Design of Stream-Road Crossings for Aquatic Organism Passage in Vermont

**Final Design**

- Pre-Design

- Design: Stream Simulation, Low slope, Hydraulic, or other

- FINAL DESIGN
  - Check flood capacity
  - Detail design
  - Or other option

**Profile Control**

**Culvert Design for Fish Passage**

- Retrofit
- Replacement
- Removal
- New

- Roughness
- Adjust profile
- Roughened channel
- Grade controls
- Regrade
- Natural Bed

**Newbury Creek Project Profile**

**Scenario C:**
Regional incision.
Forced profile necessary.
Profile control options

- a. Do nothing; allow regrade
- b. Channel Reconstruction
- c. Hybrid roughened channel
- d. Rigid weirs
- e. Boulder weirs

Profile control options

<table>
<thead>
<tr>
<th>Option</th>
<th>Slope</th>
<th>Pros / Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fishway</td>
<td>10% or &quot;vertical&quot;</td>
<td>+ Small footprint, - Species, flow, sediment, debris</td>
</tr>
<tr>
<td>Log sills</td>
<td>5%</td>
<td>+ Rigid, durable, - Species, habitat</td>
</tr>
<tr>
<td>Roughened channel</td>
<td>Durability, bedload limit</td>
<td>+ Passage diversity, - Species, failure risk</td>
</tr>
<tr>
<td>Boulder controls</td>
<td>5% (+)</td>
<td>+ Passage diversity, Habitat, - Failure risk</td>
</tr>
<tr>
<td>Channel restoration</td>
<td>Limited by channel type</td>
<td>+ Passage diversity, Habitat, - Scale</td>
</tr>
<tr>
<td>Regrade</td>
<td>?</td>
<td>- Regrade risk, time to restore</td>
</tr>
<tr>
<td>Do Nothing</td>
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</tr>
</tbody>
</table>

Fishways

- Pool and weir styles typically used downstream of culverts.
- Passage behavior by species; leaping, swimming
- Criteria
  - Step height, step shape
  - Energy dissipation - limits flow range
- Debris, sediment maintenance

Fishways

- Objectives:
  - Steepen grade
  - Rigid permanent bed control
  - Optimize passage for target species, not diverse
  - Narrow flow range
  - 10% grade max in small channels. Bypass fishways "vertical"
  - Minimum footprint
  - High construction, operation, maintenance cost
  - Designs available
Concrete, sheet pile, ...

- Objectives:
  - Steepen grade
  - Rigid permanent bed control to maintain steep grade
- Less than 5% grade max in streams
- Designs available
- Prefabricated; installation easy but demands care
- Shape to fit channel and control thalweg
- Built-in abutments, energy dissipation, cutoff, crest shape

Fishways as grade control

Little Park Cr

3 pre-cast panels for channels up to 12 ft.

Notch to maintain channel thalweg

Elevation View

Plan View

Modular Arch Drop Structure
Design of Stream-Road Crossings for Aquatic Organism Passage in Vermont

Log Controls
Used to raise incised channel
Passage optimized, Habitat not

Wildcat Cr Dam bypass channel
Constructed 1983
Failed after 20 years because no bedload recruitment.

Wildcat Cr Dam bypass channel
Constructed 1983

Bank failure
Log control structurally sound

Three keys to stability
1. Double log
2. Tiedown
3. Ballast


Index Creek
Vee log weirs
**Log controls**

- **Straight**
  - Objective: Steepen grade, optimize select passage, minimize cost and length, secure elevation control
  - 5% grade max as bed retention
  - Uniform channel
  - Secure designs available
- **Vee log**
  - Objective: Steepen grade, deepen thalweg, narrow channel, provide select passage
  - More diverse channel
- Can be made complex
- Durable

**Boulder Weirs**

- Details
  - Select materials, construct arch, use footer rocks, key individual rocks
  - Careful construction and supervision necessary
- Good option for upstream "flexible" control
  - 5% grade max in small channels
- Designs available
- Easily adjusted
- Maintains channel shape
- Cascading failure possible
Boulder weirs

Great Brook waterline
before
With boulder weirs

Barnard - WDFW
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Cedar Creek rock vees for bed retention

Chutes

Spring Prairie Cr
Cobble riffle

Design: Robert Newbury
Photo: Jane Watts, Fundy NP

Luther Aadland

Design: Robert Newbury
Photo: Jane Watts, Fundy NP
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Looking downstream

Before

After

Individual weirs
- Energy dissipation
- Diversity

Weir shape
- top width
- head differential
- plan vee
- cross section vee
- low flow channel

Critical construction supervision
Design of Stream-Road Crossings for Aquatic Organism Passage in Vermont

First fish passage since 1900 and four months later...

