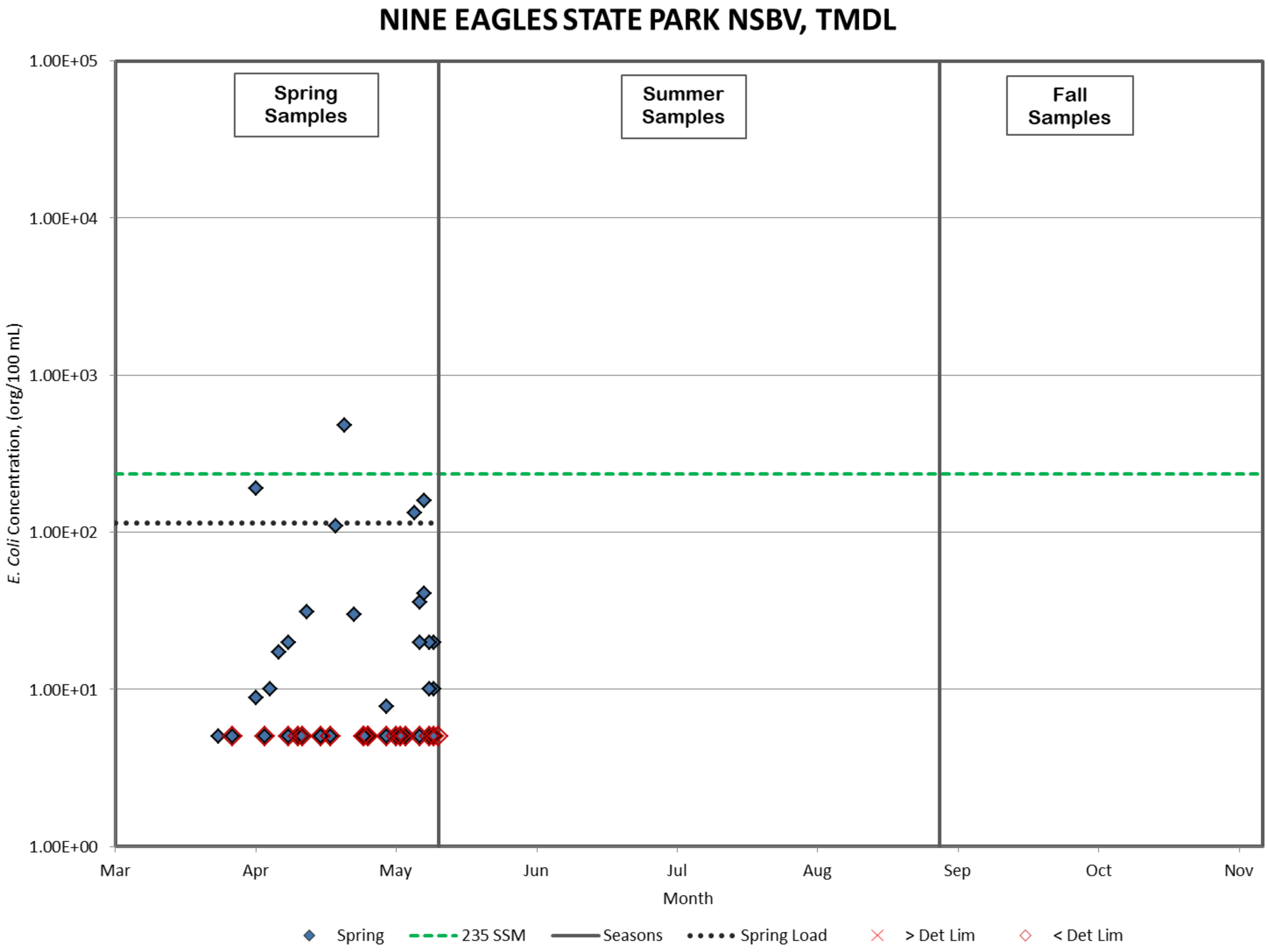


IOWA DNR WATERSHED IMPROVEMENT



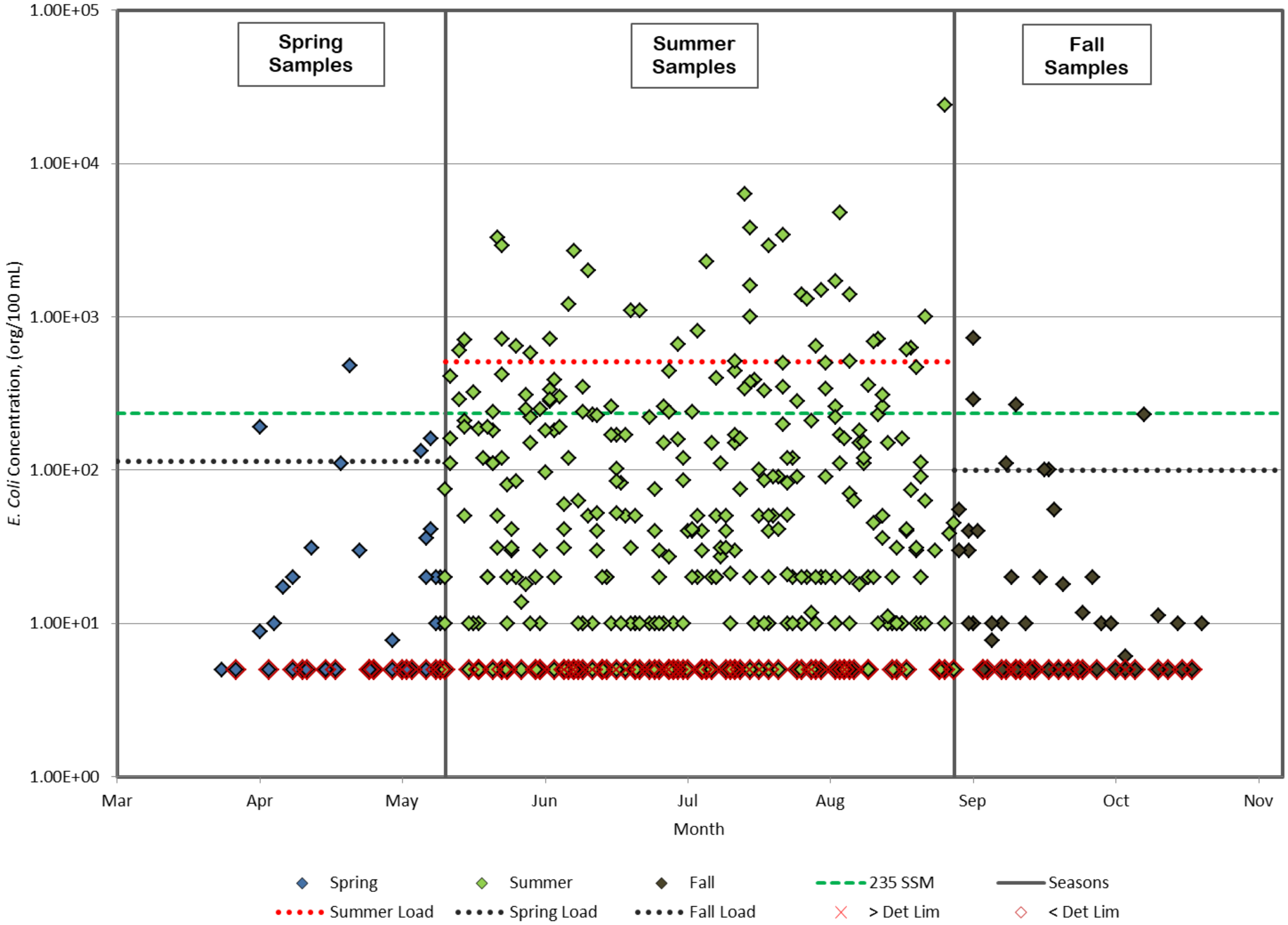
Beach sampling point
Lake Assessment Point
Only 2 of 161 samples < 235 MPN/100ml over last 4 years
N
Meters
0
1,250
2,500
5,000


NINE EAGLES
Location within watershed.
Swimming Area
Beach Shed Area



NINE EAGLES STATE PARK NSBV, TMDL
Spring Samples
Summer Samples
Fall Samples
1.00E+05
1.00E+04
1.00E+03
1.00E+02
1.00E+01
1.00E+00
E. Coli Concentration, (org/100 mL)
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Month
Spring
235 SSM
Seasons
Spring Load
> Det Lim
< Det Lim

NINE EAGLES STATE PARK NSBV, TMDL



Nine Eagles Lake

Load Summary	Seasonal Loads (org/100 mL)		
	Spring	Summer	Fall
Observed Load	114.7	510.0	100.0
Allowable Load	235	235	235
Departure	N/A	275.0	N/A
(% Reduction)	0	(53.9)	0
TMDL	---	235.0	---
WLA	---	0.0	---
LA	---	211.5	---
MOS	---	23.5	---

Load Summary	Seasonal Loads (org/day)		
	Spring	Summer	Fall
Observed Load	1.26E+06	5.62E+06	1.10E+06
Allowable Load	2.59E+06	2.59E+06	2.59E+06
Departure	N/A	3.03E+06	N/A
(% Reduction)	0	(53.9)	0
TMDL	---	2.59E+06	---
WLA	---	0.00E+00	---
LA	---	2.33E+06	---
MOS	---	2.59E+05	---

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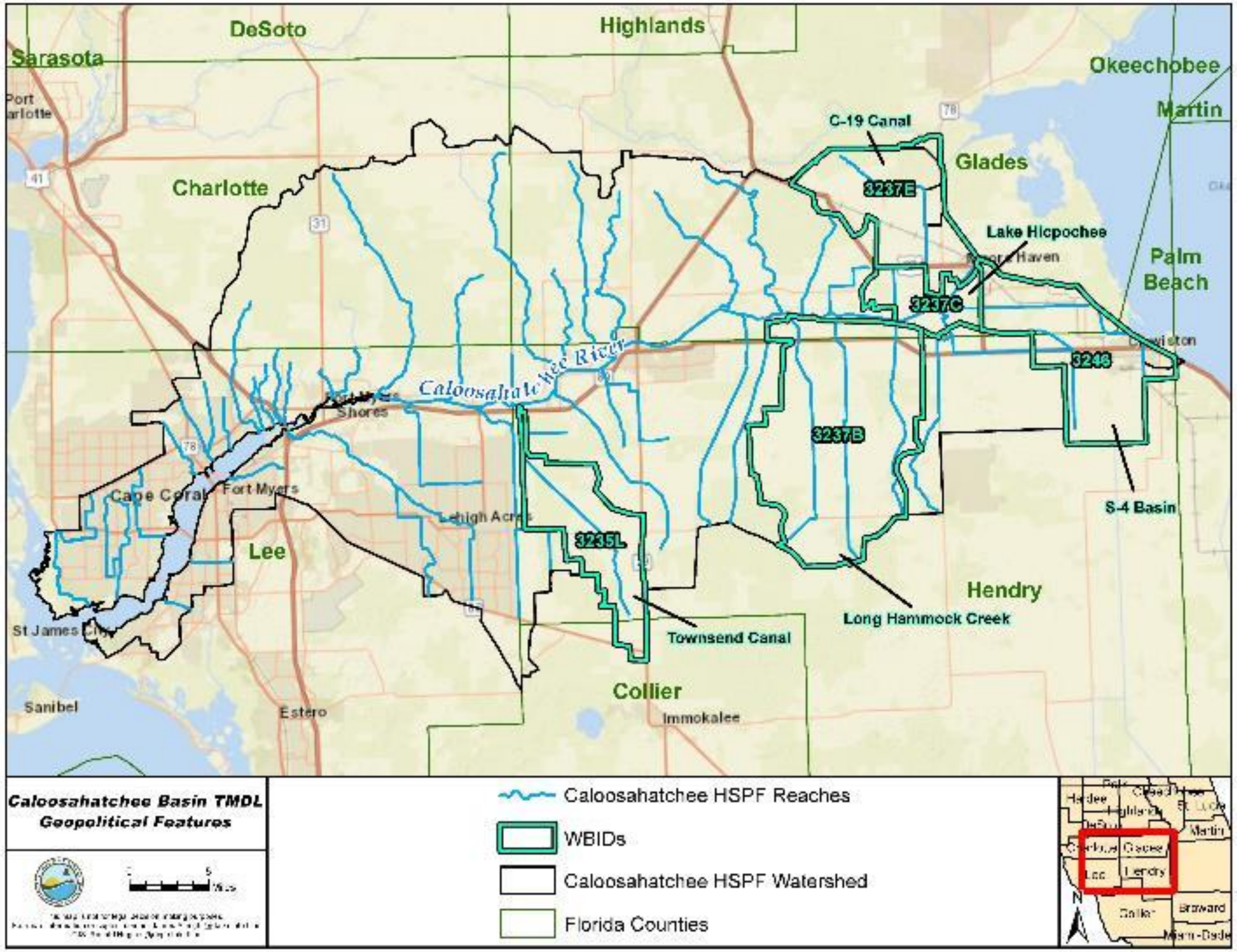
Division of Environmental Assessment and Restoration
Water Quality Evaluation and TMDL Program

