Jun 26th, 3:50 PM - 4:10 PM

Concurrent Sessions A: Co-Benefits of Barrier Removal: Fish Passage and Public Safety - Flood Resiliency, Aquatic Organism Passage, Critical Infrastructure, and Economics

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Presenter Information
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Flood Resiliency, Aquatic Organism Passage, Critical Infrastructure, and Economics
A Case for Stream Simulation Design and ERFO Policy Changes

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- Susan Wells, Jan Rowan, Curt Orvis, US Fish & Wildlife Service
- Rich Kirn, Vermont Fish & Wildlife Department
- Amy Singler, Eileen Fretz, American Rivers
- Alison Bowden, Jessica Levine, The Nature Conservancy
Discussion Topics

- Define terms
- Why does this matter
- Why & how structures fail
- Stream Sim design methodology
- Upper White River case study and hydraulic results
- Why did stream sim design survive
- Cost Comparisons
- Recommendations
Why does this matter?

Undersized structures effect more than just aquatic resources. Private property and critical infrastructure are lost, with climate change this will only get worse.

We are going broke with constant repairs and maintenance which are not necessarily considered in the true life cycle costs.
ERFO REGULATIONS

• Under the Public Assistance Program, FEMA funds between 75%-90% of the estimated cost for a culvert replacement if it passes the “50% rule” (a structure is eligible for replacement if the repair cost exceeds 50% of the replacement cost). Otherwise, FEMA provides financial assistance at the 75%-90% rate to repair the original structure, but not necessarily the costs to repair roads or other structures damaged by the culvert failure.

• Repair costs of a damaged site (emergency and permanent repairs) totaling less than $5,000 are NOT eligible for ERFO funding. In addition, damages at two or more sites shall NOT be combined to meet that threshold.
Definitions

- **Flood Resiliency** – A road crossing structure that is capable of surviving a flow greater than the design flood with minimal maintenance required.

- **AOP** (Aquatic Organism Passage) – A road crossing structure that allows passage of aquatic organisms of all species and life stages in addition to other terrestrial, amphibian, reptile species of importance.
Definitions

- Critical infrastructure – Road crossing of importance where loss can have dramatic impacts on public safety, emergency management, and commerce.

- Economics – The true cost of structures and how we pay for it all
Failure Mechanism During Floods

Failure Mechanism

- Hydraulic Exceedance (capacity)
- Sediment “Slug”
- Woody Debris Lodgment (slower by collection of woody debris and sediment buildup)
- Debris flow (Large / catastrophic - Natural or from upstream crossing failure)
How and Why do Structures Fail (In Floods)

Plugging Hazard Mechanism

- Design flood overtops structure (hydraulic capacity exceeded)
- Abrupt Transitions
- Poor vertical alignment with channel
- Poor stream to structure geometry (skewed). Structure and geometry disrupt sediment transport (transitions)
- ***Poor geomorphic location or design not accounting for diversion potential*** Furniss et al 1998
Diversion Potential

Small plugged culverts can create big messes on hill slopes. Failure point not built into the design
Poor Geomorphic Location

I Fought the Fan and the Fan Won!

Even Good Designs In Poor Locations Fail If They Are Not Designed To Fail!
?How Do We Achieve Flood Resiliency and AOP? Or Can We Have Our Cake And Eat It Too!

Stream Simulation Design: A channel that simulates characteristics of the adjacent natural channel (reference reach), will present no more of a challenge to movement of organisms than the natural channel.

Simulated high gradient channel
Mitkof Island, AK. Tongass NF

At bankfull flow
5 to 7+” of rainfall in less than 48 hours in steep mountainous terrain
Tropical Storm Irene Affected Structures

~1,240 structure were damaged or destroyed State-wide

Jenny Coolidge Area

Bridge & Highway Status as of August 31, 2011

State / Town Bridge Closures:
- Closed
- Open with restrictions
- Open with construction delays
- Open

State Highway Closures:
- Road closed
- Closed - Authorized vehicles only
- Open with restrictions
- Open with construction delays
- Normal service restored
- No reported damage - expect normal

Legend:
- State Highways
- White River
- Streams
- Roads
- GNIS

Economic Analysis Area
Damage on GMNF

- 24 Forest Service System Roads 21 miles
- Estimates repair costs = $6.4+ million
- $284,000 in trail damage

Forest Road 58 - $688,000
Kelley Stand Road System - $3,500,000
Stream Simulation
Design Study Site
Jenny Coolidge Brook

Structure - Bottomless SPPA
5.49 x 1.75 x 16.66 m @ 5.1% as built gradient
On 3m high concrete footing

What structures survived the floods with no real damage?
Jenny Coolidge Brook – Pre & Post Flood Profile

Pre flood / As-built profile

Post flood profile

Structure - Bottomless SPPA
5.49 m x 1.75 m x 16.66 m
On 3m high concrete footing

