A Compartmental Screening Model for Stage and Water Quality in a Large Everglades Wetland

U.S. Fish & Wildlife Service
Arthur R. Marshall
Loxahatchee National Wildlife Refuge

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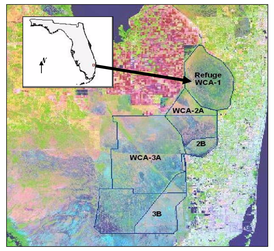
Summary

The Simple Refuge Screening Model (SRSM) version 4 simulates coupled hydrodynamics and water quality within the 58,000-ha Arthur R. Marshall Loxahatchee National Wildlife Refuge. The SRSM is implemented using the ordinary differential equations solver Berkeley Madonna (www.berkeleymadonna.com). The compartment size and arrangement in version 4 are identical to earlier versions of this model, whereas the constituent modeling approach has become more refined. Concentrations are calculated for chloride as a conservative tracer, sulfate using a Monod relationship, and total phosphorus dynamics as described by Walker and Kadlec in their Dynamic Model for Everglades Stormwater Treatment Areas (DMSTA).

The Refuge

Study Area
- Freshwater remnant of the Northern Everglades
- Located in Palm Beach County, Florida
- Overlays Water Conservation Area 1 (WCA-1)

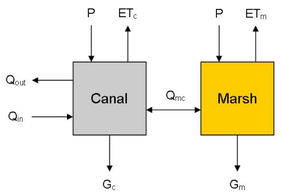
Motivation
- Alterations to water quantity, quality, and timing have caused various impacts on the Refuge
- Assessment of scenarios will guide future restoration efforts



Water Budget Model

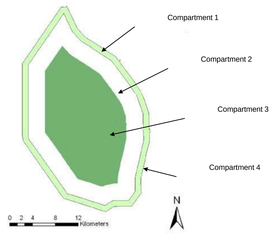
2 Compartments
- based upon the major features in the Refuge
  - Canal
  - Marsh

Necessary input
- Data used for model:
  - precipitation
  - ET
  - inflow
  - outflow
- Types of outflow data
  - Water supply
  - Emergency Release
  - Historic



WQ Compartment Arrangement

Model Structure
- 4 compartments
  - 3 marsh
  - 1 canal
- Compartments nested concentrically
- Constituent transport is based on water budget model flow and flat marsh pool assumption



Model Attributes

Assumptions

- Average soil elevations are used for canal and marsh compartments
- Water surface of canal and marsh are flat
- Canal surface area is constant
- Precipitation is uniform
- Chloride is a conservative constituent
- TP and SO4 are conservative constituents in the Canal compartment

Runtime information

- Time step
  - dt = 0.005 day
- Simulation period extended
  - Start: Jan-95
  - End: Jun-09
- Completes 14.5-year simulation in ~ 9 minutes

Units

- Water budget model: stage in meters NGVD 29
- Concentration in mg/L and mass in grams

Total Phosphorous (TP) Model

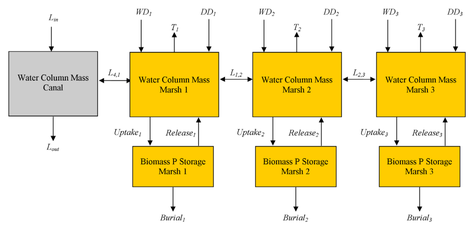
Uses dynamics derived from the DMSTA (Walker and Kadlec)

Water Column Concentration

$$\frac{dhC}{dt} = L - QC - F_C F_z k_1 SC + k_2 S^2$$

Storage

$$\frac{dS}{dt} = F_C F_z k_1 SC - k_2 S^2 - k_3 S$$

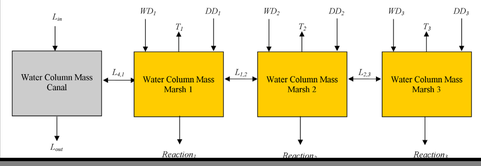


S = temporary storage in biomass (mg/m^2)
C = concentration of surface water (mg/m^3)
F_c = concentration multiplier
F_z = depth multiplier
k_1 = maximum uptake rate (m^3/mg-yr)
k_2 = recycle rate (m^2/mg-yr)
k_3 = burial rate (1/yr)
h = water depth (m)
L = loading rate in the cell (mg/m^2-yr)
* Includes transpiration (T) and deposition (WD and DD)
Q = outflow (m/yr)