Boulder weirs and chutes

- Boulder weirs
  - Select materials, construct arch, use footer rocks, key individual rocks
  - Careful construction and supervision necessary
  - Less than 5% grade max in small channels
  - Easily adjusted
  - Cascading failure possible
- Chutes
  - Low to moderate slope
  - Good option for upstream “flexible” control
  - Maintain channel shape
  - Designs available

Channel restoration for passage of aquatic organisms

Profile restoration
Restored channel
Planform restoration

Outlet Creek – 2005
Upstream channel
Downstream channel incised
**Channel restoration**

- Objective:
  - Steepen grade
  - Optimize passage
  - Restore habitat
- Design natural channel as full stream simulation project
- High cost and project length
- Max slope is function of channel width and passage objectives

**Final Design**

- Pre-Design
- Design: Stream Simulation, Low slope, Hydraulic, or other
- Check flood capacity
- Detail design
- Final Design
- Or other option
Stream simulation regardless of type of structure

- Bridge
- Box
- Pipe Arch
- Bottomless Arch
- Embedded Round

Pipe compared to bottomless

- Pre-assembled pipe greatly reduces time for construction
- Structure not vulnerable to scour and headcut
- No measures needed to protect stream from fresh concrete
- Less costly and complex construction and less risk of error because no concrete footing
- Shape may allow narrower excavation
- Higher load capacity in poor foundation soils

Bottomless compared to pipe

- Can be placed over existing streambed or top loaded
- Can be placed over bedrock
- Footings can be shaped to bedrock.
- Concrete stemwall provides durability against abrasion and corrosion
- Construction duration increased by cast-in-place concrete
- High shear strength of bed reduces risk of bed failure
- Compaction easier without round shape

Considerations for Culvert/bridge Type

- Opening size vs. channel stability, horizontal & vertical
- Span existing channel, how far?
  - channel shape, width, and depth
  - confinement – risk of pressurized pipe
- Geology – bedrock and soil foundation characteristics
- Road fill height, culvert cover, loading, right of way
- Durability of structure & life cycle costs,
- Construction – construction time, excavation, dewatering, traffic
Other culvert shape and material considerations

- Prefabricated or precast can be installed as single or few pieces
- Precast box can be top loaded
- Structural plates can be pre-assembled
- Concrete is more durable
- Corrugations have more shear stress
- Compaction of round haunches is difficult

Culvert Types - Yea and Nay

<table>
<thead>
<tr>
<th>Culvert Type</th>
<th>Advantages</th>
<th>Disadvantages</th>
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<tbody>
<tr>
<td>Box</td>
<td>Prefabricated (concrete)</td>
<td>Weight (concrete)</td>
</tr>
<tr>
<td></td>
<td>Durability (concrete)</td>
<td>Bed to structure shear (concrete)</td>
</tr>
<tr>
<td></td>
<td>Top loaded? (concrete)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Backfill compaction easiest</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Greatest foundation capacity</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Greater top width at flood flows</td>
<td></td>
</tr>
<tr>
<td>Round</td>
<td>Prefab or Pre-assemble</td>
<td>Deep excavation for economical width</td>
</tr>
<tr>
<td></td>
<td>Highest bed capacity</td>
<td>Compaction difficult</td>
</tr>
<tr>
<td>Pipe Arch</td>
<td>Prefab or Pre-assemble</td>
<td>Narrow range of headroom, bed depth</td>
</tr>
<tr>
<td></td>
<td>Low profile; cover and excavation</td>
<td>Compaction critical</td>
</tr>
<tr>
<td>Bottomless</td>
<td>Place over existing bed</td>
<td>Time for construction, fabrication</td>
</tr>
<tr>
<td>Arch</td>
<td>Place over bedrock</td>
<td>Footing construction often deep and wide</td>
</tr>
<tr>
<td></td>
<td>Construct independent footings</td>
<td>Structure vulnerable to scour at headcut</td>
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<tr>
<td></td>
<td>Degrading channel is structural issue</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bed to sub-bed shear strength</td>
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