***Delta Modeling User Group Meeting***
***Sacramento, CA***
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# USACE Plug-In Water Quality Modules Developed for a Variety of Hydrologic and Hydraulic (H&H) Models


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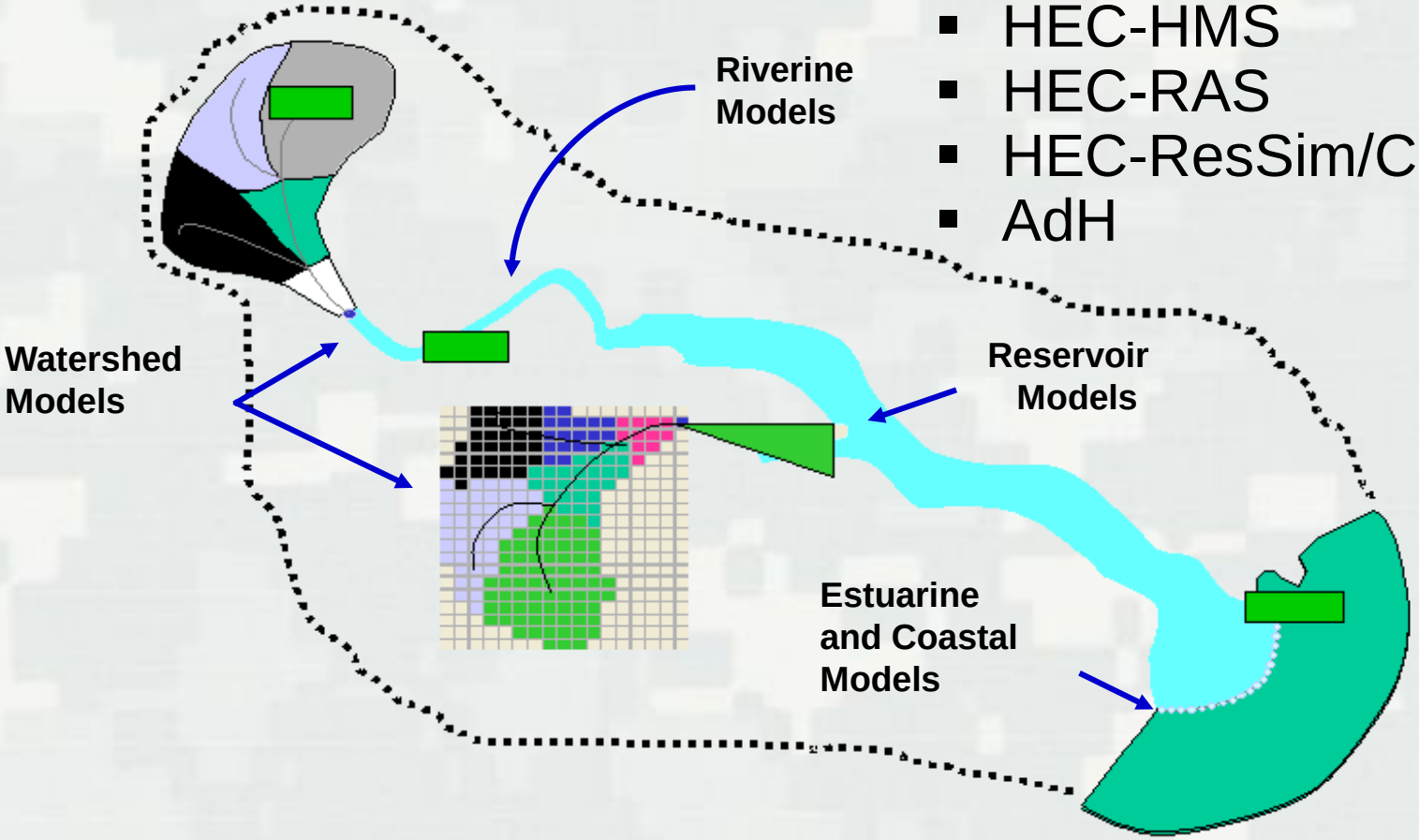
# Outline

- Background
- Water quality modules – dynamic linked libraries
- Water quality capabilities in a variety of H&H models
- Riparian vegetation simulation module

# System Wide Water Resources Program

- GSSHA
- HEC-HMS
- HEC-RAS
- HEC-ResSim/CE-QUAL-W2
- AdH

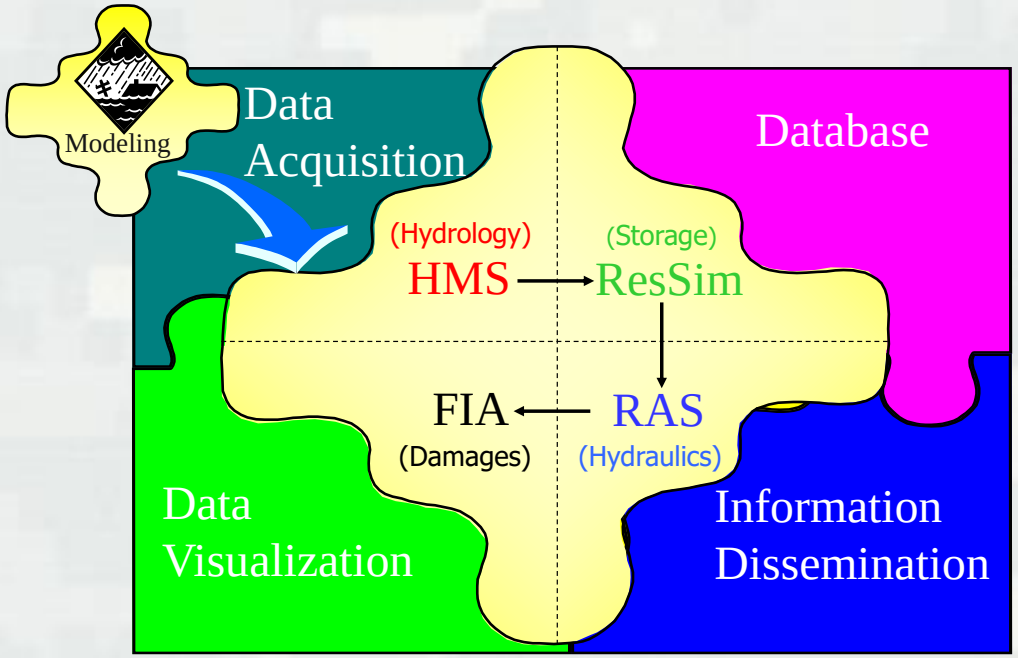


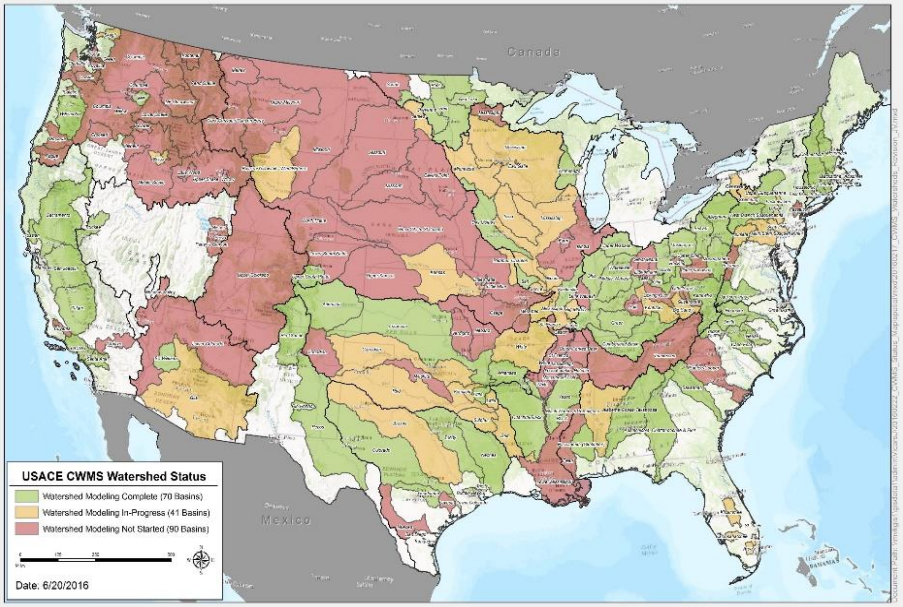
# Ecosystem Management and Restoration Research Program

- EMRRP products focus on cost-effective, science-based impact assessment, restoration, and management technologies for the Corps' water resource managers.
- EMRRP is targeted toward ecosystems of particular concern to the Corps, namely: streams, riparian and other floodplain, wetlands, and aquatic systems.

# Corps Water Management System (CWMS)

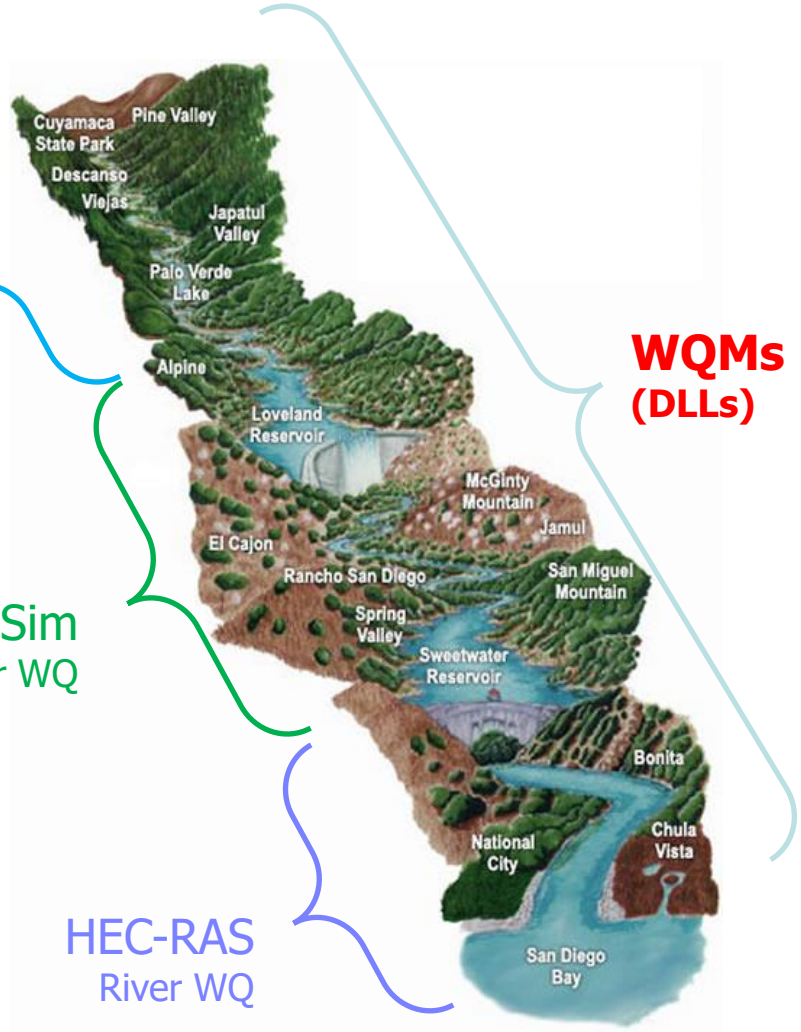
- CWMS provides real-time decision support for water management
- Features:
  - Real-time data acquisition
  - Database storage
  - Flow forecasting of watershed runoff
  - Reservoir operation decision support
  - River profile modeling
  - Inundated area determination
  - Consequence/damage analysis
  - Information dissemination
- Implementation: 201 CWMS systems by 2022




Courtesy of Todd Staissberg

# Real-Time Fully Integrated H&H Models in CWMS




HEC-HMS
Runoff WQ

HEC-ResSim
Reservoir WQ

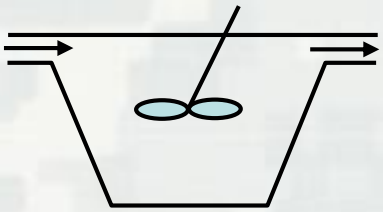
HEC-RAS
River WQ

**WQMs**
**(DLLs)**

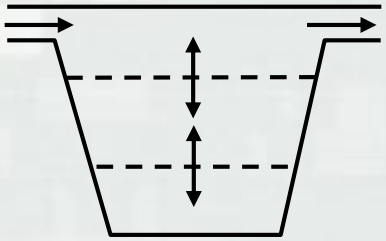
Courtesy of Todd Staissberg

# H&H Models

- Completely mixed (0-order)
- One dimensional (1-D)
  - Longitudinal/Vertical
- Two dimensional (2-D)
  - Longitudinal and vertical
  - Depth averaged
- Three dimensional (3-D)

