STORM WATER AWARENESS WEEK 2024

September 23-27

STORMWATERAWARENESS.ORG

Retrofitting Culverts to Support Fish Passage

Shane Scott – Principal Biologist and Owner

SSA Environmental

Culverts and stormwater systems are a significant impact to fish and other aquatic organisms and their habitats. This workshop will present options for retrofitting culverts to improve safe and effective passage for fish and other aquatic organisms. We will review a wide variety of projects in various locations throughout North America.

SSA Environmental

Retrofitting Culverts to Support Fish Passage

1. Introduction and Background
2. Definitions
3. Describe Magnitude of the Problem
4. History of Culvert Retrofits
5. Current Technologies
6. Case Histories
7. Q & A

Introduction and Background

Shane Scott – Fisheries Biologist

- 30 years experience as a Utility Biologist
    - Tacoma Power
    - Washington Department of Fish and Wildlife
    - Public Power Council
    - Natural Resource Consulting
- 2019 began working on AOP at culverts in North America

Definitions

Culvert – a transverse drain (Merriam-Webster)

- Corrugated Steel Pipe (CSP)
- Structural Plate CSP
- Open bottom CSP
- Concrete Pipe
- Concrete Boxes – Precast
- Concrete Boxes – Cast in Place
- Polymer (plastic) Pipe

