Utilizing Instream Flow to Predict and Protect Aquatic Habitat

Ken Kehmeier
Senior Aquatic Biologist
Colorado Parks and Wildlife
Objective: Simulate the Natural Stream Environment

Top (plan) view

Side view

- Fast water
- Slower water
- Riverbed
Methodologies

- Historic Flow Methods (Hydrology)
- Hydraulic Methods
- Hydraulic /Habitat Methods
- Standard Setting Techniques
  - Hydrology Based (Historic flow methods)
  - Tennant
    - Uses percent of mean annual flow for decision
    - Data developed from a wide variety of stream types
  - Hoppe
  - Great Plains

- Little if any field data involved, utilizes recorded or estimated flow regime of the river
• Mid-Range Techniques

• Modified Tennant – Repeats all of Tennant’s steps to develop site specific approach

• Hydraulic simulation
  • R2Cross
  • Wetted Perimeter
HABITAT (INCREMENTAL) TECHNIQUE

- High controversy project
- Project specific
- Many decision variables
- Expensive
- Designed for negotiations
Incrementalism: Development of instream flow policy that incorporates multiple or variable rules to establish flow requirements to meet the needs of aquatic ecosystem.

Methodology components include:

- Water quality
- Water supply
- Channel Hydraulics
- Aquatic biota components
- Habitat Suitability for target species
Conceptual approach
Physical descriptors of channel

Width, Depth, Velocity, Discharge and Substrate

= Physical space for aquatic biota
Hydraulic Models

- 1-D models
  - R2Cross
  - PHABSIM
    - IFG4
    - WSP
    - MANSQ

- 2-D Models
  - FESWMS
  - RMA-2
  - River2D
Hydraulic Models

- One Dimensional
  - Simulates velocity in one dimension only
  - Example Models
    - HEC
    - PHABSIM
    - RHABSIM

- Applications
  - Traditional method since the 1980s
  - Simple channels or habitat features
• Two Dimensional Models
  • Simulates velocity in 2 dimensions
    • Example Models
      • RMA-2
      • FESWMS
      • River2D

• Applications
  • The new “standard” for IFIM
  • Complex channel hydraulics
  • Investigation of local channel change
Hydraulic Model Data

- **One Dimensional**
  - Channel cross section data
  - Water Surface elevation
  - Water velocity
  - Water Depth
  - Substrate
  - Does not require geo reference between cross sections

- **Two Dimensional**
  - Channel topography data
  - Water Surface elevation
  - Water velocity
  - Water Depth
  - Substrate
  - Does require spatial reference
  - Can be geo-referenced data
HABITAT USE CRITERIA

- Describes the habitat life history requisites for the species under study
- Can be life stage or activity specific
- May include adjustments or weighting for habitat availability
- Link between behavior and hydraulics
Example Category II Univariate Criteria

- Combined SI = Depth SI * Velocity SI * Channel Index SI

- SI can be a paired suitability value or exponential equation
Example Category IV bivariate criteria

- **Rainbow Trout-Adult**

\[ Z = \left(\frac{1}{11.08667378}\right) \times \left(\exp\left(-\left(0.087184 + (11.36193 \times \text{Dep}) + (56.9357 \times \text{Vel}) + (3.539872 \times \text{Dep} \times \text{Vel}) + (-51.7545 \times \text{Dep}^2) + (-309.223 \times \text{Vel}^2) + (55.63995 \times \text{Dep}^3) + (626.7088 \times \text{Vel}^3) + (-23.3391 \times \text{Dep}^4) + (-559.162 \times \text{Vel}^4) + (3.403427 \times \text{Dep}^5) + (184.4437 \times \text{Vel}^5)\right)\right) \]
Example univariate and bivariate habitat
Habitat - Flow Relationships

- Physical Habitat Simulation System (PHABSIM)
- Habitat Criteria and Hydraulic Data must contain similar descriptions of channel variables (depth, velocity, cover, substrate)
- Hydraulic Model Calibrated and Simulations
- Habitat Use Criteria Generated
- Model linkage between hydraulic and habitat components
HABITAT MODELING

- Combines hydraulic simulations with habitat criteria
- Result shows the area of usable habitat at each particular flow modeled
Comparison of 1-D and 2-D habitat representation
Natural system vs. Model

