Large Rivers: Why Use Models?

Lower Yellowstone River Example

What is a Large River?

- No exact definition in literature; often Strahler Order ≥ 7

- DEQ used wadeability index to identify Montana rivers that were unwadeable (to deep or too fast, or both) during summer/fall baseflow

The Case for Mechanistic Models in Large Rivers

- No comparable reference sites available as for wadeable streams
- Wadeable-stream empirical relationships likely poorly transferable
- Predictive benefits: can observe effects on other water quality standards/ecological endpoints
- Better and more physically-based approaches are needed for large rivers to meet the management needs of regulators and demands of stakeholders

- Response variables related to nutrients that can by modeled:
  - Dissolved oxygen concentrations (DO)
  - Benthic algal biomass (chlorophyll *a*, AFDW) in near-shore areas
  - pH
  - Phytoplankton concentrations
  - Total organic carbon (affects drinking water)
  - Total dissolved gas (as linked via DO)

Yellowstone River Summary

– 181,480 km2 (70,100 mi^2)

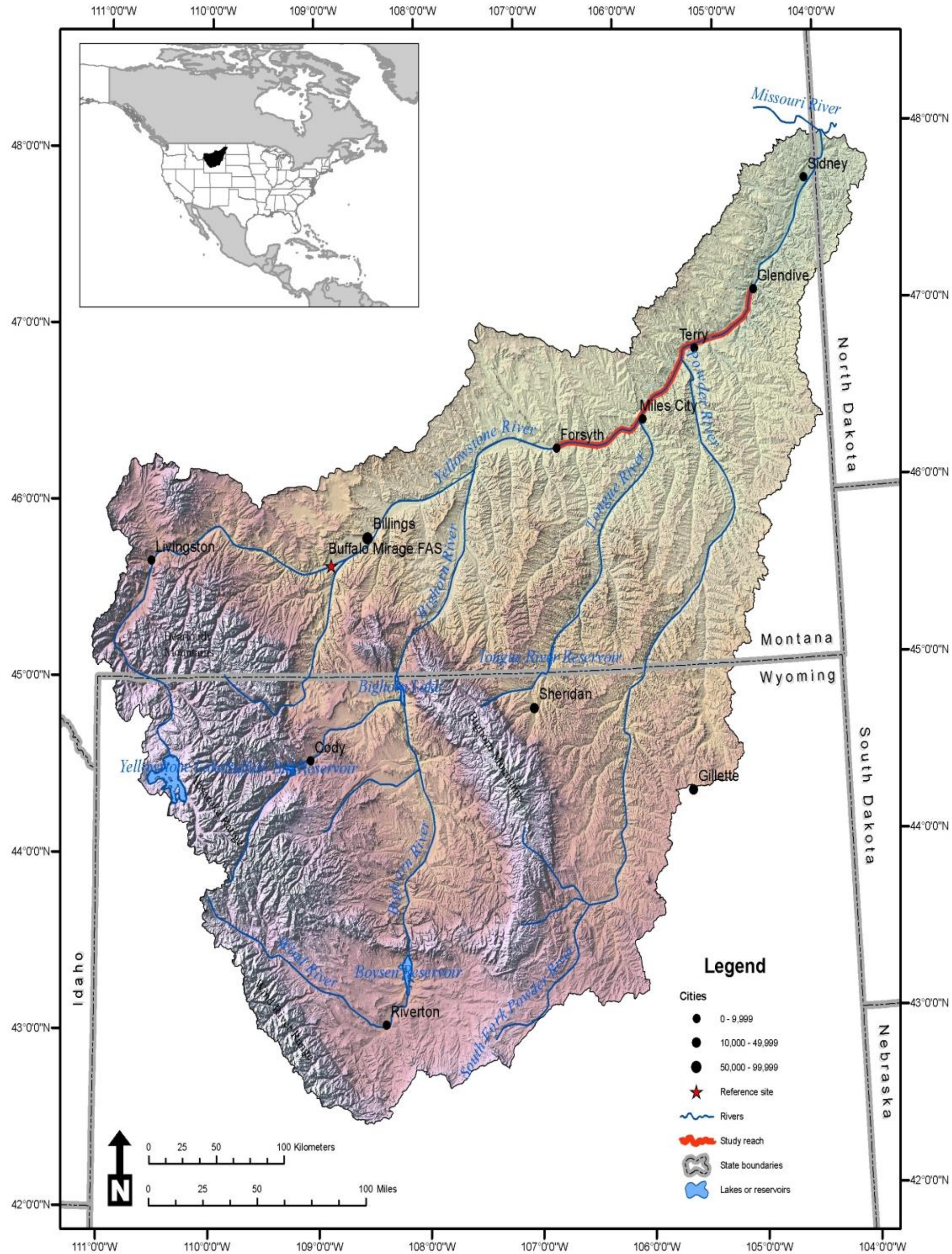
– Study reach 232.9 km or 145 miles

– 55% in Great Plains province

– Population 323,000

– 38 WWTP, 48 CAFO, 78 stormwater, 83 industrial

– Mean Q 348.3 cms (12,300 cfs) with peaks 1,430 cms (50,400 cfs), and low flows near 100 cms (3,280 cfs)



