Stantec

Bridging Fish Passage and Infrastructure Needs: Lessons from Cross- Jurisdictional Watercourse Crossing Design Guidelines

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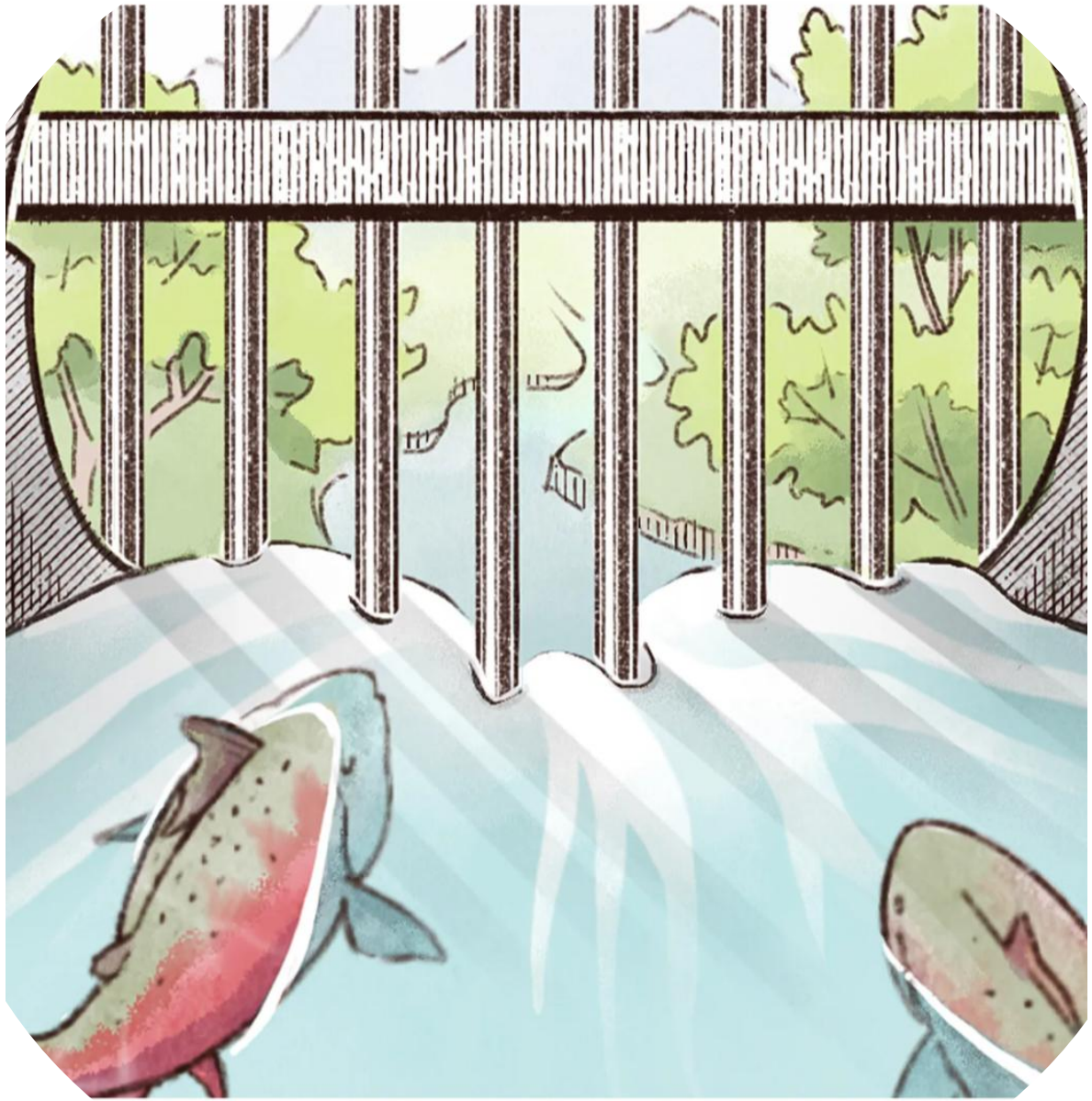


Image credit: Seattle Times, 2024

Image credit: DFO, 2022

Agenda

1. Why fish passage?
2. Culverts as barriers
3. The challenge
4. Where guidelines align
5. Where guidelines diverge
6. Let’s design a culvert
7. Comparing culverts
8. Takeaways

Why Fish Passage?

- **Fish passage**: ability of fish / other aquatic species to move through a water system
- Migration is essential for spawning and other lifecycle behaviours
- Anthropogenic barriers to fish passage disrupt movement
  - Dams
  - Weirs
  - **Culverts**

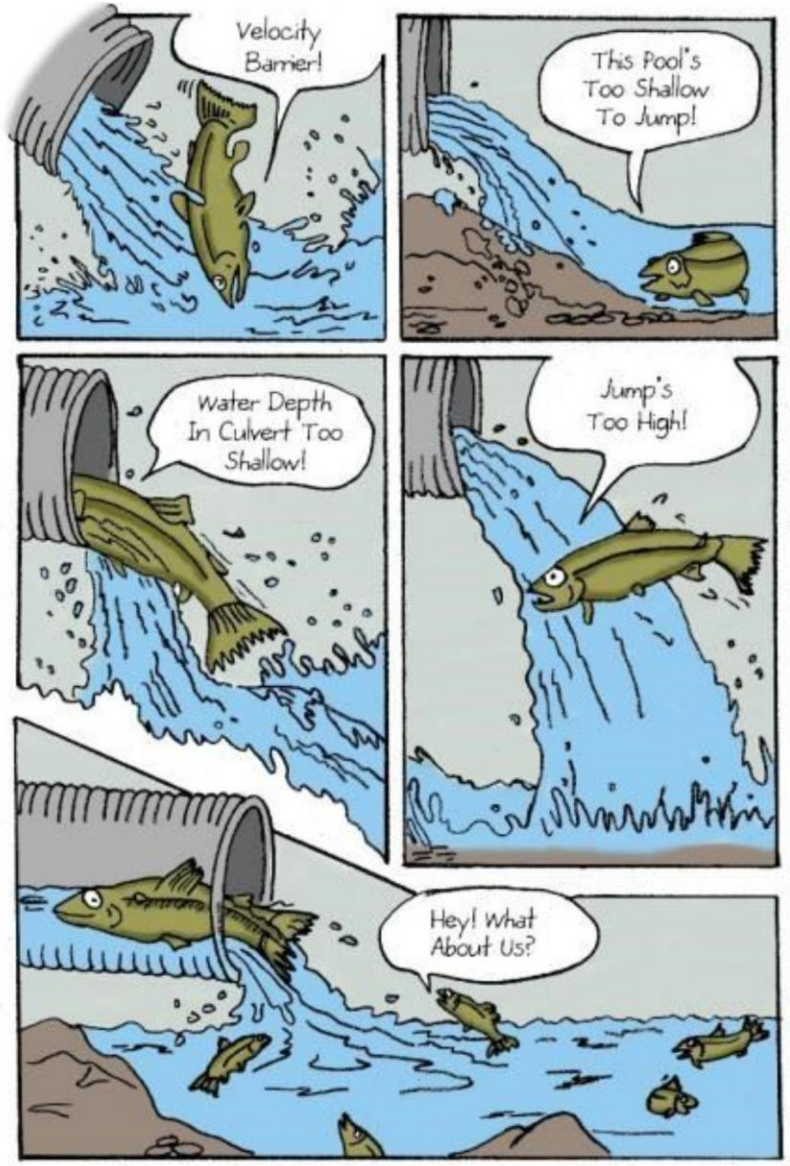


Image credit: Washington State Department of Transportation (WSDOT)