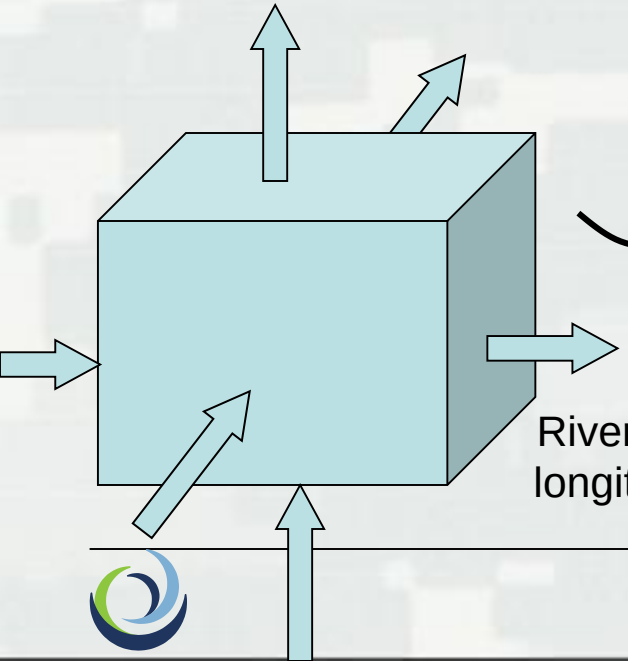


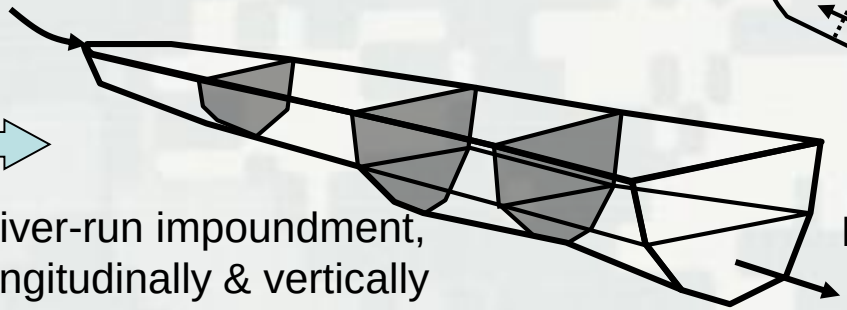
Completely mixed reactor



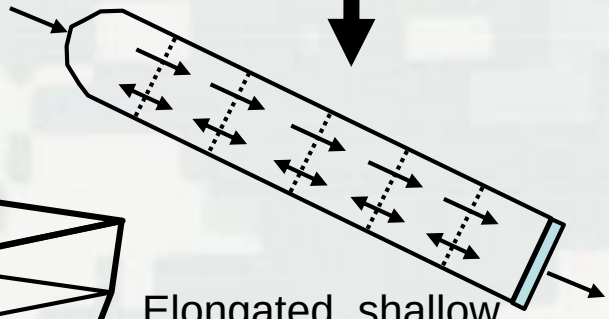
Deep, vertically segmented

**More data**





River-run impoundment, longitudinally & vertically segmented

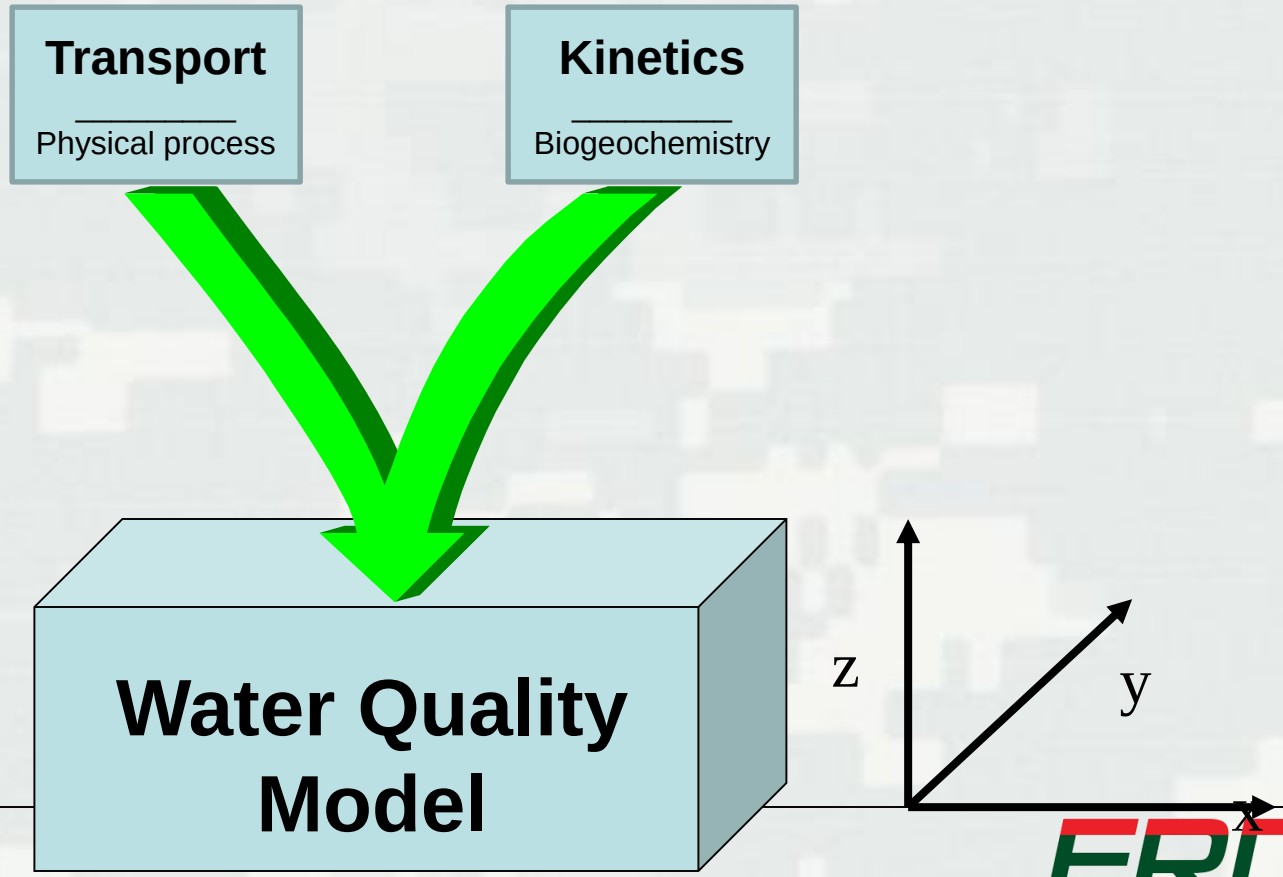


Elongated, shallow, longitudinally segmented

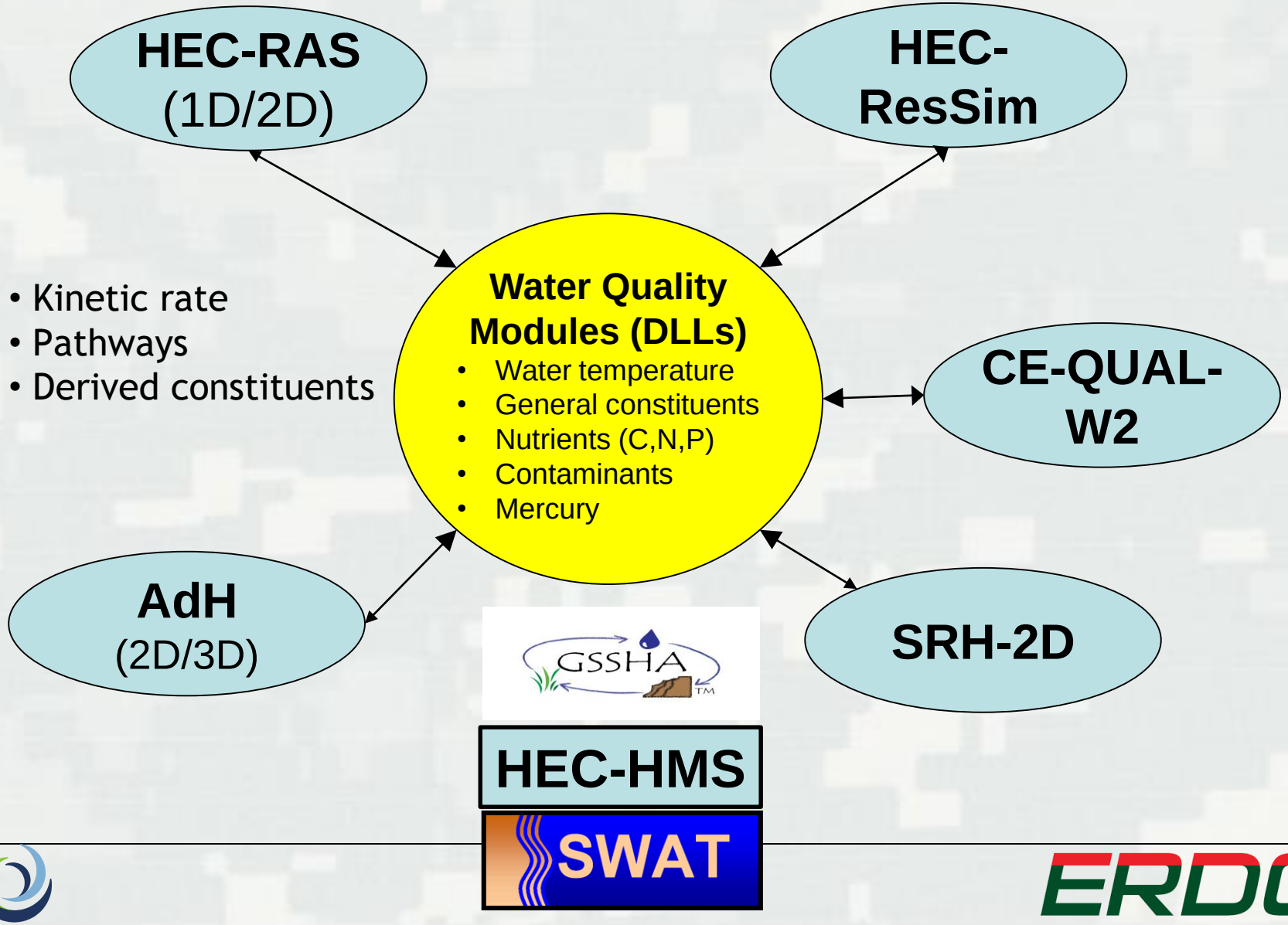
# A Water Quality Model

## 3-D Transport Equation

$$\frac{\partial C}{\partial t} = -\frac{\partial U_x C}{\partial x} + \frac{\partial}{\partial x}\left(E_x \frac{\partial C}{\partial x}\right) - \frac{\partial U_y C}{\partial y} + \frac{\partial}{\partial y}\left(E_y \frac{\partial C}{\partial y}\right) - \frac{\partial U_z C}{\partial z} + \frac{\partial}{\partial z}\left(E_z \frac{\partial C}{\partial z}\right) \boxed{\pm \textit{Sources and Sinks}}$$



# Plug-In Water Quality Modules




- Kinetic rate
- Pathways
- Derived constituents

# Plug-in Water Quality Modules

- Modules
  - Water Temperature Simulation Module (TEMP)
  - General Constituent Simulation Module (GC)
  - Solid Simulation Module (SED)
  - Nutrient Simulation Module I (NSMI + SedFlux)
  - Nutrient Simulation Module II (NSMII + SedFlux)
  - Contaminant Simulation Module (CSM)
  - Mercury Simulation Module (HgSM)
- References

**Aquatic Nutrient Simulation Modules (NSMs) developed for hydrologic and hydraulic models** http://acwc.sdp.sirsi.net/client/en_US/search/asset/1048348

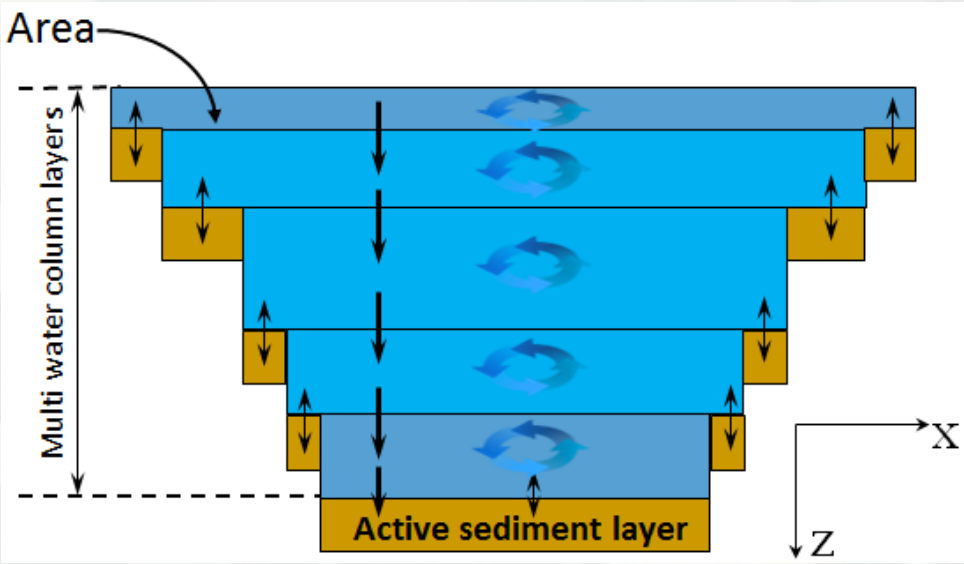
**Application and Evaluation of the HEC-RAS-Nutrient Simulation Module (NSMI)** http://acwc.sdp.sirsi.net/client/en_US/search/asset/1035283

**Aquatic Contaminant and Mercury Simulation Modules developed for hydrologic and hydraulic models** http://acwc.sdp.sirsi.net/client/en_US/default/index.assetbox.assetactionicon.view/1050727

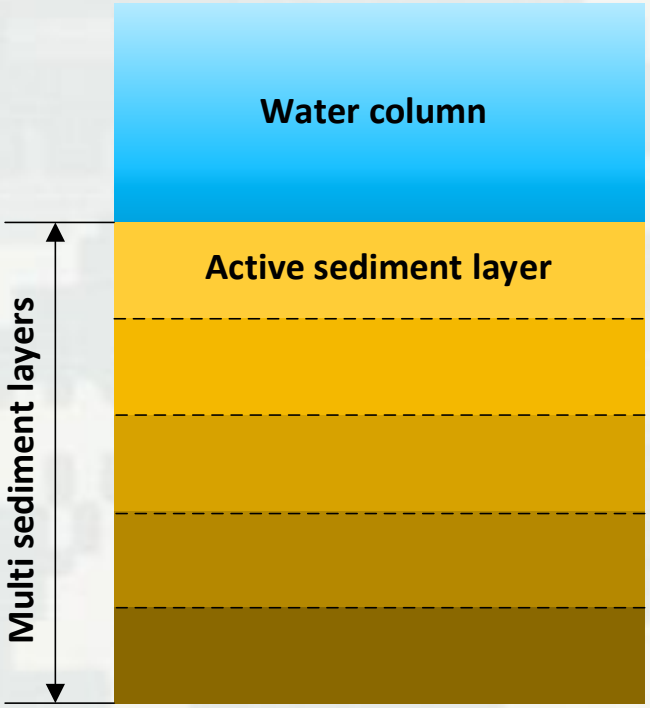
**Verification and Evaluation of Aquatic Contaminant Simulation Module (CSM)** http://acwc.sdp.sirsi.net/client/en_US/search/asset/1050988

# Water Quality Modules (DLLs) – Kinetics (Biogeochemical Reactions)

## Water column




## Bed sediment



# Nutrient Simulation Modules

**EUTROPHICATION**
Excessive plant growth

**PHYTOPLANKTON**
**Floating microscopic algae**

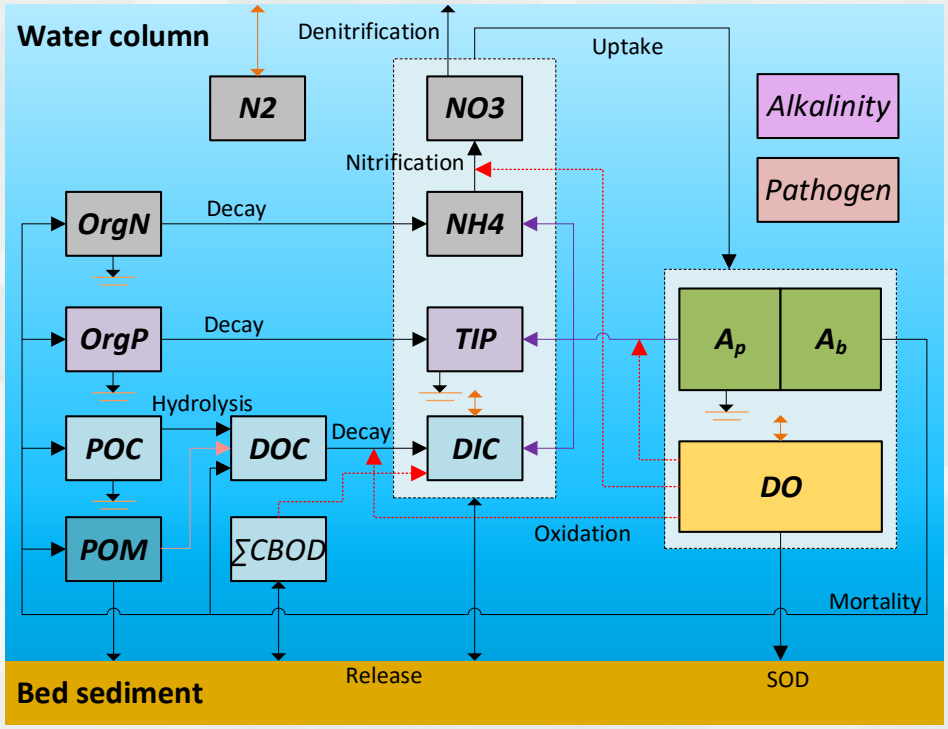
**PERIPHYTON & FILAMENTOUS ALGAE**
**Attached algae**

**MACROPHYTES**
**Higher vascular rooted plants**

Predominently in shallow systems (streams or nearshore regions of lakes & estuaries)