Sulfate (SO4) Model

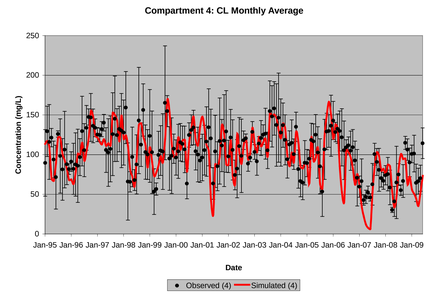
Uses Monod relationship, zeroth order at high concentration, first order at low concentration

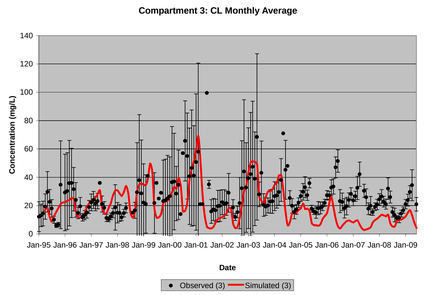
$$\frac{dM}{dt} = L - QC - \left[\frac{R_{Max}\ CA}{k_{Half} + C}\right] \qquad C = {}^{M}/_{Ah}$$



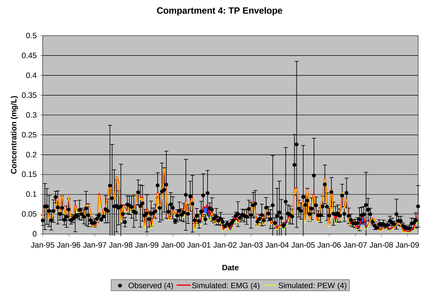
M = mass in water column (g)
L = loading rate in the cell (g/day) Includes transpiration (T) and deposition (WD and DD)
C = concentration of surface water (g/m^3)
Q = outflow (m^3/day)
A = area (m^2)
R_{Max} = maximum sulfate removal (g/m^2-yr)
k_{half} = half saturation constant (g/m^3)

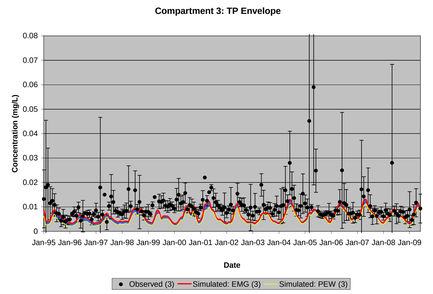
Results – Chloride (CL)



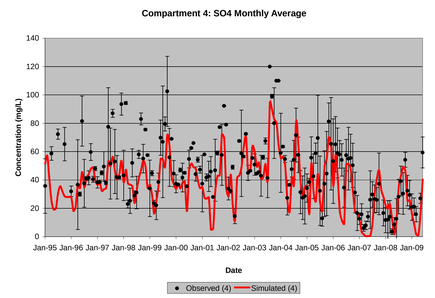


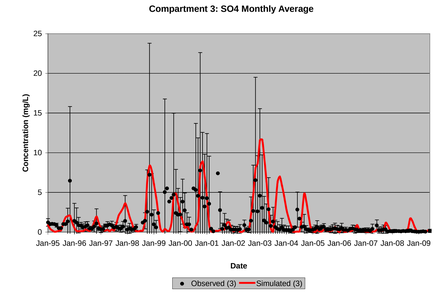
Results – Total Phosphorous (TP)



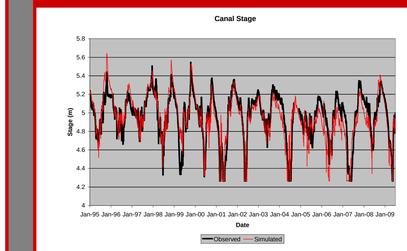


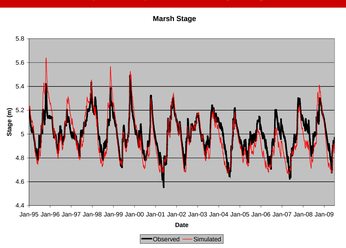
Results – Sulfate (SO4)





Results – Hydrodynamics (stage and outflow)





Conclusions

Stage and concentrations modeled by the SRSM are comparable with observed data from the Refuge marsh and canal. The generalized and spatially aggregated scheme used in the SRSM allows for only average assessments of large areas. The SRSM and similar approaches are of great value in many applications, but must be applied with judgment and technical understanding of the limitations of spatially aggregated modeling. The flexibility and speed with which this model can be applied and modified allows it to lead and instruct development of our more complex spatially-explicit model.

Acknowledgements and Disclaimer

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