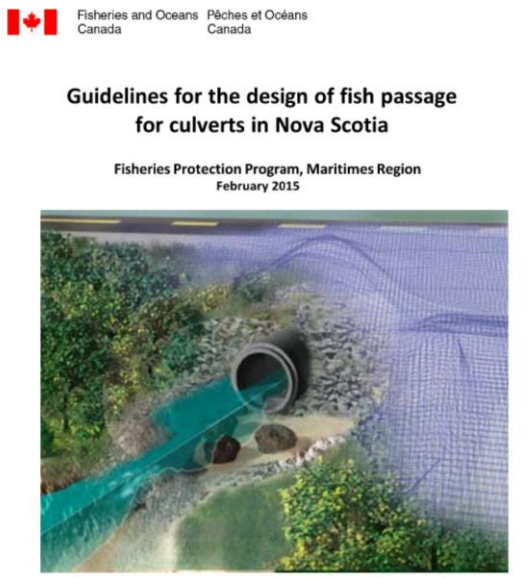
Culverts as Barriers

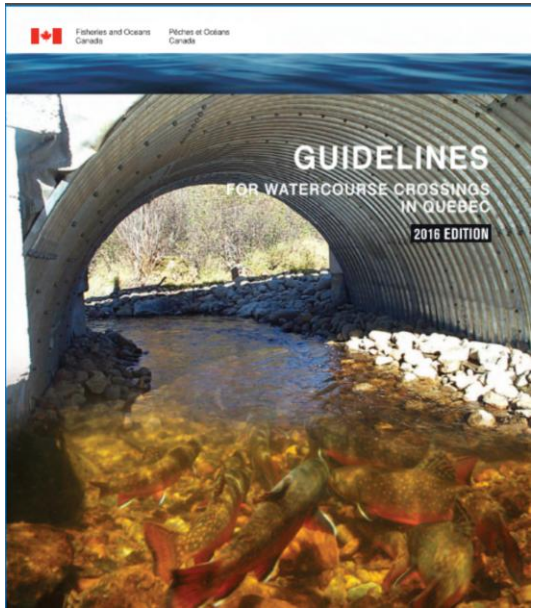
- Culverts historically designed primarily for **hydraulic conveyance**
    - **HADD** potential
- Recent recognition of importance of **ecosystem connectivity**
- **Stricter DFO requirements** for fish passage at crossings

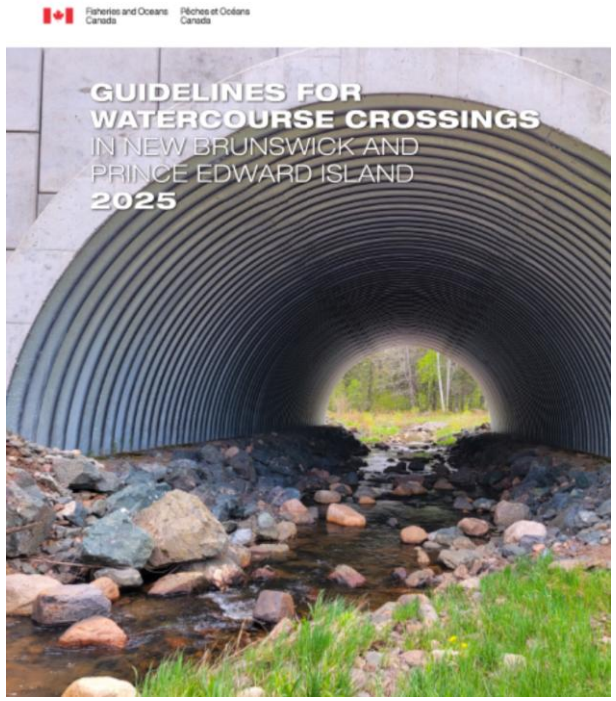
Image credit: US Forest Service (USFS), 2009

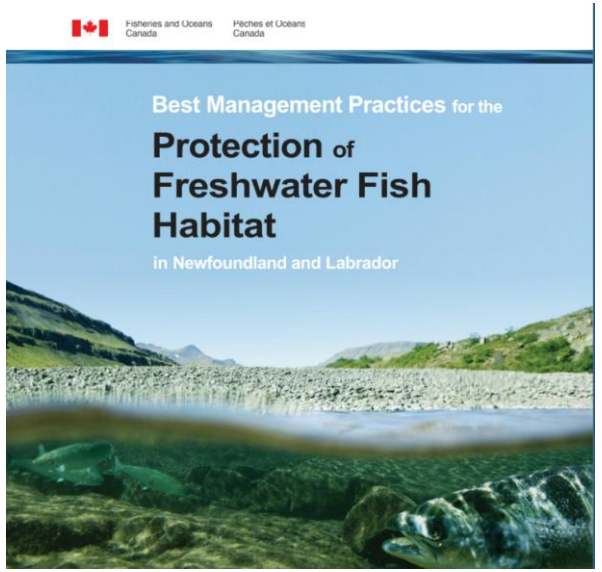
The Challenge

- A patchwork of guidance documents to navigate
- In Canada:
  - Non-unified guidelines from DFO for **some provinces**
- In U.S.:
  - Similar to Canada, select **state-issued guidelines** are available
  - **Federal guidelines** from U.S. Forest Service, focused on one method









Where Guidelines Align

Image credit: Department of Fisheries and Oceans Canada, 2016

Open-bottom always preferred

Where Guidelines Align

Image credit: Minnesota Department of Transportation (MDOT), 2019

Maintain adequate water depth under low-flow conditions (min.150-200 mm typically)