Photo: 15 cfs
Model: 14 cfs
Flow
Velocity Vectors
Graphic results
Graphic results
Habitat Time Series

- Result of Habitat modeling is the habitat versus flow relationship
  - This is theoretical based only on channel shape
  - Actual habitat over the range of flows requires link with hydrology
- Habitat time series shows habitat over time as a function of flow
  - This is the actual habitat realized by aquatic species
Hydrology Time Series

Cache la Poudre River at Canyon Mouth

- Daily Max
- Daily Mean
- Daily Min

Date

Q (cfs)

Nov    Jan    Mar    May    Jul    Sep
Habitat Time Series

Comparisons to Future Conditions - Segment A - Brown Trout Adult

- Median WUA
- Future Conditions
- Future Conditions +/- 95% C.I.
- Alternative 2
- Alternative 3
- Alternative 4

Comparisons to Future Conditions - Segment A - Trout Fry

- Median WUA
- Future Conditions
- Future Conditions +/- 95% C.I.
- Alternative 2
- Alternative 3
- Alternative 4
WORKING RIVER
HEALTHY RIVER
Median Qpeak (cfs)

<table>
<thead>
<tr>
<th>Location</th>
<th>Median Qpeak (cfs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canyon Mouth</td>
<td>1550</td>
</tr>
<tr>
<td>Fort Collins</td>
<td>750</td>
</tr>
<tr>
<td>Greeley</td>
<td>670</td>
</tr>
</tbody>
</table>

Annual Yield (acre-ft)

<table>
<thead>
<tr>
<th>Location</th>
<th>Annual Yield (acre-ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canyon Mouth</td>
<td>200,440</td>
</tr>
<tr>
<td>Fort Collins</td>
<td>57,890 (-71%)</td>
</tr>
<tr>
<td>Greeley</td>
<td>71,940 (-64%)</td>
</tr>
</tbody>
</table>
Observed vs. Naturalized

Cache la Poudre River at Canyon Mouth, 2000-2010

<table>
<thead>
<tr>
<th></th>
<th>Median Qpeak (cfs)</th>
<th>Annual Yield (acre-ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observed</td>
<td>1370 (-18%)</td>
<td>171,480 (-21%)</td>
</tr>
<tr>
<td>Naturalized</td>
<td>1680</td>
<td>218,250</td>
</tr>
</tbody>
</table>
Flood Frequency Analysis: Canyon Mouth

Cache la Poudre River at Canyon Mouth, 1882-2007

Cache la Poudre at Canyon Mouth

Annual Peak Flow (cfs)

Year

1880 1900 1920 1940 1960 1980 2000

T (year)

1.001 1.1 1.5 2.0 5.0 10.0 20.0 50.0 100.0

1882-2007

1975-2007
Flood Frequency Analysis: Fort Collins

Cache la Poudre River at Fort Collins, 1975-2011

Cache la Poudre at Fort Collins

Annual Peak Flow (cfs)

Year


1000 2000 3000 4000 5000 6000 7000

Annual Peak Flow (cfs)

T (year)

1.001 1.1 1.5 2 5 10 20 50 100

1975-2011
Channel Maintenance Flows

• Flushing
  – Remove superficial fine sediment deposits from riffles

• Channel Maintenance
  – Remove interstitial fine sediment from gravels
  – Maintain of pool-riffle morphology
  – Maintain active channel width

• Riparian Maintenance
  – Lateral connect the active channel with the riparian zone to facilitate exchange of sediment and nutrients
  – Maintain hyporheic zone through groundwater recharge, which affects water chemistry, temperature, and baseflow

• Floodplain/Valley Maintenance
  – Induce channel migration
  – Cause vertical accretion on floodplain
Stream Functions Pyramid
A Guide for Assessing & Restoring Stream Functions

1. HYDROLOGY
   Transport of water from the watershed to the channel

2. HYDRAULIC
   Transport of water in the channel, on the floodplain, and through sediments

3. GEOMORPHOLOGY
   Transport of wood and sediment to create diverse bed forms and dynamic equilibrium

4. PHYSICOCHEMICAL
   Temperature and oxygen regulation; processing of organic matter and nutrients

5. BIOLOGY
   Biodiversity and the life histories of aquatic and riparian life

Geology

Climate

StreamMechanics
How do we accomplish the Cooperation and Collaboration with flushing flows, that we have seen working on the minimum flow issue?