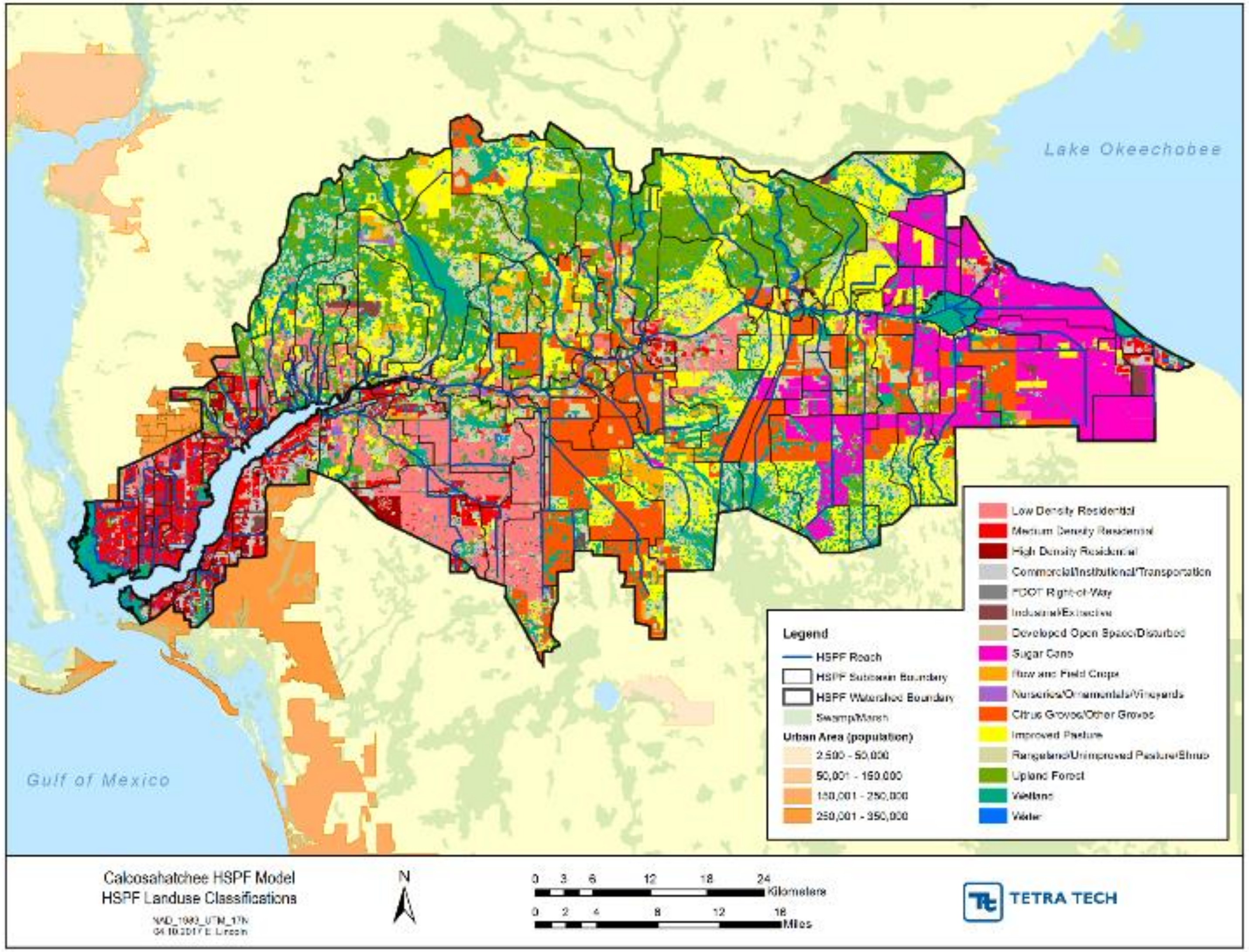
Development of Dissolved Oxygen TMDLs: Townsend Canal (3235L), Long Hammock Creek (3237B), Lake Hicpochee (3237C), C-19 Canal (3237E), and S-4 Basin (3246)

December 17, 2018

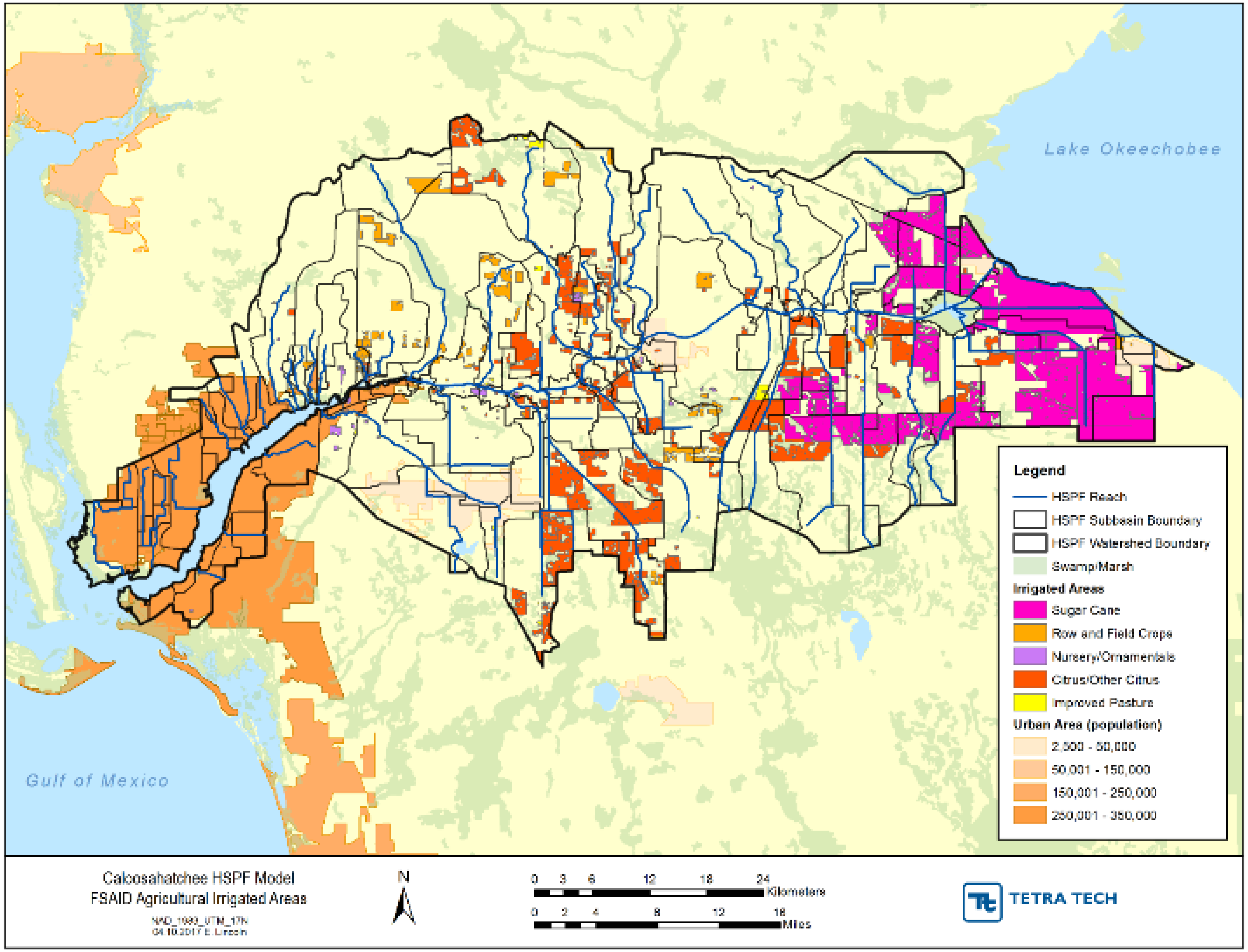
Location of the Caloosahatchee Tributary WBIDs Within the Caloosahatchee Basin



Land Use

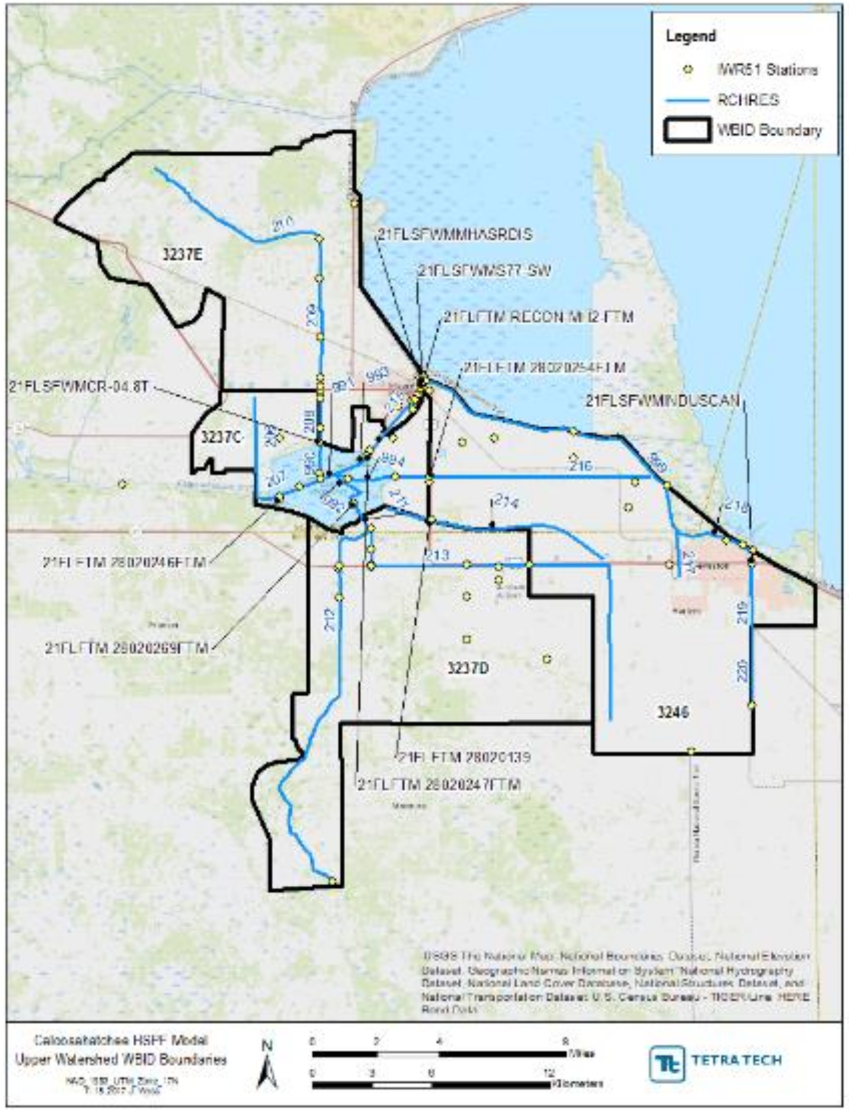

Lake Okeechobee
Gulf of Mexico
Legend
HSPF Reach
HSPF Subbasin Boundary
HSPF Watershed Boundary
Swamp/Marsh
Urban Area (population)
2,500 - 50,000
50,001 - 150,000
150,001 - 250,000
250,001 - 350,000
Low Density Residential
Medium Density Residential
High Density Residential
Commercial/Institutional/Transportation
FDOT Right-of-Way
Industrial/Extractive
Developed Open Space/Disturbed
Sugar Cane
Row and Field Crops
Nurseries/Ornamentals/Vineyards
Citrus Groves/Other Groves
Improved Pasture
Rangeland/Unimproved Pasture/Shrub
Upland Forest
Wetland
Water
Caloosahatchee HSPF Model
HSPF Landuse Classifications
N
0 3 6 12 18 24 Kilometers
0 2 4 8 12 16 Miles
TETRA TECH

Irrigation

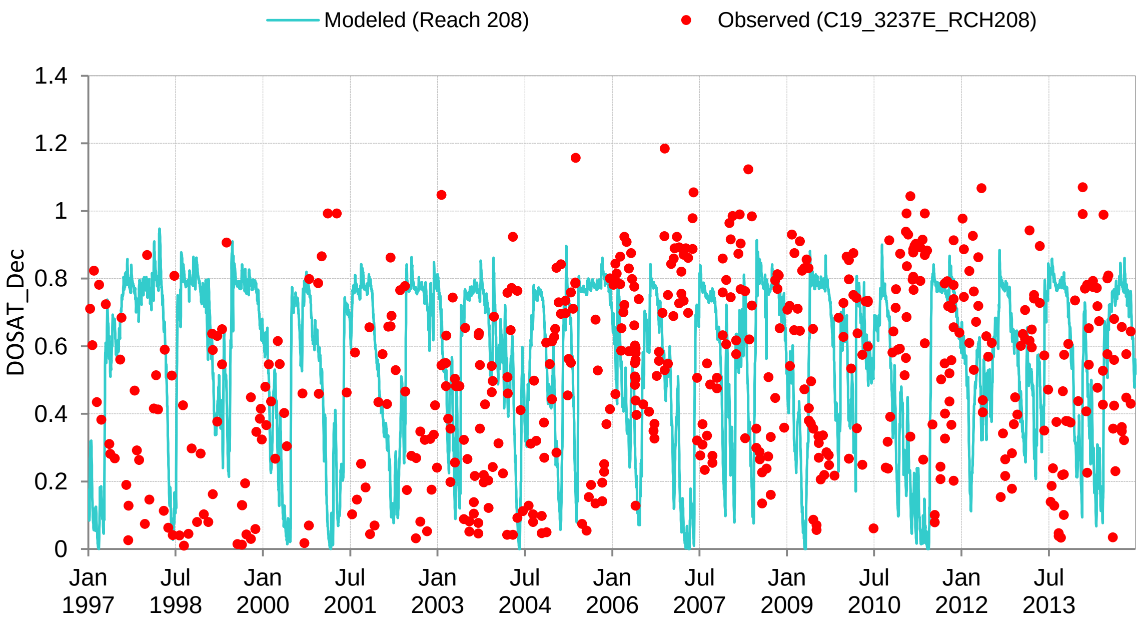


Lake Okeechobee
Gulf of Mexico
Legend
HSPF Reach
HSPF Subbasin Boundary
HSPF Watershed Boundary
Swamp/Marsh
Irrigated Areas
Sugar Cane
Row and Field Crops
Nursery/Ornamentals
Citrus/Other Citrus
Improved Pasture
Urban Area (population)
2,500 - 50,000
50,001 - 150,000
150,001 - 250,000
250,001 - 350,000
Calcosahatchee HSPF Model
FSAID Agricultural Irrigated Areas
N
0 3 6 12 18 24 Kilometers
0 2 4 8 12 16 Miles
TETRA TECH