Where Guidelines Align

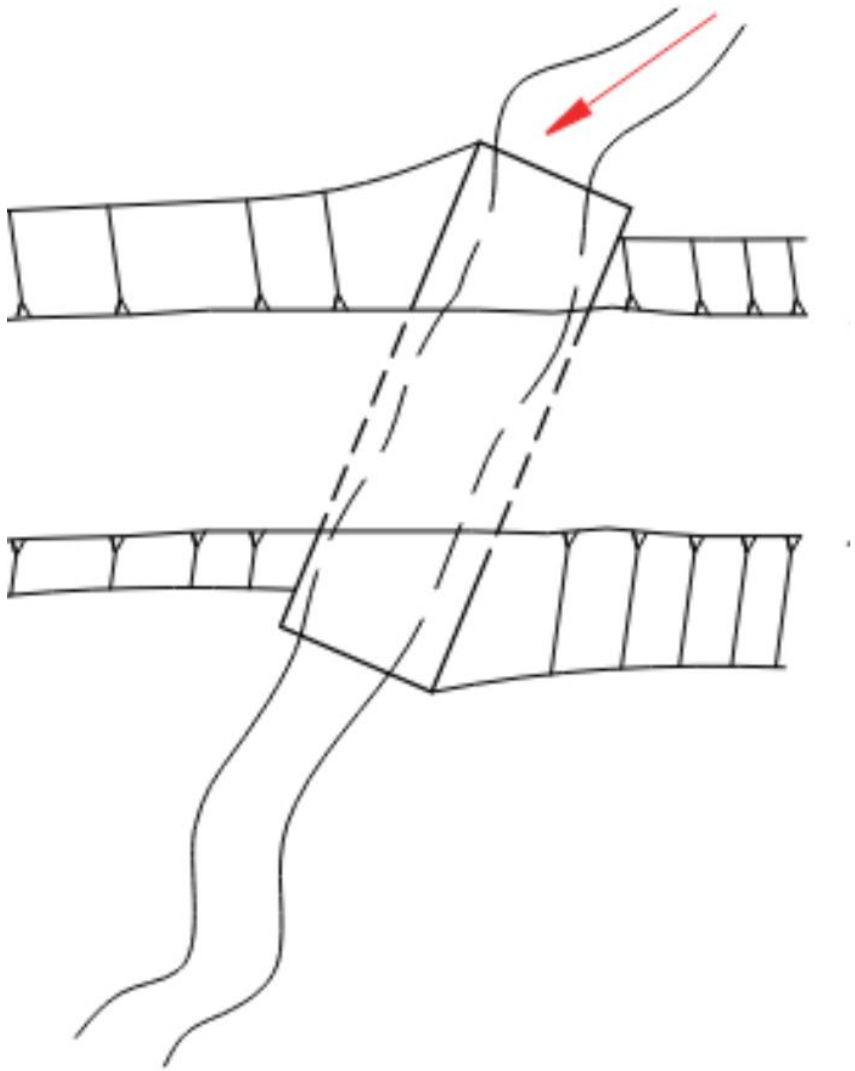


Image credit: USFS, 2009

Align culvert with natural channel to extent possible

Image credit: MDOT, 2019

Where Guidelines Align

Avoid excessive velocities, max. 0.6 – 1.2 m/s typically

Where Guidelines Align

Image credit: Seattle Times, 2024

Follow natural channel slope

Image credit: USFS, 2009

Where Guidelines Align

Avoid elevation drops/perches

Where Guidelines Diverge: Three Main Culvert Design Approaches

Stream Simulation

- Mimics natural channel substrate and slope
- Span larger than bankfull width

Hydraulic Simulation

- Needs steady sediment regiment

Hydraulic Design

- Best ecological option; mostly discussed in U.S. guidelines
- $$$

Image credit: USFS, 2009

Where Guidelines Diverge: Three Main Culvert Design Approaches

Stream Simulation

Hydraulic Simulation

Hydraulic Design

- Span equal to or larger than bankfull width
- Recreates hydraulic diversity
- Relies on oversized substrate
- Mostly discussed in newer Canadian guidelines
- $$

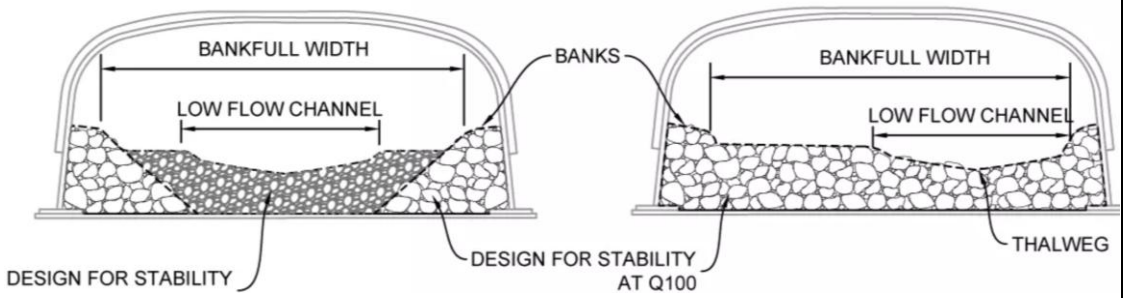


Image credit: U.S. Fish and Wildlife Service (USFWS), 2025

Where Guidelines Diverge: Three Main Culvert Design Approaches

Stream Simulation

- Meets species-specific criteria

Hydraulic Simulation

- Often smaller spans

Hydraulic Design

- May use baffles
- In some older DFO guidance, but recently discouraged
- $

Image credit: DFO, 2016

Let's Design a Culvert!

Imagine you are a highway engineer tasked with designing a fish passable culvert. You consult DFO guidance to do so.

Your site presents:

- Road width = 12 m
- Channel slope = 1%
- Bankfull width = 2.0 m
- Brook Trout present
- D84 = 120 mm
- Urban system with very little sediment load

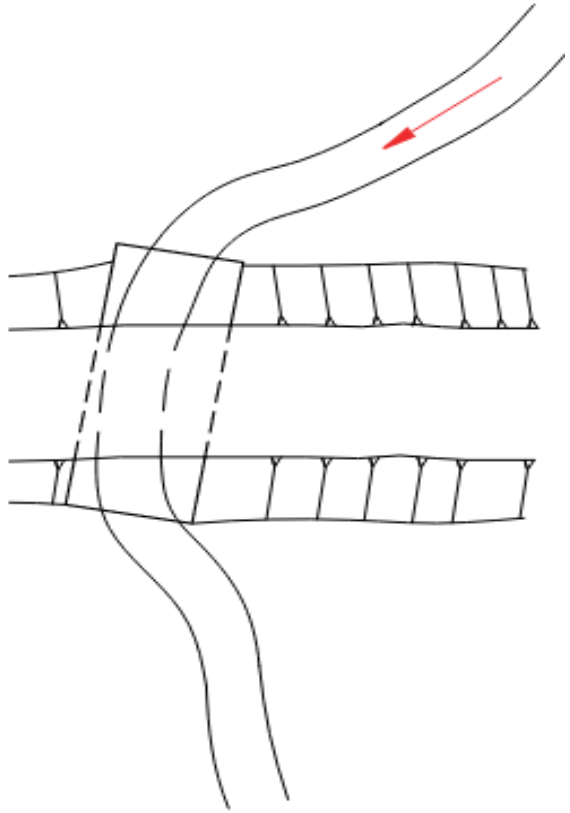


Image credit: USFS, 2009

Let's Design a Culvert!

