Hydroperiod Effects on Annual Release Rates of N, P, and DOC in a Floodplain Wetland

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WSIS Biogeochemistry Objectives

Develop tools to support evaluation of specific proposals of water withdrawals or management.

- Wetland Release Model – Mass released
- Reduction Model – Mass transferred
- Response Model – Effect on waterbody

Assess specific withdrawal scenarios.
Limiting Conditions

- Only predominately organic soils are considered.
- Only wetlands (soils) potentially affected by water withdrawals are considered.
- Only the effects of loading on the river are addressed.
St. Johns River - Main Stem

Ecologically similar Segments. River slope of <9 meters over 500 kilometers
Lakes with Potential Affects from Withdrawals
Biogeochemical Working Group
Hypotheses

Inundated

Exposed

C inputs

Oxidation

O$_2$

TP

TOC

C inputs

Oxidation

O$_2$

TP

TOC

C inputs

Oxidation

TP

TOC

C inputs

Oxidation

TP

TOC

C inputs

Oxidation

TP

TOC
Effects of Hydroperiod on Release of Dissolved Products of Oxidation
Fish Kills Associated with Rain Events When River Stage is Above Wetland Surface

Lake Winder

- Water Elevation (m NGVD 29)
- Rainfall (cm/month)

- # Not Noted
- Fish Kill Reported
- # of Fish if noted

Legend:
- "Rainfall"
- "Water Elevation"

Graph shows changes in water elevation and rainfall over time, with specific notes on fish kills and wetland conditions.
Amplification through the chain of causation.

Minor change in water elevations (stage)

May result disproportionately increase in exposure period of organic soils

Resultant increase in loading may be greatly magnified effect acting over a broad expanse of wetland soils

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**Exceedence Curves**

- Difference in water level
- Difference in time exceeded

Water Level ➞

Percent of time level is exceeded ➞
Effects of Hydroperiod on Release of Dissolved Products of Oxidation

Daily Release Rate (R) = \frac{\text{Increase in Mass}}{\text{Increase in time of exposure}}

Increase in time of exposure

Increase in Mass

Mass released / m^2

Time

Baseline

Test
Soil Sample Locations

Lakes Winder & Poinsett
The overall conceptual model illustrates the complexity of potential hydroecological effects.
Conceptual model for Biogeochemistry

Model for Predicting DOC, TP, and TN Releases

Hydrologic / hydrodynamic model

Hydrology / Hydrodynamics Group

Key Attribute

Causal linkage

Predictive linkage

Linkage to other group

↓ Water level

↓ Inundation

↑ Oxidation Soil Organic Matter

↑ N,P Release dissolved nutrients

↑ TOC/DOC Release

↓ NPP – shading, inhibition

↑ Nutrient Loading

↑ Respiration

↓ [DO]

 Fisheries Group

Benthos Group

Littoral Group

Plankton Group

Wetlands Group

DEM

Calculation

Calculate Daily Δ Oxidation

Annual Accumulator

Area Inundated (Base)

Area Inundated (95 Full NN)

Temperature

Late Summer/fall Release

C_o = \frac{(C_i-C^*)}{(1+K/Pq)^P}

Model for Predicting DOC, TP, and TN Removal
Release Model

Additional mass released/yr

Removal Model

Additional mass in Lake

Flow / Mass Balance

Additional concentration in Lake

Response model equation fit of Lake WQ

Decrease in DO in Lake
STEELA© Wetland Hydrologic Model

Based on Kadlec & Wallace, 2008, Generalized Friction Equations for Wetland Flow

\[ u = a \cdot h^{(1-b)} \cdot S^c \]

Velocity = cross-sectional area x Depth to the (1-b) power x Slope to the (c) power
### Wetland Release Model Input Values

<table>
<thead>
<tr>
<th>Variable</th>
<th>Study</th>
<th>Days of Exposure</th>
<th>N</th>
<th>Release per day of exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td>DOC</td>
<td>Field Cores</td>
<td>30</td>
<td>12</td>
<td>18.7</td>
</tr>
<tr>
<td>TKN</td>
<td>Diameter</td>
<td>61</td>
<td>30</td>
<td>2.28</td>
</tr>
<tr>
<td>TP</td>
<td>Diameter</td>
<td>61</td>
<td>30</td>
<td>0.59</td>
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</tbody>
</table>

### Reduction Model Input Values

<table>
<thead>
<tr>
<th>Constituent</th>
<th>1&lt;sup&gt;st&lt;/sup&gt; Quartile</th>
<th>2&lt;sup&gt;nd&lt;/sup&gt; Quartile</th>
<th>3&lt;sup&gt;rd&lt;/sup&gt; Quartile</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD/DOC</td>
<td>0.03</td>
<td>2.72</td>
<td>6.79</td>
</tr>
<tr>
<td>TKN</td>
<td>1.21</td>
<td>3.69</td>
<td>7.08</td>
</tr>
<tr>
<td>TP</td>
<td>-0.33</td>
<td>5.80</td>
<td>11.89</td>
</tr>
</tbody>
</table>