Clipped Model Area

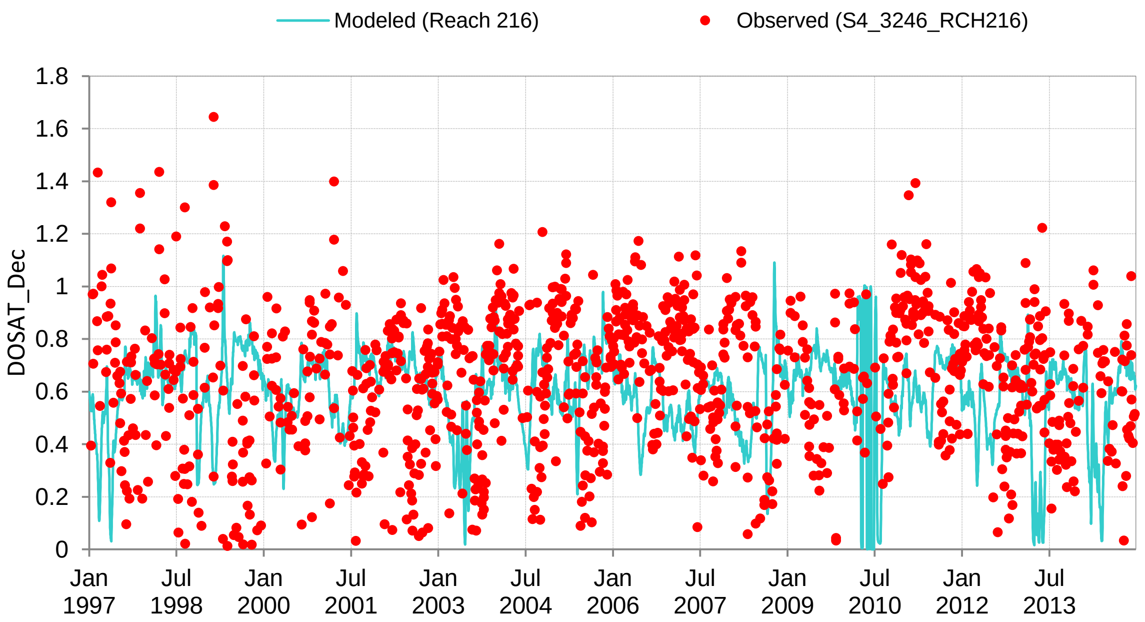


C-19 Results



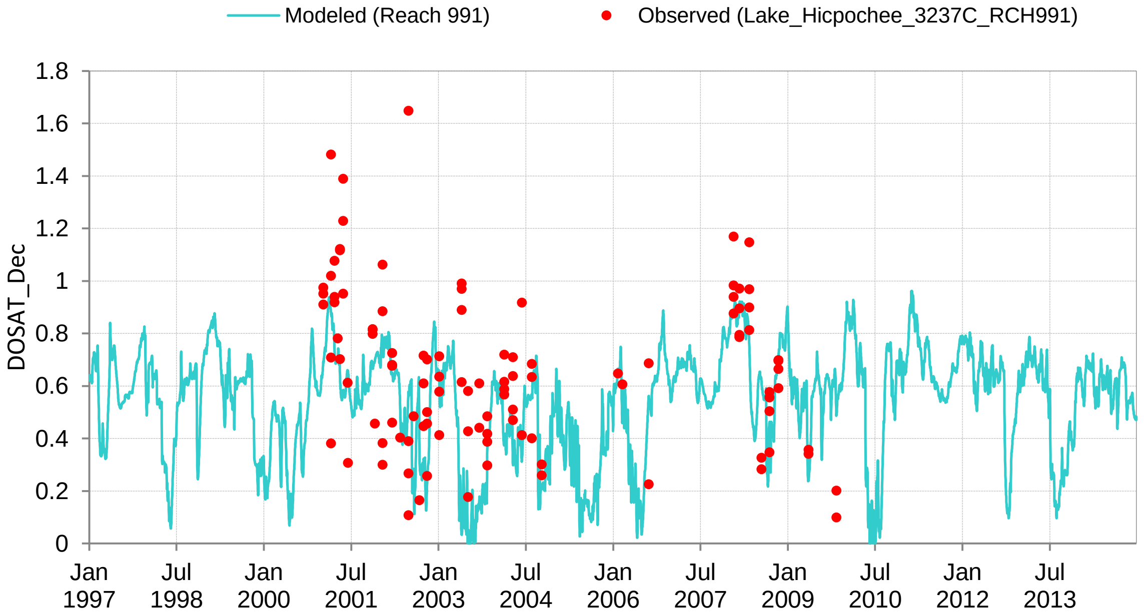
Parameter	Average Annual % Error	Average Annual Error Rating	Median Annual % Error	Median Annual Error Rating
DOSAT	13.4%	Very Good	13.2%	Very Good
TN	17.8%	Very Good	21.0%	Very Good
TP	-20.6%	Very Good	-30.7%	Good

S4 Results



Parameter	Average Annual % Error	Average Annual Error Rating	Median Annual % Error	Median Annual Error Rating
DOSAT	-8.4%	Very Good	-7.2%	Very Good
TN	-24.5%	Very Good	-29.1%	Very Good
TP	-19.1%	Very Good	-32.7%	Good

Hicopochee Results



Parameter	Average Annual % Error	Average Annual Error Rating	Median Annual % Error	Median Annual Error Rating
DOSAT	-8.0%	Very Good	-1.5%	Very Good
TN	-2.0%	Very Good	6.7%	Very Good
TP	87.5%	Poor	162.5%	Poor

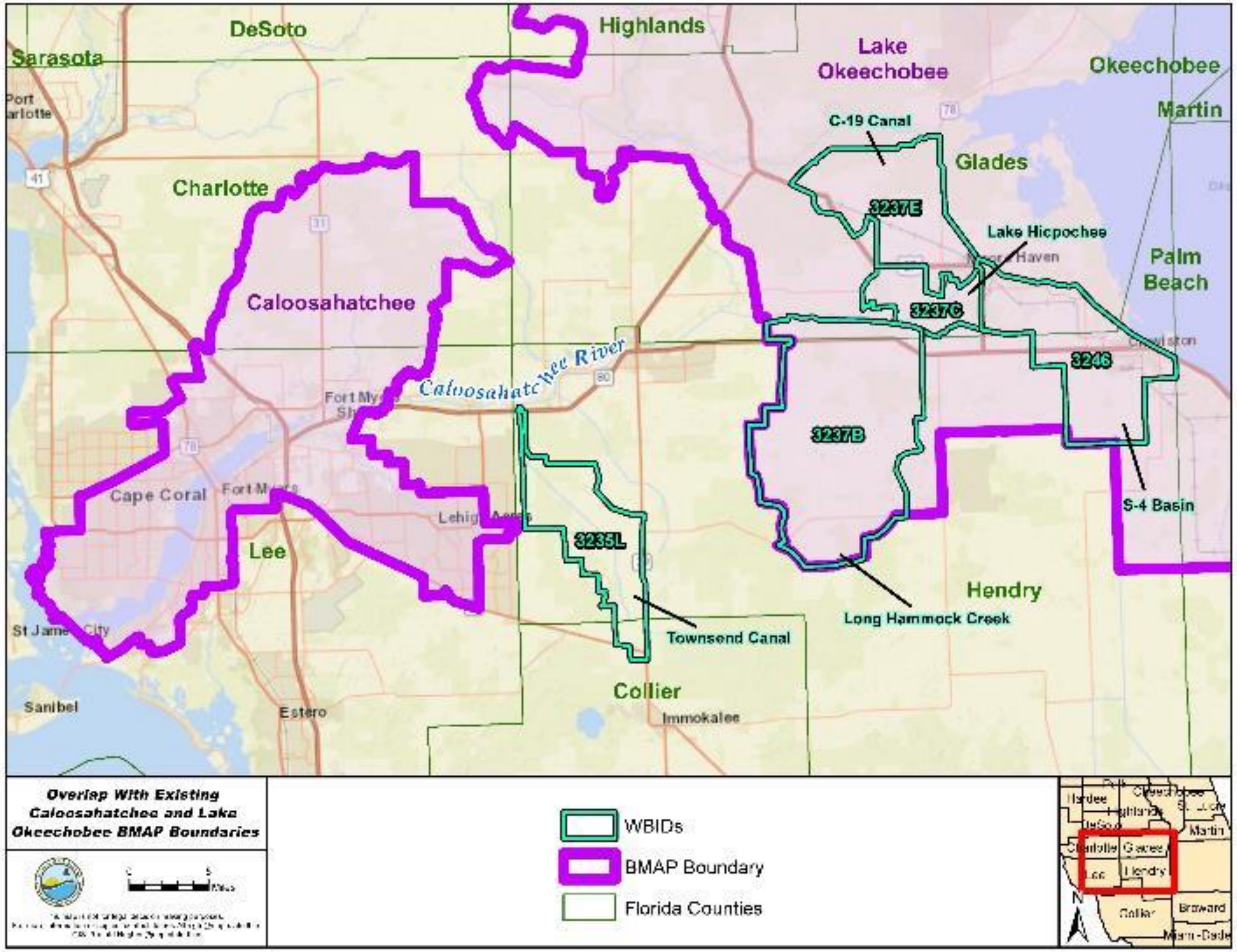
TMDL Modeling

- TN, TP, & BOD concentrations from surface runoff were reduced by the same amount in iterative model runs until DO % saturation excursions (below 38 % saturation) occurred less than 10 % of the time

Final TMDL Loads & Percent Reductions

Waterbody (WBID)	Parameter	TMDL (maximum 7-year average load in lbs)	WLA Wastewater (% reduction)	WLA NPDES Stormwater % reduction	LA (% reduction)
S-4 Basin (3246)	TN	430,844	NA	NA	23
S-4 Basin (3246)	TP	28,622	NA	NA	27
S-4 Basin (3246)	BOD	664,946	NA	NA	28
C-19 Canal (3237E)	TN	78,114	NA	NA	48
C-19 Canal (3237E)	TP	5,167	NA	NA	48
C-19 Canal (3237E)	BOD	186,354	NA	NA	48
Lake Hicpochee (3237C)	TN	4,175,743	NA	NA	2
Lake Hicpochee (3237C)	TP	227,423	NA	NA	2
Lake Hicpochee (3237C)	BOD	5,768,701	NA	NA	3
Long Hammock Creek (3237B)	TN	330,381	NA	NA	42
Long Hammock Creek (3237B)	TP	25,384	NA	NA	42
Long Hammock Creek (3237B)	BOD	773,946	NA	NA	42
Townsend Canal (3235L)	TN	300,564	NA	37	37
Townsend Canal (3235L)	TP	28,749	NA	38	38
Townsend Canal (3235L)	BOD	673,151	NA	37	37

Existing Caloosahatchee Estuary and Lake Okeechobee BMAP Boundaries



FLORIDA DEPARTMENT OF ENVIRONMENTAL PROTECTION

Using a Computer Water-Quality Model to Derive Numeric Nutrient Criteria in Large Rivers

William Howard George

Approaches to Criteria Development and Past Model

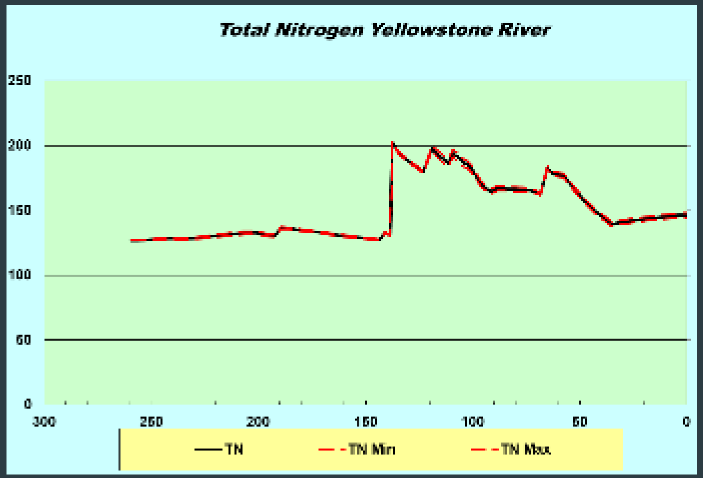
- Reference/Statistical Approaches
- Predictive empirical relationships that link nutrients with specified water quality endpoints
- Process-based computer simulation models

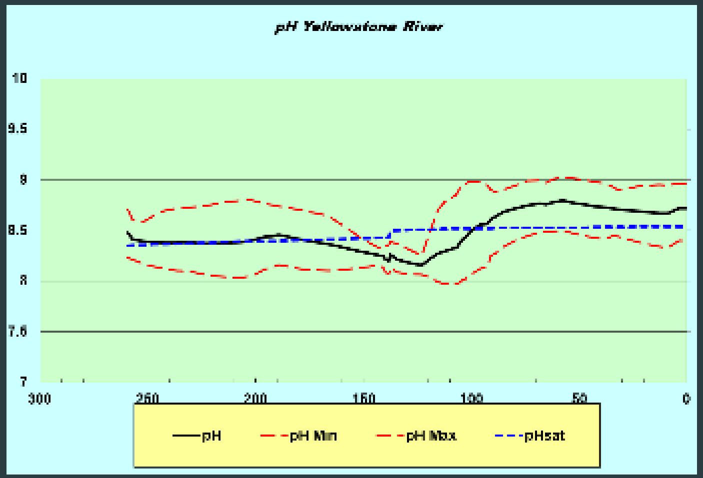
- 2013 Qual2K Nutrient Model on 233 km segment of Lower Yellowstone River in Eastern Montana.

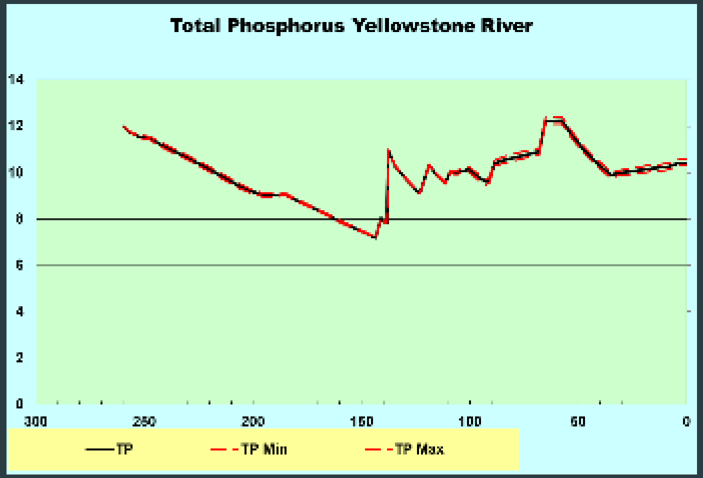
Qual2K - Applicability

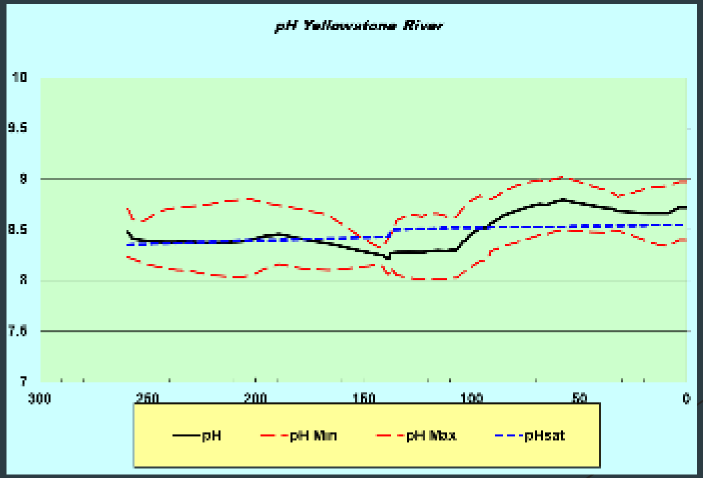
- Process Based
  - Simulates state variables in well mixed (vertically and laterally) streams and rivers
    - Temp, DO, SC, N (all species), P (all Species), Phytoplankton, Benthic Algae, pH, alkalinity, ISS, CBOD
    - Handles multiple dischargers, withdrawals, tributaries, etc.
- Steady-state 1-d