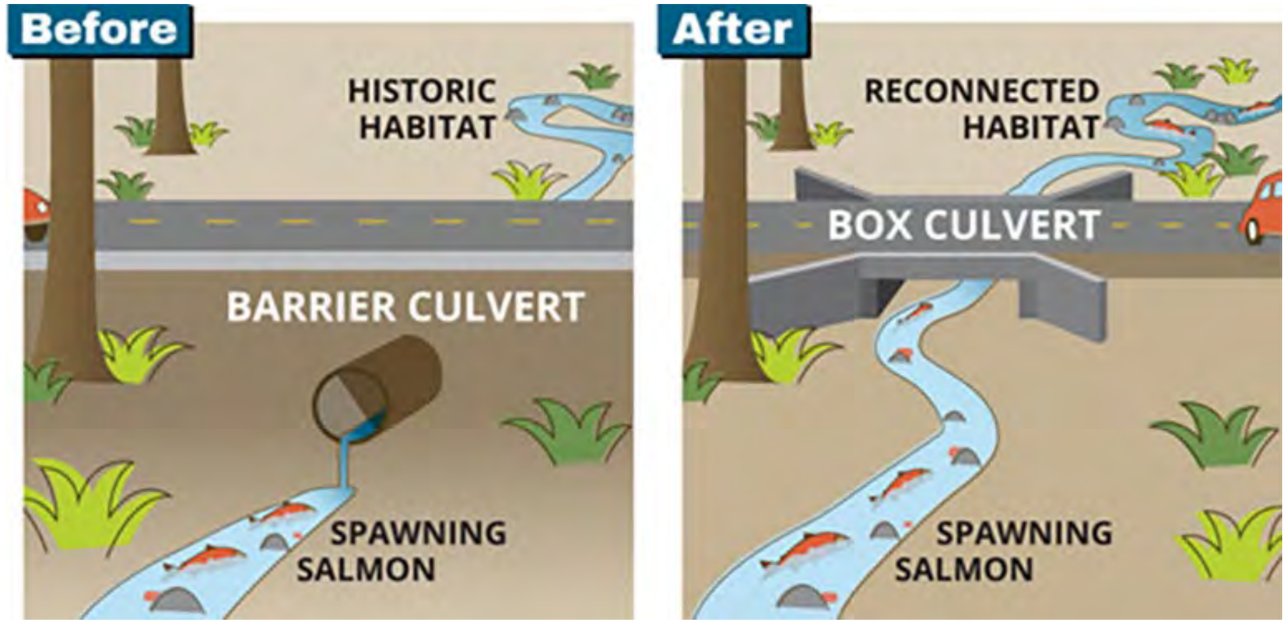
Definitions

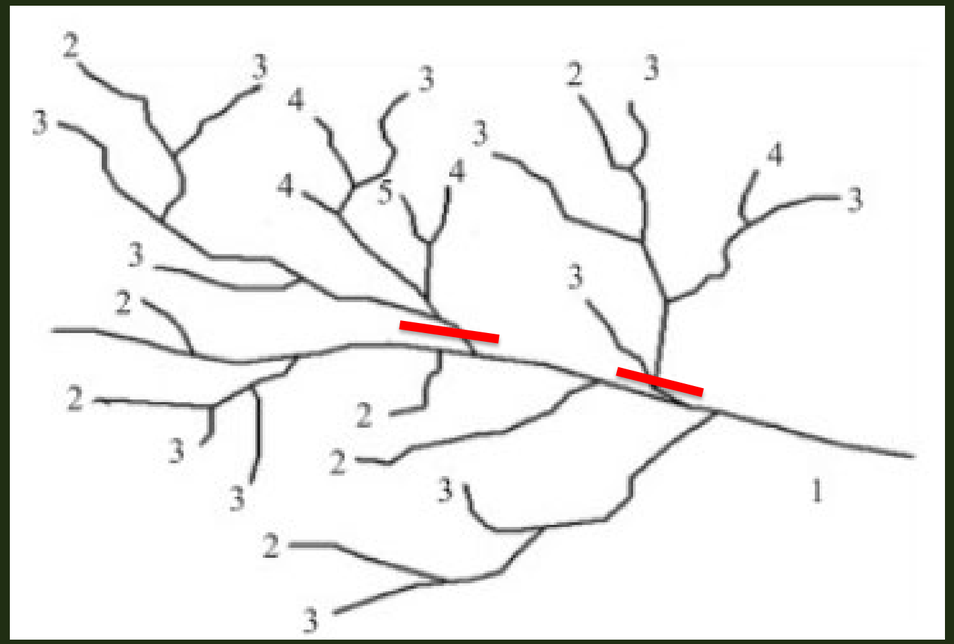
AOP – Aquatic Organism Passage

- All aquatic organisms including:
  - Fish
  - Amphibians
  - Reptiles
  - Insects
  - Etc.

Definitions

Habitat Fragmentation - discontinuities in an organism's preferred environment





Definitions

Success – Depends upon Conservation Goals

- Expanded AOP Opportunity
- Species Reintroduction
- Reduced Habitat Fragmentation

Magnitude

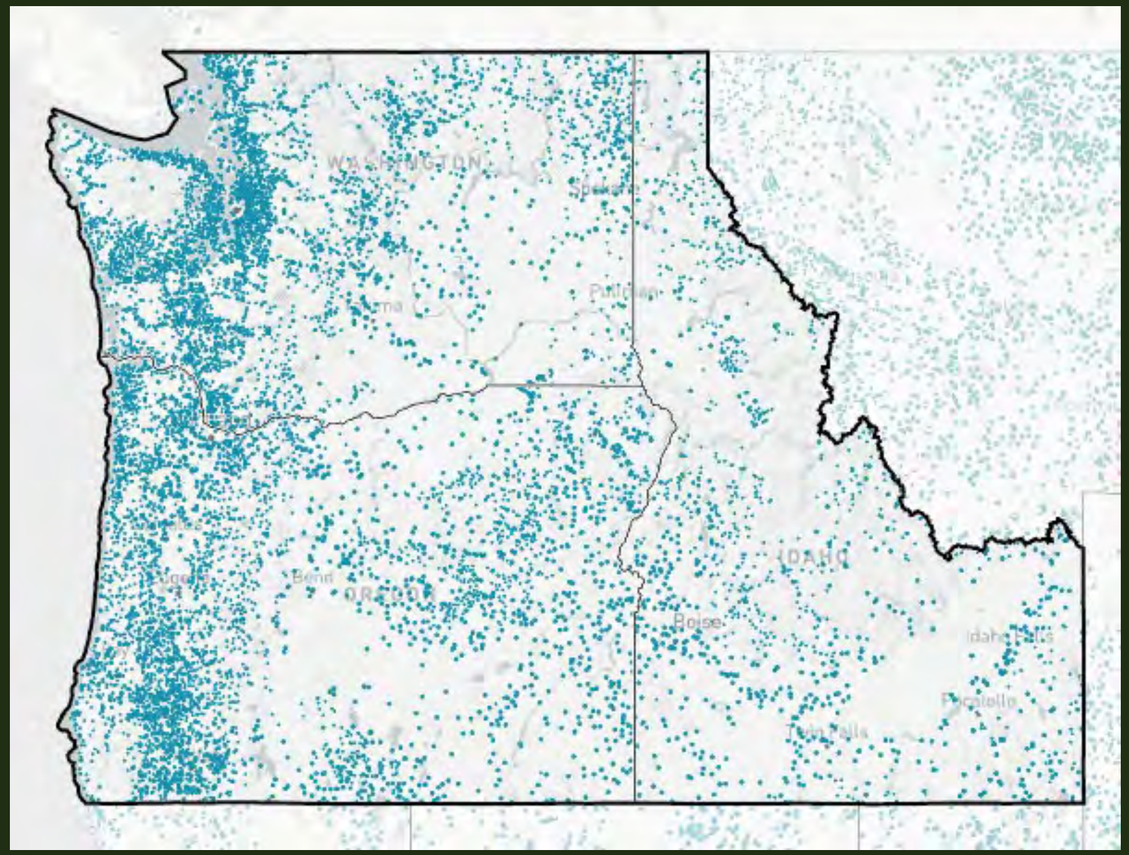
How Many Fish Passage Barriers are Out There?