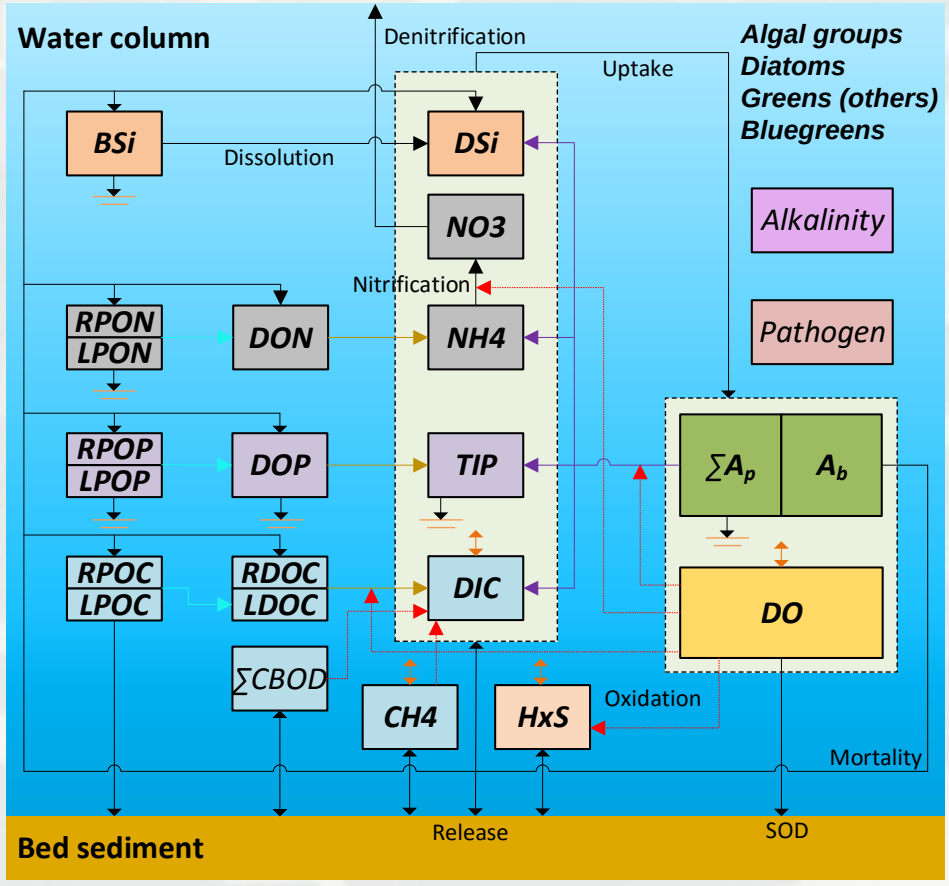
# Nutrient Simulation Modules

## NSMI



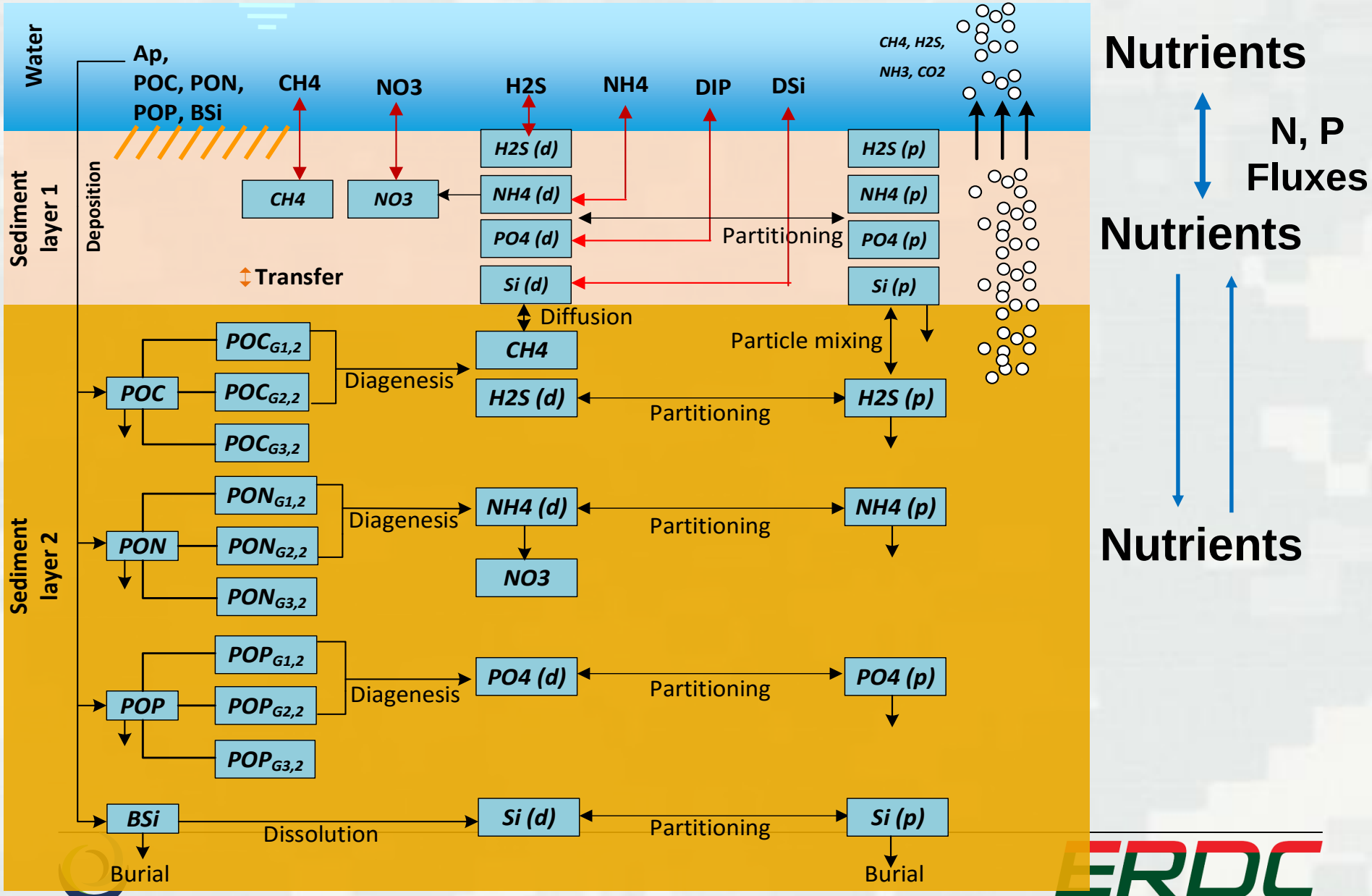

Respiration Dissolution Atmospheric reaeration Settling

## NSMII




Respiration Hydrolysis Mineralization Atmospheric reaeration Settling

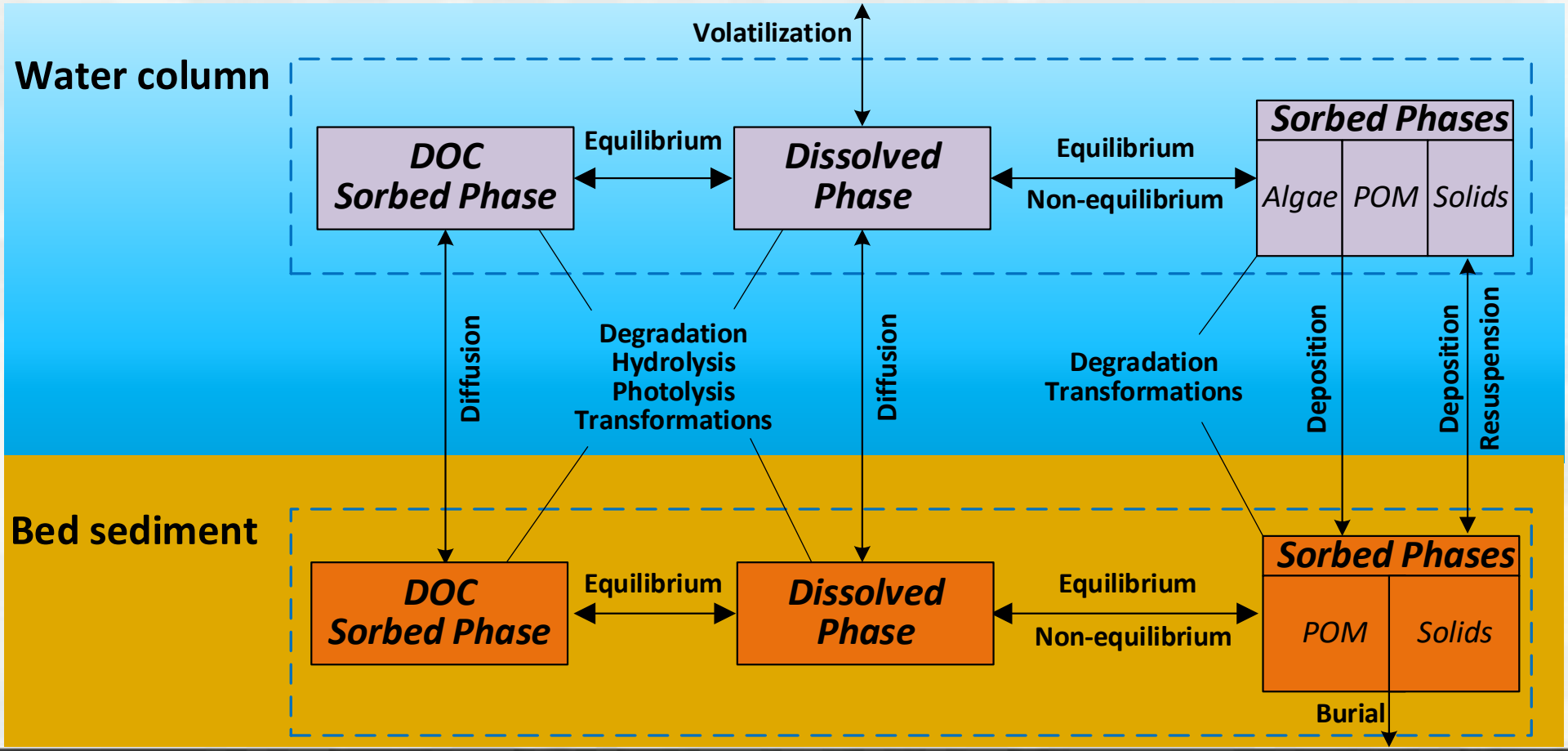
# Sediment Diagenesis Module



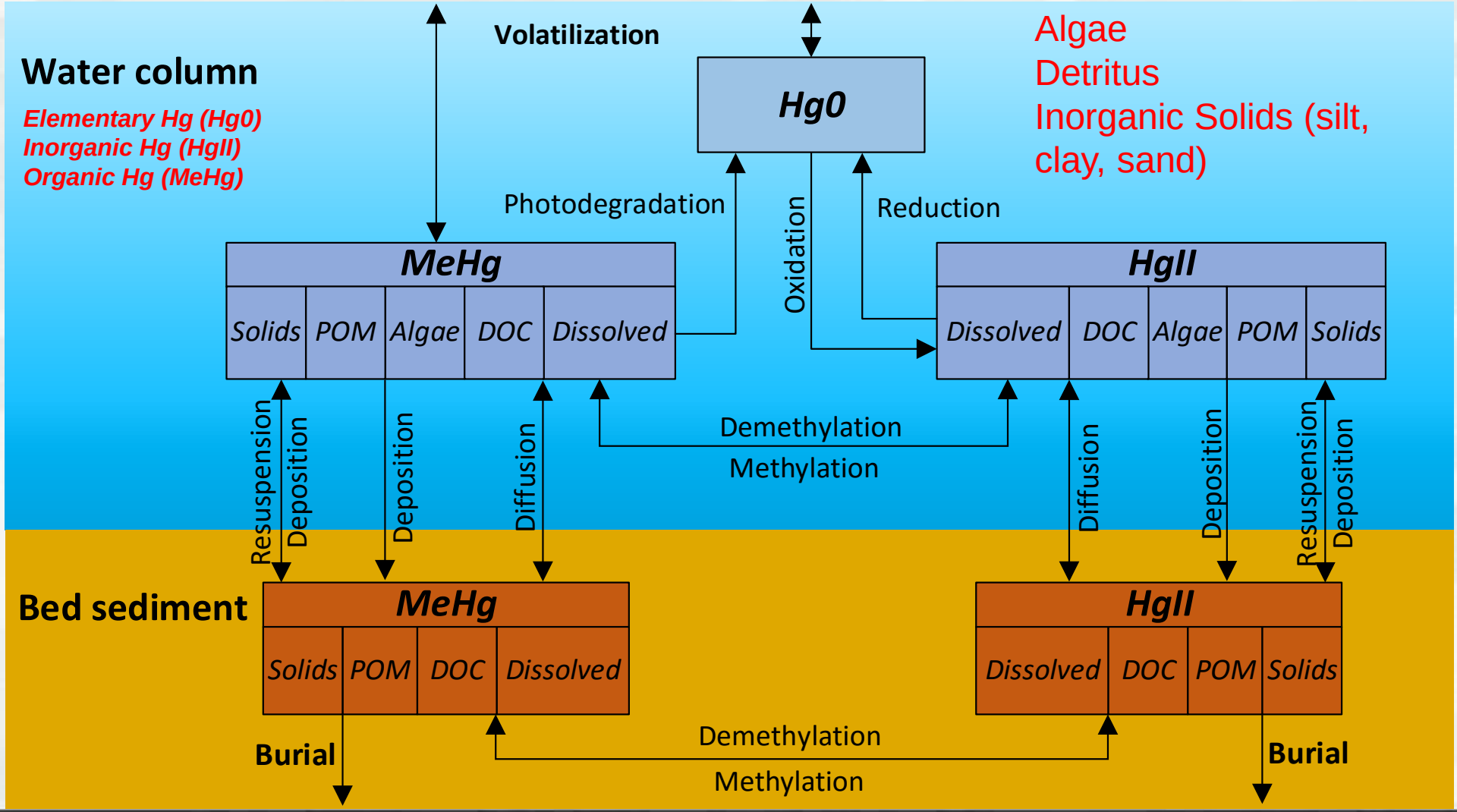
# Contaminant Simulation Module

- Soluble
- Complexes with organic ligands

- Algae
- Detritus
- Inorganic Solids (silt, clay, sand)