Qual2k – Model Outline/Preliminary Results



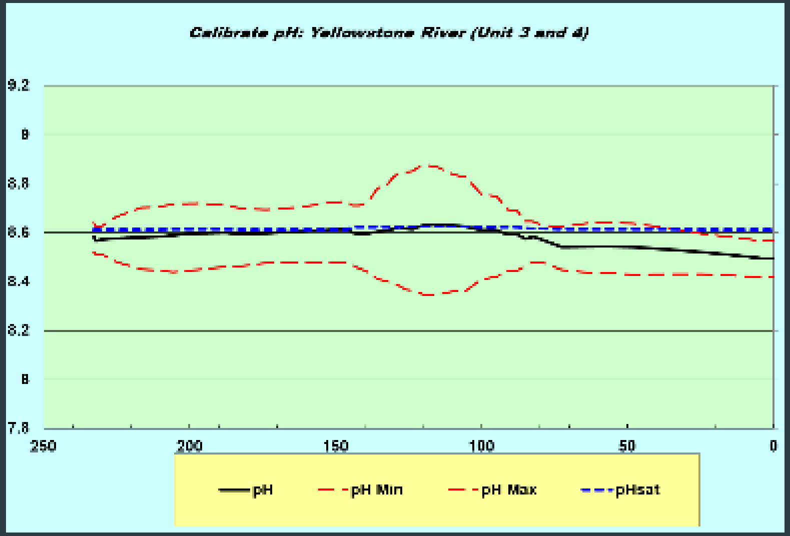


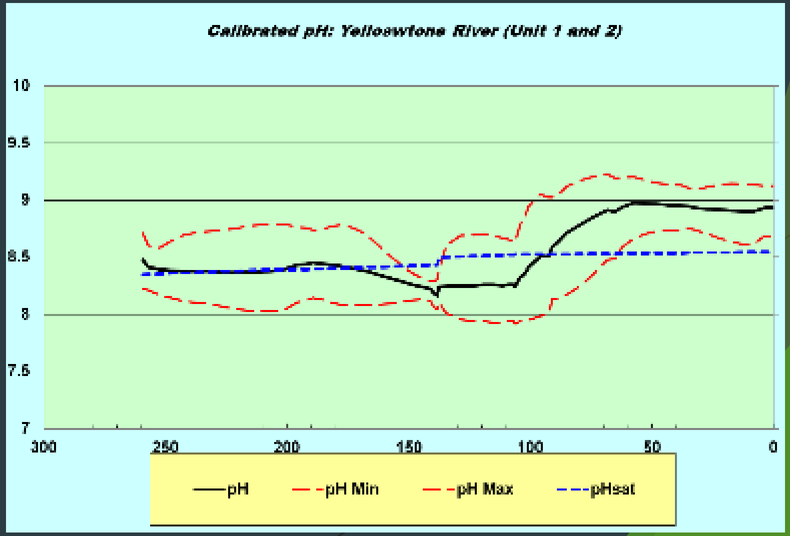




Qual2K – Moving Forward/Unique Problems

- AT2K modelling still to occur
- Low Alkalinity/TSS
- Unit 1 exceeding pH standards (Class 1 pH limit 8.5)
- High Groundwater NO3 levels in Clarks Fork
- Low assimilative capacity/points sources already exceeding pH standards





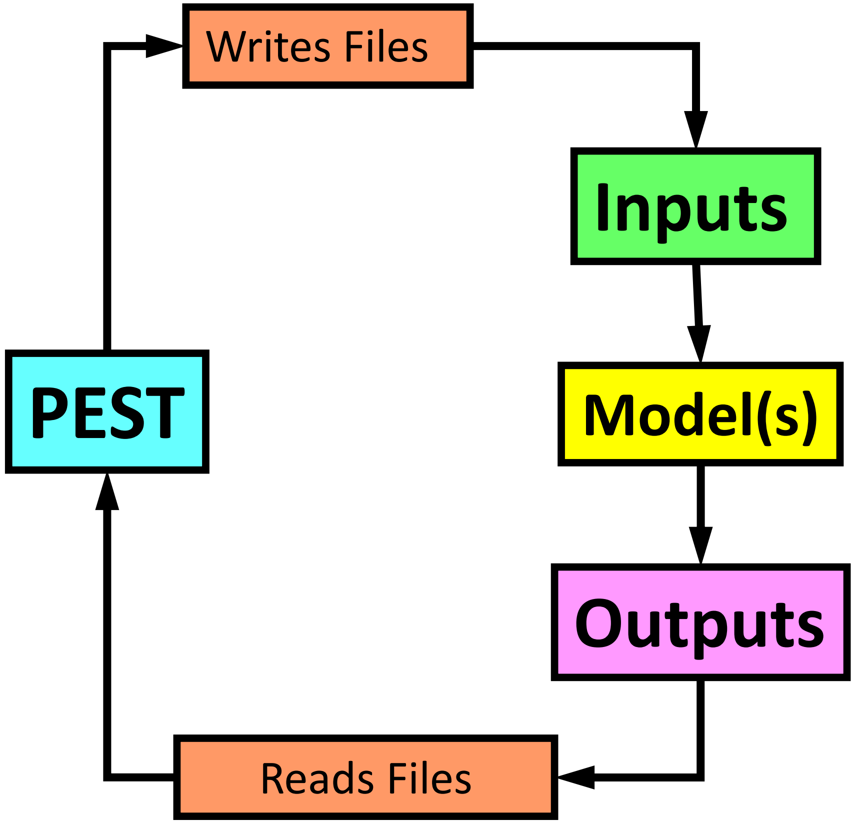
Thank you. Questions?

Using PEST to Support Oregon Midcoast TMDL Development

- Oregon Midcoast Region: Temperate, wet, largely non-point source
- TMDLs in development:
  - Dissolved oxygen – Nutrient, light/heat
  - Temperature – Solar driven energy budget
  - Bacteria – Cattle and on-site inputs
- Models and methods used:
  - HSPF
  - QUAL2Kw
  - Heat Source
  - Statistical models
  - Load Duration Curves

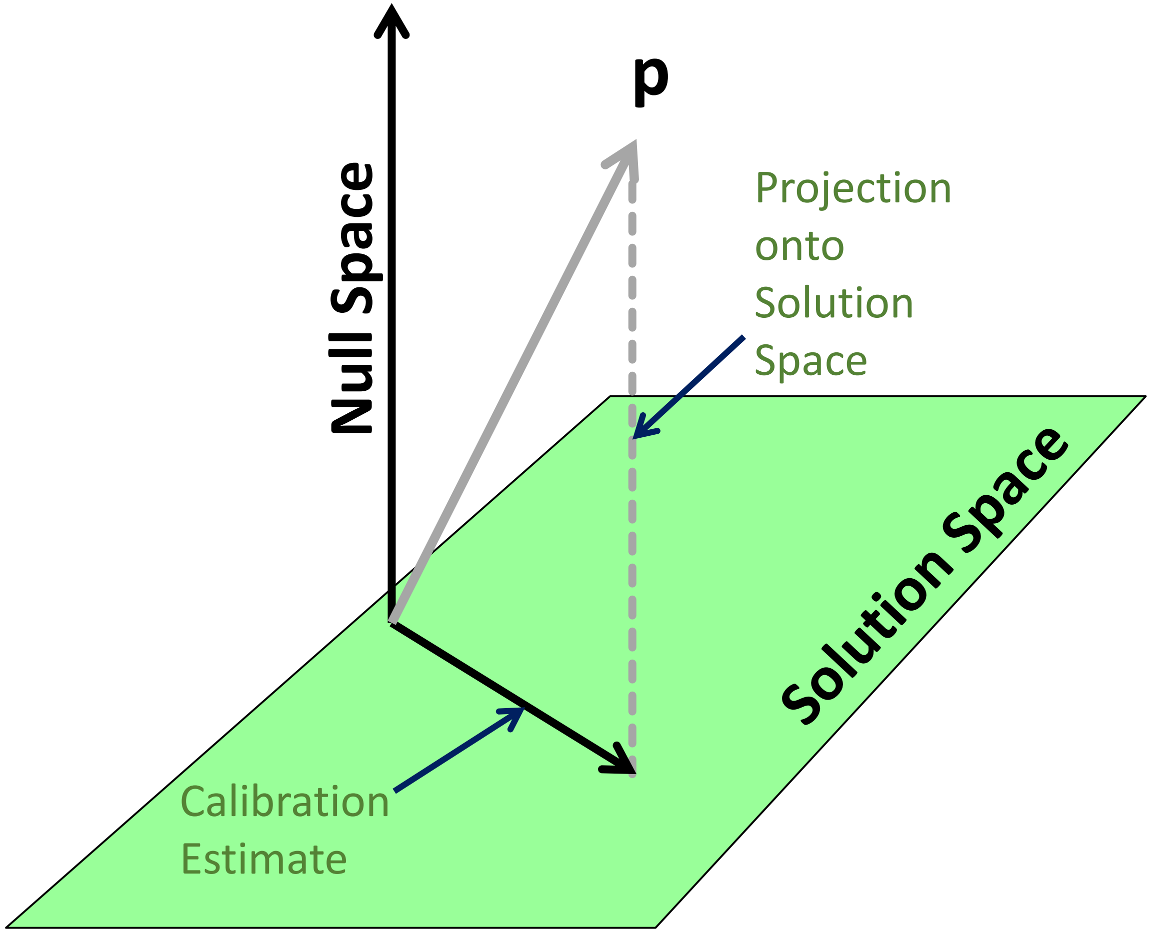
Using PEST to Support Oregon Midcoast TMDL Development

- PEST stands for Parameter Estimation Tool, but it does so much more
- Developed by John Doherty, though many have had a hand in its progress to date
- PEST is model independent—it can be used for any type of numeric model or suite of integrated models
- Achieves solution to ill-posed problems through inverse methods