**Note:**
- BOD/DOC = biochemical oxygen demand equated to dissolved organic carbon
- TKN = total Kjeldahl nitrogen
- TP = total phosphorus

www.sjrwmd.com/watersupplyimpactstudy/
Release Model calculates area of difference (A) for each day of the scenarios.

\[ M = \sum_{1}^{365} (R \cdot A \cdot K) \]

- \( M \) = potential change in mass release (g)
- \( R \) = areal daily increase in release when exposed (g m\(^{-2}\) d\(^{-1}\))
- \( A \) = additional area exposed (m\(^2\) d\(^{-1}\))
- \( K \) = temperature correction
Release Model Estimates

![Box plots showing release model estimates for DOC, TP, and TKN for Poinsett and Winder.](image-url)
Reduction Model Calculations

\[ L_r = M_i \left( 1 + \left( \frac{K}{P \times q} \right) \right)^{-p} \]

- \( L_r \) = Outflow load (g)
- \( M_i \) = Inflow Mass (g)
- \( K \) = Removal coefficient (m d\(^{-1}\))
- \( P \) = Number of tanks in series
  - corrects for variable flow path lengths and eddy diffusivity
- \( q \) = Hydraulic loading (m d\(^{-1}\))

Derived from Tanks in Series Model, Kadlec and Wallace (2008)
Mass Balance Estimates: Combined Concentrations

Grams per Cubic Meter

Quartile

[DOC] [TP] [TKN]
Response Model for Change in Dissolved Oxygen - Multiple Regression Model

The best model ($p<0.0001$; adjusted $r^2 = 0.415$) for predicting changes in [DO] in lake water from available information was a multiple regression:

$$\Delta [DO] = (-0.1014 \text{ mg L}^{-1} \text{ m}^{-1} \times \Delta \text{ water elevation}) + (-4.61097 \times \Delta [TP]) + (-0.07393 \times \Delta [TOC])$$

where water elevation is in meters above sea level NGVD29 and all concentrations are in mg L$^{-1}$. All parameters were significant at the $p < 0.05$ level.
Predicted Monthly Dissolved Oxygen Changes for Different Removal Rate Quartiles

Additional Dissolved Oxygen (g m\(^{-3}\))

- 1st Quartile
- 2nd Quartile
- 3rd Quartile
Soil Organic Activity in Different Areas

<table>
<thead>
<tr>
<th>Marsh Conservation Area (MCA)</th>
<th>n</th>
<th>Histosol Suborder</th>
<th>Bulk Density (g cm(^{-3}))</th>
<th>Loss on Ignition (%)</th>
<th>C:N Ratio (mass basis)</th>
<th>Soil Organic Matter (SOM) Activity*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fort Drum MCA</td>
<td>12</td>
<td>Fibrists</td>
<td>0.06</td>
<td>95</td>
<td>17</td>
<td>Active</td>
</tr>
<tr>
<td>St. Johns MCA</td>
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<td>Hemists</td>
<td>0.13</td>
<td>91</td>
<td>14</td>
<td>Slow</td>
</tr>
<tr>
<td>Blue Cypress MCA</td>
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<td>Fibrists</td>
<td>0.08</td>
<td>95</td>
<td>17</td>
<td>Active</td>
</tr>
<tr>
<td>Three Forks MCA</td>
<td>6</td>
<td>Hemists</td>
<td>0.08</td>
<td>90</td>
<td>14</td>
<td>Slow</td>
</tr>
<tr>
<td>Lake Poinsett Wetlands</td>
<td>6</td>
<td>Sapristis</td>
<td>0.2</td>
<td>58</td>
<td>10</td>
<td>Passive</td>
</tr>
</tbody>
</table>

Note:
*Soil organic matter activity is a measure of how quickly the organic matter fraction of soil will decompose, and is categorized as active, slow, or passive based on the C:N ratio.

n = Number of observations
C:N = Carbon to nitrogen ratio

**Active SOM** = C:N of 15 to 30, decomposition in 1 to 2 yrs
**Slow SOM** = C:N of 10 to 20, decomposition in 15 to 100 yrs
**Passive SOM** = C:N of 7 to 10, decomposition in 500 to 5,000 yrs
Results

- The refractory Lake Poinsett soils predicted less than a 0.05 mg L$^{-1}$ decrease in DO.

- However, if we use the release rates from labile Blue Cypress Marsh soils, the median decrease would be 2.45 mg L$^{-1}$.

- Results are VERY soil (site) specific!
Conclusions

- The specific water withdrawal scenarios in this study were predicted to have only negligible ecological effects due to wetland biogeochemical dynamics.

- Modeling tools developed in this study are applicable to assist in assessing water withdrawals or management effects when site specific information is available.
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