# Hg Simulation Module



# HEC-ResSim (Reservoir System Simulation) Water Quality

***Water quality should influence flows***

*Releases*

WQ Rules

WQ Libraries

HEC-ResSim

Evaluate Flow and WQ at every time step

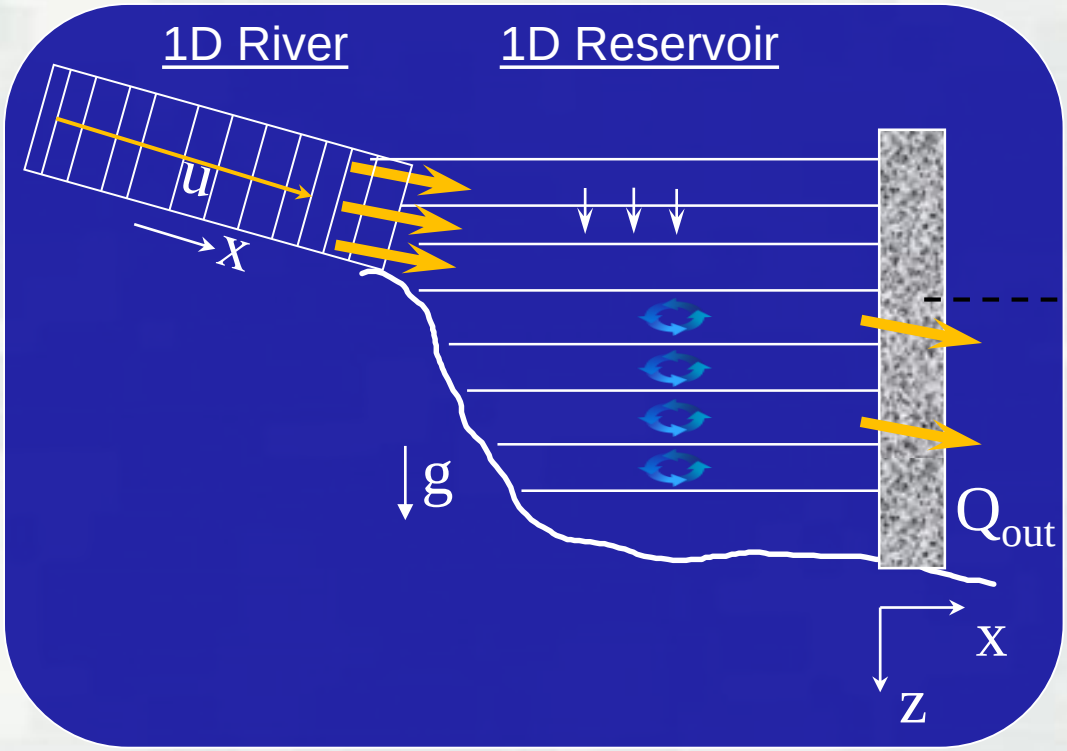
Decision Engine

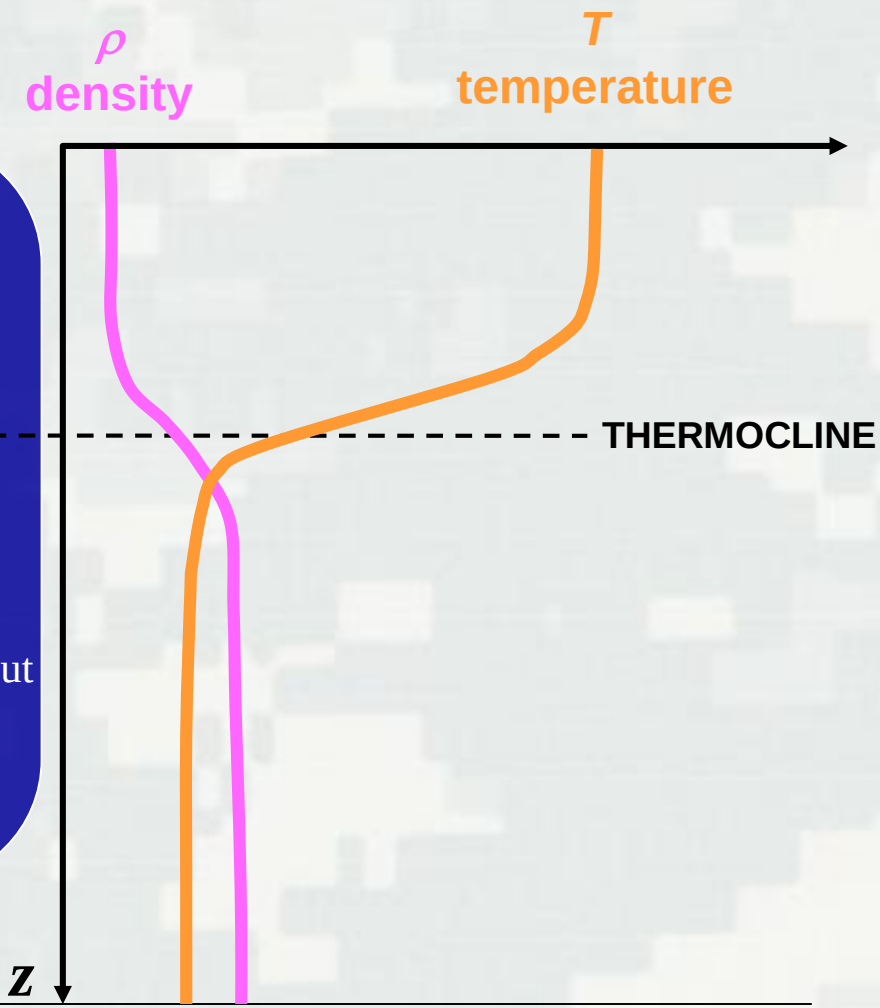
WQ Engine

Courtesy of Todd Staissberg

ERDC

# HEC-ResSim Water Quality

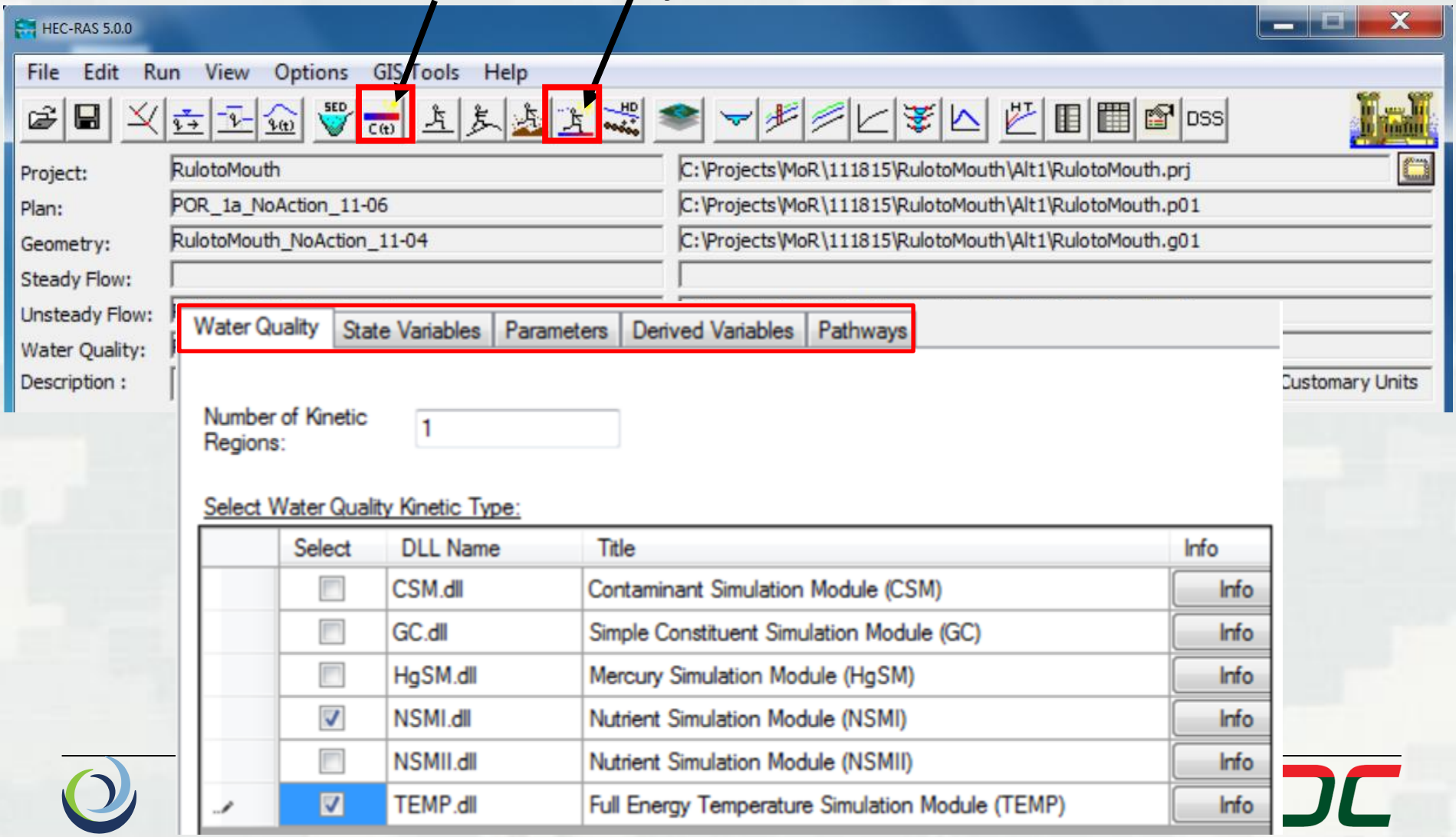


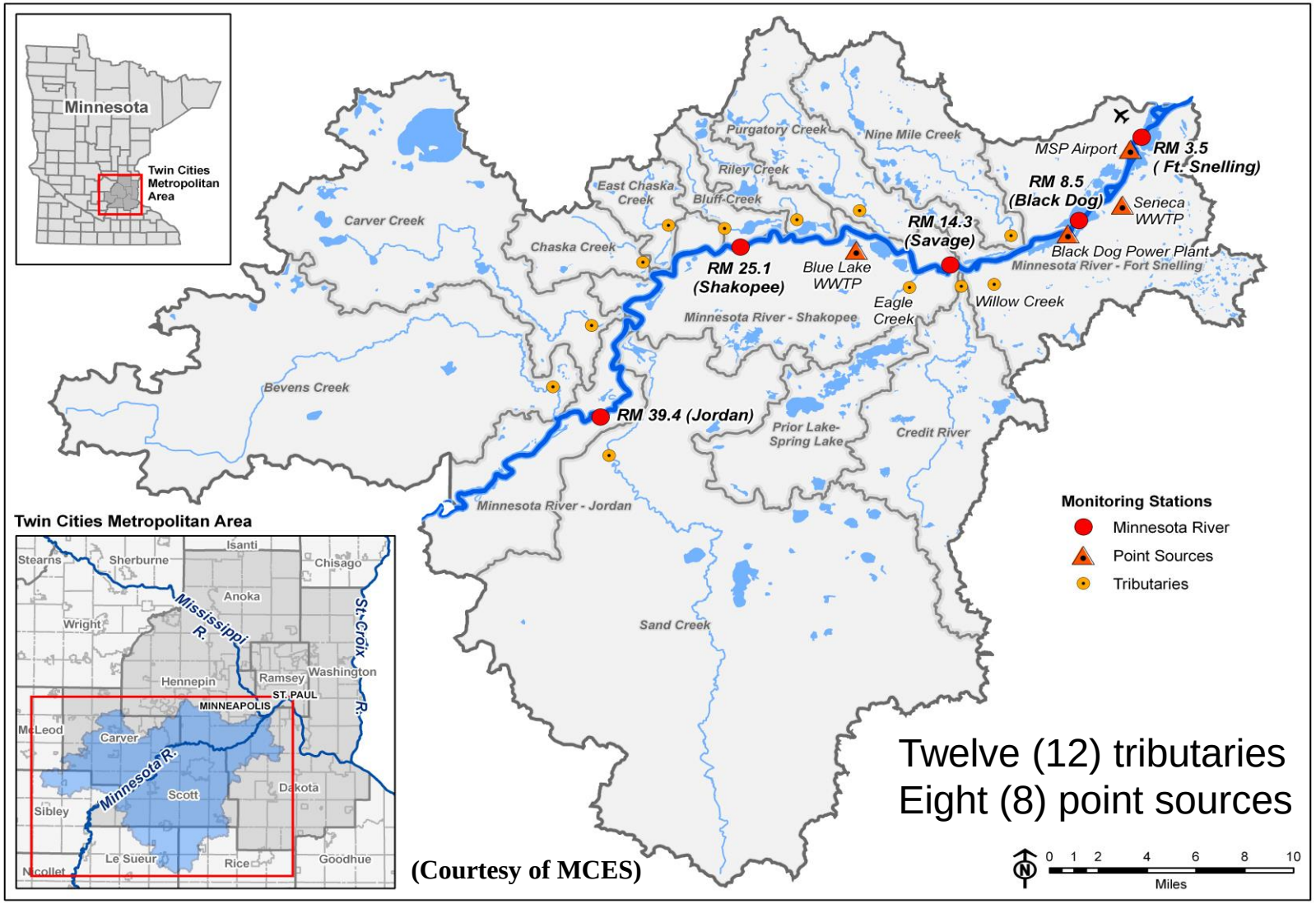
# HEC-RAS (River Analysis System) Water Quality

Water Quality Data

Water Quality Analysis



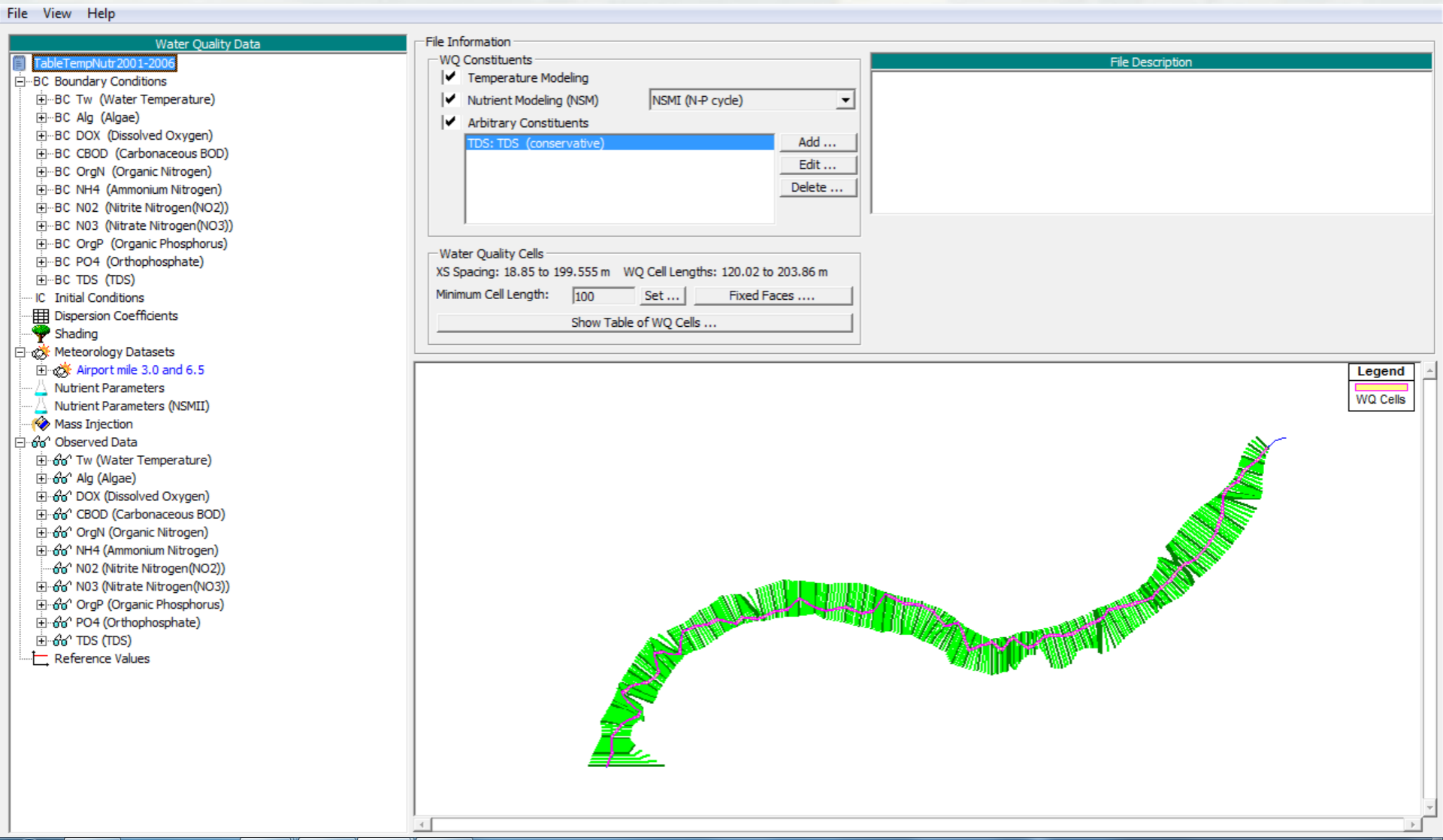
# Lower Minnesota River TMDL



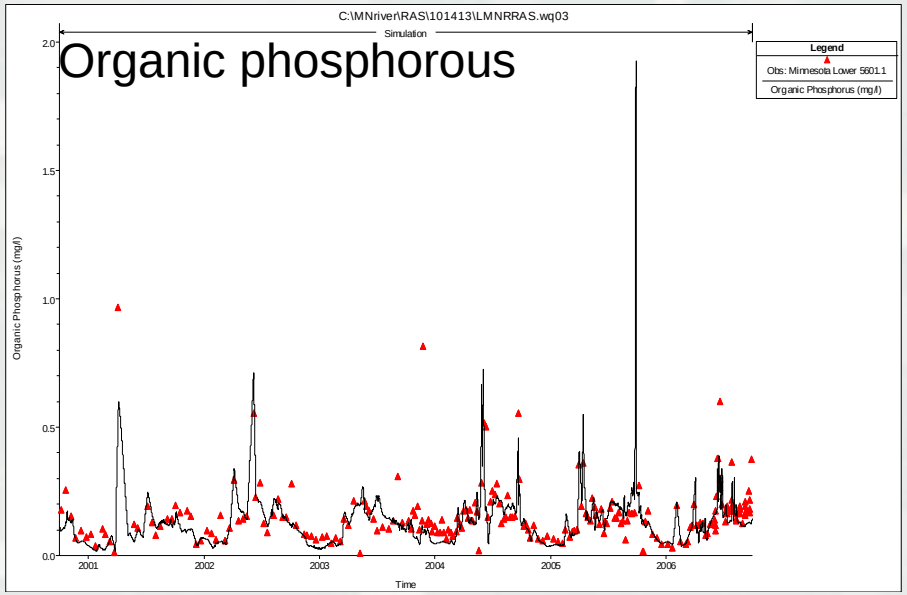

Twelve (12) tributaries
Eight (8) point sources

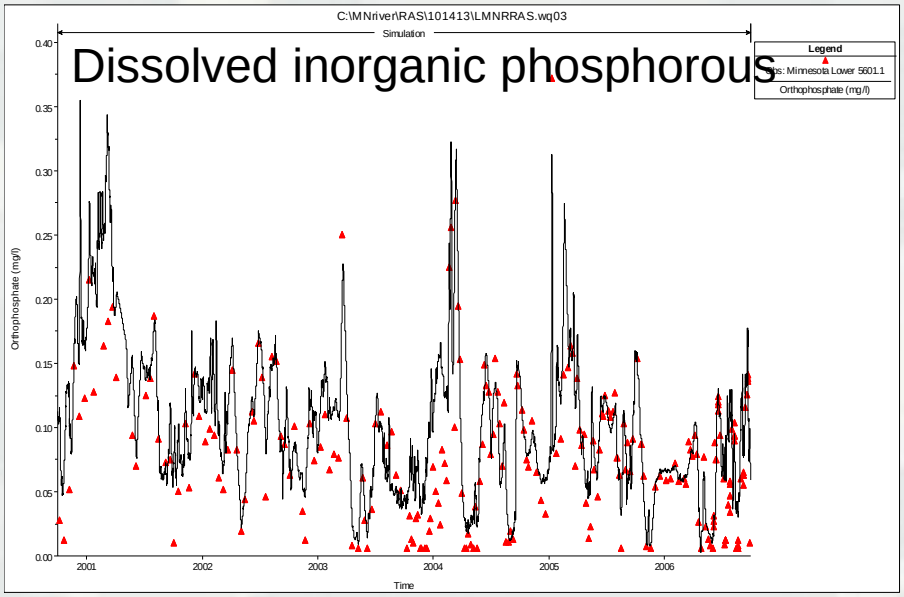
(Courtesy of MCES)

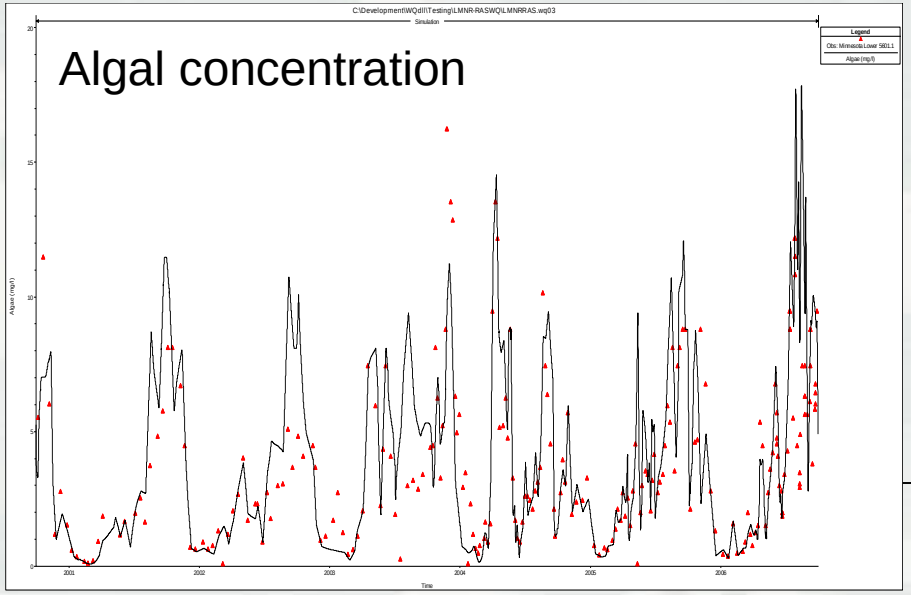
# Lower Minnesota River HEC-RAS Water Quality Model

