Ecological Modeling of Channel Deepening Effects, St. Johns River Estuary, Florida

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Ecological Effects of Channel Deepening

1. The Channel Deepening Project and Ecological Modeling of Salinity Change Effects
2. Conclusions – Likely Effects of Channel Deepening
3. Findings for Wetlands, SAV, BMI, and Fish
4. Important Factors in Deepening Impacts in the St. Johns River Estuary
St. Johns River Estuary

- Over 100 river miles long
- S→N flow, very low slope
- Diverse physical, chemical environment
- Highly diverse plant and animal communities
- Densely populated near mouth (Jacksonville, FL)
- Large agricultural industry south of Jacksonville

Salinity

- Salinity ~ 22 ppt project construction end
- Salinity < 1.0 ppt river mile 50
- Salinity < 0.05 ppt river mile 90
Jacksonville Harbor Channel Deepening Project

- Project purpose: *Deepen the first 13 miles of federal channel from 40 ft. to 47 ft. for post-panamax vessel access:*
  - Deepening requires congressional authorization
  - Authorization requires General Reevaluation Report, (GRR) including EIS
  - EIS required assessment of potential salinity change effects
  - Salinity simulations and site-specific ecological models provided the basis for ecological effects evaluation
**Existing Conditions**
- Channel template mile 0 - seaward: 50 ft. deep – for Mayport Naval Station
- Channel template mile 0 – 20: 40 ft. deep

**Proposed Deepening**
- 7 ft. (40 ft. to 47 ft.) of miles 0 - 13
Ecological Modeling

- Based on existing ecological models and datasets developed for the Water Supply Impact Study (WSIS) - St. Johns River Water Management District (2012)
- Some models used “as-is”; other models developed from WSIS data
  - 3-dimensional EFDC salinity model
  - Calibrated and validated for stage, flow, and salinity
- Ecological models of salinity effects on:
  - Wetlands
  - SAV – submerged aquatic vegetation
  - BMI – benthic macroinvertebrates
  - Fish
## Scenarios - (Baselines and Worst Cases in Yellow)

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Project Depth (ft)</th>
<th>Deepening Length(^1) (miles)</th>
<th>Water Withdrawal</th>
<th>Sea Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without Project</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2018 Baseline</td>
<td>40</td>
<td>44</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>46</td>
<td>47</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>50</td>
<td>13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2068 FWOP</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Future without Project</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2018 44-ft</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>2068 44-ft</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2018 46-ft</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Selected Project</td>
<td>47 ft</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2018 TSP</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>2068 TSP</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2018 50-ft</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>2068 50-ft</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^1\)Not applicable with 2018 Baseline or 2068 FWOP alternatives

\(^2\)Sea level rise represents continuation of current rate, defined by USACE curve 1
Salinity Statistics -

Salinity analyzed using hydrologic concepts:

• Salinity exceedence frequencies
  ➢ annual percent exceedence of 1 ppt. salinity

• Salinity duration and partial duration analyses
  ➢ duration (days) of salinities exceeding 18 ppt.

• Simulation period water column average salinity by ppt.
  ➢ 1 ppt, 2 ppt, 5 ppt salinity isoclines
Summary of Effects Assessments

- Only minor effects identified
  - Wetland impacts from slight upstream salinity shift
  - SAV - slightly increased salinity stress at downstream-most SAV locations
  - BMI salinity habitat zones shifted upstream, but without loss of appropriate physical habitat
  - Fish salinity habitat reductions downstream generally offset by upstream salinity habitat gains.
Salinity Effects Zone and Wetlands

- Bracket: Salinity change area of the main channel first 50 river miles
- Large wetland (Timicuan Preserve) at the mouth of the river; large wetlands also occur south of Shands Bridge
Wetland Types and Baseline High Tide Salinity Frequency

• **Baseline conditions**: 1 ppt salinity exceedence percentages
  - Tidal Marsh - Red
    - > 25% annual exceedence
  - Transition Zone - Yellow
    - 12% - 25% annual exceedence
  - Tidal Swamp - Green
    - < 12% annual exceedence

• **Worst Case Scenario Effects** (50-ft channel, 2068 conditions)
  - Upstream shift in > 1 ppt salinity frequencies of about 3 miles
High Tide Salinity Increase– Worst Case Simulation

- 0.7 ppt at Fuller Warren Bridge (top of screen)
- Red, orange, green
  - 0.3 – 0.7 ppt increase
- Blues, pinks
  - 0.1 – 0.3 ppt increase
- White – no significant change
SAV Model – Changes in EFDC Cell Salinity Durations

- Assessment: salinity duration (percent time) changes in 90-day moving average simulation data
- No seagrass (high salinity SAV) in the estuary
- *Vallisneria americana* completely dominant in brackish and freshwater portions of the estuary.
- Other brackish/freshwater species — (e.g. *Najas guadalupensis, Ruppia maritima*) also occur
- Assessment Stress Scale (Dobbeffuhl et al 2012)
Increased Stress Acres

- Total SAV potential habitat ~3,487 acres (estimated habitat area – not observed SAV)
- Greatest increase with worst case scenario (2068 conditions: 50-ft. - FWOP)
  - 47 acres of increased extreme stress
  - 51 acres of increased moderate stress
- Change associated with sea level rise (FWOP – Baseline)
  - 55 acres increased extreme stress
  - 151 acres increased moderate stress