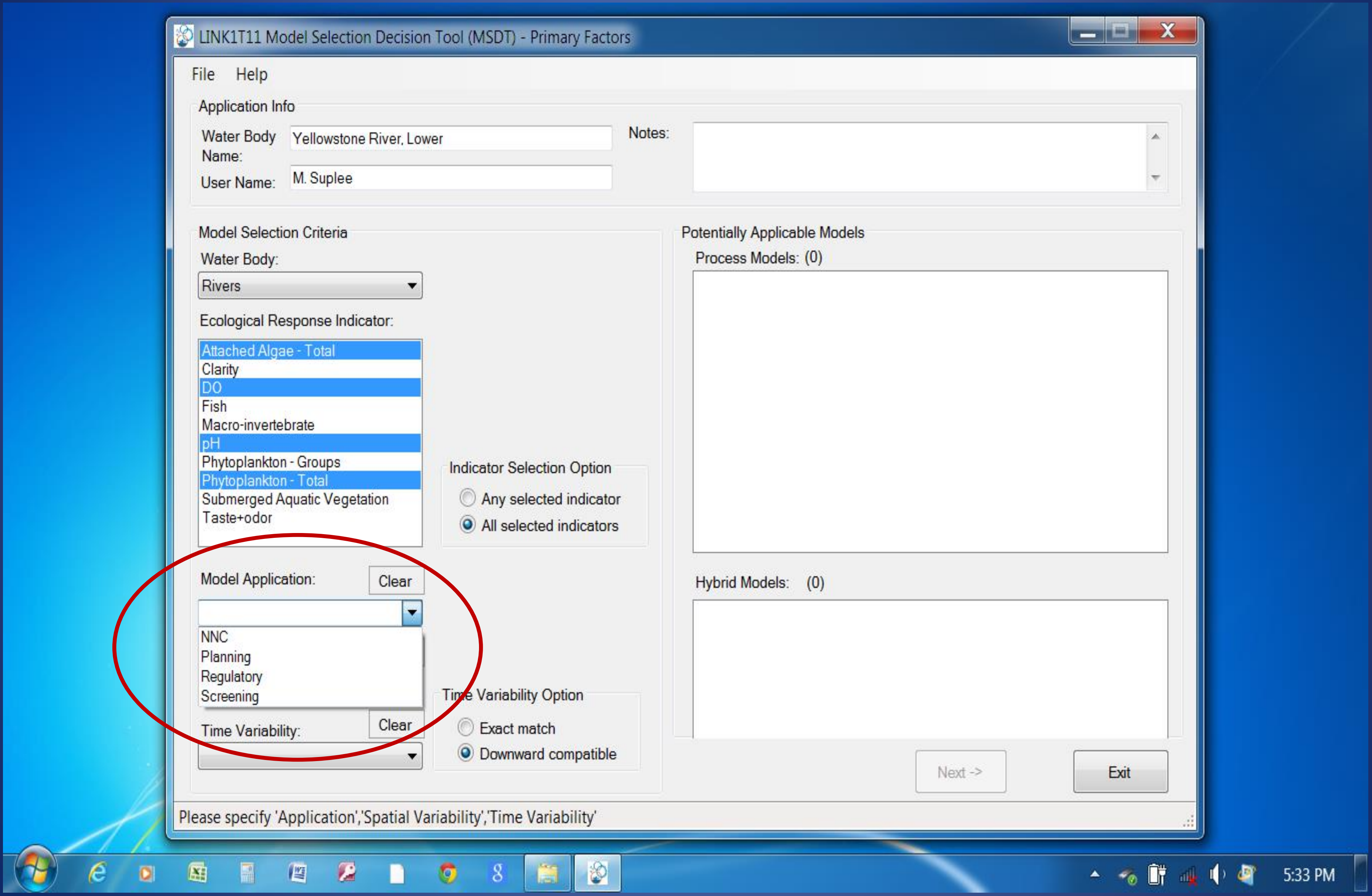
Standards Endpoints / Ecological Response Variables

Segment Description	Use Class	Beneficial Uses
Yellowstone River mainstem from the Billings water supply intake to the North Dakota state line	B-3	Drinking, recreation, non-salmonid fishery and associated aquatic life, waterfowl and furbearers, agricultural and industrial water supply