National Aquatic Barrier Inventory:

775,166 or more potential road-related aquatic barriers, including:

- 60,022 (7.7%) have been assessed for impacts to aquatic organisms
- 38,292 that are likely to impact aquatic organisms
- 3,746 (0.5%) have been removed or mitigated

Pacific Northwest Region:



Magnitude

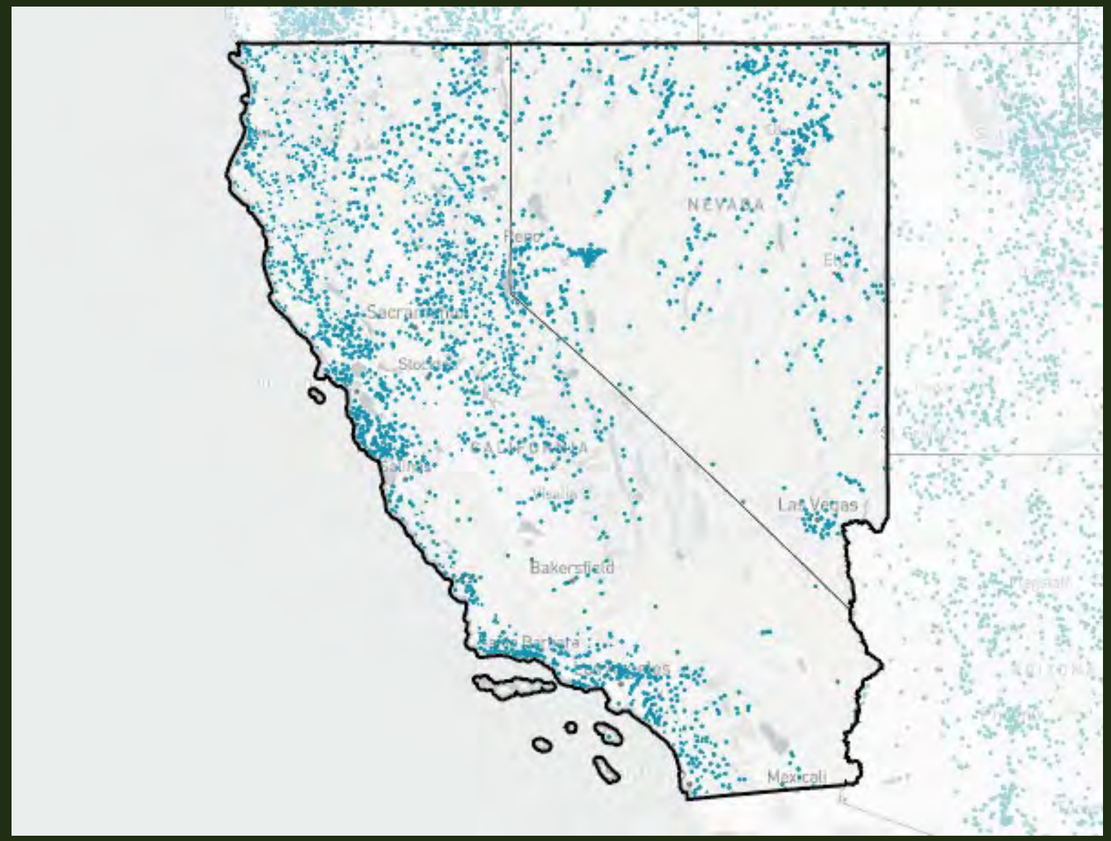
How Many Fish Passage Barriers are Out There?

National Aquatic Barrier Inventory:

678,462 or more potential road-related aquatic barriers, including:

- 17,316 (2.6%) have been assessed for impacts to aquatic organisms
- 3,938 that are likely to impact aquatic organisms
- 350 (0.05%)have been removed or mitigated

Pacific Southwest Region



Magnitude

How Many Fish Passage Barriers are Out There?