Stream gradients - ~3 to 6%
Residual Pool depth – 0.35 m (stream) to 0.47 m (structure)
Outlet aggradation - +0.48 m
Inlet and adjacent upstream reach degradation – - 0.5 to 0.6 m
• Original As-Built conditions modeled
• Roughness determined by empirical methods (Limerinos & Jarrett method)
• Regression equations used to determine flows.
• Flood indicators surveyed in the field both up and downstream
• Modeled Q500 flow approximately matches flood indicators in several locations
Lost largest boulders near outlet and some roughness along stem walls.
Structure and road undamaged and structure passes all aquatic organisms
Stream Simulation Flood Proof!
Green Mountain National Forest - FR17A - Bottomless Arch Inlet

Completed Construction 2010

Post TS Irene  September 2011

Storm flows did not overtop the road. Minimal scour on left side of arch
Stream Simulation Design
Jenny Coolidge Brook

Prior to Reconstruction

Post Irene Construction Outlet

Aggradation

Post Irene Condition Outlet
Stream Simulation Design
Jenny Coolidge Brook

Pre Irene Construction
Upstream of Structure

Post Irene Condition
Upstream of Structure
Stream Simulation Design

Jenny Coolidge Brook

Pre Irene Construction
Inside Structure

Post Irene Condition
Inside Structure
What Design Attributes Contributed to Stream Simulation Success in Surviving Large Floods?

- **Structure Width > Bankfull Width**
  
  `{ Larger cross section area / no constriction}`
What Design Attributes Contributed to Stream Simulation Success in Surviving Large Floods?

- **HW:D < 0.8** (usually 0.6 – 0.7) @ Q100
  
  \{ increased hydraulic capacity & debris capacity \}
What Design Attributes Contributed to Stream Simulation Success in Surviving Large Floods?

- **Vertical adjustment Potential** is understood
  
  `max scour based on pool depth, pool controls, materials, and risk`

![Diagram showing stream simulation success and vertical adjustment potential](image-url)
What Design Attributes Contributed to Stream Simulation Success in Surviving Large Floods?

- **Structure design profile gradient based on reference conditions (within 25%).**

{ Slope in sync with reach – sustainable }
What Design Attributes Contributed to Stream Simulation Success in Surviving Large Floods?

- **Smooth inlet and outlet bank transitions** prevent debris capture.
What Design Attributes Contributed to Stream Simulation Success in Surviving Large Floods?

- Equal mobility & stability of bed material and key bedforms (steps, roughness elements)

**Bed moves at same time as reference conditions, Key pieces stable to Q100 (banks, grade controls)**
What Design Attributes Contributed to Stream Simulation Success in Surviving Large Floods?

- *Floodplain conveyance accounted for in design*
Economic Arguments for a New Approach

“Another reason bigger is sometimes better”

Culvert failures can cause significant road damage
Plugged Culvert cause $1.1 Million road damage

Example – Churchville Rd, Hancock, VT

- 12', Q25 steel pipe remained intact but washed out 1200 FT of Churchville Rd in August 2011
- As of April 2012, Churchville Rd is still closed
- An unmaintained road had to be upgraded so residents could continue to access Route 100, though less directly
- Town was not eligible for FEMA grant money to upgrade the culvert
- FEMA will pay for the replacement of the road at $1.1 million
- Tentative plans to install a bridge in 2013 at a cost of $200,000

<table>
<thead>
<tr>
<th>Structure</th>
<th>Estimated Repair Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Culvert</td>
<td>$0 (no damage to culvert, plugged at inlet)</td>
</tr>
<tr>
<td>Churchville Rd</td>
<td>$1.1 million</td>
</tr>
<tr>
<td>Class 4 Road improvement</td>
<td>$84,000</td>
</tr>
<tr>
<td>Traffic Delay Costs</td>
<td>TBD (gas, lost work time, etc)</td>
</tr>
<tr>
<td>Total Cost of Failure</td>
<td>$1,184,000 +</td>
</tr>
</tbody>
</table>
Upper White River Basin Culvert Costs

Cost increase for Stream simulation versus traditional hydraulic designs in the Upper White River Basin ranged from 9% to 22% of the installation costs.

- These are in line with other analyses (Gubernick 2006) that ranged from 10% to 30% increased in costs.
Future Recommendations

✓ Adopt consistent standards at state and local levels! Incorporate stream simulation road crossing designs into state standards.

✓ Design for failure! Avoid Diversion Potential

✓ Identify critical infrastructure and prioritize at watershed scale with critical aquatic habitat

✓ Modify regulations to help towns invest in appropriate road-stream crossing designs. Remove the current “INCENTIVE” to replace undersized structures with undersized structures

✓ Improved record-keeping and prioritization of “repeat offenders” for upgrades

✓ Educate engineers, politicians, and the public about improved design methods and the real costs of undersized structures / cheap decisions in a riverine environment
one fish
two fish
red fish
Gube fish

\[ Q = \frac{1.49}{n} AR^{\frac{2}{3}} S^{\frac{1}{2}} \]

???QUESTIONS???

Art By Tomas Dunklin