<table>
<thead>
<tr>
<th>SAV Salinity Stress</th>
<th>Baseline</th>
<th>2018 Condition</th>
<th>2068 Condition</th>
<th>2018 Condition</th>
<th>2068 Condition</th>
<th>2018 Condition</th>
<th>2068 Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel Depth</td>
<td>40-ft</td>
<td>44-ft</td>
<td>46-ft</td>
<td>47-ft</td>
<td>50-ft</td>
<td>40-ft</td>
<td>44-ft</td>
</tr>
<tr>
<td>No Stress</td>
<td>10,881</td>
<td>10,845</td>
<td>10,826</td>
<td>10,837</td>
<td>10,764</td>
<td>10,343</td>
<td>10,303</td>
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<tr>
<td>Low</td>
<td>2,367</td>
<td>2,374</td>
<td>2,379</td>
<td>2,373</td>
<td>2,405</td>
<td>2,700</td>
<td>2,704</td>
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<tr>
<td>Moderate</td>
<td>633</td>
<td>651</td>
<td>660</td>
<td>656</td>
<td>681</td>
<td>784</td>
<td>804</td>
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<tr>
<td>Extreme</td>
<td>65</td>
<td>77</td>
<td>83</td>
<td>81</td>
<td>98</td>
<td>120</td>
<td>137</td>
</tr>
</tbody>
</table>
Deepening effects on SAV – Worst Case

- SAV model area – river miles 24 – 48 (140 littoral zone model cells) ~ 3,487 habitat ac.
  - Mile 24 is the downstream limit of SAV in the estuary
  - Baseline simulation – 698 acres of moderate + severe stress (20%)
  - Selected project – 737 ac moderate + severe stress (21%)
  - 50 ft. simulation: 779 acre (22%)
- Interannual variability of baseline salinities drive greater stress than channel deepening alternatives
- 2068 simulation – most of stress increase resulted from sea level rise.

Small potential changes in project-related SAV salinity stress may be obscured by larger temporal variability caused by other factors such as drought, high rainfall, or predicted sea level rise.
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BMI Model - Salinity Zone Areas, Species Habitat Areas

- BMI analysis in WSIS focused on
  - Changes in salinity zones areas
  - Changes in Blue Crab and White Shrimp salinity habitat areas

<table>
<thead>
<tr>
<th>Salinity Breakpoint (ppt)</th>
<th>Salinity Zone Range (ppt)</th>
<th>Salinity Category</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>x &lt; 0.5</td>
<td>limnetic</td>
</tr>
<tr>
<td>0.5</td>
<td>0.5 ≤ x &lt; 5.0</td>
<td>oligohaline</td>
</tr>
<tr>
<td>5.0</td>
<td>5.0 ≤ x &lt; 12.0</td>
<td>low mesohaline</td>
</tr>
<tr>
<td>12.0</td>
<td>12 ≤ x &lt; 18.0</td>
<td>high mesohaline</td>
</tr>
<tr>
<td>18.0</td>
<td>18 ≤ x &lt; 24.0</td>
<td>low polyhaline</td>
</tr>
<tr>
<td>24.0</td>
<td>24 ≤ x &lt; 30.0</td>
<td>high polyhaline</td>
</tr>
<tr>
<td>30.0</td>
<td>x ≥ 30.0</td>
<td>euhaline</td>
</tr>
</tbody>
</table>
Changes in Maximum Bottom Salinity Zone Areas

- Total model area = 94,822 ac
- 30-day moving average provided greatest changes
- Area changes always small
- Loss of 5 – 18 ppt salinity area
- Gain in ≥ 18 ppt salinity areas

Interannual variability greater than changes associated with alternate channel depths
Changes in Salinity Habitat

- Blue Crab (*Callinectes sapidus*)
  - size (cw) = 20 - 30 mm
- Salinity habitat 4 – 20 ppt
- Loss of habitat in shallow lentic conditions near river mouth
  - total habitat area = 32,580 ac
  - Downstream loss = 1,005 ac
  - Upstream gain = 145 ac
Fish Species Effects

- Used 8-year dataset 2001-2009 of project area fish sampling
- Salinity habitat area tested on species by month/season/ size class/sampling gear datasets
- Loss of downstream habitat (25%-75% salinity habitat) offset by upstream habitat gains in most cases
- Example of net habitat loss
  - White Mullet (20-29 mm SL, May, 21.3 m seine): Baseline 6,930 ac
  - 50-ft alternative: 6,314 ac
  - Downstream loss – 1,118 ac
  - Upstream gain – 502 ac
Possible Reasons for Minimal Effects Findings

- Proposed deepening produces a relatively small increase in the existing river cross section – resulting in small net increase in tidal exchanges.

- River channel morphology limits upstream salt wedge movement.

- Salinity–related ecological changes may be ongoing (result of hydrologic changes in the watershed, rising sea level). “Baseline” ecological conditions developed from field sampling and experimental data may not reflect stable ecological conditions.
Possible Reasons for Minimal Change Results

Depth Changes in Harbor Channel (River Mile 1-20) 1880 - 2010

Source - Lesser, Murphy and Blake, WEDA 2006
Possible Reasons for Minimal Change Results

Historic and proposed channel deepening affect the most downstream and narrowest portion of the river.
Possible Reasons for Minimal Change Results

- River morphology limits upstream salt wedge movement
Possible Reasons for Minimal Change Results

Salinity impacts ongoing in St. Johns River estuary

Area of observed vegetation impacts very similar to area of predicted changes
Worst Case: Dead trees in *Spartina* marsh, St. Johns River
Thank You!

Questions?