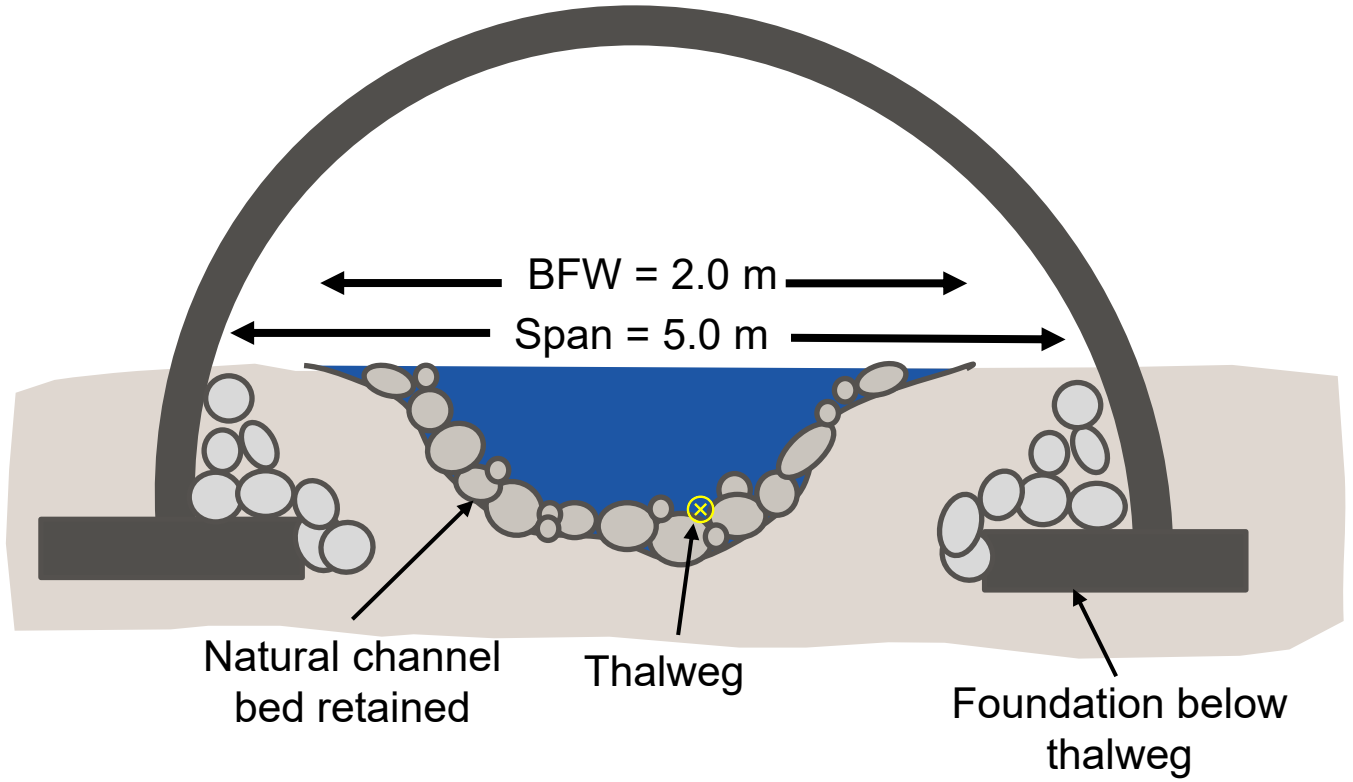
Open-Bottom Stream Simulation

Using DFO guidelines for **PEI/NB (2025)**

- Design to retain channel bed

Design Checklist:
- Alignment ✓
- Slope ✓
- Span ✓
- Substrate ✓
- Length ✓

Cross-section view of designed culvert



Culvert slope	1%
Culvert length	15 m
Culvert alignment	Directly with channel

Let's Design a Culvert!

Open-Bottom Stream Simulation

Design Implications

- Excellent ecologically
- $$$

Image credit: USFS, 2009

Let's Design a Culvert!

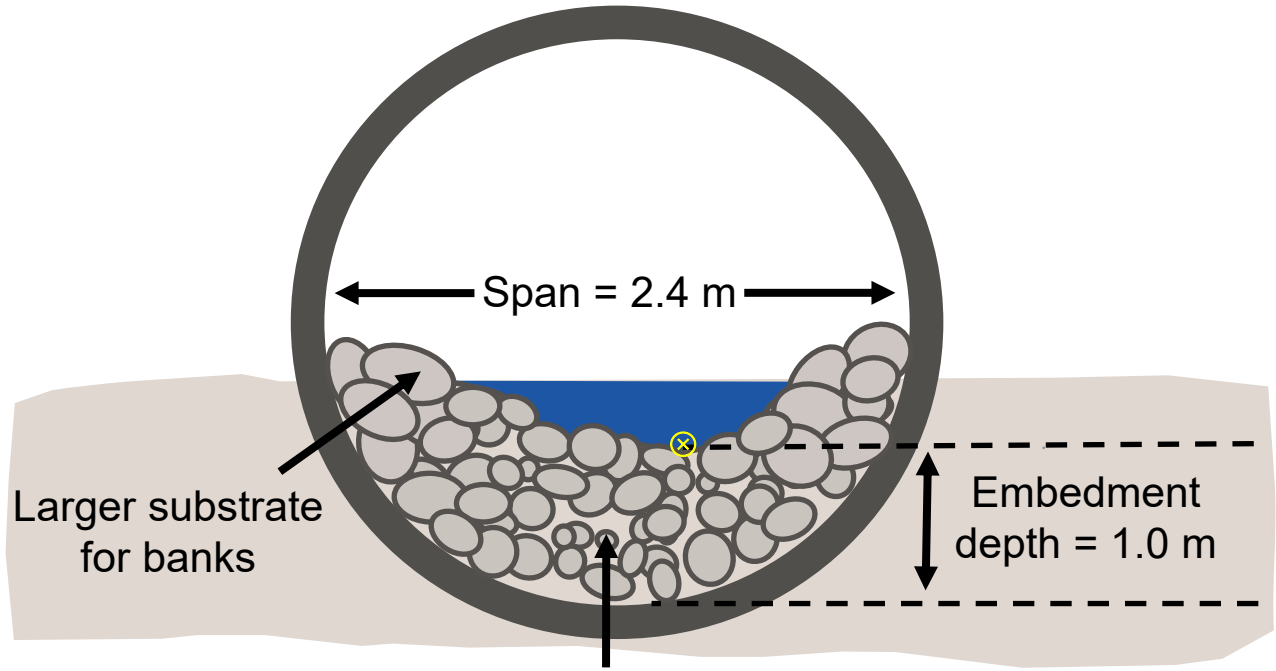
Closed-Bottom Stream Simulation

Using DFO guidelines for **PEI/NB (2025)**

- Design to recreate channel bed
- Substrate to be stable under design flow
  - Analyzed to be 180 mm

Design Checklist:
- Alignment ✓
- Slope ✓
- Span ✓
- Substrate ×
- Length ✓

Cross-section view of designed culvert



Bed substrate sized based on natural channel (D_{84} = 120 mm)

Culvert slope	1%
Culvert length	15 m
Culvert alignment	Directly with channel

Let's Design a Culvert!

