Jun 28th, 4:25 PM - 4:45 PM

Session A6- Design of Steep Channels for Fish Passage; Dam Removals, Bypass Channels, and Rocky Ramps

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FISH PASSAGE GOALS

• Selected finfish
• Finfish and eels
• All aquatic species
• Passage only
• Passage plus habitat
• Sediment continuity
• Regulatory reviewers
• The public, viewing areas, aesthetics
# FISH PASSAGE SELECTION FACTORS

<table>
<thead>
<tr>
<th>Constraints</th>
<th>Breach Dam</th>
<th>Ramp Over Dam</th>
<th>Bypass Around Dam</th>
<th>Fish Ladder</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dam Height &lt; 10 Feet</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>10-20</td>
<td>A</td>
<td>B</td>
<td>B</td>
<td>A</td>
</tr>
<tr>
<td>&gt;20</td>
<td>A</td>
<td>C</td>
<td>B</td>
<td>B</td>
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<tr>
<td>Dam Remains in Active Use</td>
<td>C</td>
<td>A</td>
<td>A</td>
<td>A</td>
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<tr>
<td>Dam Safety Issues</td>
<td>A</td>
<td>B</td>
<td>B</td>
<td>B</td>
</tr>
<tr>
<td>Variable Pool Levels</td>
<td>A</td>
<td>C</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>Anticipated Passage Efficiency</td>
<td>A</td>
<td>B, C</td>
<td>B</td>
<td>B, C</td>
</tr>
<tr>
<td>Range of Species</td>
<td>A</td>
<td>B</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>High Downstream Banks</td>
<td>A</td>
<td>A</td>
<td>C</td>
<td>A</td>
</tr>
<tr>
<td>Steep Downstream Channel</td>
<td>A</td>
<td>C</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>Impounded Sediment Concerns</td>
<td>B, C</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>Weak Swimming Fish</td>
<td>A</td>
<td>C</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>Large Flood Flows</td>
<td>A</td>
<td>C</td>
<td>C</td>
<td>A</td>
</tr>
<tr>
<td>Large Base Flows</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>Active Floodplain</td>
<td>A</td>
<td>A</td>
<td>B</td>
<td>A</td>
</tr>
</tbody>
</table>

A – Feasible / B – Moderate Difficult / C – Most Difficult
NATURALISTIC FISH PASSAGE

**Location**
- Thru Channel (breach dam)
- Full bypass (around dam)
- Partial flow bypass
- Downstream rock fill ramp (over the dam)
- Upstream structural ramp (over the dam)

**Profile Form**
- Cascades; boulder or bedrock
- Steps; Chutes, Weirs, Slots
- Rapids; rough or very rough
- Runs; slow or fast
- Riffles
- Pools; scour or backwater
- Combination
CONVENTIONAL CHANNEL DESIGN VARIABLES

- DISCHARGE RATE
- CHANNEL GRADIENT
- CHANNEL WIDTH & DEPTH
- FLOW RESISTANCE
- MATERIALS
- IN-CHANNEL FEATURES
Platts Mill Dam
Conventional Thru Channel

1998 Pre Construction

2011, High Flow

1999 Post Construction
Low flow
STEEP CHANNEL DESIGN ISSUES

- Profile form; slope versus discharge
- Channel bed structure
- Static versus dynamic bed composition
- Relative roughness versus form resistance
- Roughness elements, type and spacing
- Sediment continuity
- Erosive metrics; velocity, shear stress, stream power
- Naturalistic or pseudo natural
Design Issues

• Rivers have many degrees of freedom
• Require simultaneous solutions & feedback
• Not enough equations for each unknown
• Supplement analysis with empirical relations
• Need sustainable systems, tolerate hydrologic modifications
• Use physical models
FLUVIAL SYSTEM UNDERSTANDING

Physical models
- Canal Regime Theory
- River Regime Theory
- Hydraulic Geometry Relations
- Reference Reaches
- Multiple Regression Analysis

Empirical

Steady Uniform Flow
- Non-Uniform Flow
- Computer Hydraulics
- Sediment Transport
- Mixed Bed Transport
- Tractive Force

Analytical

1775
1879
1890

Theoretical

Extremal Hypothesis
- Extremal Regime Hypothesis
- Dimensionless Analysis

1970's
CLASSIC GRADIENT VERSUS BED FORM RELATIONSHIPS

MONTGOMERY & BUFFINGTON, 1993

BUT THEY DO NOT ADDRESS THE INFLUENCE OF DISCHARGE

GRANT, 1990

Figure 5.22 Relationship Between Gradient and Bed Forms (after Grant et al., 1990)
1.2 % Slope

2 % Slope

3.2 % Slope

3.5 % Slope
STREAM POWER VERSUS BED FORM

Fig. 2. Total stream power versus discharge for step-pool, plane-bed, and pool-riffle channel types.

Wohl & Merritt, 2008
RELATIVE ROUGHNESS

Slope vs. natural relative submergence

Relative submergence vs. roughness
Bathurst, 2002

Pool Headloss
SMALL SCALE PROFILE ELEMENTS

- Figure 47: The general design layout of experimental rock-ramp fishways in New South Wales, Australia (after Harris et al., 1998)
- Newbury, 1993
- Rosgen, 2006
- UK EA, 2009
- UN/DVWK, 2002

Figure 4.3: Construction of bottom ramps and slopes

Fig. 4.5: Bottom step in boulder bar construction (plan view)
BED MOBILITY

Bankfull Dimensionless Shear Stress

Bagnold, 1966

Stable

Bedload

Mixed load

Shields-Parker, in Garcia, 2010
BRIGGSVILLE DAM REMOVAL, 2010

IMPOUNDED SEDIMENT

POST DAM CHANNEL

1.4 %
Natural Steps
Deerfield River

Created Step
Briggsville Dam
BALLOU DAM PROFILE

Post Dam 2.8 % Slope
Fig. 2. Total stream power versus discharge for step-pool, plane-bed, and pool-riffle channel types.

Wohl & Merritt, 2008
# Howland Dam

<table>
<thead>
<tr>
<th>Feature</th>
<th>Specification</th>
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<tbody>
<tr>
<td>Length</td>
<td>700 Feet</td>
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<tr>
<td>Hydraulic Height</td>
<td>19 Feet</td>
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<tr>
<td>Structural Height</td>
<td>30 Feet</td>
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<td>Type</td>
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<tr>
<td>Material</td>
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<tr>
<td>Hazard Classification</td>
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<td>Sediment</td>
<td>Trace</td>
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<tr>
<td>Age</td>
<td>Constructed Early 1900’s</td>
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<td>Use</td>
<td>Hydroelectric</td>
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<tr>
<td>Mean April Flow</td>
<td>8800 CFS</td>
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<tr>
<td>Comments</td>
<td>Denil Fish ladder</td>
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</tbody>
</table>
Piscataquis Bypass Channel

1-D Model

Dam

Pool Riffle Bed Form
Physical Model??

PROPOSED CONDITIONS - HOWLAND BYPASS CHANNEL

PENOBSCOT RIVER RESTORATION

PENOBSCOT RIVER  STATE OF MAINE  MAY 27, 2008

Fig. 2. Total stream power versus discharge for step-pool, plane-bed, and pool-riffle channel types.
DISCUSSION