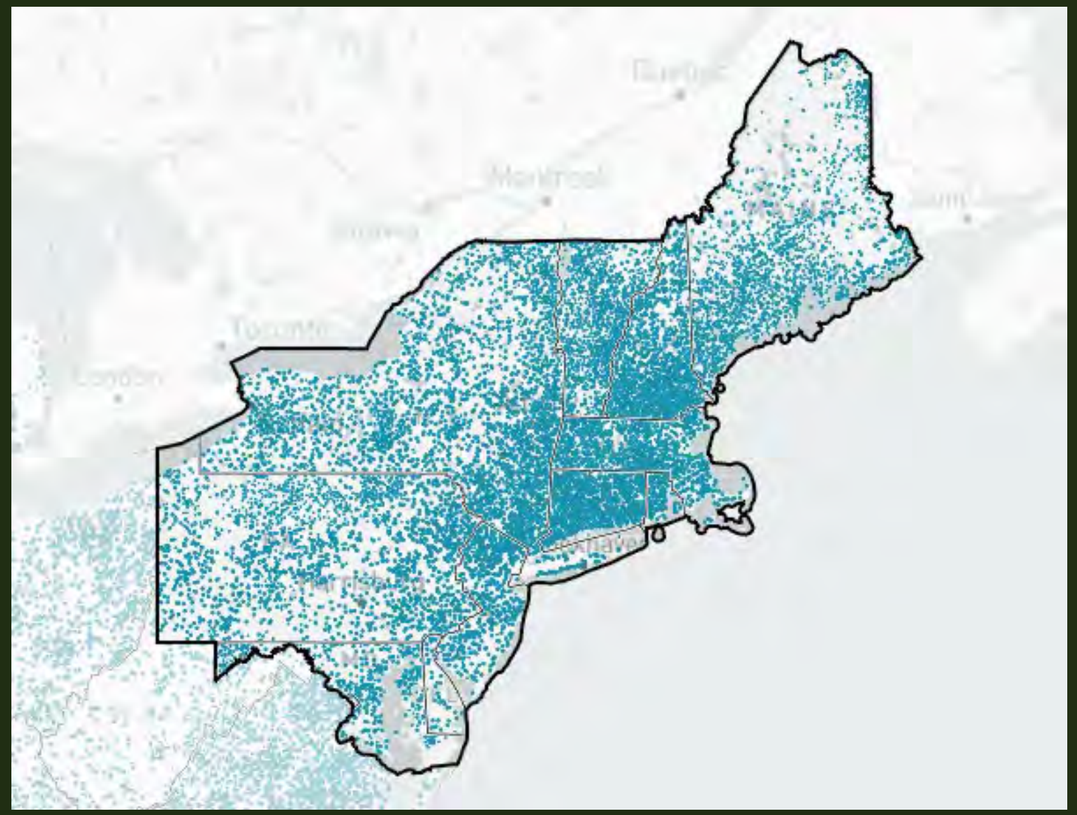
National Aquatic Barrier Inventory:

453,413 or more potential road-related aquatic barriers, including:

- 110,274 (24.3%) have been assessed for impacts to aquatic organisms
- 62,822 that are likely to impact aquatic organisms
- 136 (0.03%) have been removed or mitigated

Pacific Northwest Region

Northeast Region:



Magnitude

Culverts in Washington State

A 2013 federal court injunction requires WSDOT to open 90% of habitat blocked by state culverts by 2030:

- Replace 400 Culverts by 2030
- 146 corrected as of June 2024
- Current estimated cost - $7.8B
- Original cost estimate - $1.88B

WSDOT - Fish Passage US v. WA Case Area Boundary

Magnitude

Washington Department of Fish And Wildlife

Brian Abbott Fish Barrier Removal Board

- 2023 – 2025 Approved Project List
- 99 Total Projects - $85.7M
  - Planning Projects
    - 35 Projects – $9.6M
  - Restoration Projects
    - 67 Projects - $76.1M