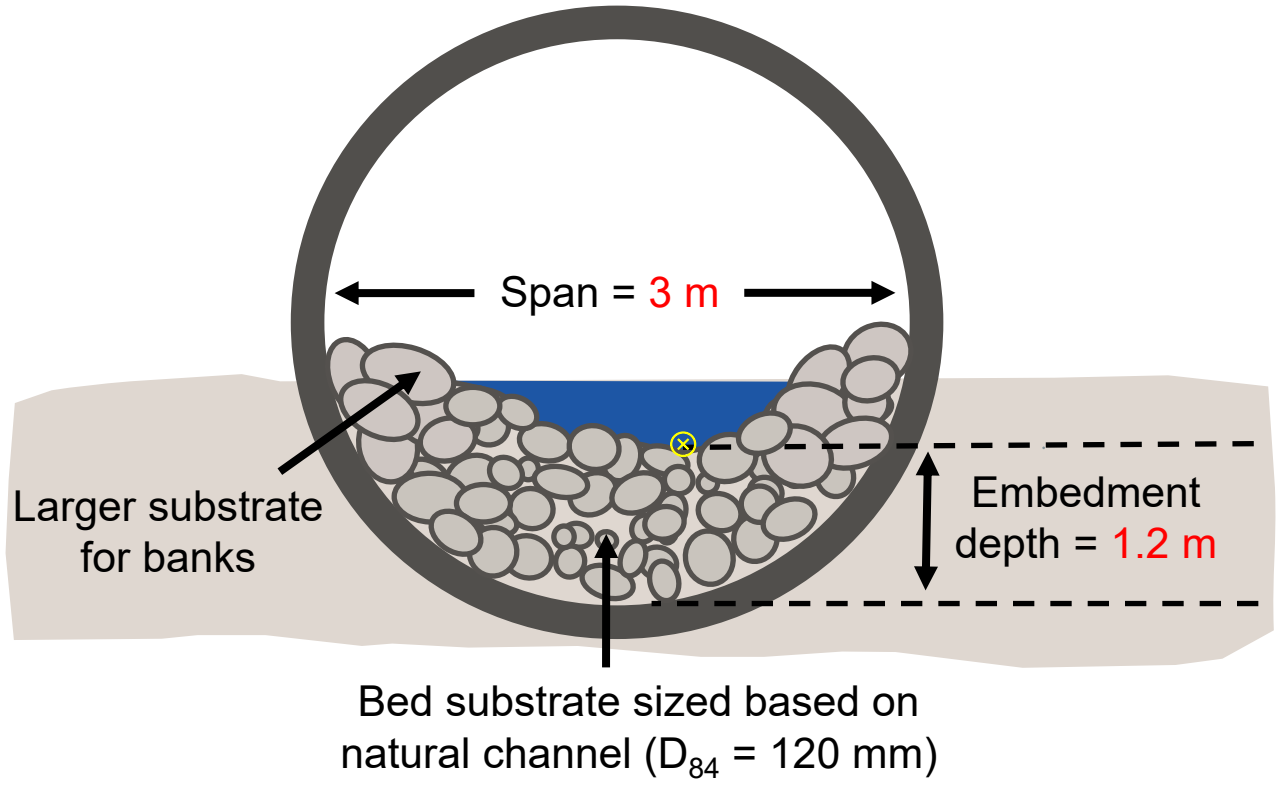
Closed-Bottom Stream Simulation

Using DFO guidelines for **PEI/NB**

- Revising design to meet substrate criteria
  - Resulting in increased span

Design Checklist:
- Alignment ✓
- Slope ✓
- Span ✓
- Substrate ✓
- Length ✓

Cross-section view of designed culvert



Culvert slope	1%
Culvert length	15 m
Culvert alignment	Directly with channel

Let's Design a Culvert!

Closed-Bottom Stream Simulation

Design Implications

- Excellent ecologically
- $$$

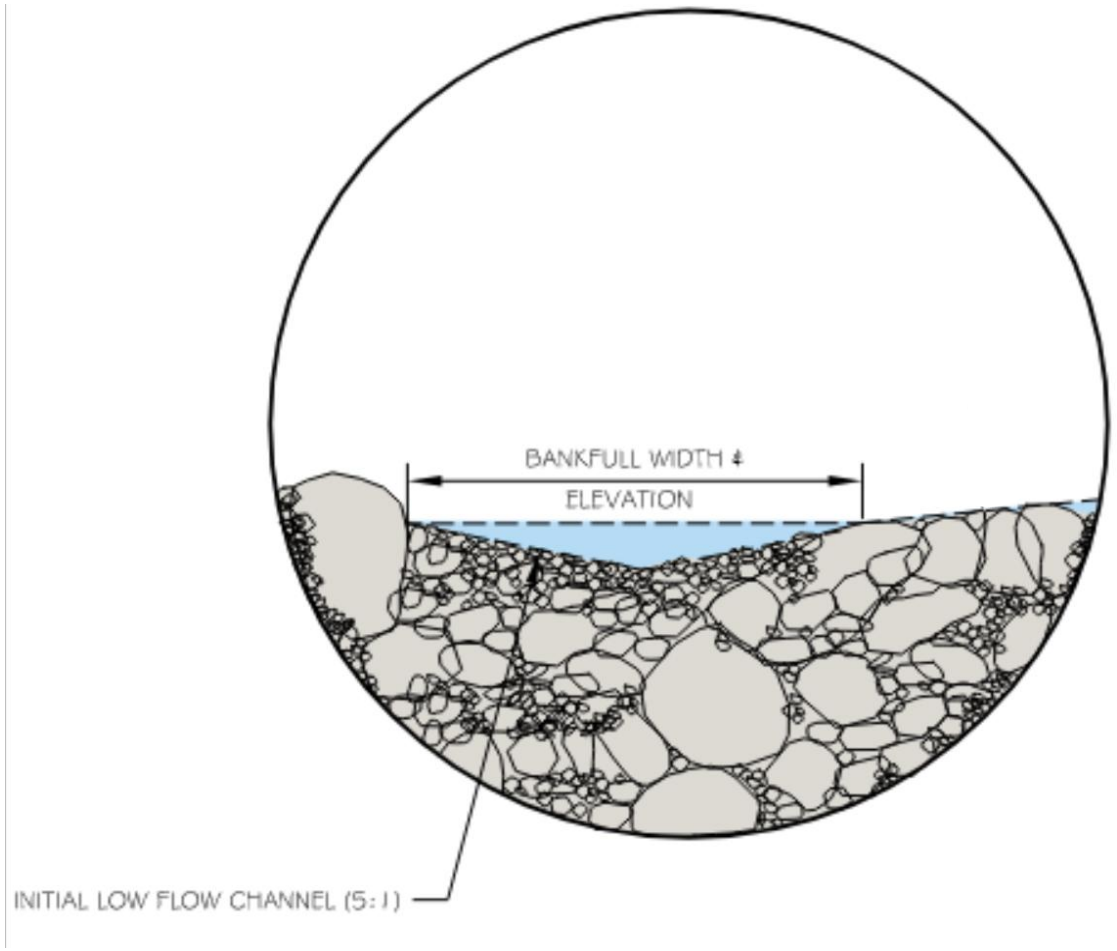


Image credit: USFS, 2009

Let's Design a Culvert!