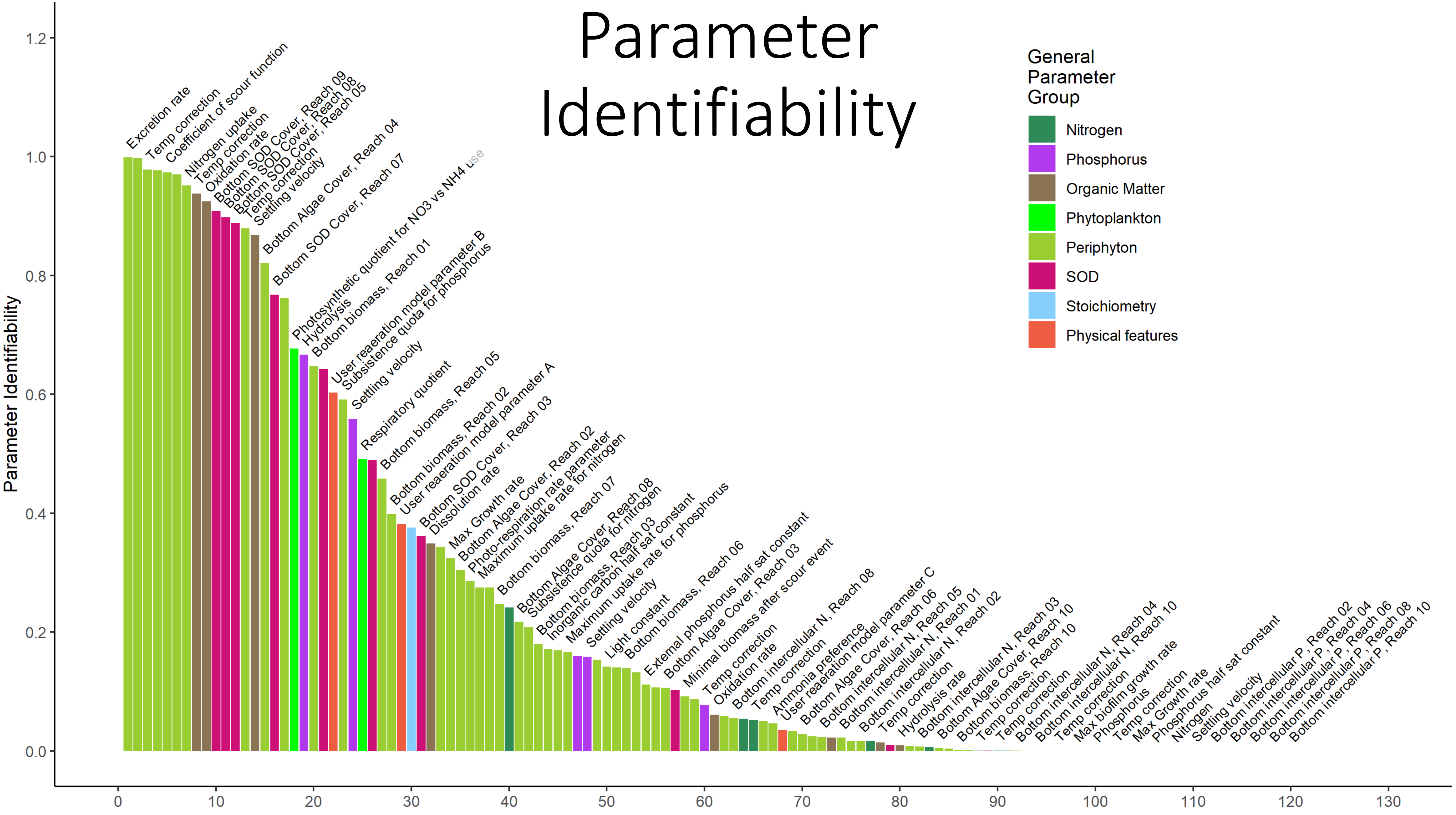


Using PEST to Support Oregon Midcoast TMDL Development

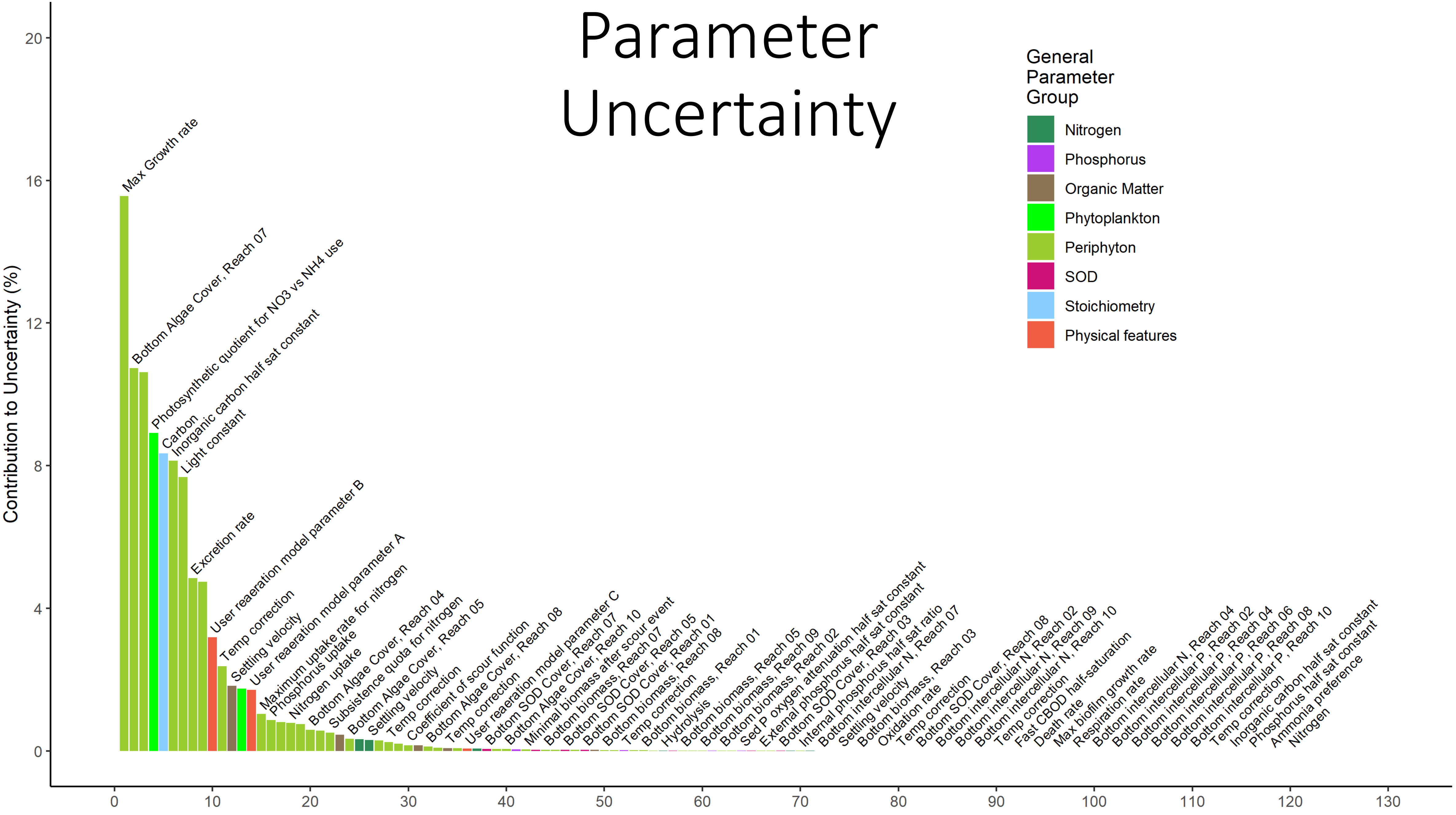
- Model parameterization (Calibration) – PEST provides a systematic, reproducible, and transparent way of arriving at a "unique" solution with minimized error
- Pre and post calibration analysis:
  - Solution space/null space
  - Parameter identifiability
  - Parameter uncertainty
  - Observation worth



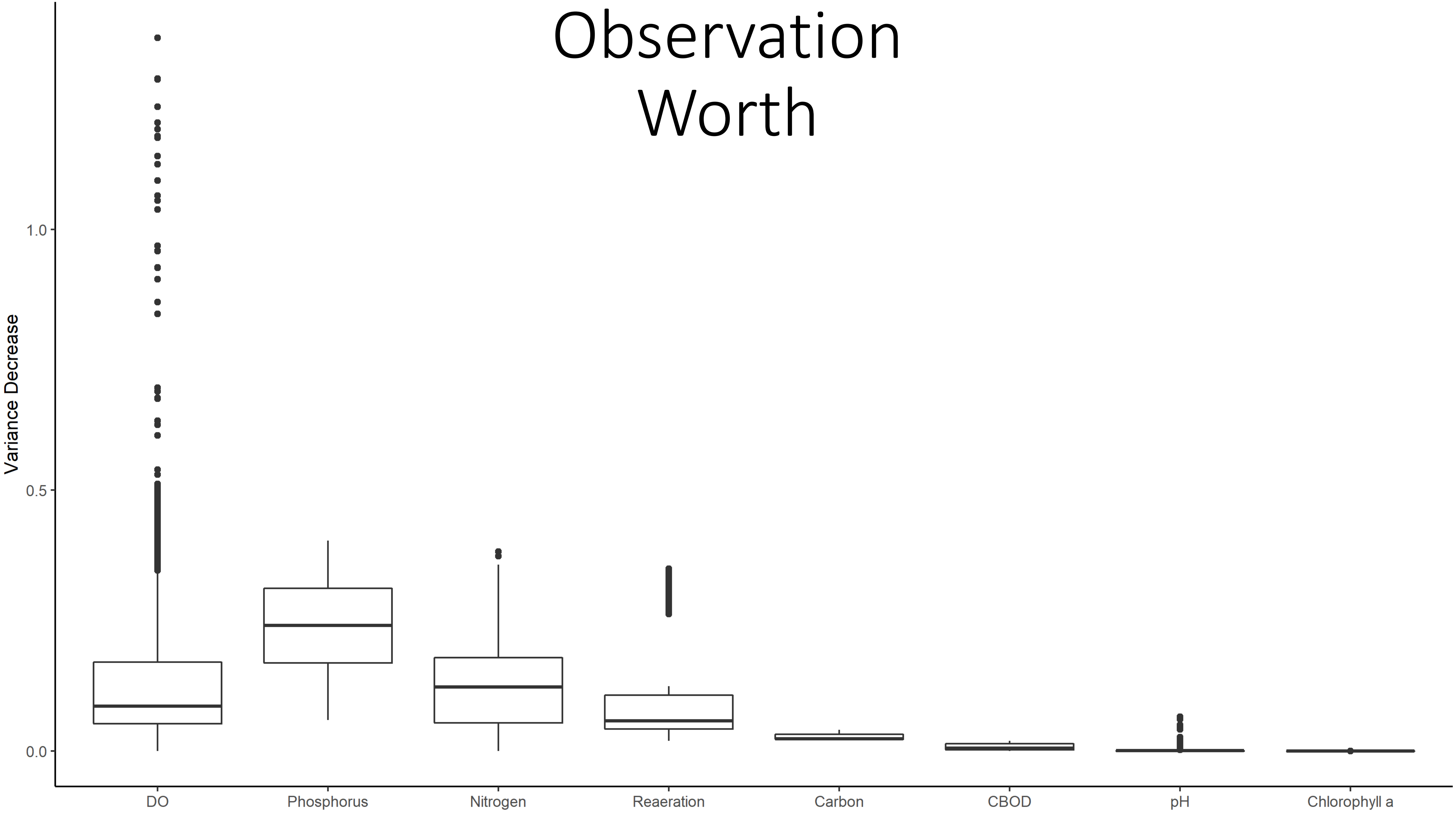
Parameter Identifiability



Parameter Uncertainty



Observation Worth



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WATER QUALITY

Utah Lake Nutrient Model

Nicholas von Stackelberg
EPA TMDL Workshop 5/28/2020

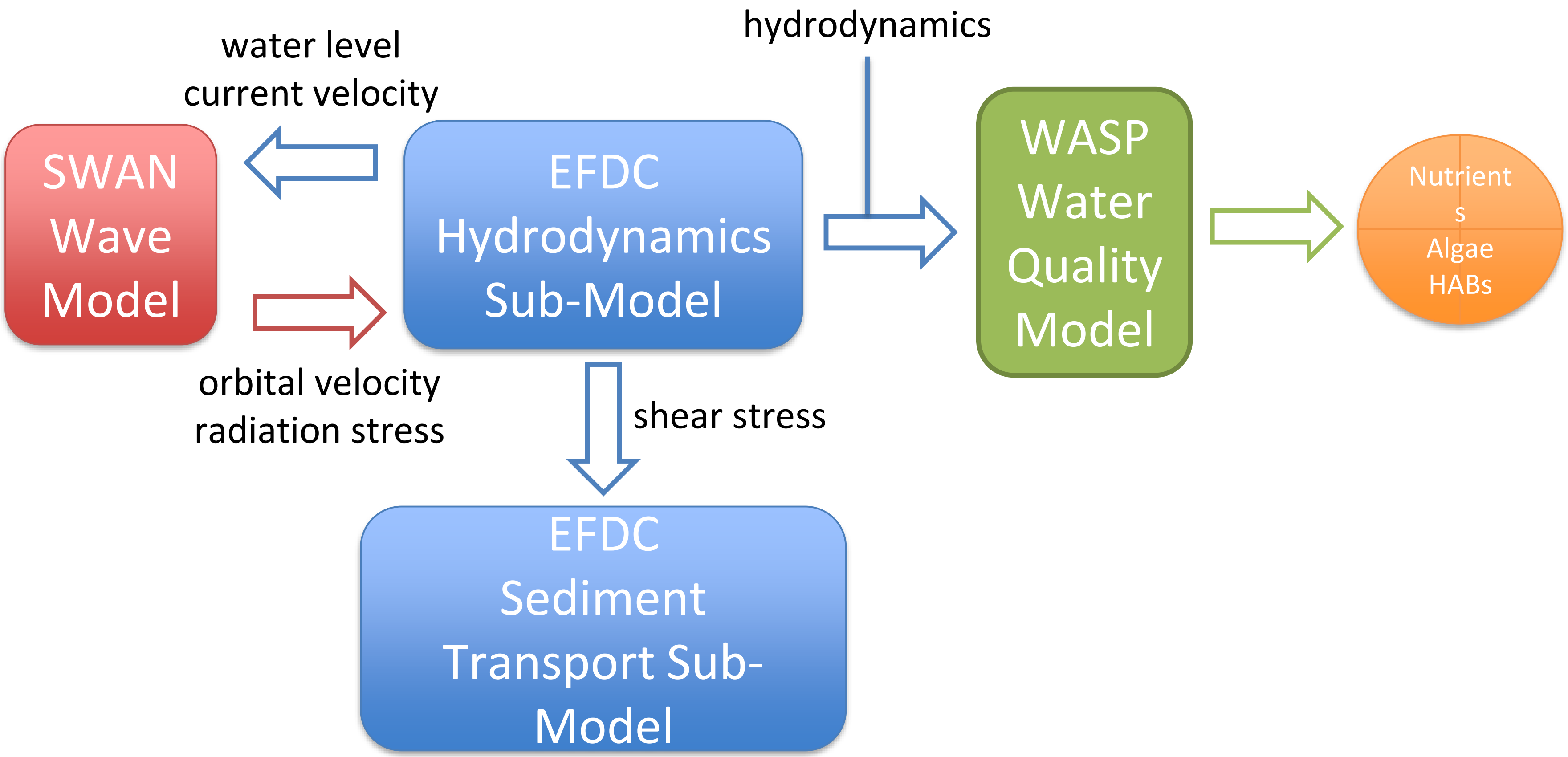
Utah Lake Background

- ➢ Large and shallow lake
  - 380 km^2 and 3.2 m mean depth
  - Reservoir managed for irrigation water supply - “fill and spill”
- ➢ Water quality characteristics
  - Turbid with low transparency
  - Nutrient rich with algal blooms
  - Listed as impaired for harmful algal blooms
- ➢ Important considerations
  - Sediment resuspension due to wind/waves
  - Light attenuation due to turbidity
  - Wetting/drying of shallow bays
  - High phosphorus retention in sediments
  - Bioturbation by carp

Model Objectives

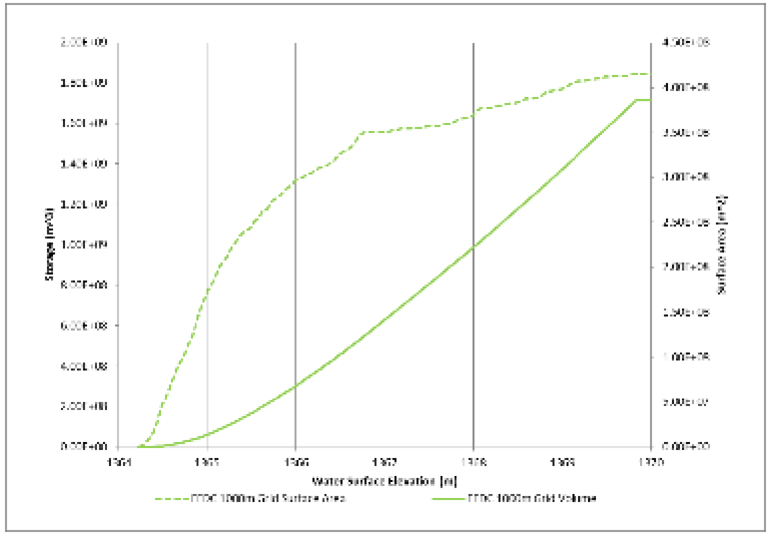
1) Numeric nutrient criteria development
2) Nutrient load allocation
3) Lake restoration

Utah Lake Nutrient Model Framework

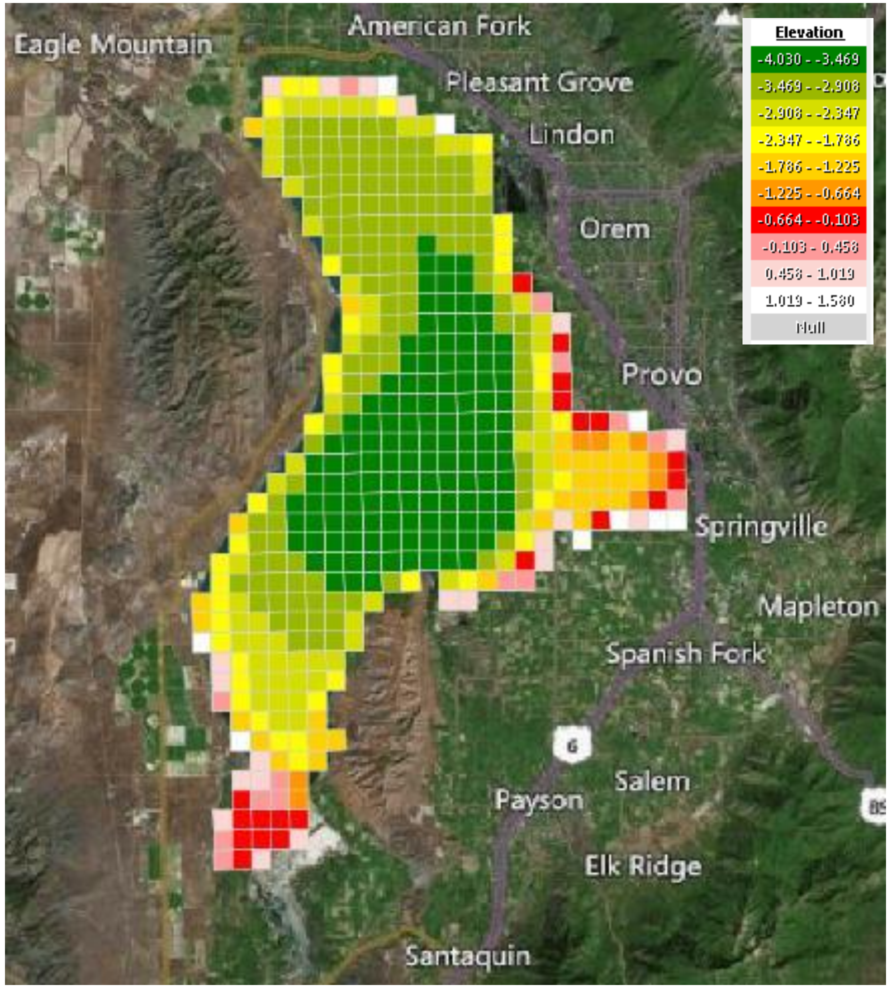


Model Structure

- Cartesian grid
- 1,000 m x 1,000 m cell size
- 452 cells
- 3 vertical layers
  Variable depth (sigma stretched)