<u>**Standards for B-3 waters (i.e., lower Yellowstone River):**</u>

1. **Dissolved oxygen levels ≥ 5 mg L^{-1} to protect aquatic life and fishery uses (early life stages; DEQ 2012).**
2. **Total dissolved gas levels, which must be ≤ 110% of saturation to protect aquatic life (Circular DEQ-7).**
3. **Induced variation of hydrogen ion concentration (pH), which must be less than 0.5 pH units within the range of 6.5 to 9.0, or without change if natural is outside this range [ARM 17.30.625(2)(c)] to protect aquatic life.**
4. **Turbidity levels, which a maximum increase of 10 nephelometric turbidity units (NTU) is acceptable; except as permitted in 75-5-318, MCA [ARM 17.30.625(2)(d)] to protect aquatic life.**
5. **Benthic algae levels, which DEQ interprets per our narrative standard (ARM 17.30.637(1)(e) should be maintained below a nuisance threshold of 150 mg Chla m^{-2} to protect recreational use.**

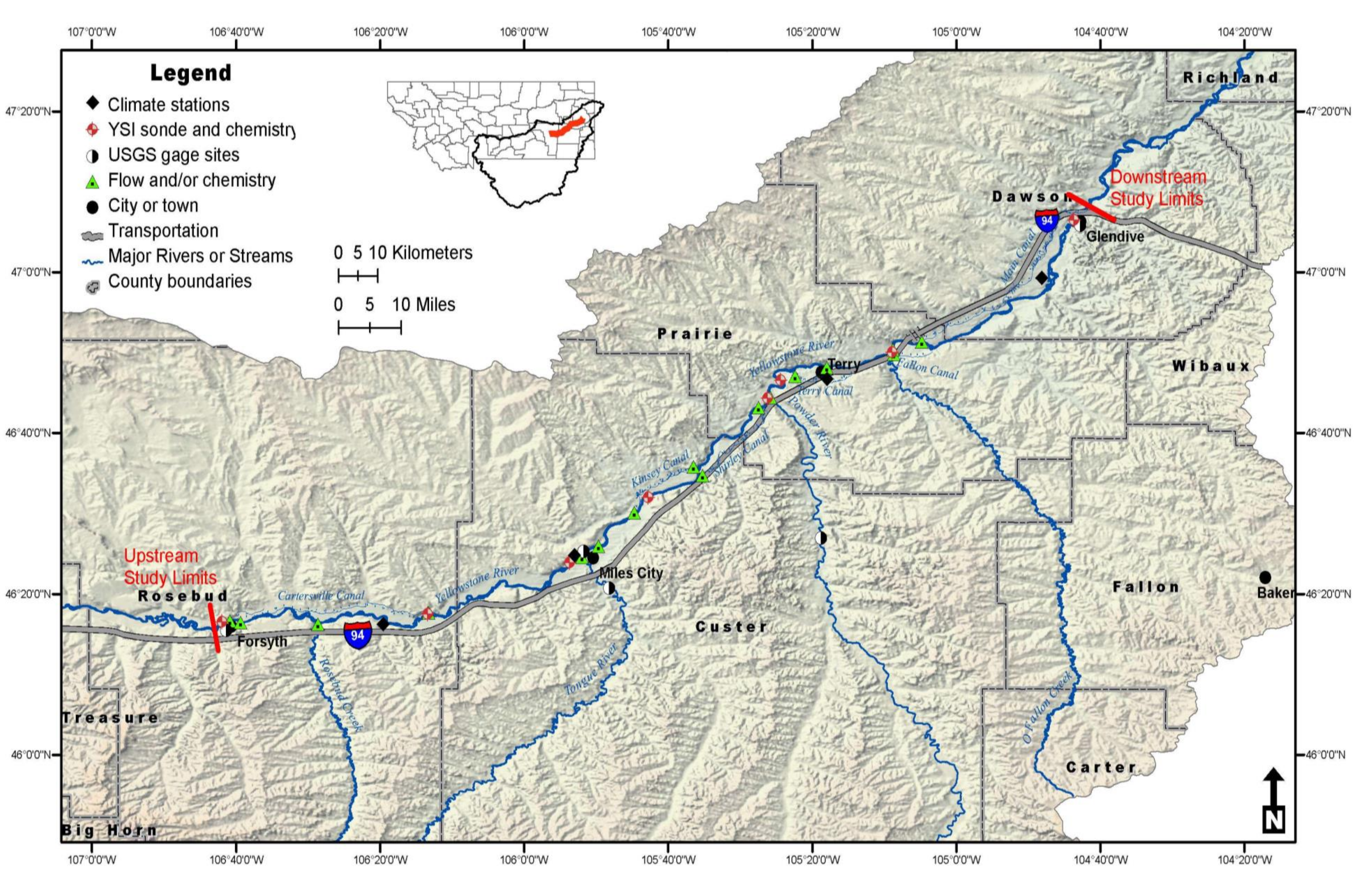
Tools are available to help you choose a model



Model Selected for Yellowstone R.