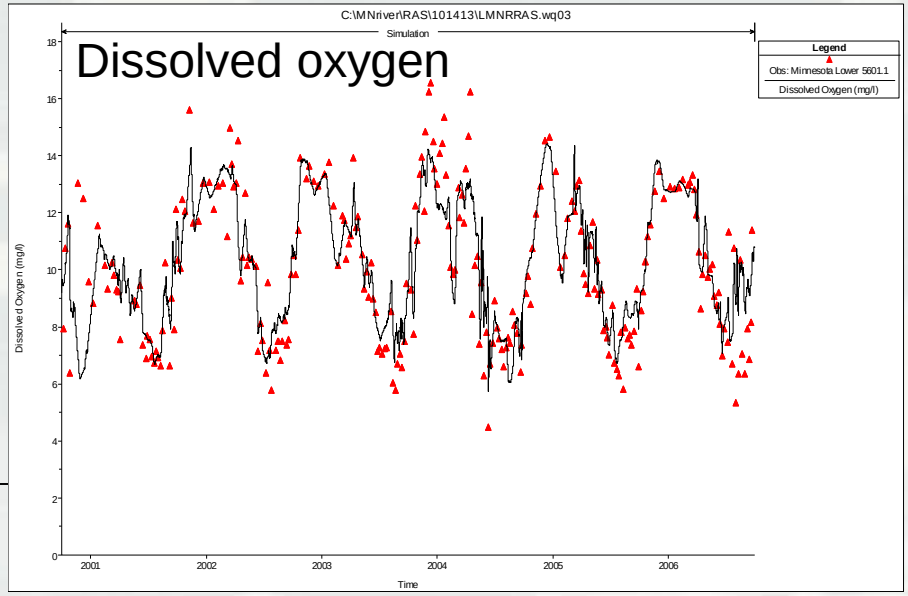


# Comparison of Modeled Results and Observed Data at RM 3.5



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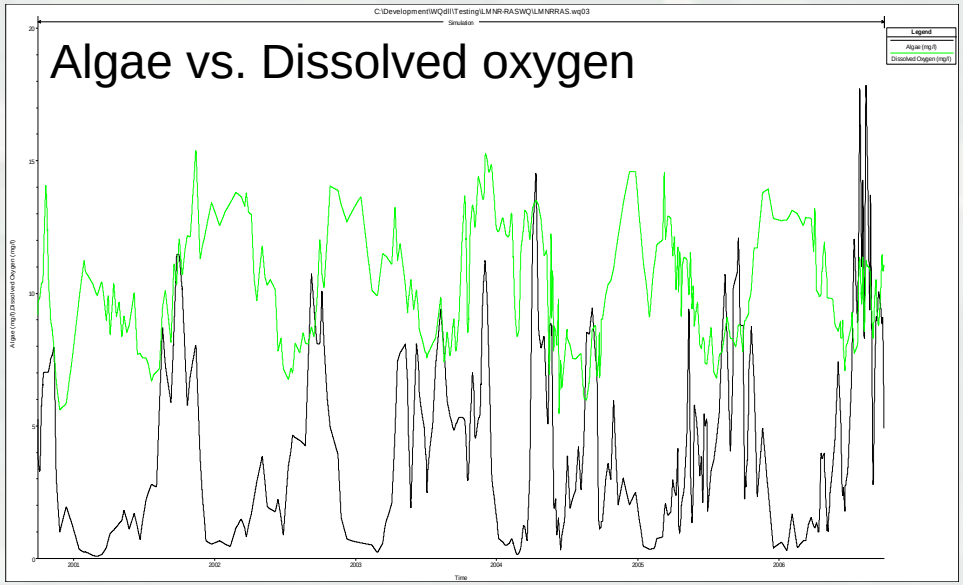
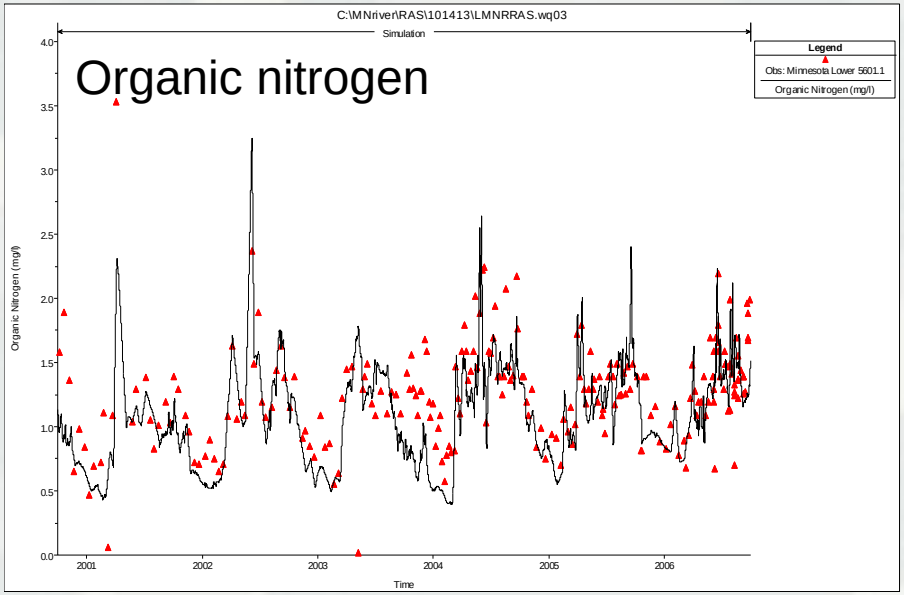
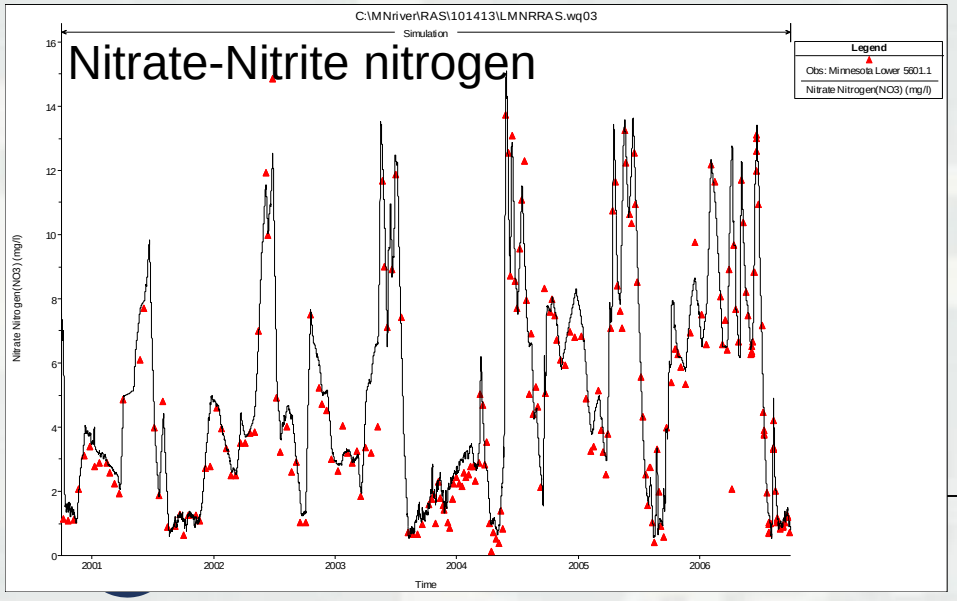
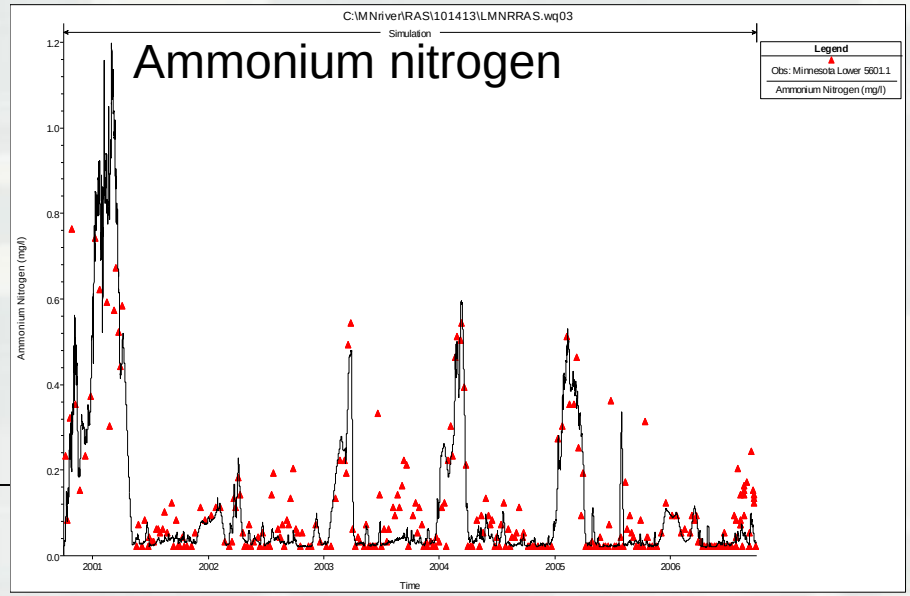
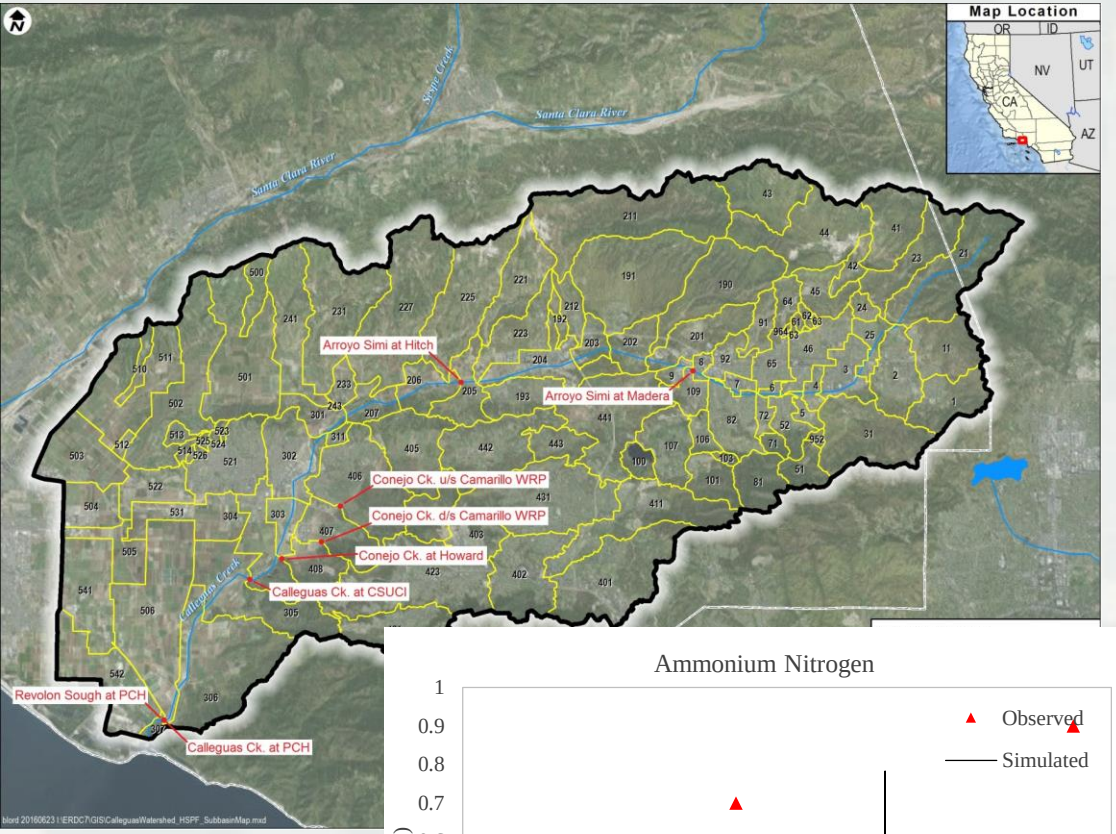


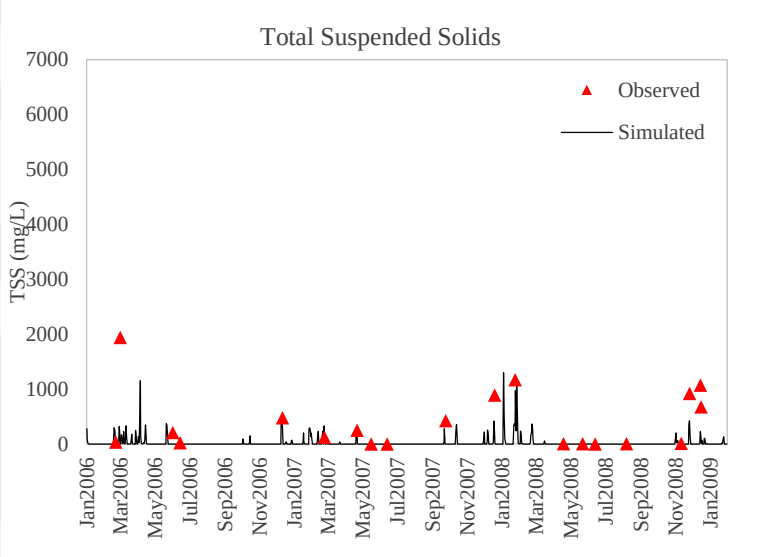



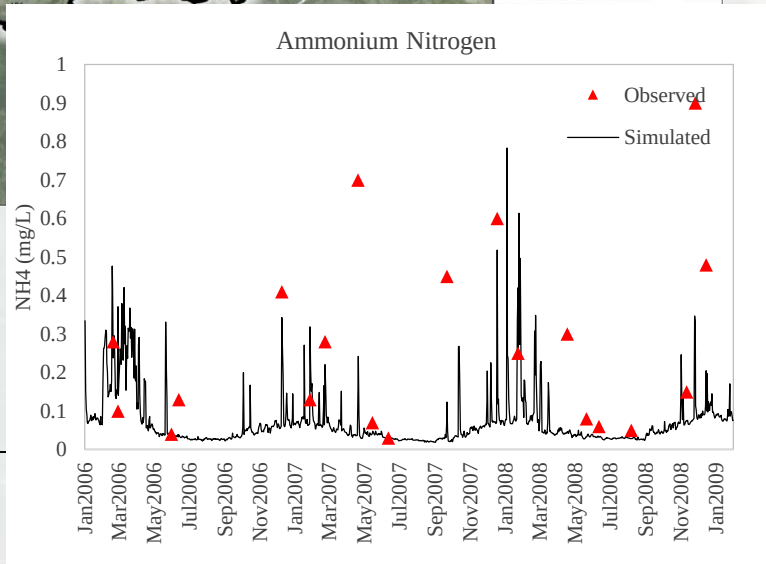



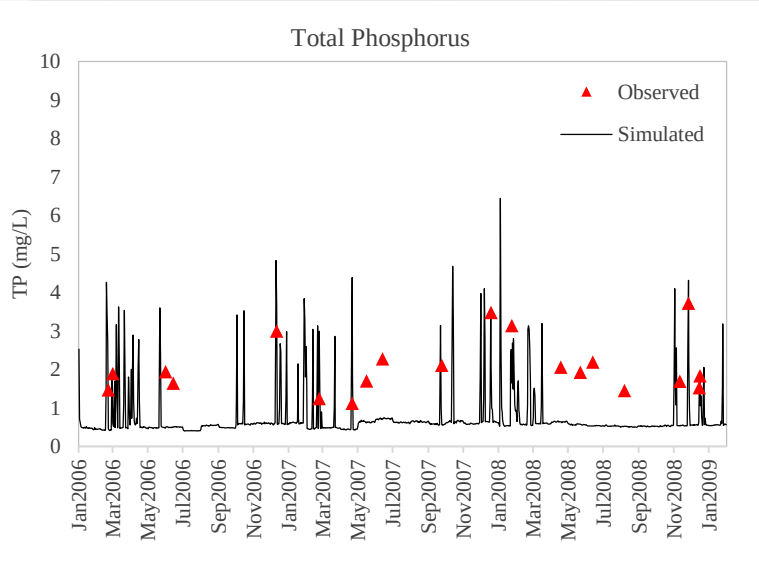



# Linked HSPF and HEC-RAS model for the Calleguas Creek Watershed

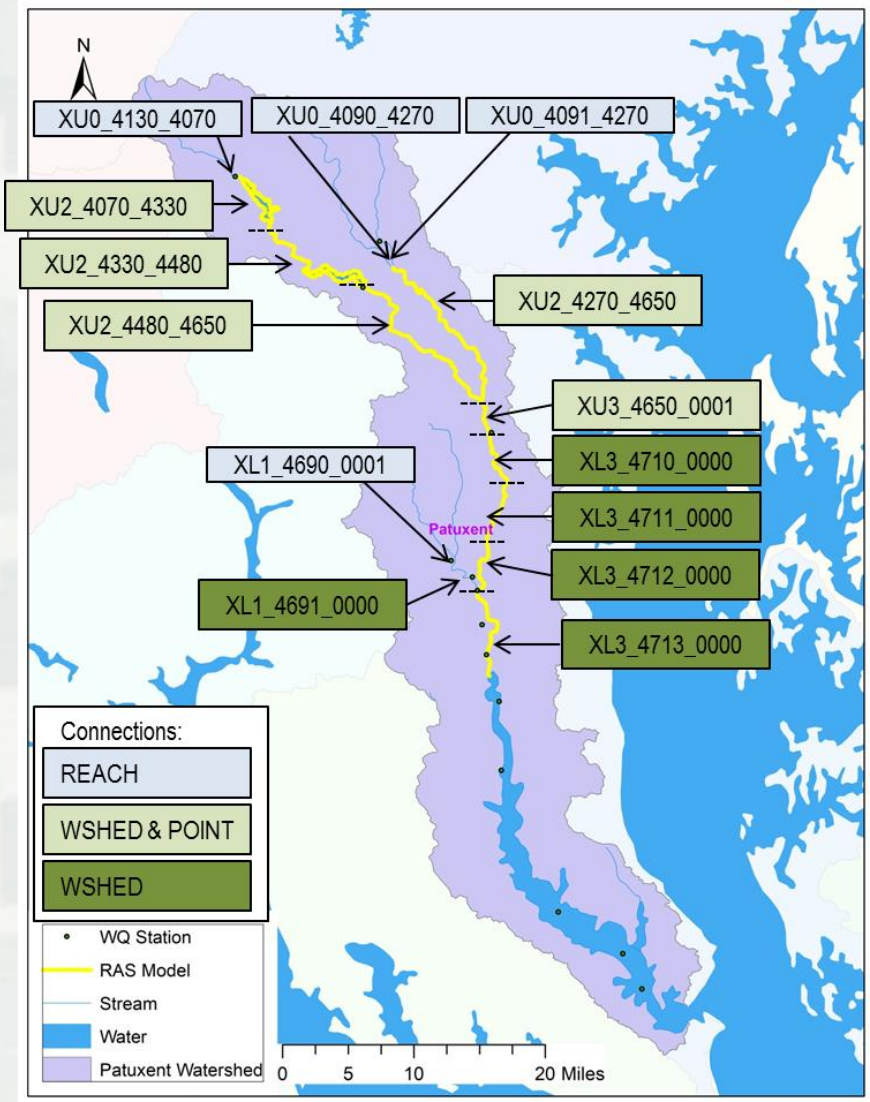


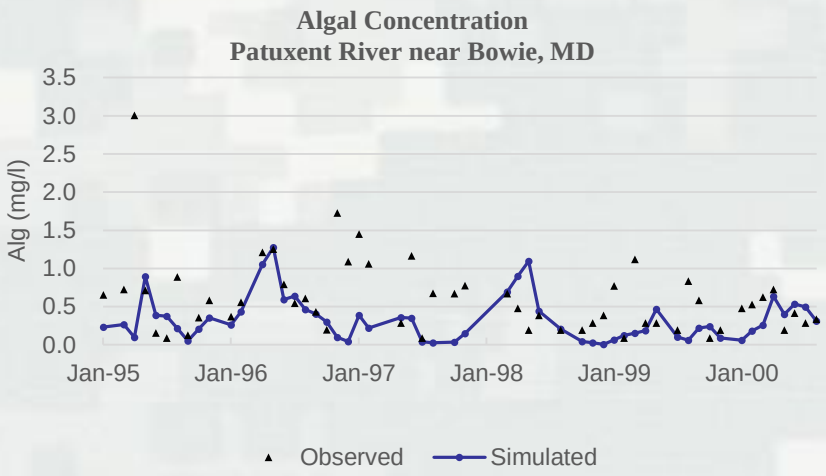



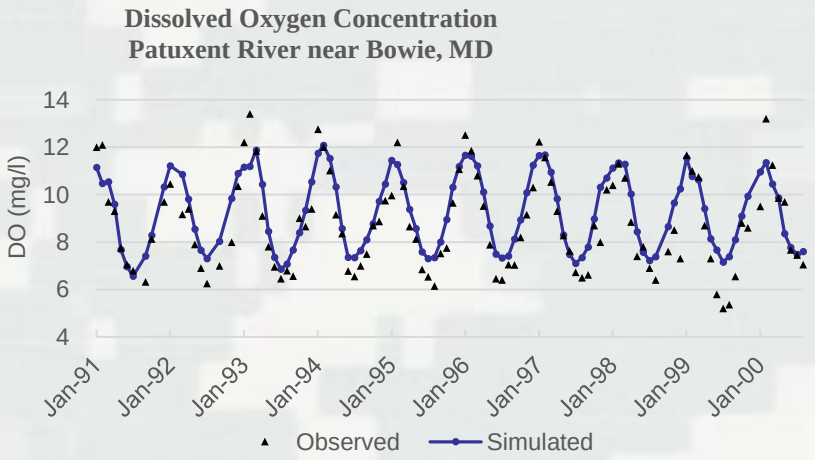



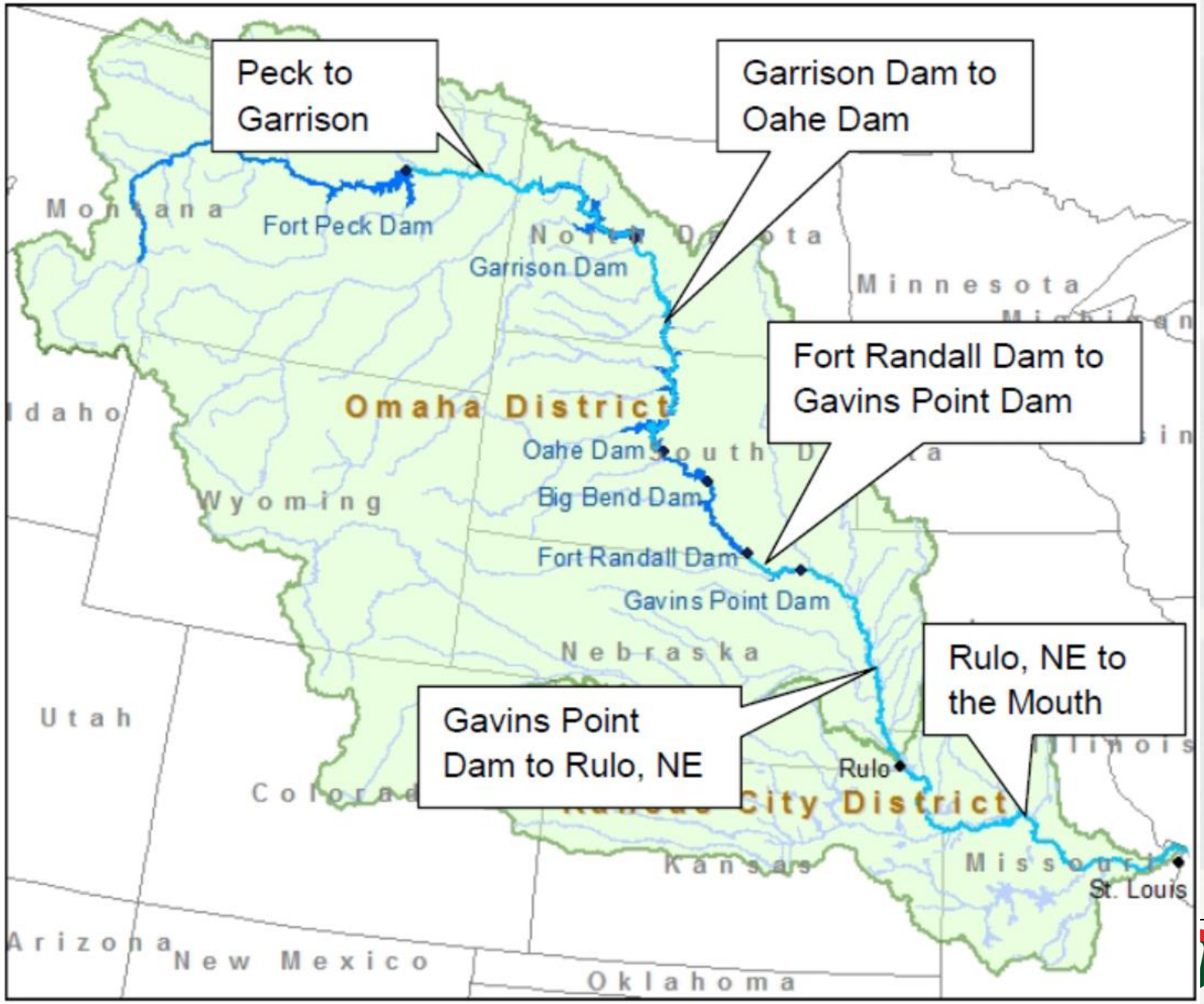
# Linked HSPF and HEC-RAS model for the Patuxent Watershed