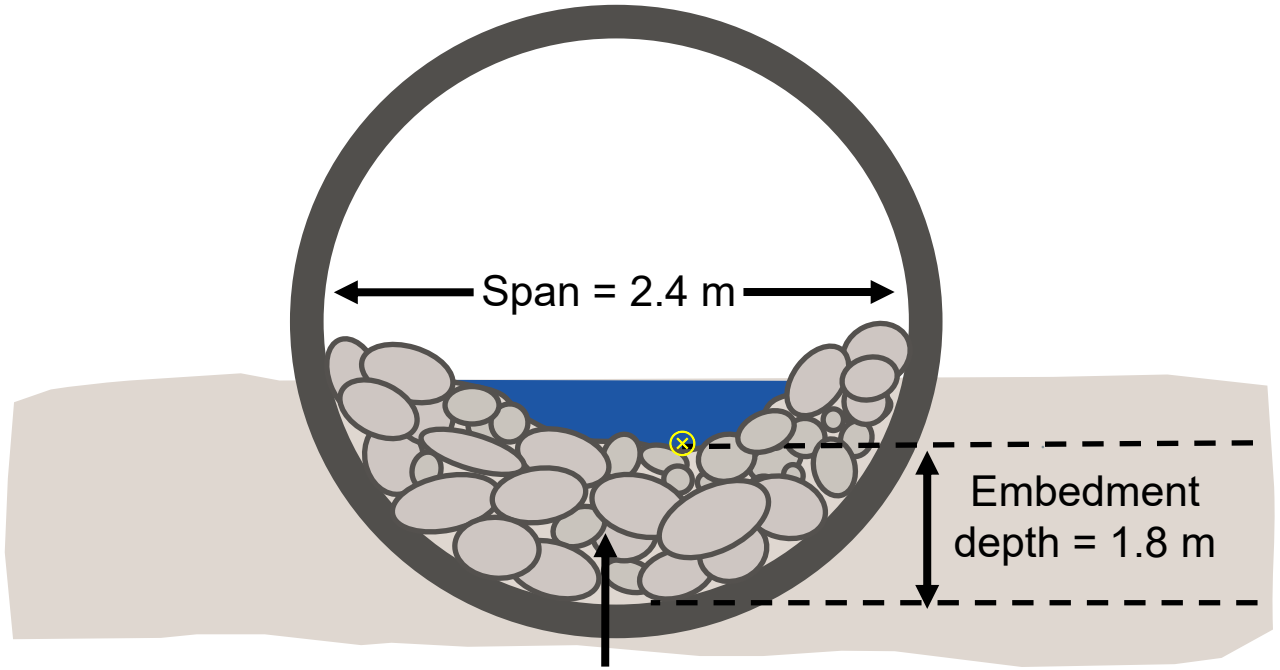
Hydraulic Simulation

Using DFO guidelines for **Quebec (2016)**

- Oversized substrate in channel bed (stable under design flow)
- Span ≥ (2*D_{100}) + BFW
  - D_{100} analyzed to be 220 mm

Design Checklist:
- Alignment ✓
- Slope ✓
- Span ✓
- Substrate ✓
- Length ✓

Cross-section view of designed culvert



Culvert slope	1%
Culvert length	25 m
Culvert alignment	Directly with channel

Let's Design a Culvert!

Hydraulic Simulation

Design Implications

- Good ecologically
- $$

Image credit: Washington Department of Fish and Wildlife (WDFW), 2003

Let's Design a Culvert!

Hydraulic Design

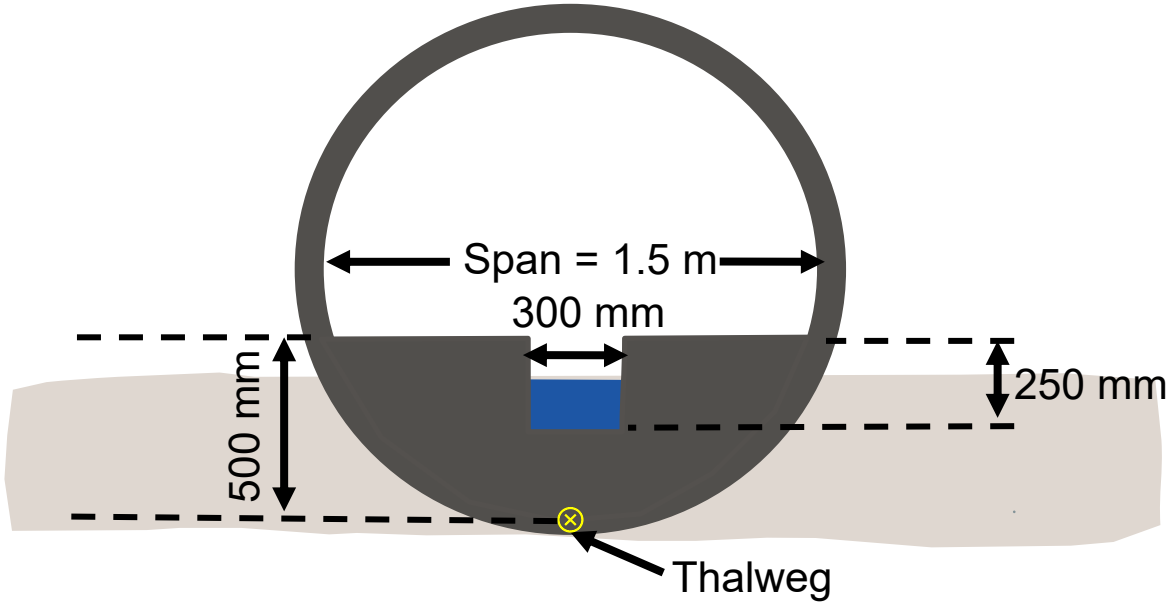
Using DFO guidelines for **Nova Scotia (2015)**

- Design for target species based on low-flow conditions
- Use baffles
- Include energy dissipation pool at outlet

Design Checklist:

- Alignment ✓
- Slope ✓
- Span ✓
- Substrate ✓
- Length ✓

Cross-section view of designed culvert



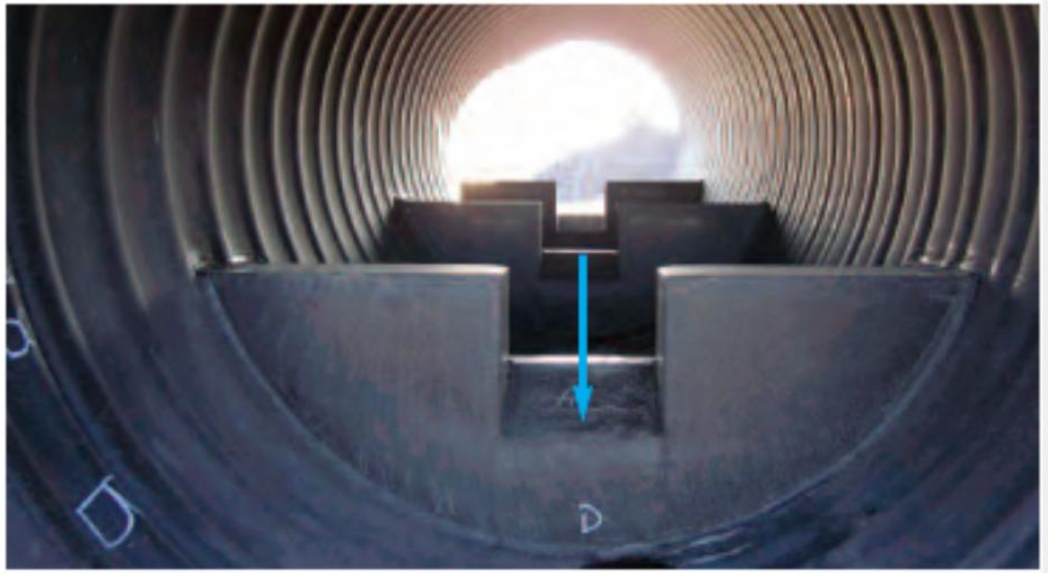
Culvert slope	1%
Culvert length	25 m
Culvert alignment	Directly with channel
Baffle width	300 mm
Drop between baffles	200 mm
Baffle spacing	2.0 m
Number of baffles	12

Let's Design a Culvert!