- Ability to simulate eutrophication response variables
- Spatial considerations (dimensionality)
- Temporal considerations (time-variable vs. steady)
- Endorsement by EPA

	MIKE11	Q2K	WASP
State-variables (DO, pH, benthic algae)	•	•	•
Steady simulation	•	•	•
Dynamic simulation	•		•
Application in TMDLs		•	•
Simplicity		•	
Documentation	•	•	•
User support	•	•	

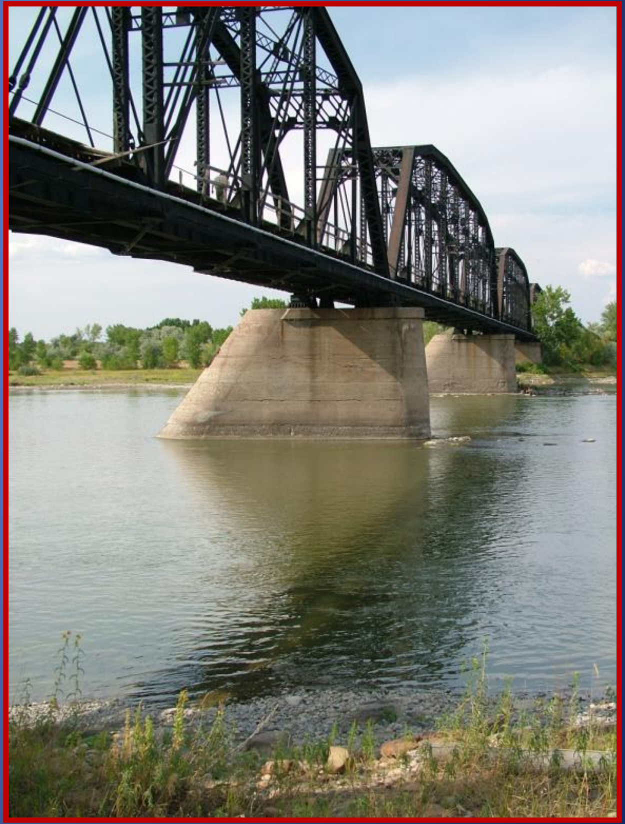

Legend
Climate stations
YSI sonde and chemistry
USGS gage sites
Flow and/or chemistry
City or town
Transportation
Major Rivers or Streams
County boundaries
0 5 10 Kilometers
0 5 10 Miles
Downstream Study Limits
Upstream Study Limits
Richland
Dawson
Glendive
Prairie
Wibaux
Terry
Yellowstone River
Fallon Canal
Terry Canal
Powder River
Shirley Canal
Kinsey Canal
Miles City
Rosebud
Forsyth
Cartersville Canal
Custer
Fallon
Baker
Tongue River
Rosebud Creek
O'Fallon Creek
Treasure
Carter
Big Horn
Main Canal
94
107°0'0"W
106°40'0"W
106°20'0"W
106°0'0"W
105°40'0"W
105°20'0"W
105°0'0"W
104°40'0"W
104°20'0"W
47°20'0"N
47°0'0"N
46°40'0"N
46°20'0"N
46°0'0"N
N

Temporal Considerations

Modeling for the lower Yellowstone River was developed for the time when use-impact potential was maximal

JUNE

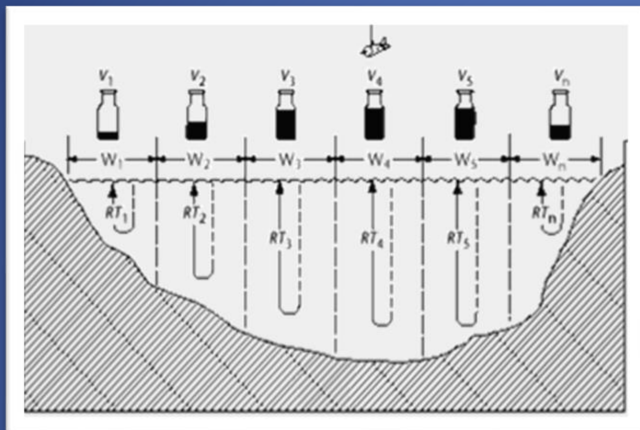
FEBRUARY



AUGUST

Model Data-2007

Water chemistry



Diurnal variables-DO, pH, etc.
(YSI sondes)

Model Calibration and Confirmation

- Details are in a final DEQ technical report (Flynn and Suplee, 2013) at:

https://deq.mt.gov/files/Water/WQPB/Standards/PDF/LowerYellowstoneModel2013/WQPBDMSTECH22FinalCombo.pdf

- And in peer review journals (*available on request*)
  - Ecological Modelling (2013)
  - JAWRA (2015)

Lower Yellowstone River