# Missouri River Recovery Management Plan



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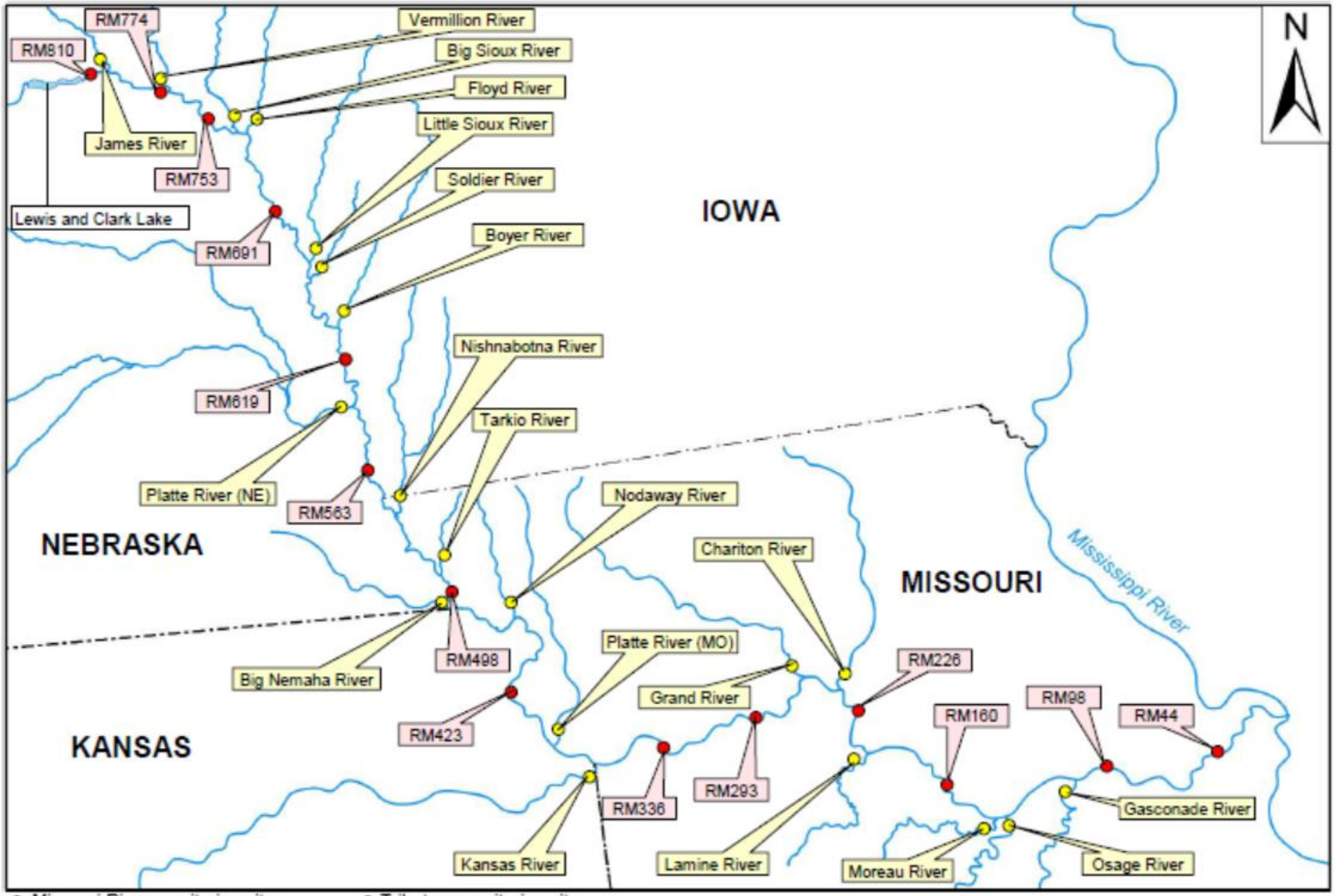

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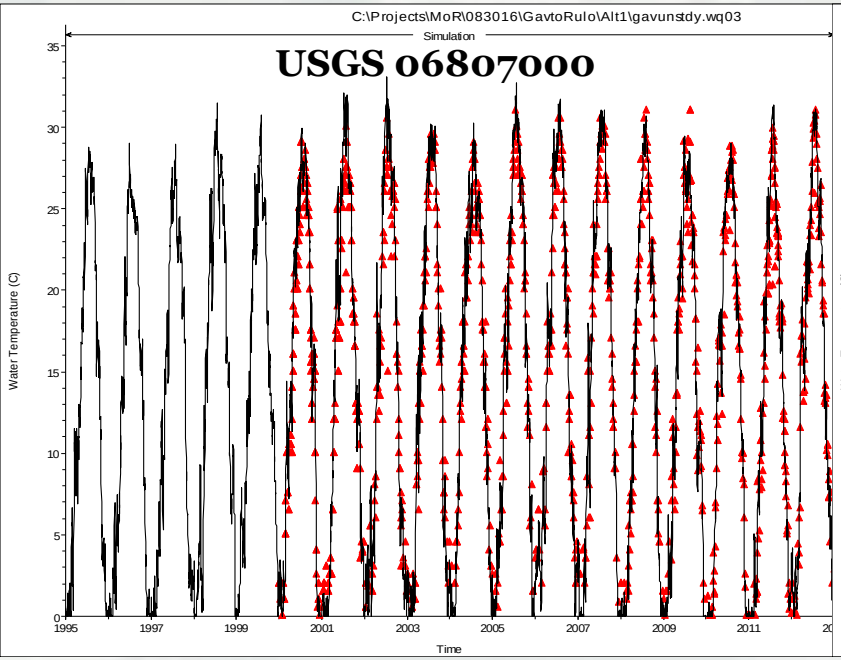
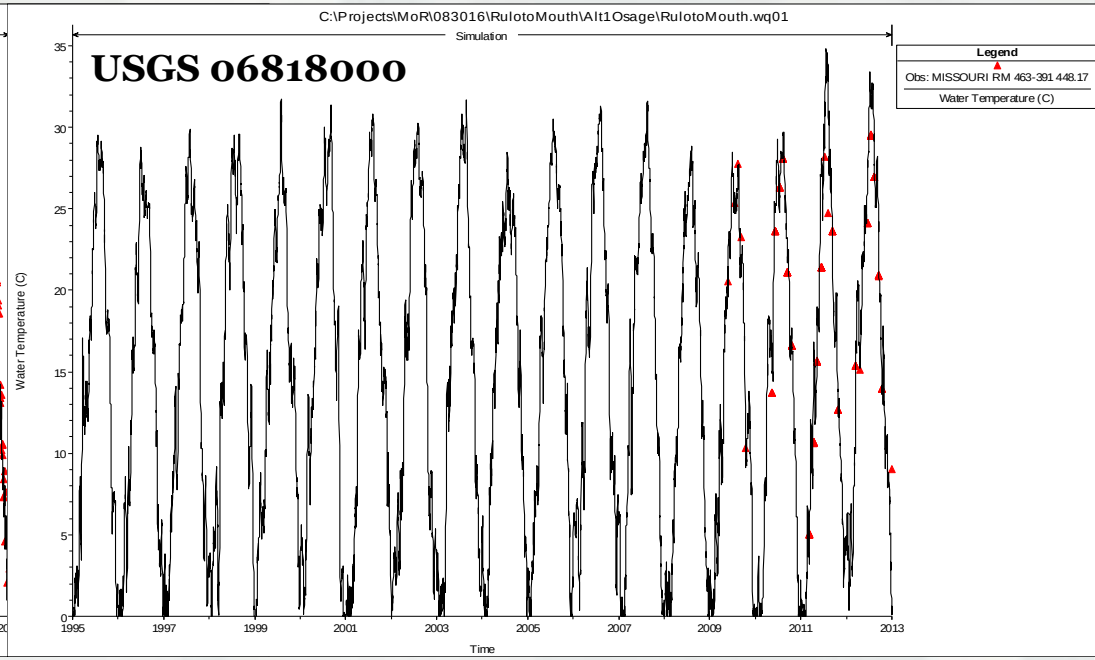
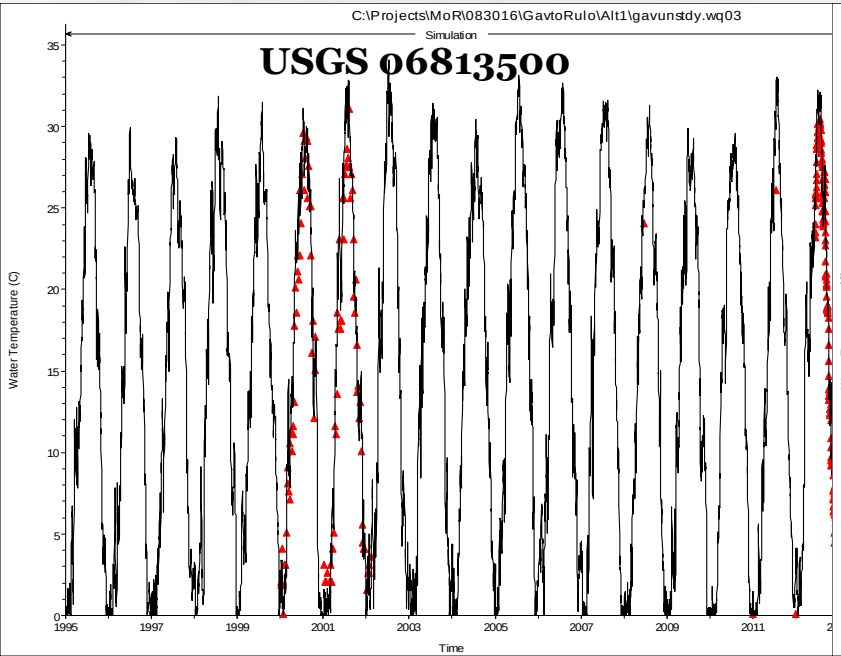
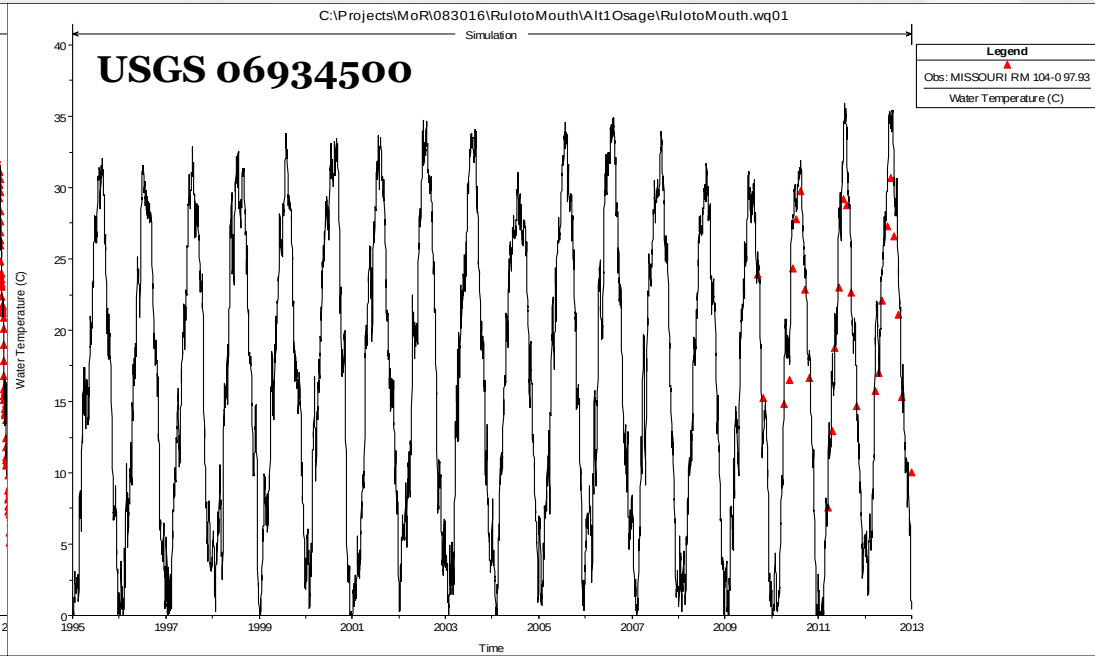


# Columbia River System Operations (CRSO)

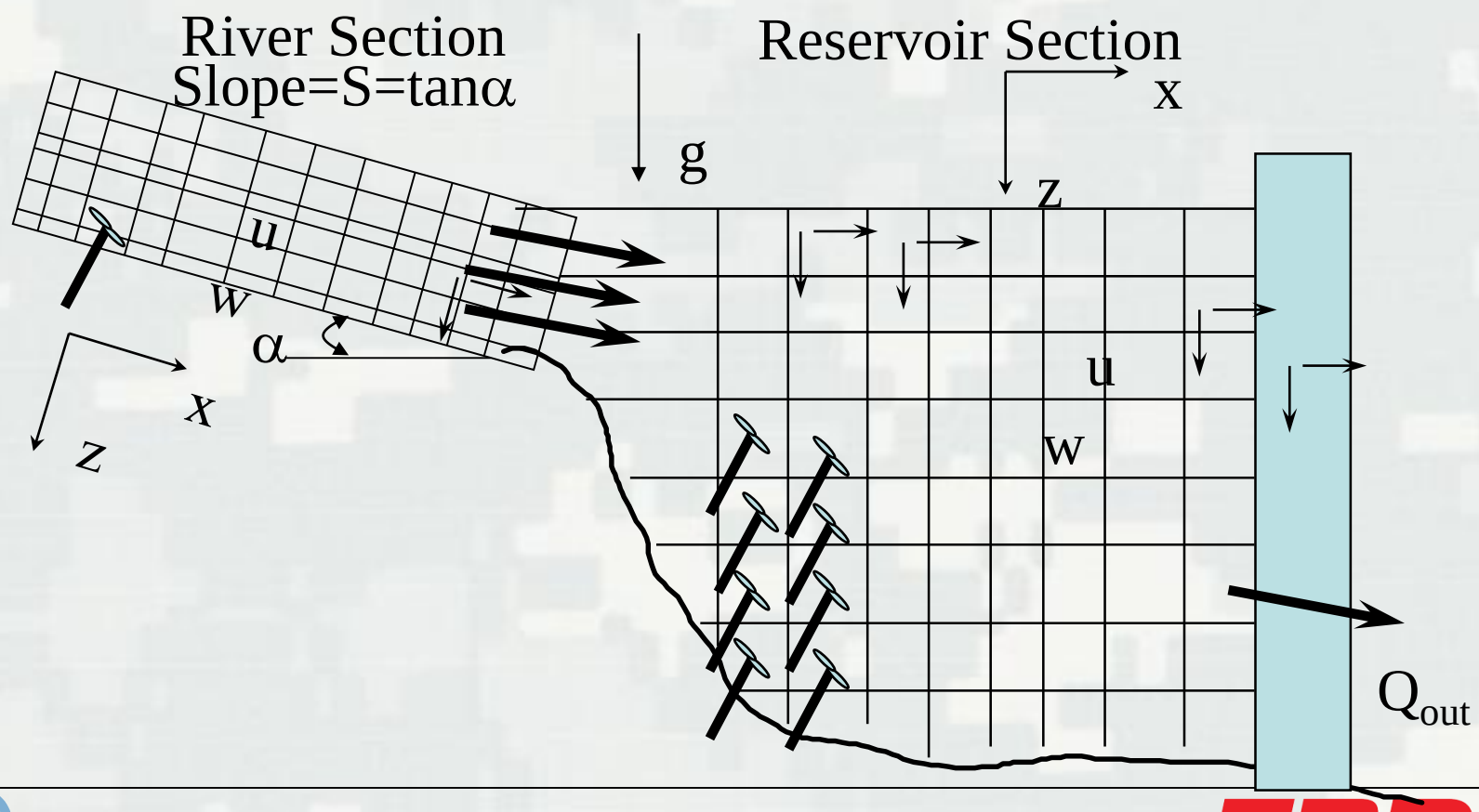
- CRSO
  - 12 Corps dams
  - 2 BOR dams
  - BPA markets the power generated from the dam
- Evaluate impact of operation and configuration of federal dams on:
  - Water temperature
  - Total dissolved gases (TDG)

