Examining the Impact of River-Management Actions on Aquatic Resources Using 2-D Flow and Bioenergetics Models


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Study Site

- Glacial fed river with suspended fine glacial till
- Historic spawning river for 6 anadromous salmonids
- 3 Federally listed salmonids
- Levees currently on both banks
- ~3,475 m
- Mean flow = 913 cfs (19 years)
- Mean flow after 2003 = 1740 cfs
- Bed material poorly sorted sand to medium gravel
Common Approaches

1. Instream Flow Incremental Methodology (IFIM)
2. Toe-Width Method
   - relationship between stream wetted width and salmon and steelhead spawning and rearing area
3. Wetted Perimeter Method
   - series of flow and wetted width measurements to identify the minimum flow where stream width is stable
4. Hatfield and Bruce Method
   - Office based “optimization” approach using IFIM output
IFIM Limitations

1. Assumes physical habitat (depth, velocity, substrate) alone determine fish habitat selection.

2. Linkage between food supply and habitat curves (WUA) are weak in biological realism.

3. Temperature often not integrated into habitat curves.

4. Traditional habitat suitability approach does not include a functional understanding of fish foraging behavior and habitat selection.
Incorporating Biological “Realism” With Flow Assessment Studies

Potential Solution to IFIM Limitations

1. Drift-feeding fish feed across velocity differentials (slow–moderate into faster) - Behavior is energetically profitable and results in high net rate of energy intake (NREI).

2. Incorporate functional understanding of drift foraging behavior of fish to predict habitat quality and selection, based on NREI.

3. NREI models must assume non-uniform drift.
Biological “Realism” And Flow Assessment Study Modeling Framework

2D Hydraulic Model → Stream Cell Model → Invertebrate (Fish Food) Drift Dispersion Model → Fish Foraging and NREI Model

Drift Density → Invertebrate Drift Characteristics → Fish Characteristics
2D Hydraulic Modeling

- 2D-Flow and Sediment Transport Morphological Evolution of Channels (FaStMECH) module within the International River Interface Cooperative (iRIC) modeling framework (McDonald, Nelson, Smith et al. 2010) used to simulate water velocity and depth for current and future conditions.

- Terrain mesh for current conditions based on topographic surveys

- Hypothetical terrain mesh for future conditions based on existing topographic data and expert judgment.

- Model simulations performed for:
  1. Current conditions 913cfs
  2. Future conditions 913cfs
  3. Current conditions 1740cfs
  4. Future conditions 1740cfs
Stream Cell Model

- 2D – Velocity / depth from hydraulic model
- Transects perpendicular to max. velocity. 2,691 transects = transect every 1.4 meter
- Horizontal tubes of equal discharge: 20 horizontal tubes
- Horizontal tubes vertically divided into 5 cells of equal discharge

269,000 computational cells per model run
Invertebrate Drift Dispersion Model

1. Combines depth and flow information from Stream Cell Model with invertebrate density and behavior information.
3. Based on River Mixing models with modifications to account for invertebrate behavior (i.e. settling and entry rates).
Invertebrate Drift Dispersion Model – Input and Output

**Input**
1. Invertebrate taxa and size
2. Entry into the drift rate (#/m\(^2\)/s)
3. Settling Velocity (m/s)
4. Length of weight of invertebrate
5. Time spent near the bottom
6. Initial drift density entering study reach (#/m\(^3\))

**Output**
Cell by cell density of specific invertebrate prey types and sizes
Fish Foraging and NREI Model

Predict net rate of energy intake for points throughout the study reach based on depth, velocity, size and density of drifting invertebrates, size of fish and temperature.

Net Rate of Energy Intake = Gross Rate of Energy Intake - Swimming Energy Cost Within Cell

Well established bioenergetics models used to calculate swimming costs.
Fish Foraging and NREI Model- Input

1. Fish length
2. Fish weight
3. Minimum invertebrate prey size fish can capture
4. Maximum invertebrate prey size fish can capture
5. Probability prey is captured**
6. Water temperature
Energetic Cost Results
Energetic Costs For Current and Future Conditions By Season

Costs (Joules/sec)
- Green: <0.01
- Yellow: 0.01 to 0.1
- Light Blue: 0.1 to 1
- Red: >1

Current Conditions (1740 cfs)
Hypothesized Future Conditions (1740 cfs)

Winter
Summer
Percent Distribution of Energetic Costs for Current and Future Conditions by Season For 1740 CFS

<table>
<thead>
<tr>
<th>Costs (Joules/Sec)</th>
<th>Winter Current</th>
<th>Winter Future</th>
<th>Spring Current</th>
<th>Spring Future</th>
<th>Summer Current</th>
<th>Summer Future</th>
<th>Fall Current</th>
<th>Fall Future</th>
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<td>&lt;0.01</td>
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<td>13.4</td>
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<tr>
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<td>0.4</td>
<td>0.5</td>
<td>0.2</td>
<td>0.3</td>
</tr>
</tbody>
</table>

All Current vs. Future comparisons by season are significantly different at 0.05 level (Chi square test)
NREI Results
NREI For Current and Future Conditions by Season

Winter

Spring
Mean Percent of Modeled Reach Characterized As Having Positive or Negative NREI For Current and Future Conditions
Conclusions

- Mean costs consistently lower after levee setback under all turbidity/seasonal conditions.

- Abundance of low cost positions significantly higher after levee setback for both flow conditions.

- Higher abundance of very costly positions. These positions could be productive areas for invertebrates or algae.

- Increase in abundance of positive NREI positions for all turbidity/seasonal conditions.
Levee Setback Project Status

- Design 60% complete
- 2014 levee setback construction
- 2015 old levee removal
- Continued monitoring of fish, habitat, wood recruitment, floodplain vegetation
Acknowledgements

- King County Water and Land Resources Division
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