Washington Department of Fish and Wildlife

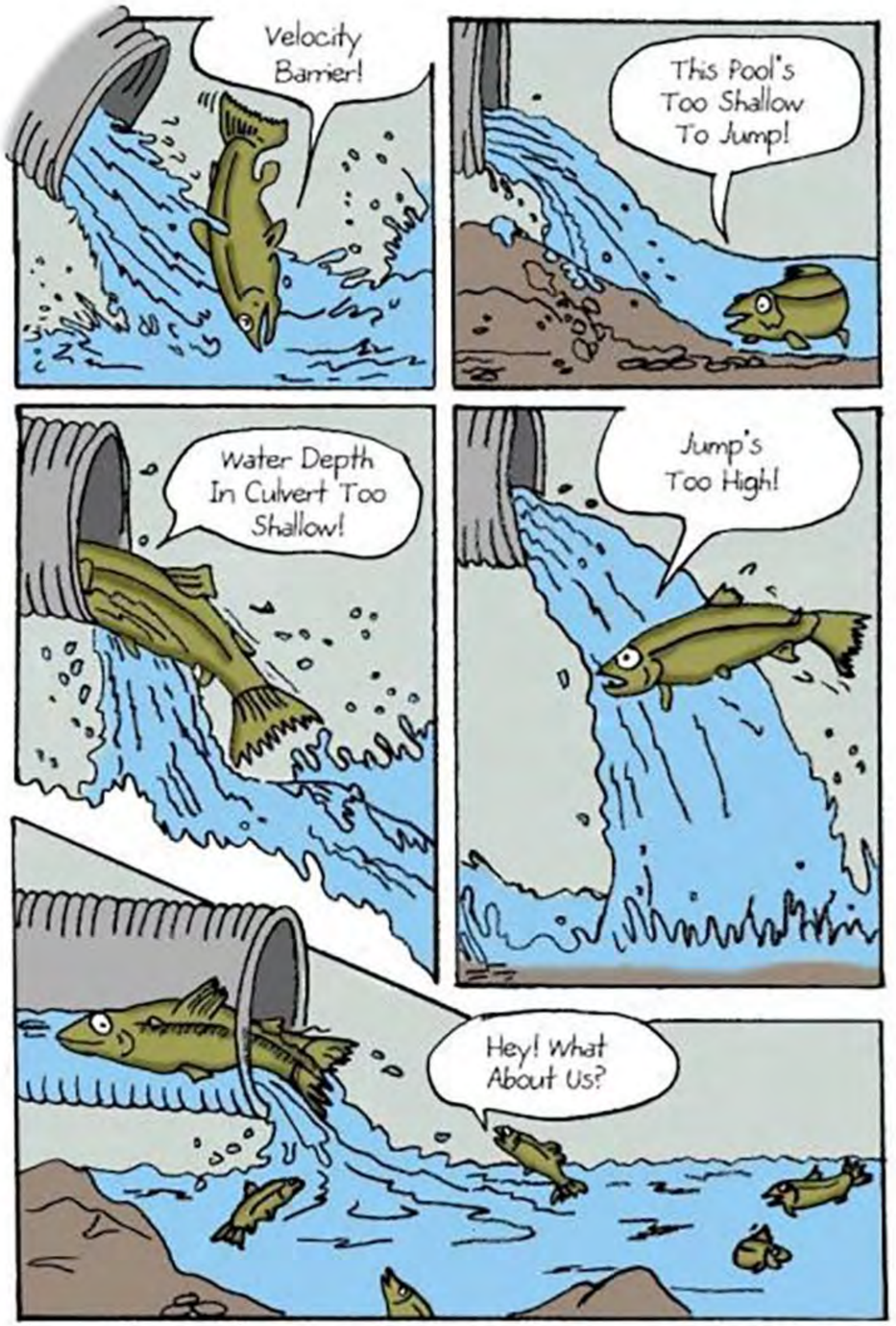
BRIAN ABBOTT FISH BARRIER REMOVAL BOARD

Dam(n) Culverts...

The Problem:

- High Water Velocities
- Shallow Water Depth
- Steep Gradient
- Plunge Height and Distance

= Passage Barrier



(Image courtesy of King County Fish Passage Program)

NOW WHAT?