Courtesy of Dan Turner

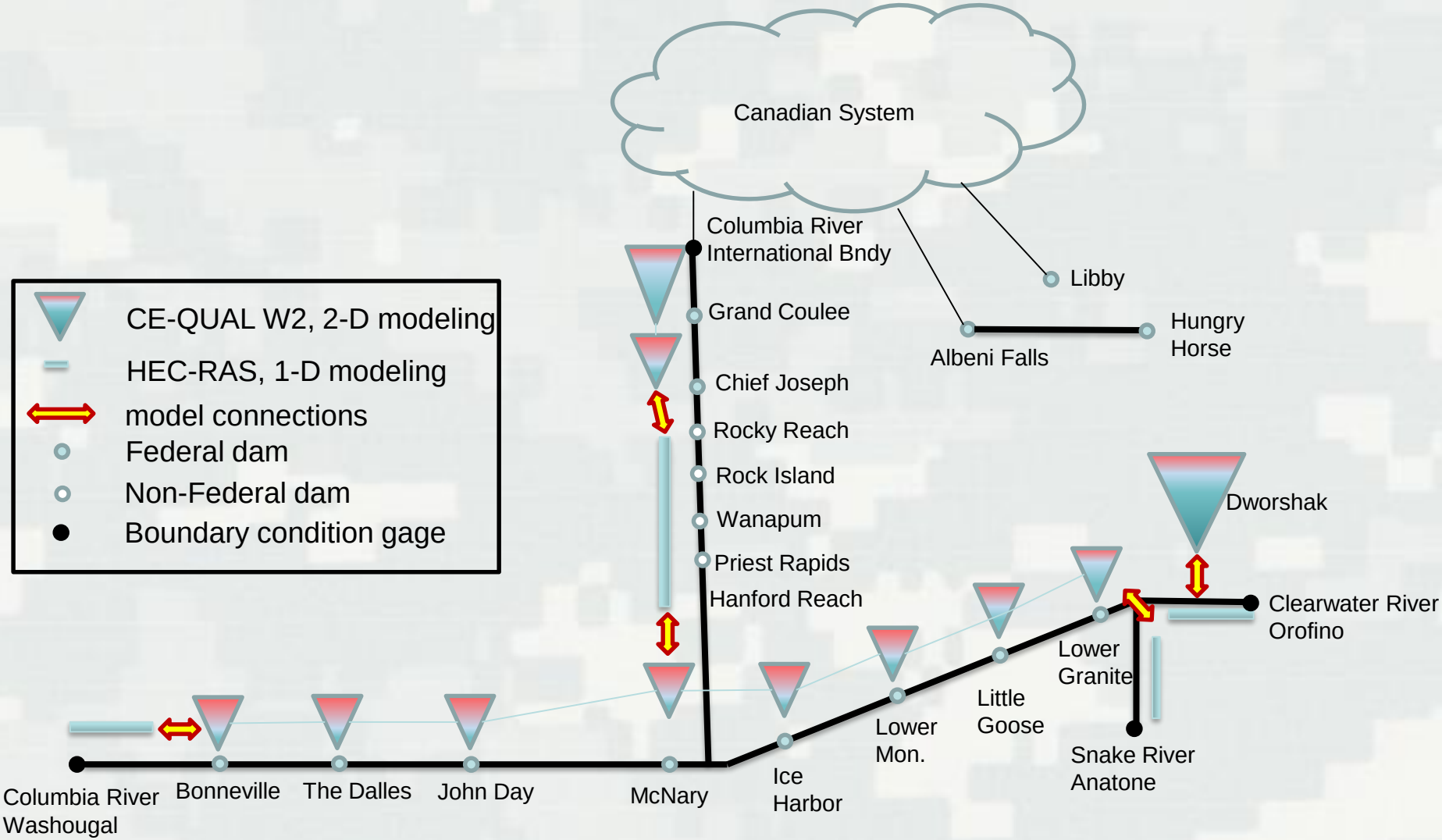
Evergreen Hwy
14
Bonneville Dam
Dam Rd
Star Route
30
© 2016 Google
Google earth
Trail #400

# Enhancement of CE-QUAL-W2

- SYSTDG
- SedFlux, Carbon Cycle, HgSM



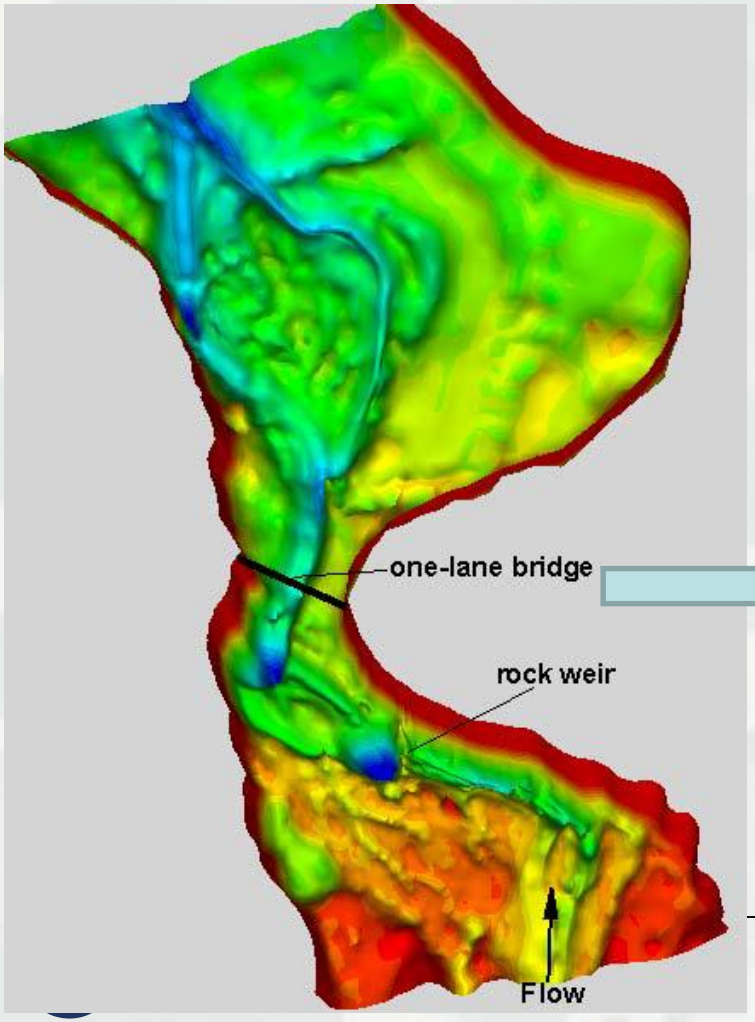
# CRSO Water Quality Models

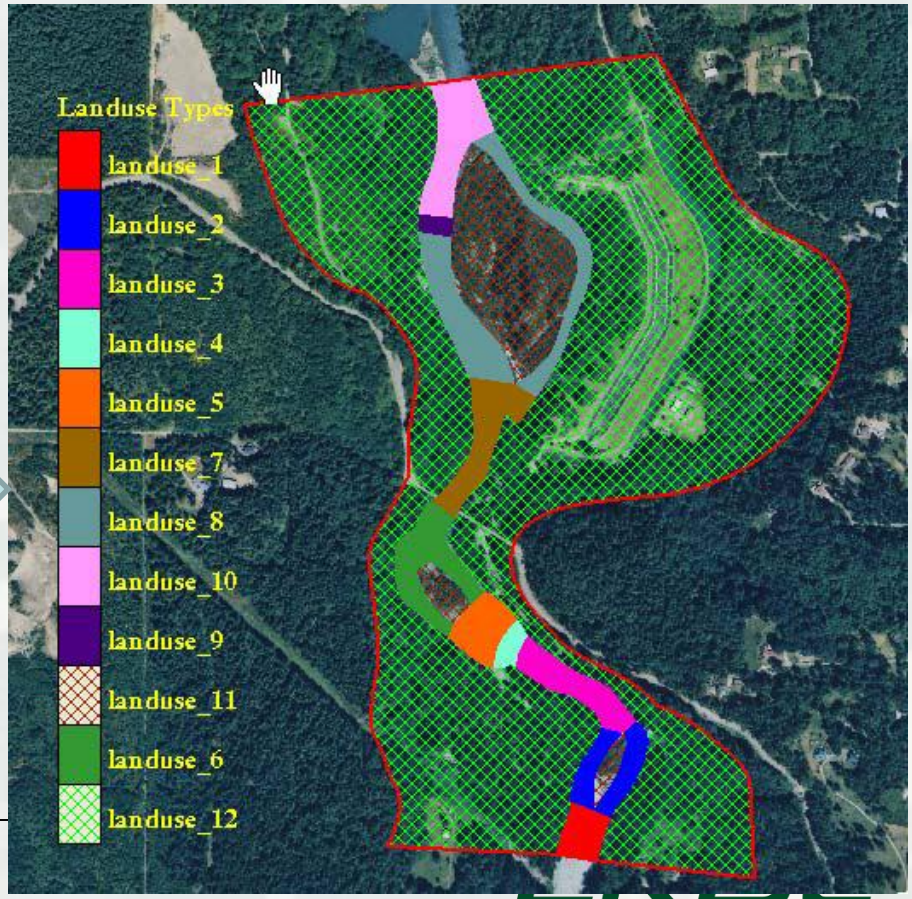



Courtesy of Dan Turner

# SRH-2D (Sedimentation and River Hydraulics) Water Quality

- TEMP, GC modules
- NSMI, HgSM modules



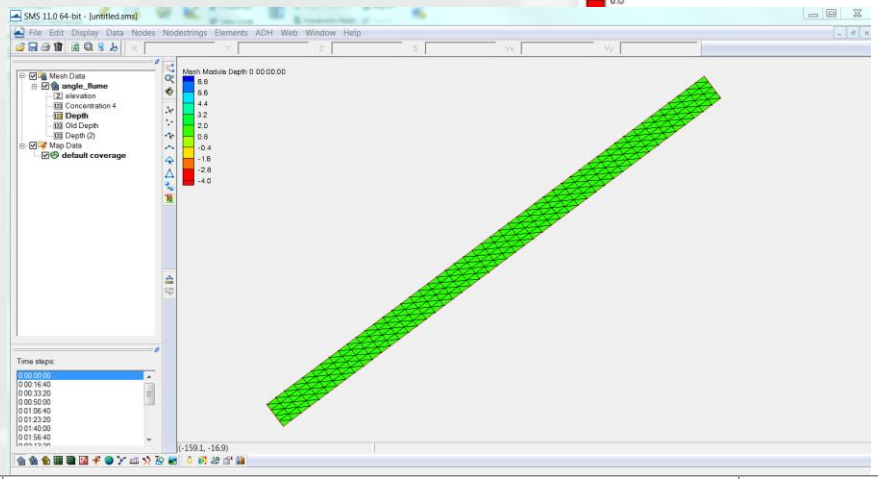



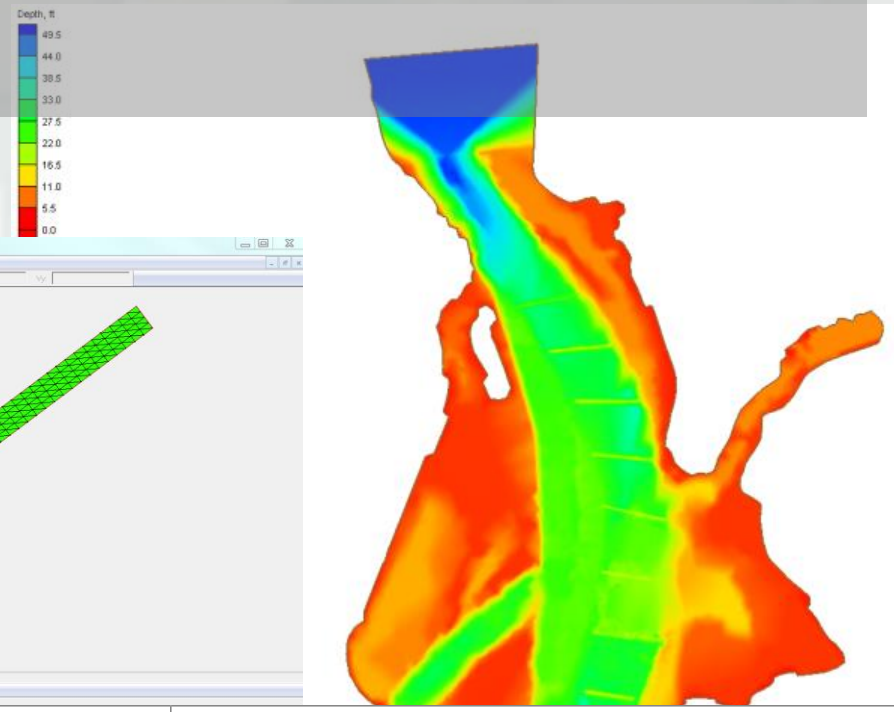
# AdH (Adaptive Hydraulics) Water Quality

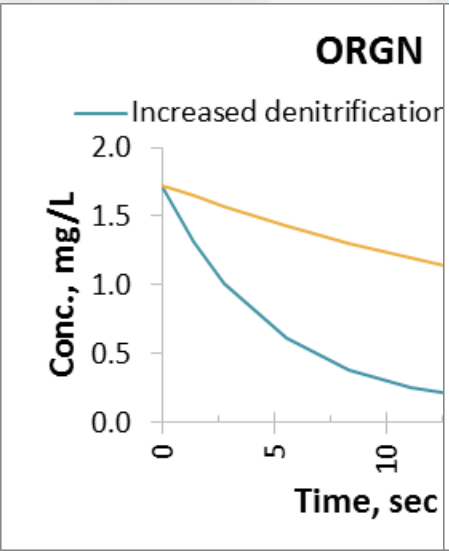
- TEMP, GC modules
- NSMI, CSM modules

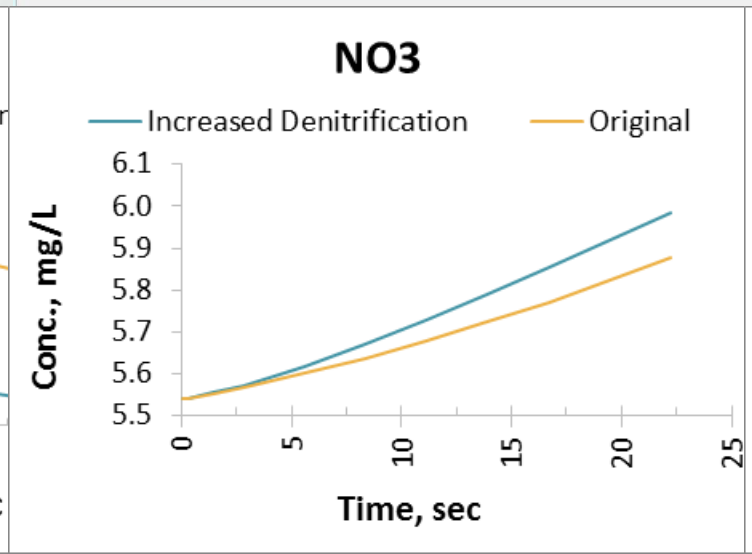
**Three testing modes:**

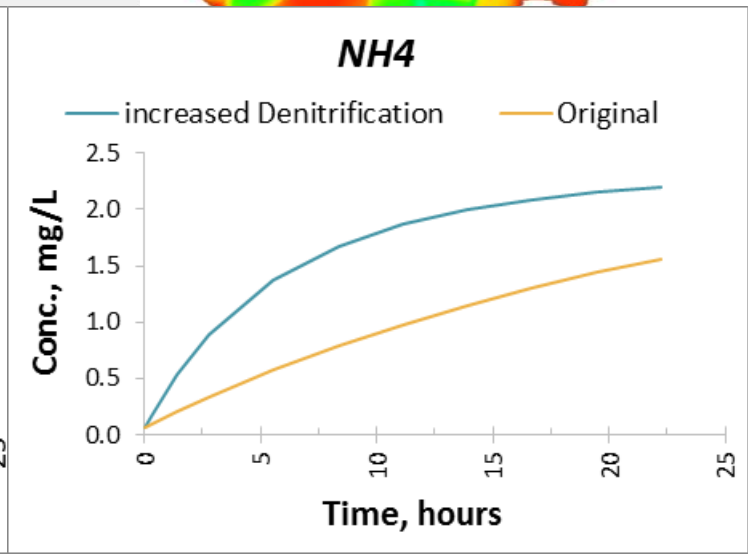
- No flow “bathtub”
- Simple flume
- Field case