Stage-Surface Area-Storage



Bathymetry

Model State Variables (Water Column)

EFDC

- Flow
  - Depth
  - Velocity
  - Shear Stress
- Water Temperature
- *Inorganic Solids (3 classes)

•* *Constituent not output to WASP*

WASP

Ammonia [NH_3 / NH_4^+]

Nitrate [NO_2^- + NO_3^-]

Dissolved Inorganic Phosphate
[H_2PO_4 / HPO_4^- / PO_4^{2-}]

Dissolved Oxygen

Solids (3 classes)
– Sand, silt, clay

Water Temperature
(from WASP)

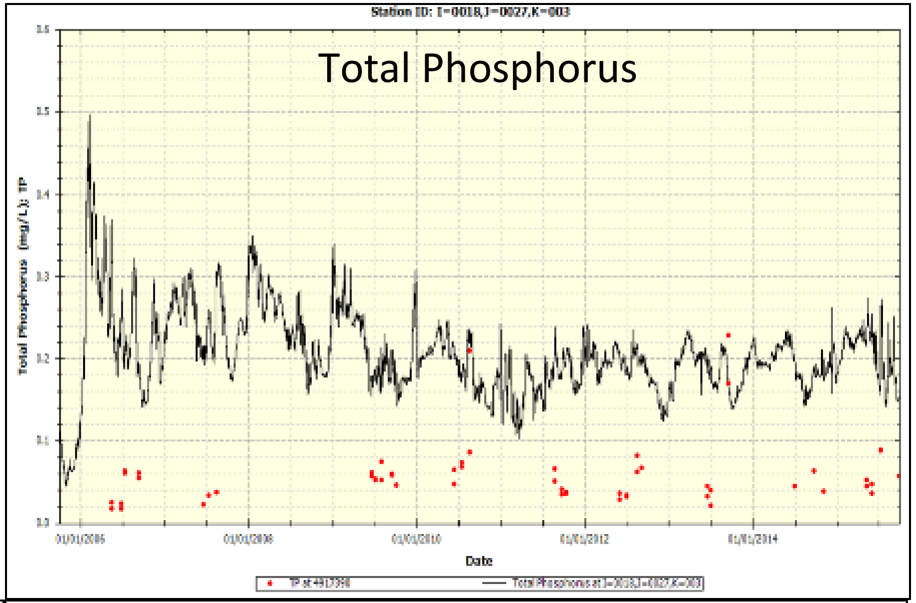
Alkalinity *(not implemented yet)*

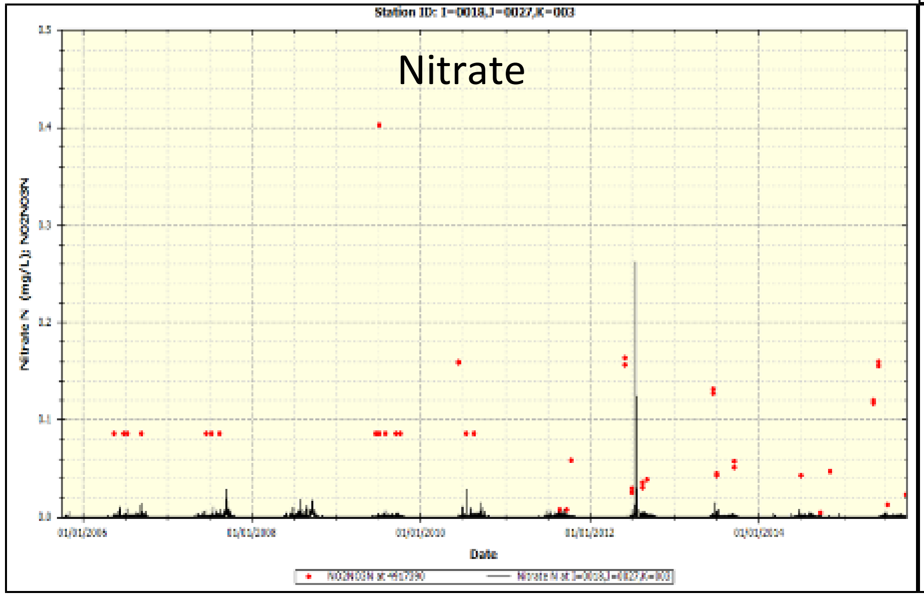
pH *(not implemented yet)*

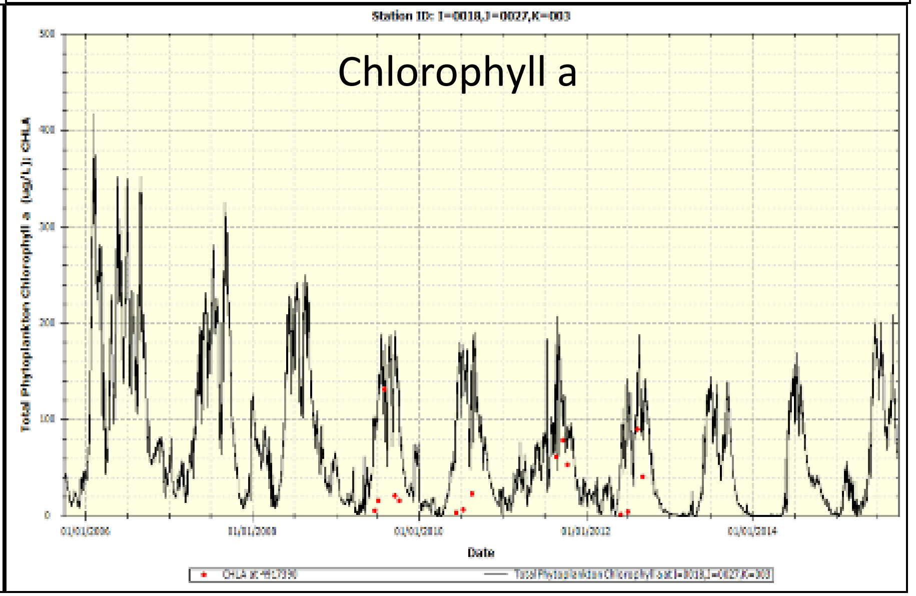
- Phytoplankton (4 classes)
  - Diatoms *(Bacillariophyta)*
  - Green Algae as Phytoplankton
  - Cyanobacteria *(Aphanizomenon gracile)*
  - Cyanobacteria *(Synechococcus; Not Nitrogen-fixed)*
- Periphyton
- Particulate Organic Matter (POM)
  - Particulate Organic Carbon (POC)
  - Particulate Organic Nitrogen (PON)
  - Particulate Organic Phosphorus (POP)
- Dissolved Organic Matter
  - CBOD Ultimate (1 class)
  - Dissolved Organic Nitrogen (DON)
  - Dissolved Organic Phosphorus (DOP)

Model Calibration

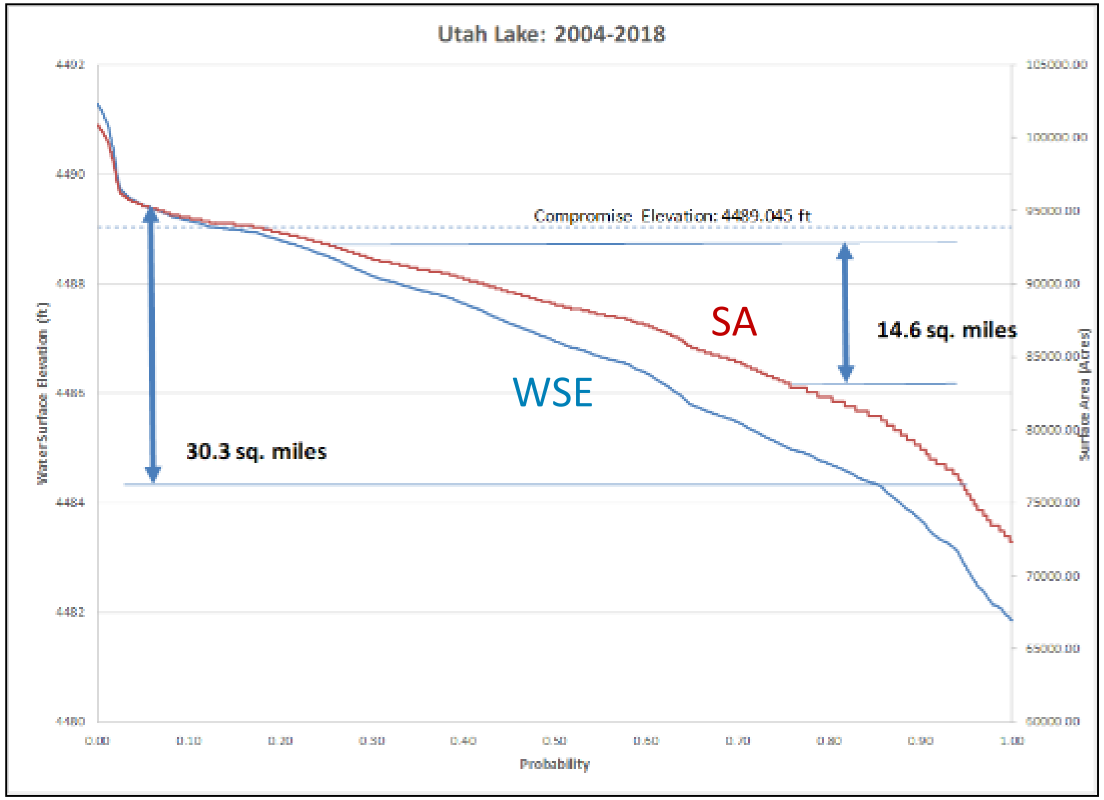
- Preliminary (Complete)
  - Water Year 2006-2015
- Refinement (Ongoing)
  - Water Year 2009-2013







Wetting/Drying



- Biogeochemical processes?
- Standard sediment diagenesis formulation apply?
- WASP run times

Phosphorus Retention in Sediments

- ~25-50% P bound to Ca minerals
  - Stable under alkaline lake conditions
  - How to model calcite formation and incorporation of P?
- ~40-60% P bound to Fe minerals
  - Highly labile
  - Redox sensitive – can be released under anoxic conditions

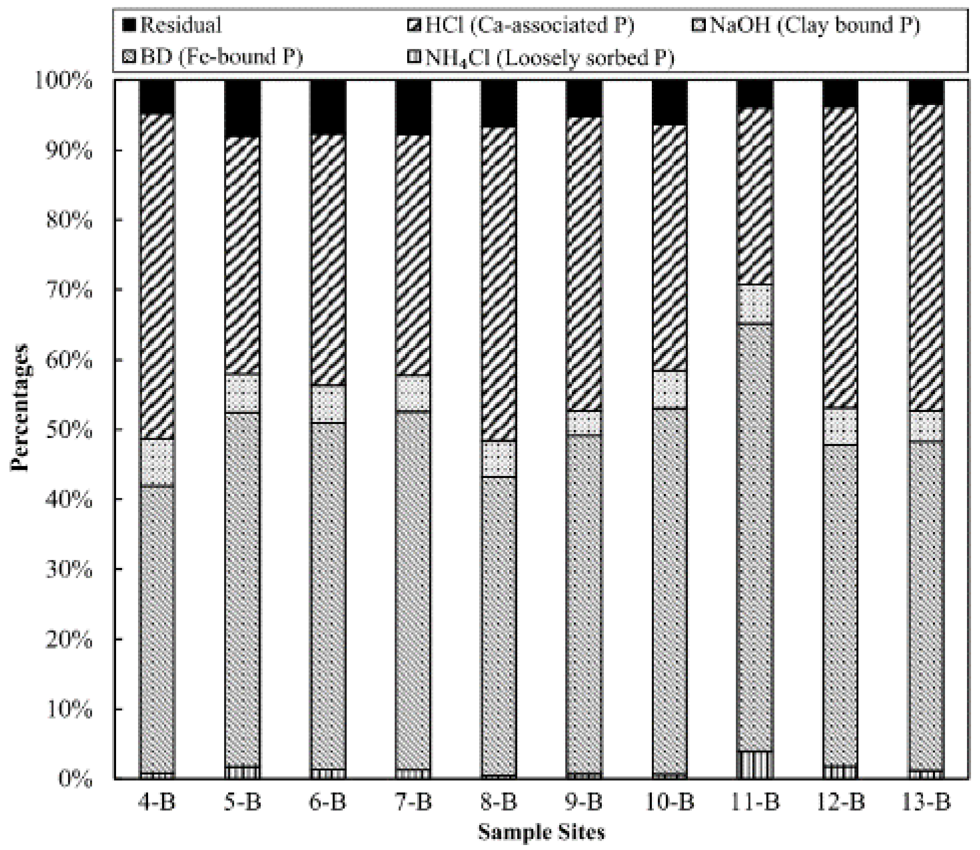
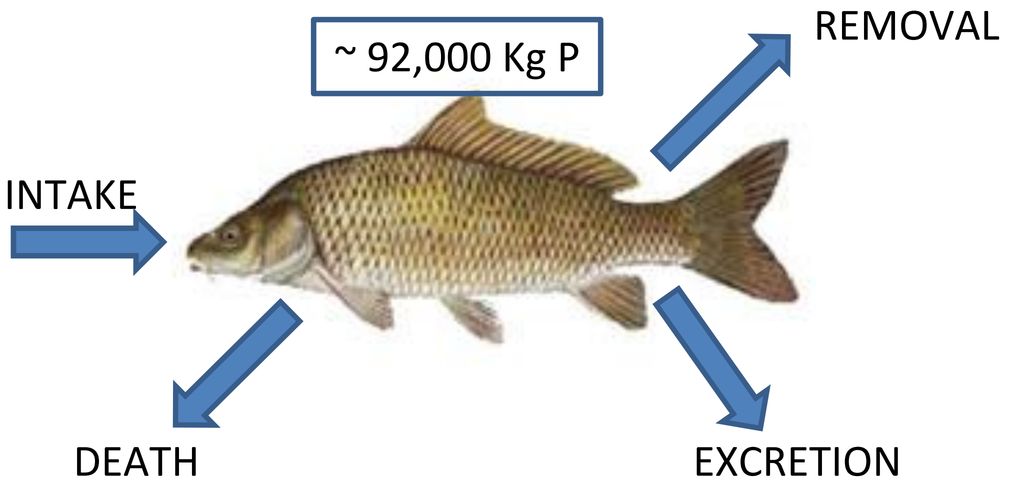


Figure 10. Percentage distribution of total phosphorus (TP) fractions in Utah Lake sediments (n=10) collected May 2016. Average values are shown for the ten samples.