Hydraulic Design

Design Implications

- Not ecologically optimal
- $



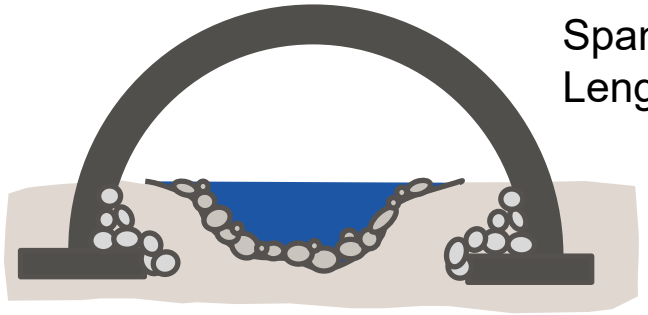
Polyethylene baffles (view from downstream)

Concrete baffles (view from upstream)

Image credit: DFO, 2016

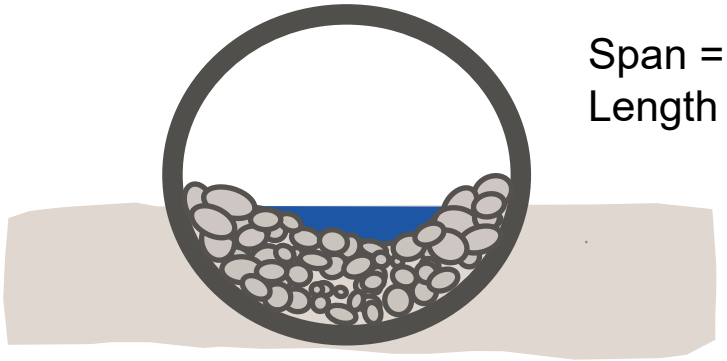
Comparing Culverts

Open-Bottom Stream Simulation - PEI/NB



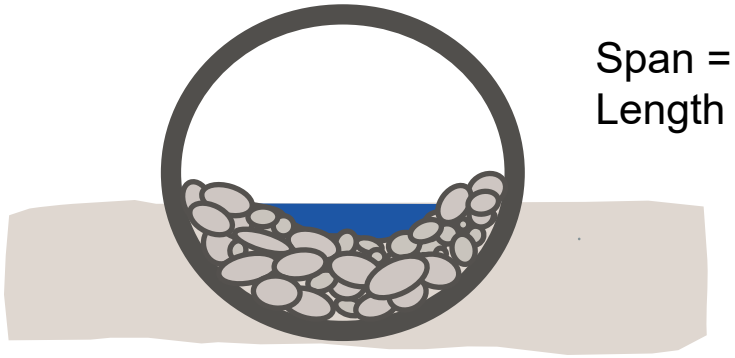
Span = 5.0 m
Length = 15 m

Closed-Bottom Stream Simulation - PEI/NB



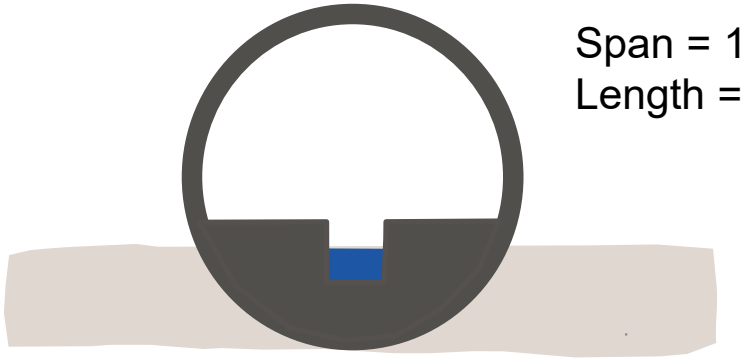
Span = 3.0 m
Length = 15 m

Hydraulic Simulation - Quebec



Span = 2.4 m
Length = 25 m

Hydraulic Design - Nova Scotia



Span = 1.5 m
Length = 25 m

Takeaways

- Not as simple as designing for hydraulic conveyance **OR** designing to match natural channel exactly
- Urban environments require special consideration
- Various ways to be successful in designing a channel crossing

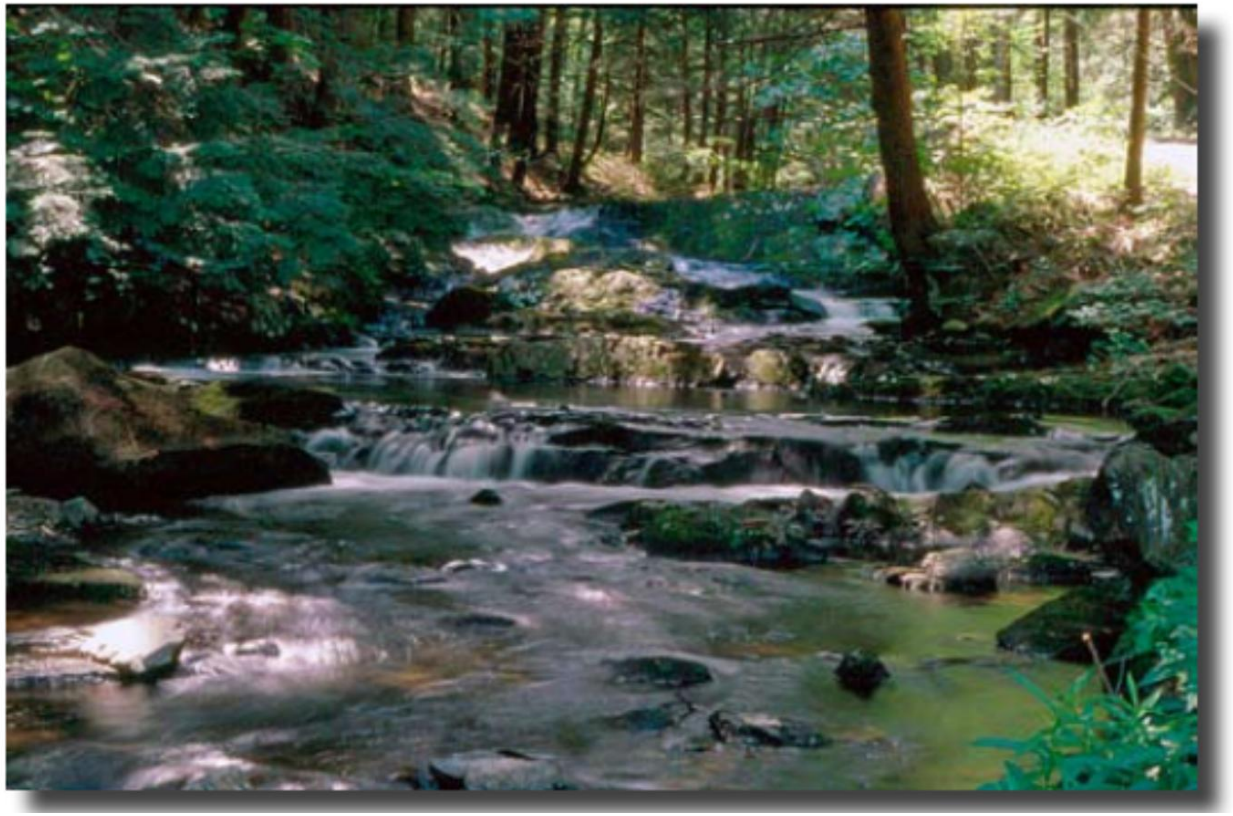


Image credit: USFS, 2009

Takeaways

- Design holistically for success
  - Consider hydraulics, ecology, fluvial geomorphology, and transportation
- Opportunity to harmonize fish passage guidance