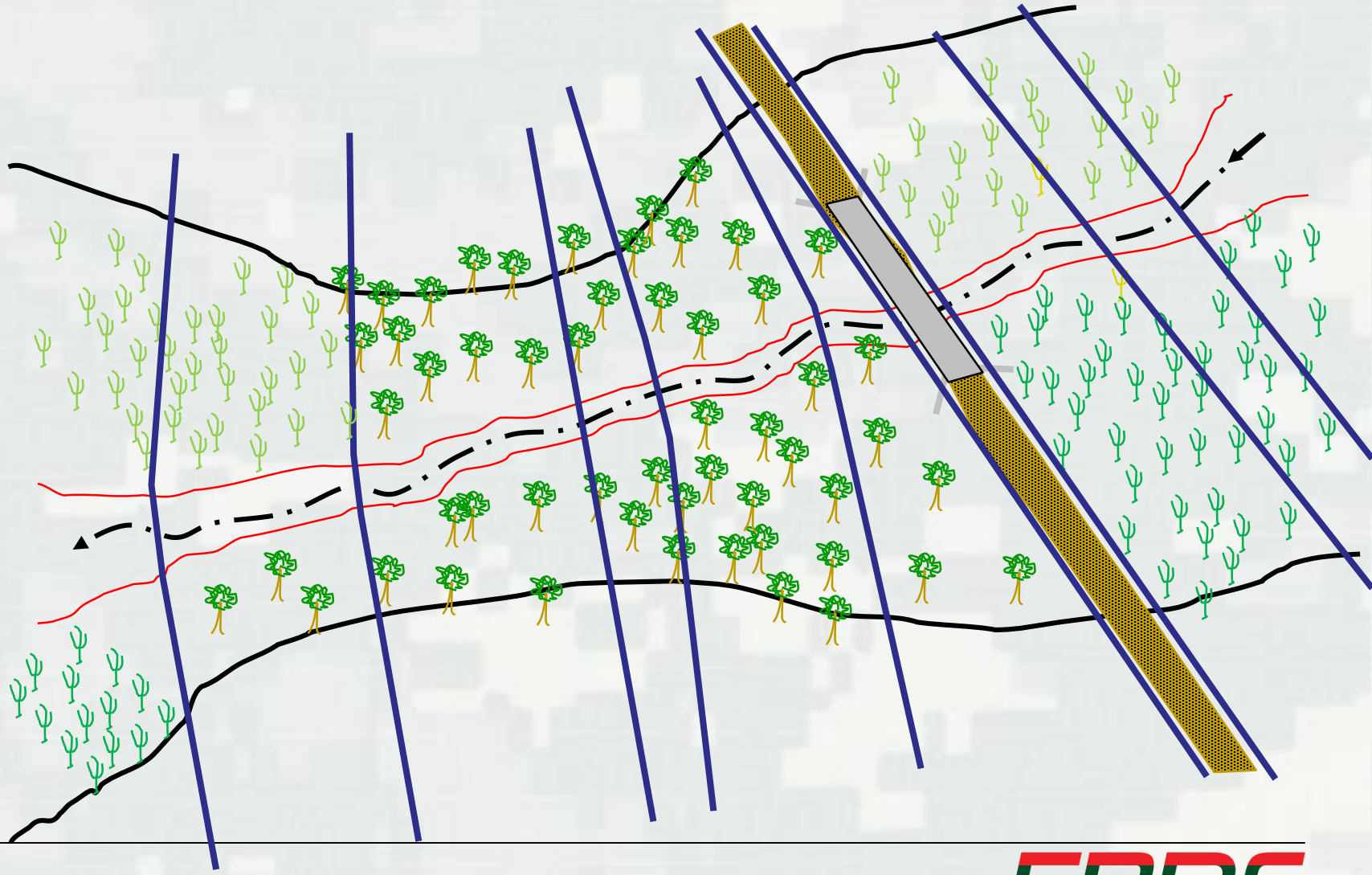


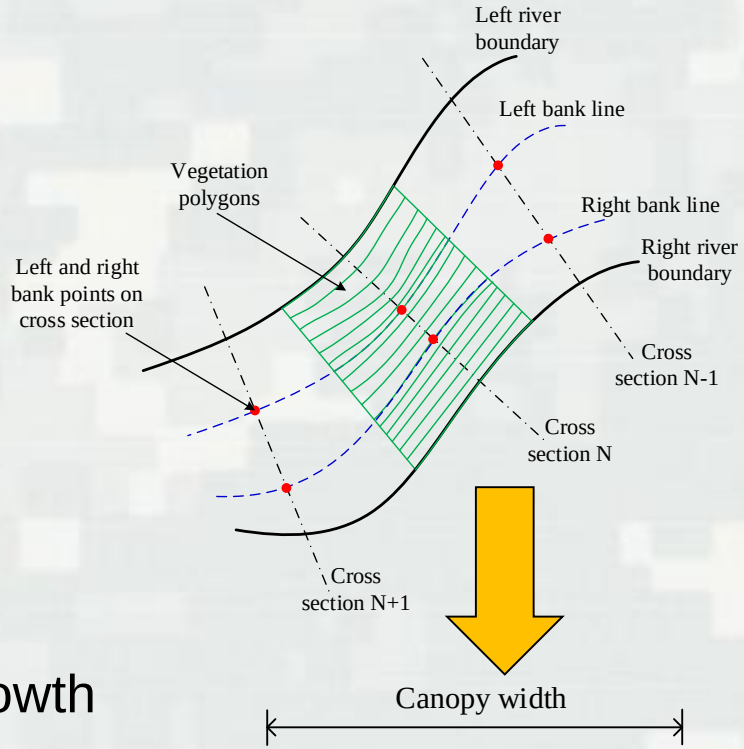



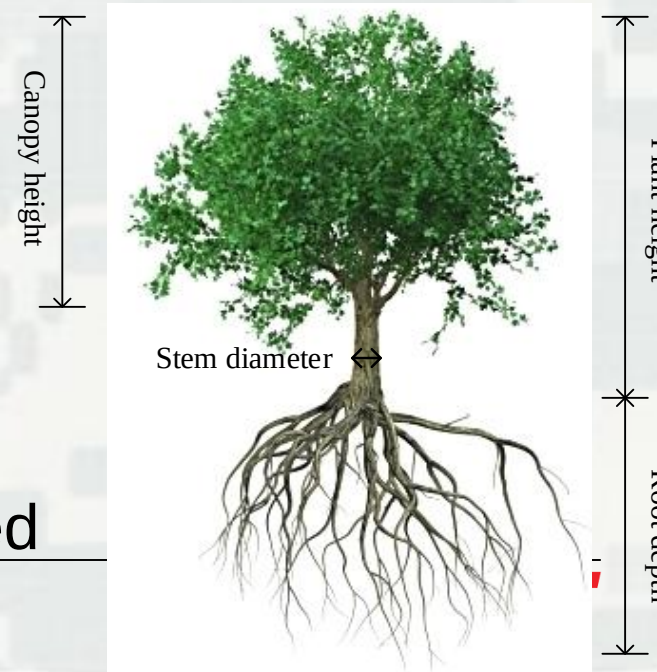
# RVSM (Riparian Vegetation Simulation Module) Developed for 1D and 2D Hydraulic Models



# RVSM

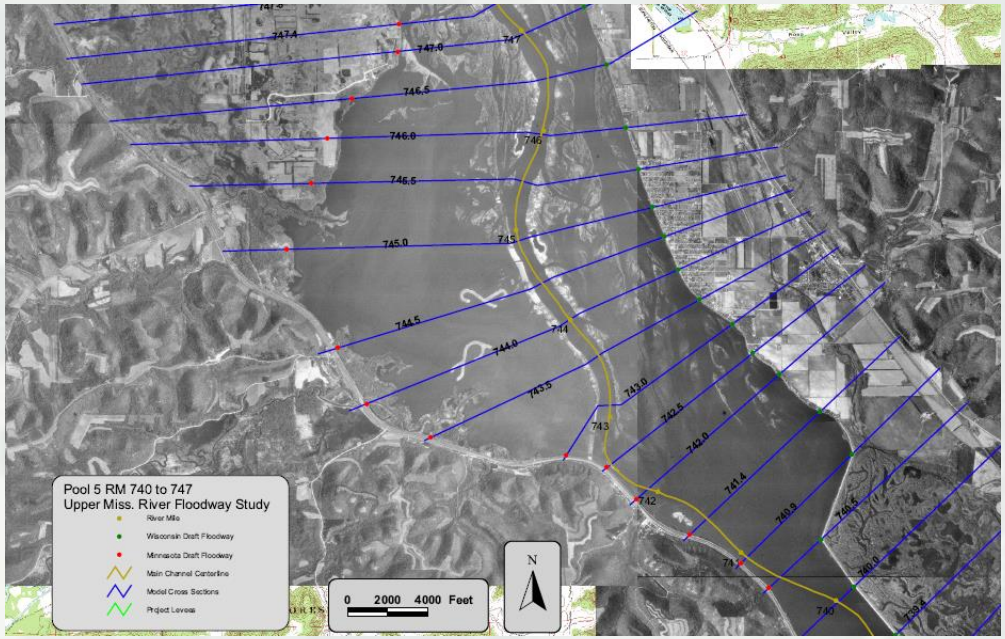
- Processes of vegetation life cycle
  - Seedling establishment
    - Germination period
    - Seed dispersal
  - Plant growth
    - Growth rate (stalk, root)
    - Max height/depth for stalk/root
    - Effects on roughness through growth
  - Mortality
    - Competition
    - Scour (high flows on young plant)
    - Drowning (inundated for duration)
    - Desiccation (root growth < GW drop)
    - *Ice, burying*
- Plant height, root depth, canopy width, stem diameter etc. are computed



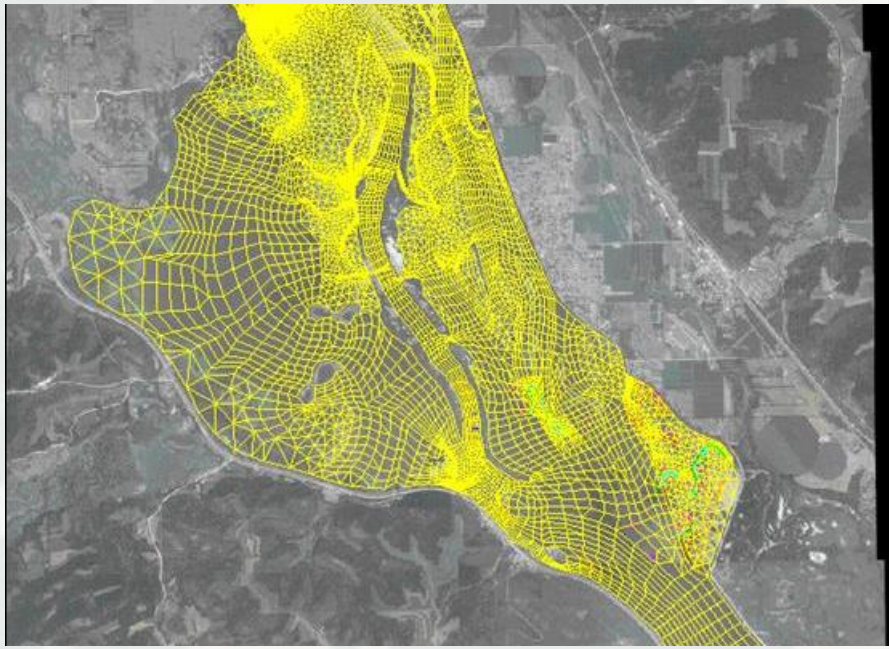



# RVSM --> 1D/2D Hydraulic Models

- **HEC-RAS** – 1D/2D
- **SRH** - 1D/2D




One-dimensional (1D) models

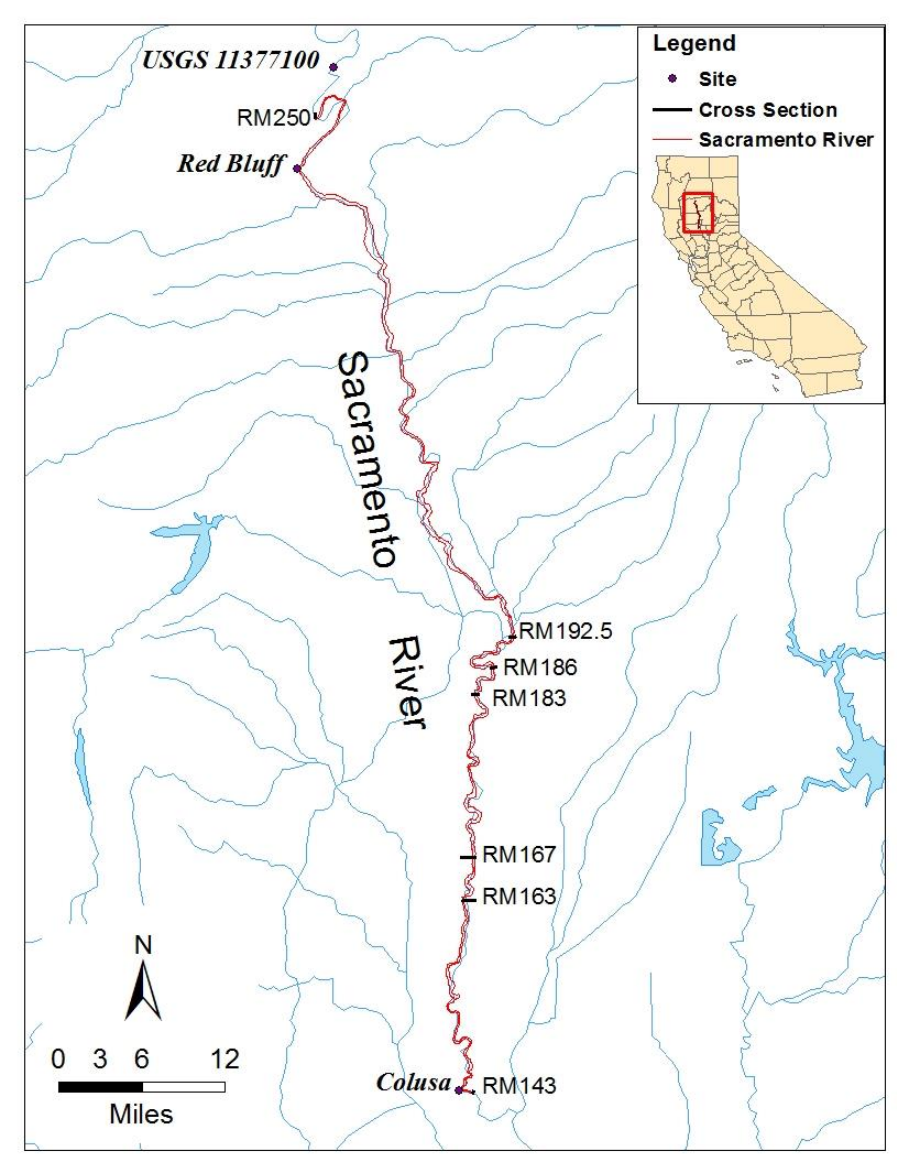


Two-dimensional (2D) models

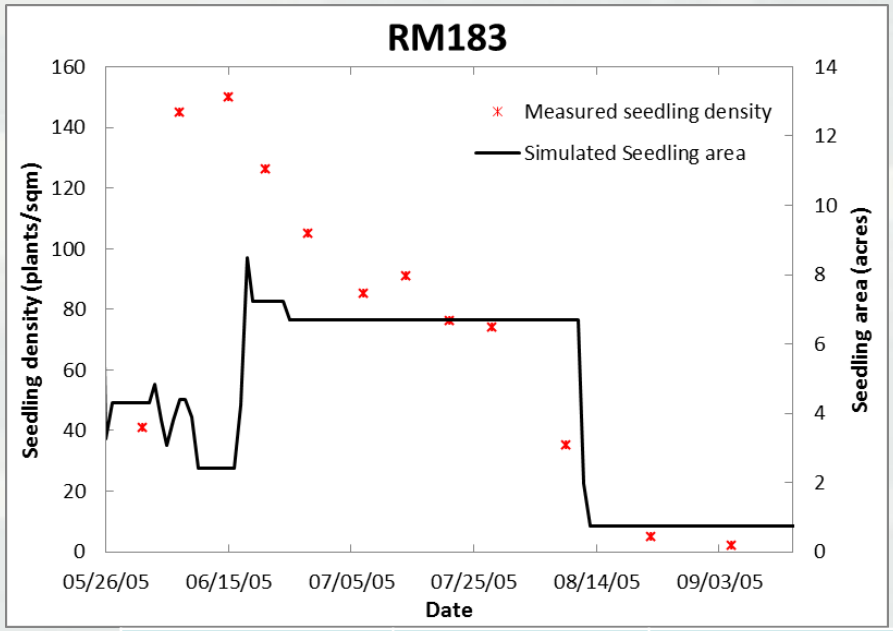
# Application of HEC-RAS-1D-RVSM to Sacramento River

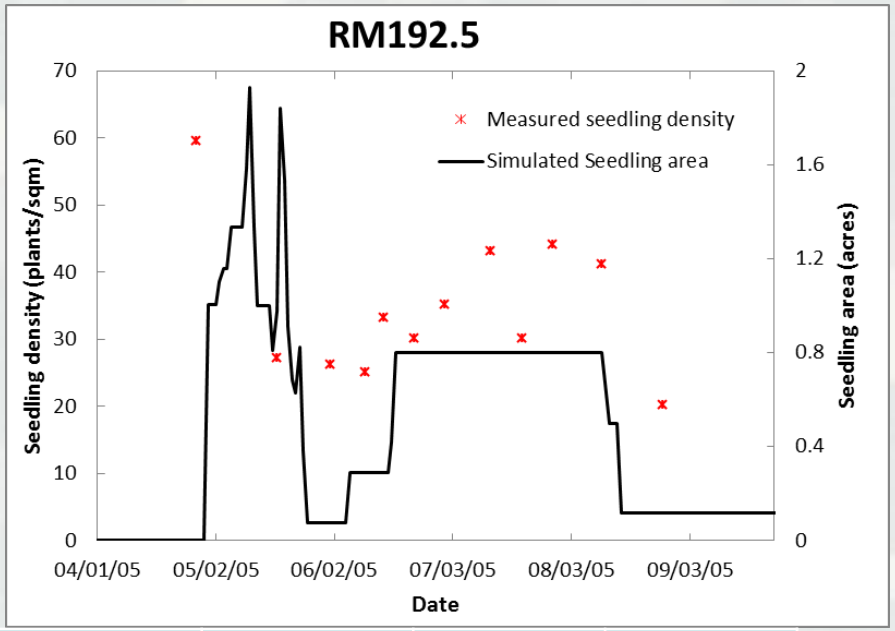
- Study area
  - from Red Bluff to Colusa with 107 miles
  - Ecological management zone
  - Abundant vegetation data
  - Restoration projects were implemented

- Purposes
  - Model interactions between flow and vegetation
  - Predict vegetation area change
  - Examine what caused vegetation establishment change



# Application of HEC-RAS-1D-RVSM to Sacramento River




| | Year | Cottonwood | Mixed forest | Riparian shrub | Invasive species | Grass |
|---|---|---|---|---|---|---|
| Area from mapping (acre) | 1999 | 5319 | 8842 | 3310 | 77 | 3169 |
| | 2007 | 6621 | 6621 | 4127 | 122 | 4280 |
| | Change ratio | 1.35 | 0.75 | 1.25 | 1.59 | 1.35 |
| Area from model (acre) | 1999 | 5308 | 8827 | 3275 | 72 | 3233 |
| | 2007 | 6028 | 8246 | 3891 | 153 | 4609 |
| | Change ratio | 1.14 | 0.93 | 1.19 | 2.12 | 1.42 |

# Acknowledgements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  - Kathryn Tackley, Dan Turner
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