Source: Randall 2017

Carp

- Nutrient cycling
  - Carp removal project
- Bioturbation
  - Sediment resuspension
  - Macrophyte reestablishment
- Model
  - Separate food web model
  - Describe or predict carp?



Collaborators

University of Utah

- Juhn-Yuan Su, PhD Candidate
- Dr. Michael Barber, Advisor

Utah Lake Science Panel

- Dr. James Martin

EPA

- Tina Laidlaw
- Tim Wool

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EPA Region 4 Modeling Approach

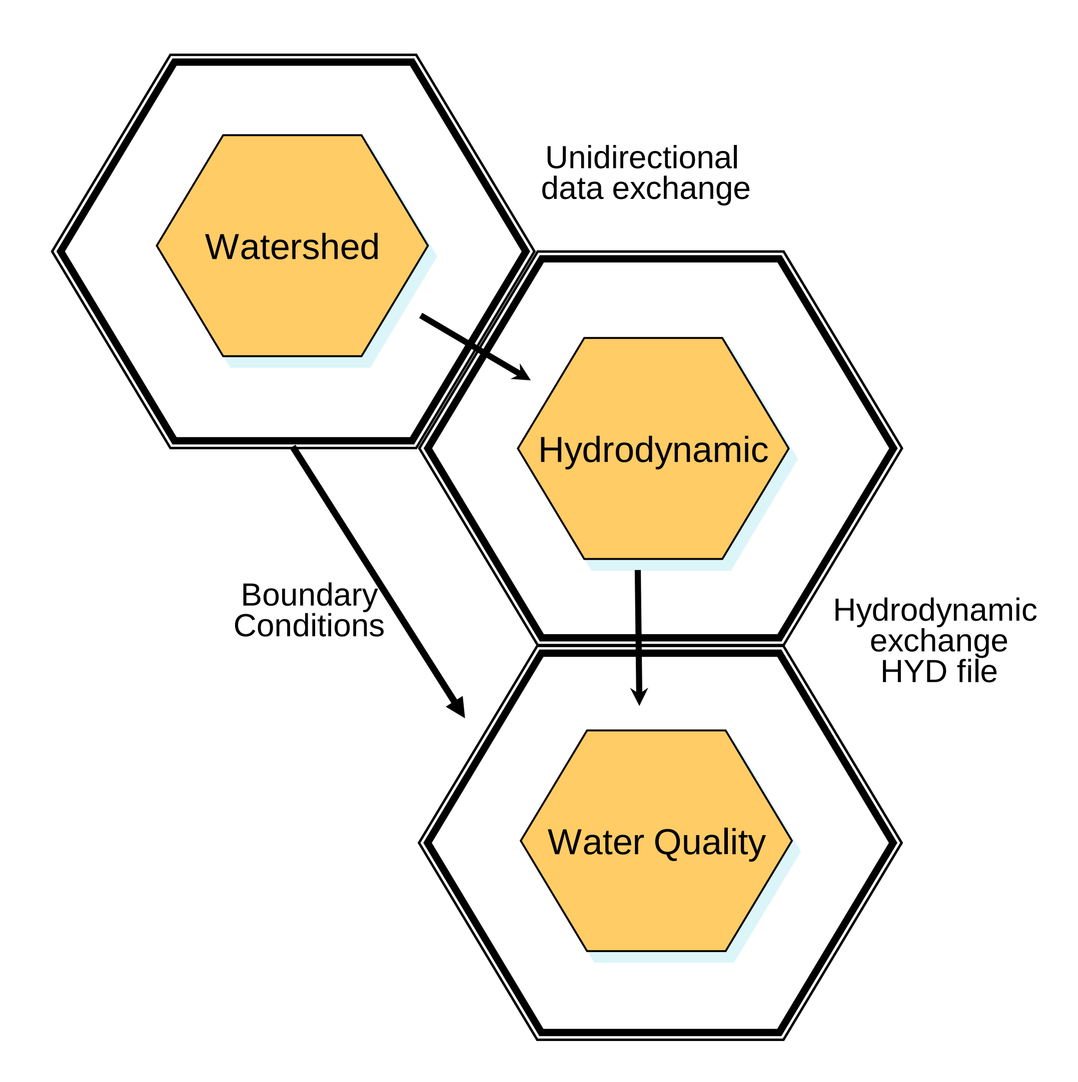
J. Davis

EPA Region 4

EPA Region 4
Modeling overview

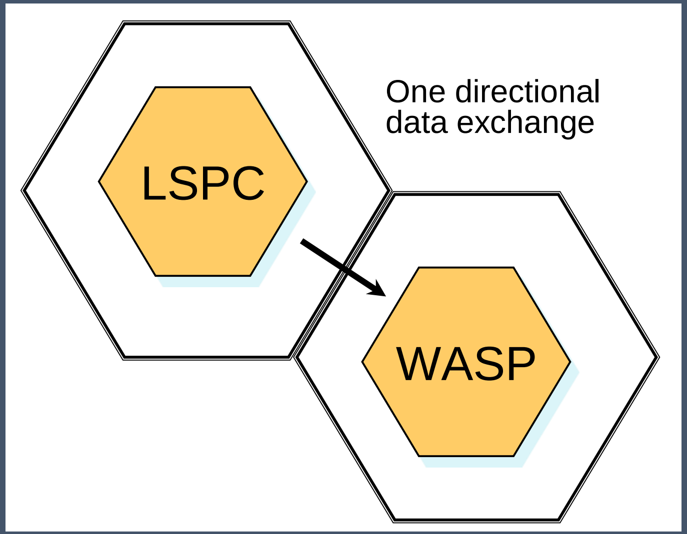
Overview of nutrient modeling

- Whole watershed approach
- Linked models
  - Watershed
  - Hydrodynamic (estuaries & lakes)
  - Water quality
- Multi-year continuous simulation
  - 6 – 10 years
- Models used for:
  - TMDL load calculations
  - NPDES permit limits
  - Numeric nutrient criteria



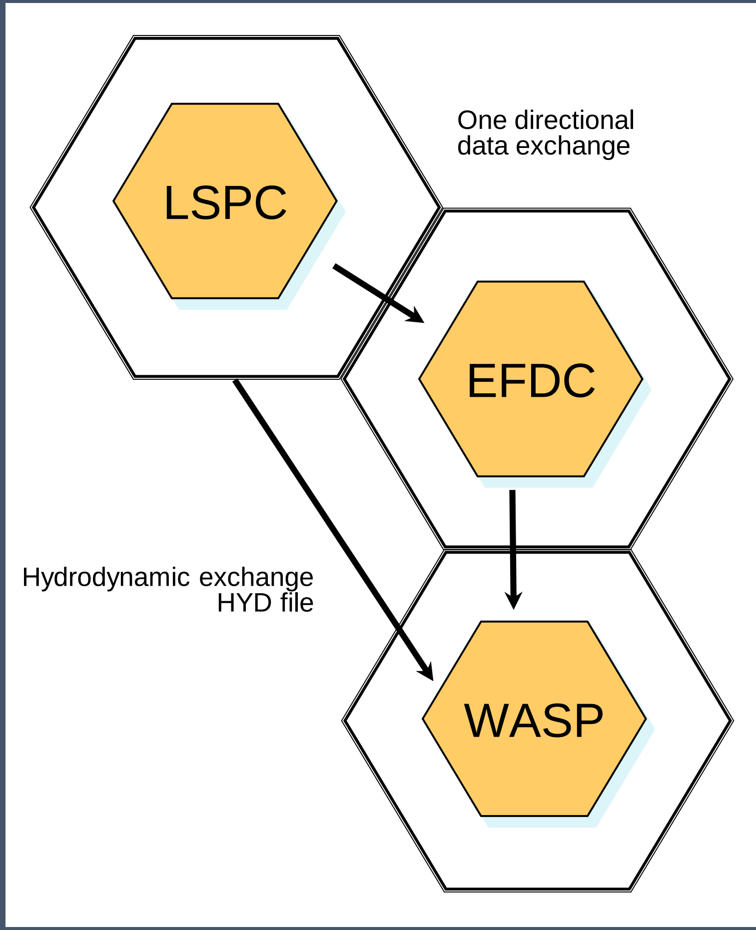
Model configuration: Riverine

- Two-model system to represent water quality in riverine systems
  - LSPC simulates watershed loadings
  - WASP simulates instream water quality response



Model configuration: Lakes/Estuaries

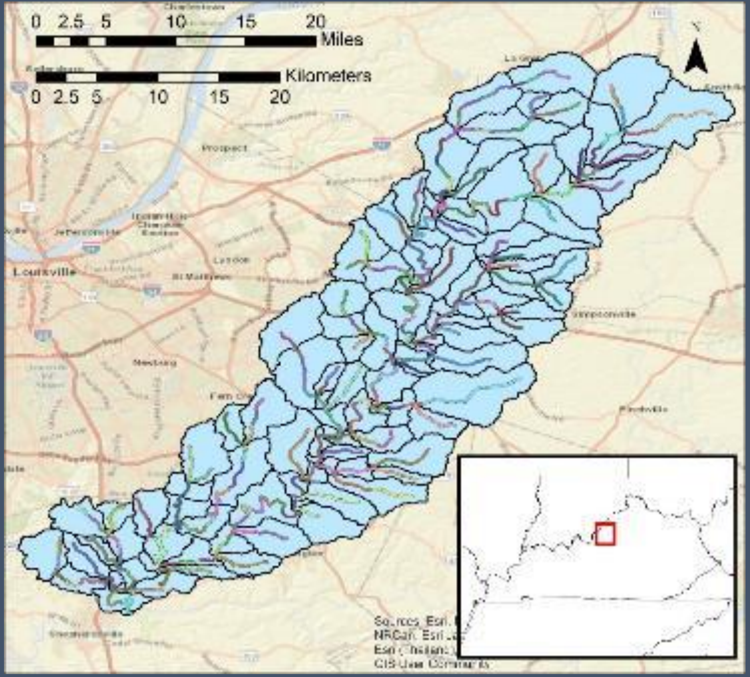
- Three-model system to represent water quality in lakes and estuaries
  - LSPC simulates watershed loadings
  - EFDC simulates hydrodynamics
  - WASP simulates water quality response