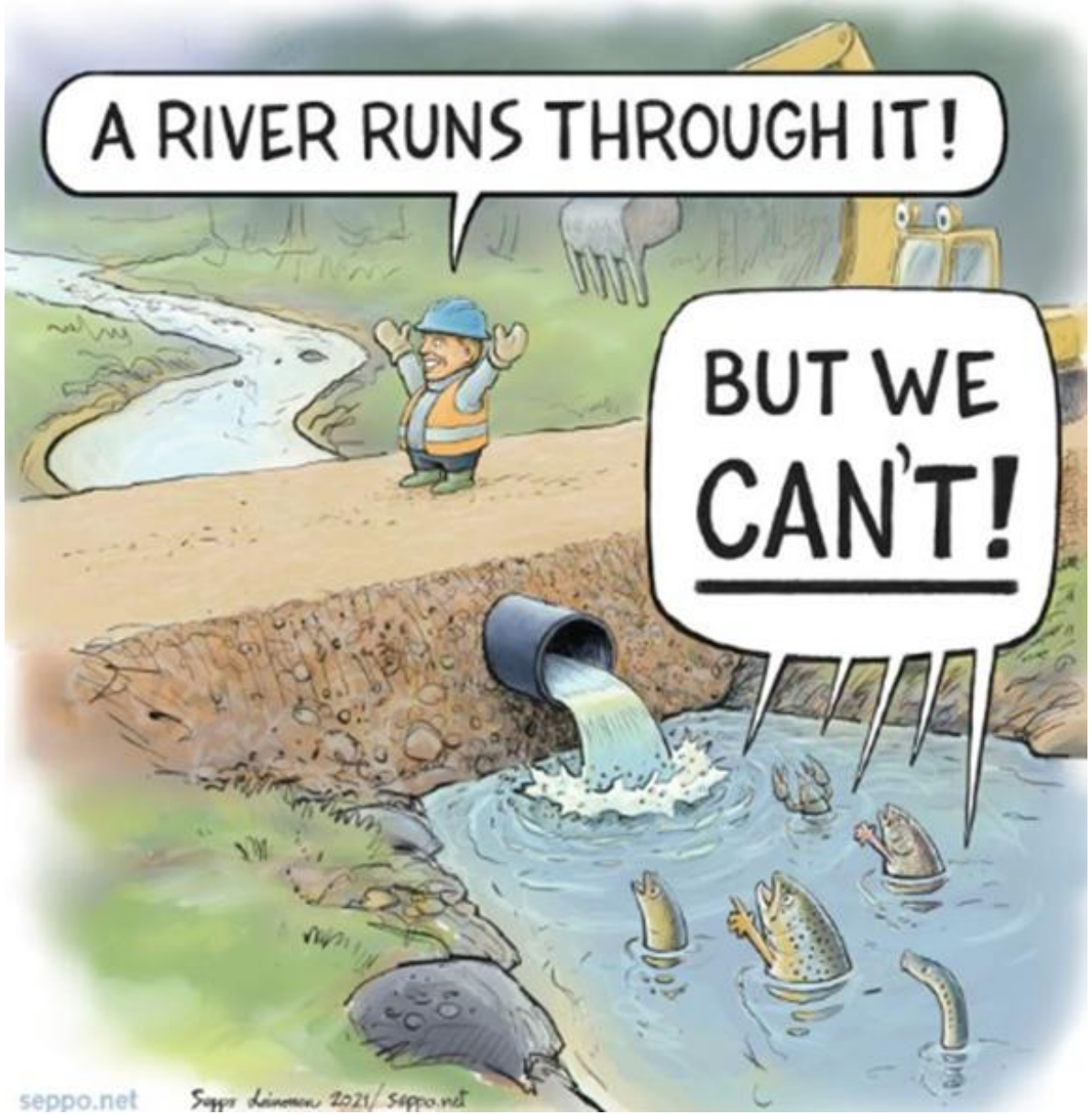


Image credit: Seppo Leinonen

Questions?

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Thank you!

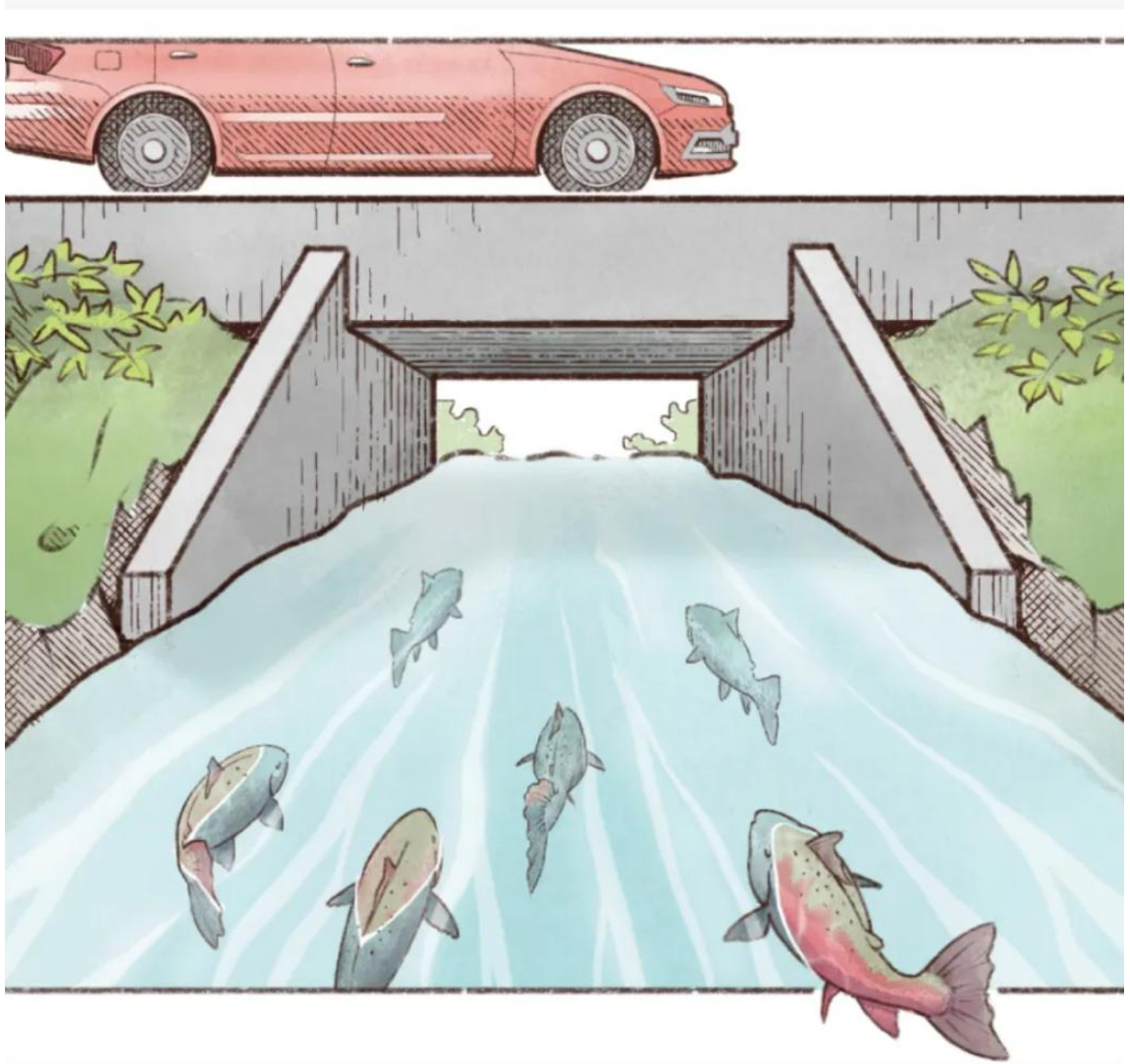

Image credit: Seattle Times, 2024