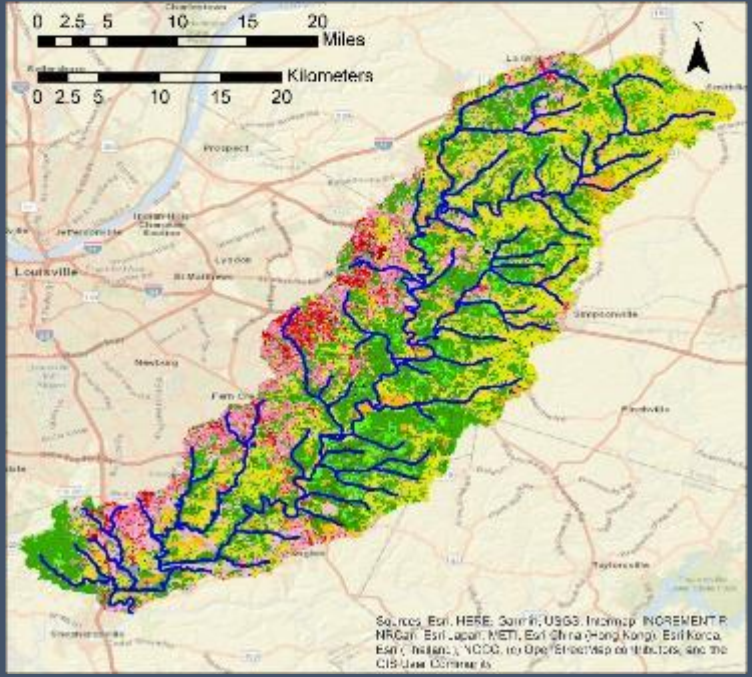


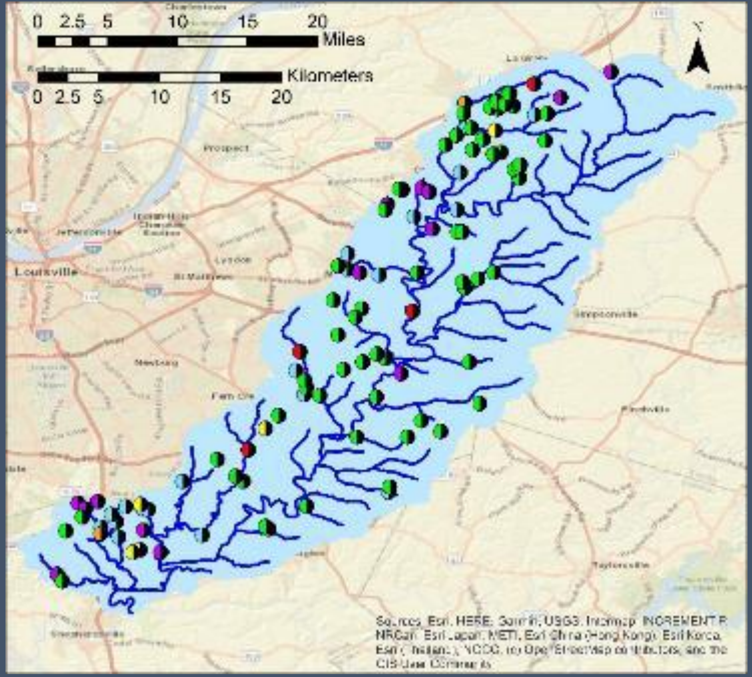
EPA Region 4

Modeling overview

Example linked LSPC/WASP model

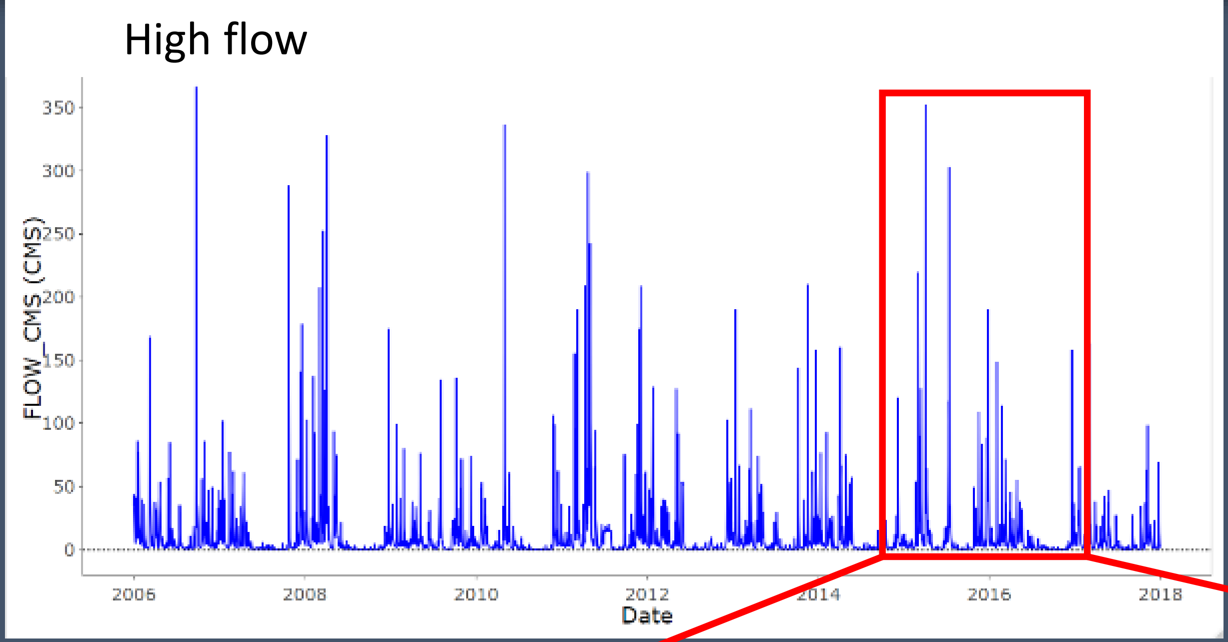


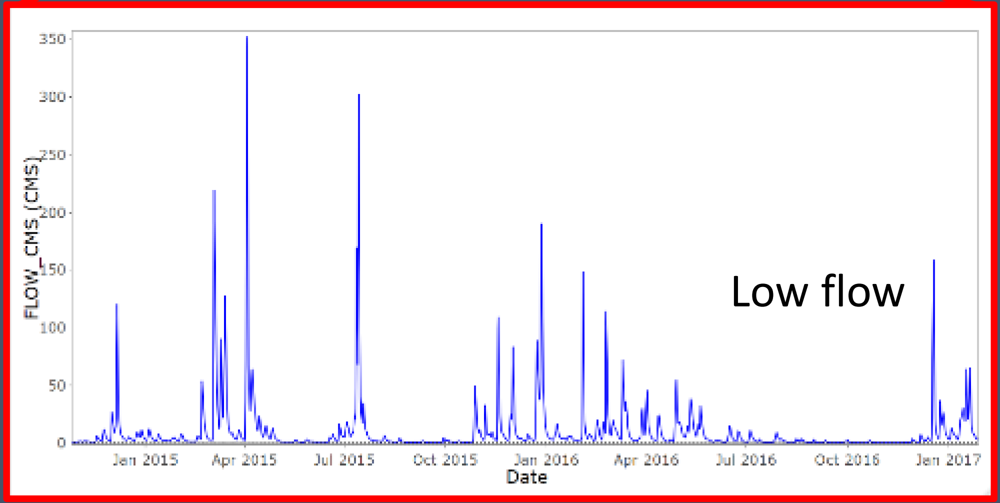




- 285 square mile watershed
- Mix of forested/urban/agricultural land use
- 120 LSPC subbasins & 181 WASP stream segments
- ~80 point sources

Multi-year comparison: Hydrology



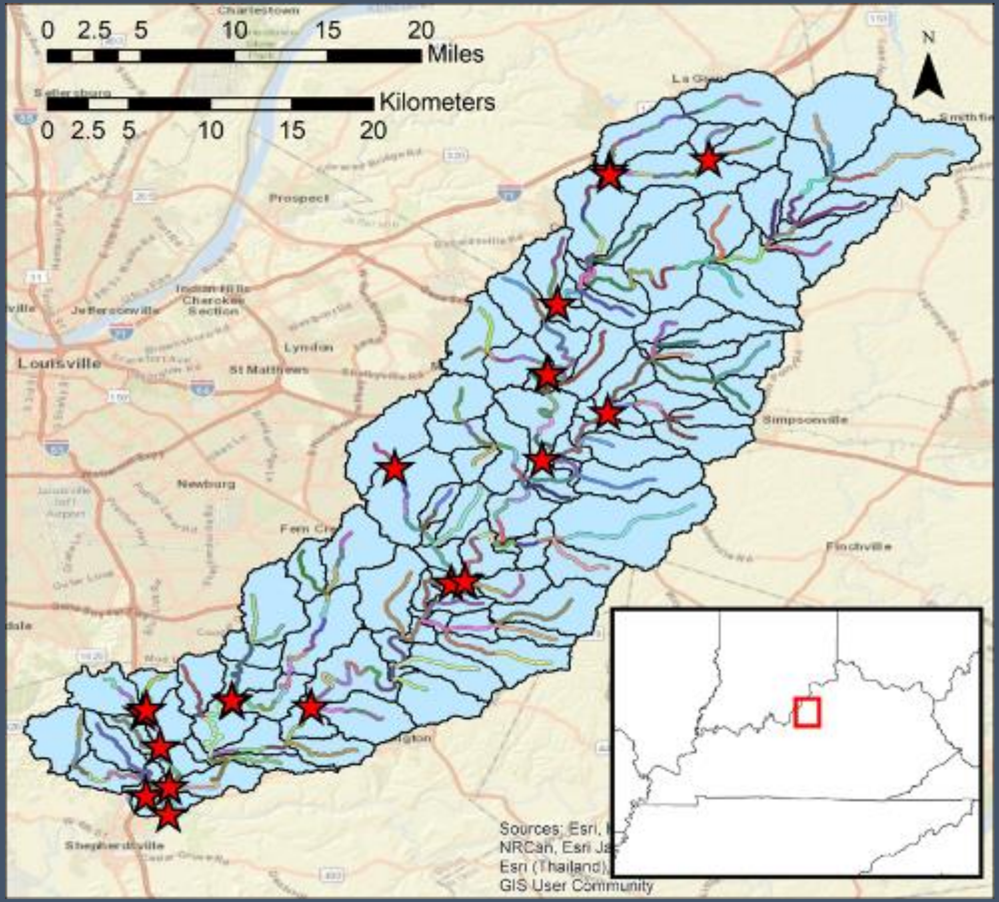


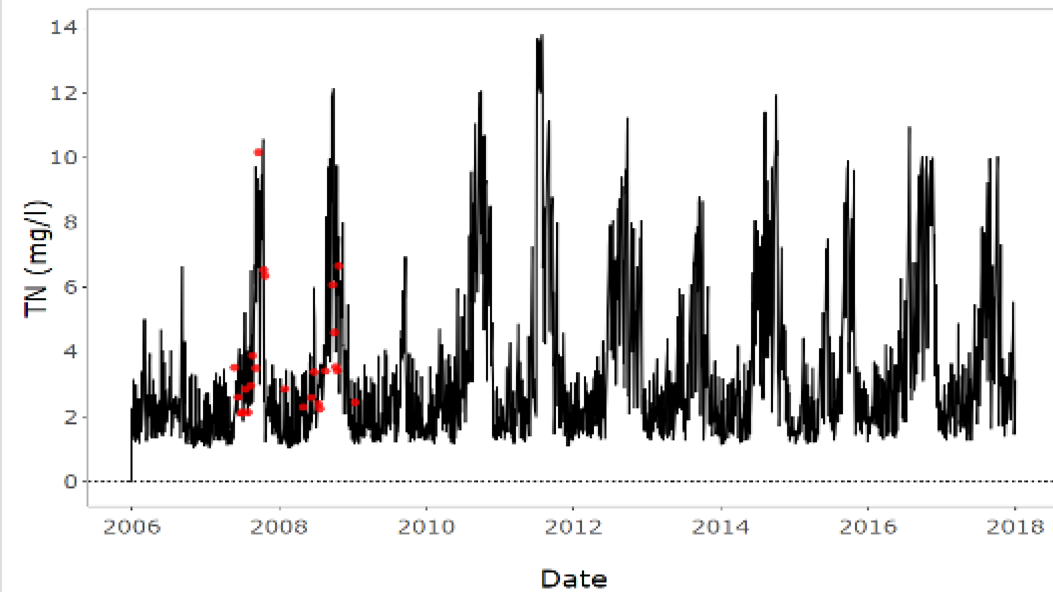
- Multi-year simulations capture high and low-flow conditions

- Varying meteorological conditions

Model objectives: Assessment points

- Calibrated model can interpolate data gaps
  - Spatially / Temporally



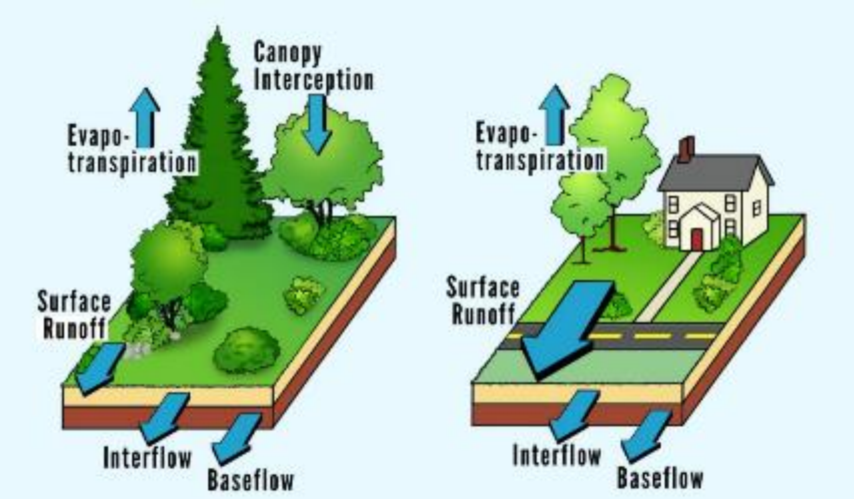


- Predict / evaluate conditions
  - Across watershed
  - At low flow / critical conditions

- Assess endpoints that vary spatially
  - Headwater vs. Wadable vs. Boatable

Model objectives: Scenario runs

- Extrapolate to novel environmental conditions
  - Current conditions
  - Natural conditions (no anthropogenic inputs)
  - TMDL conditions
  - Low-flow critical conditions
  - BMP implementation / evaluation



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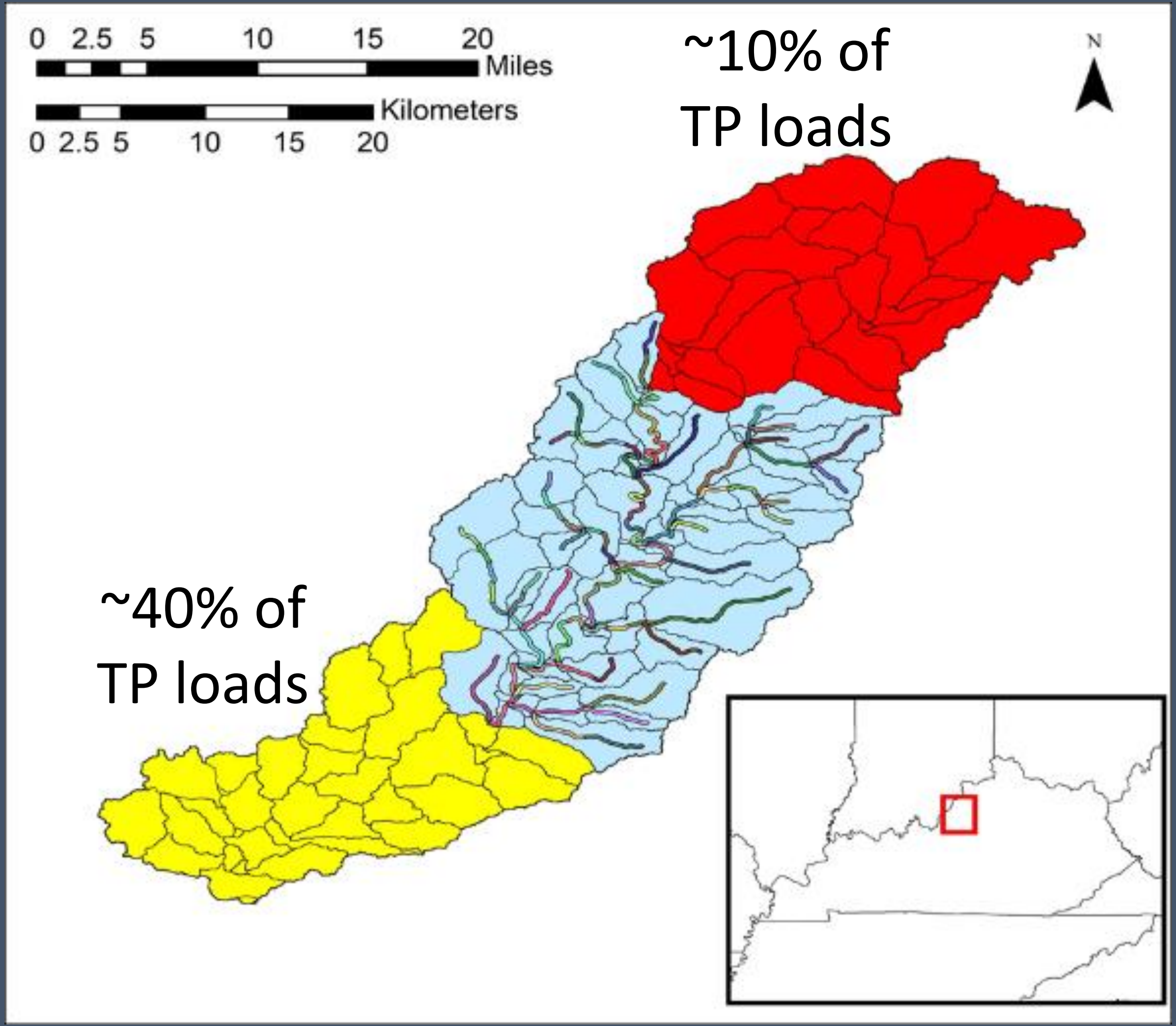
Model objectives: Load assessment



- Identify spatial distribution of nutrient loads
- Identify new monitoring locations
- Inform monitoring plans