1. Culvert Replacement

2. Culvert Modification/Retrofit

Culvert Replacement

(Image courtesy of Washington Department of Natural Resources

Culvert Replacement

Culvert Retrofit

Culverts:

- Shallow water
- High velocity
- No “complexity”

Culvert Retrofit

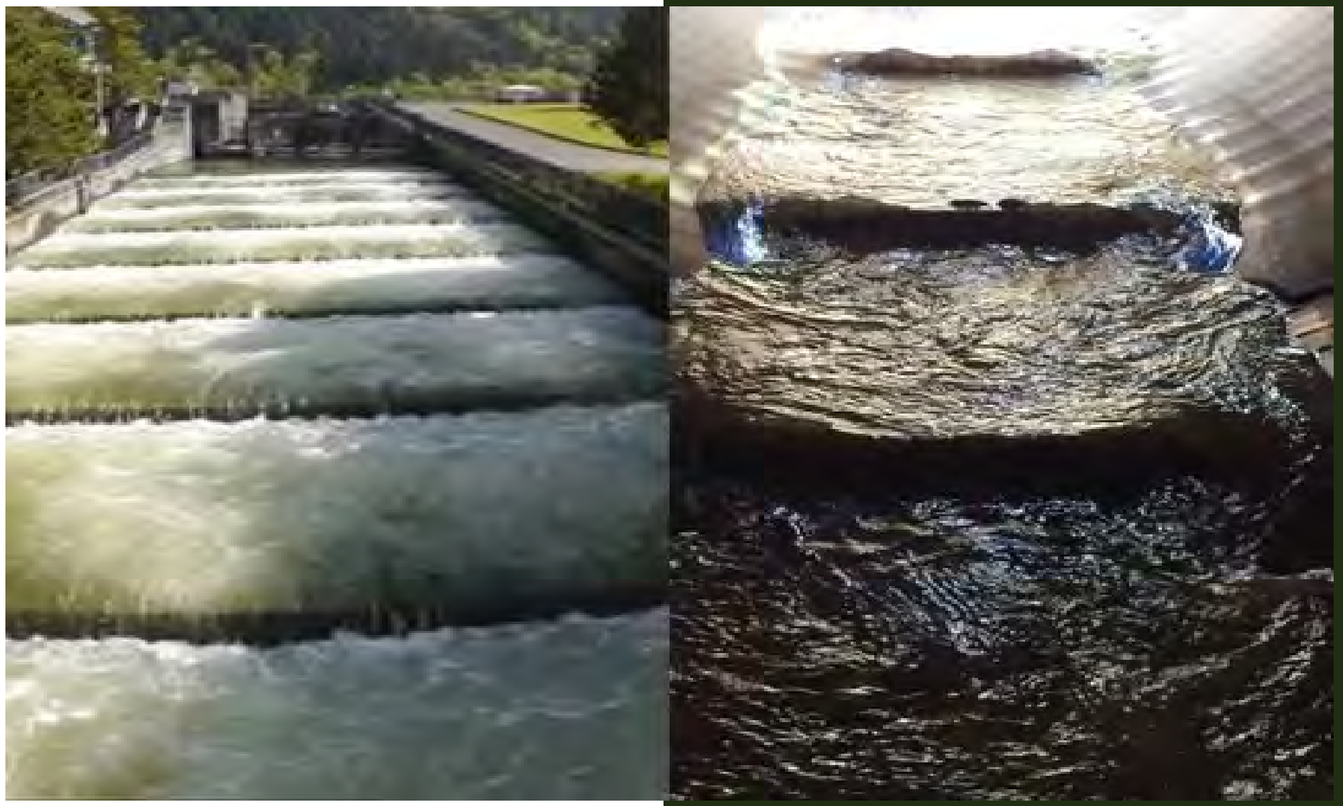
Recreate stream “complexity”

- Pools
- Riffles
- Depth
- Edges

Recreate stream “complexity”.

Baffles recreate:

- Pools
- Riffles
- Depth
- Edges

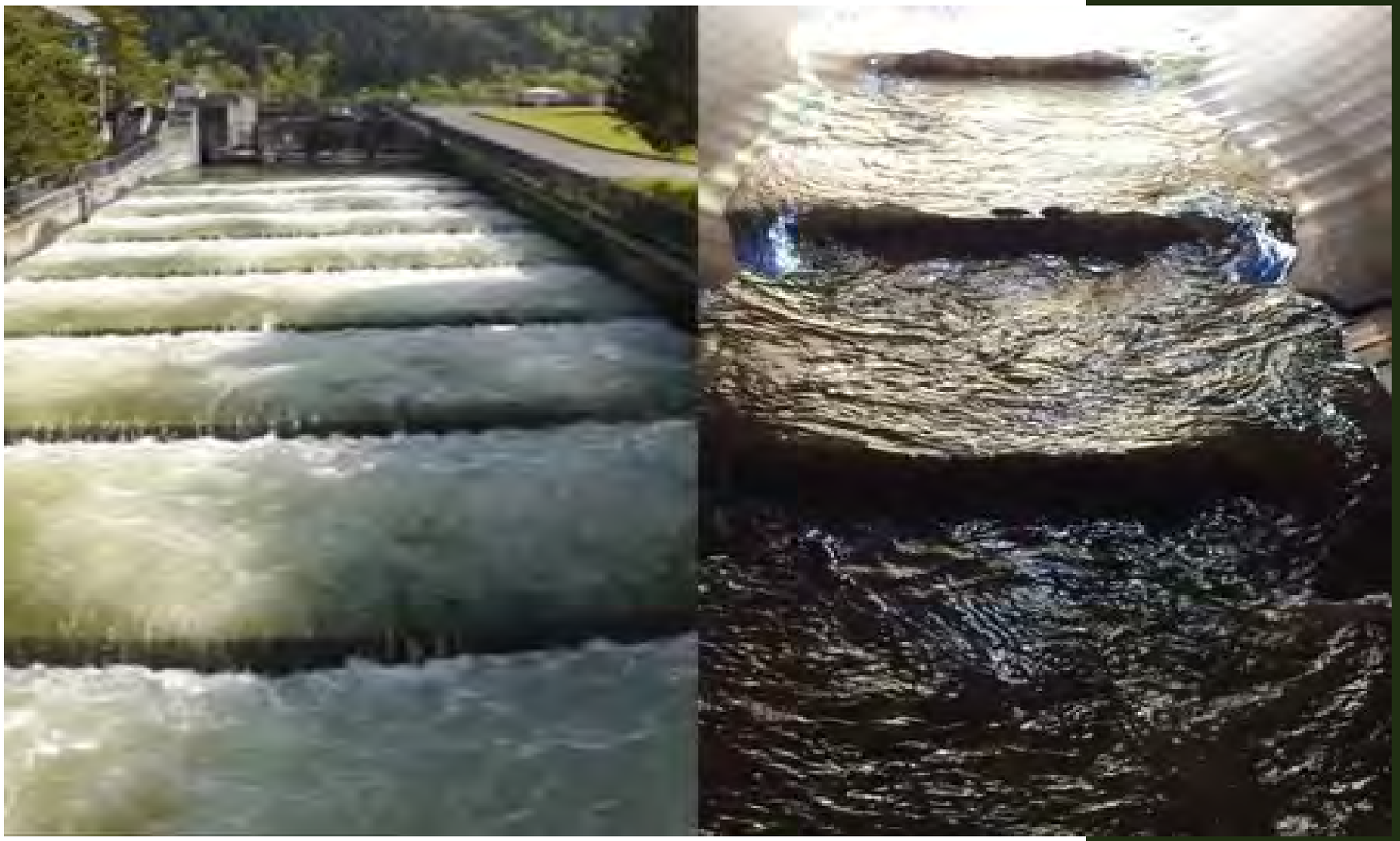


Recreate stream “complexity”.

Conservation Goals:

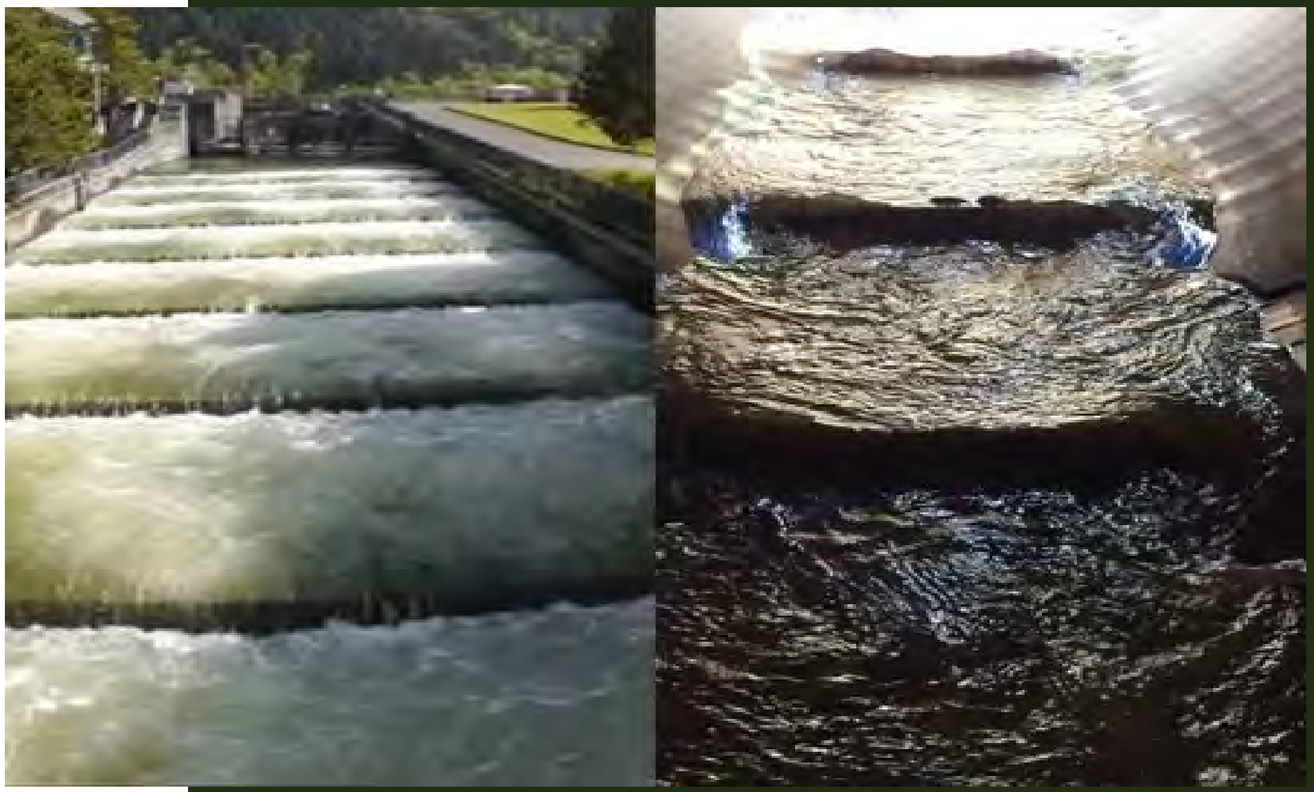
- Baffles within the culvert mimic the surrounding stream habitat
- AOP in the culvert will be similar as surrounding stream

Culvert Retrofit with Baffles or Weirs



Culvert Retrofit with Baffles or Weirs

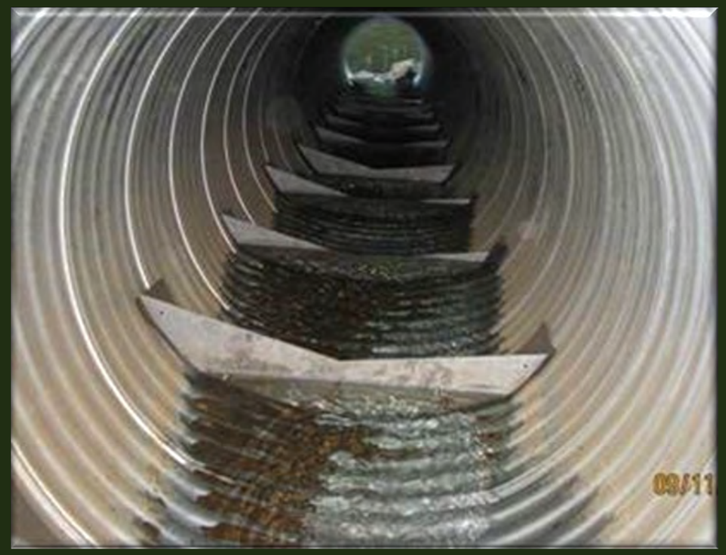
- Proven technology – fish ladders
  - Invented in Scotland in 1837
- Slow water velocities
- Create a series of steps or pools
- Creates “complexity” in the culvert
- Expands AOP opportunity



Solid Baffles

Solid Baffles:

- Metal
- Wood
- Concrete
- Plastic



Solid Baffles

Problems:

- Retain debris
- Reduce hydraulic capacity
- Expensive
- Difficult to maintain

Solid Baffles

Problems:

- Plugging and failure

Flexible Baffles

- Similar benefits as solid baffles
- Do not retain debris
- Minimal effect on hydraulic capacity
- Less costly to install than solid baffles
- Simple to maintain
- Non-toxic rubber polymer
- Resistant to extreme temperatures
- Temporary or permanent installation
- Will require periodic inspections

Flexible Baffles

Size and shape is customizable

- Small baffles for weak swimming

Flexible Baffles

Size and shape is customizable

- Larger baffles for strong swimming fish

Flexible Baffles

Size and shape is customizable

- Buried to retain gravel
- Offset

Flexible Baffles

Installation:

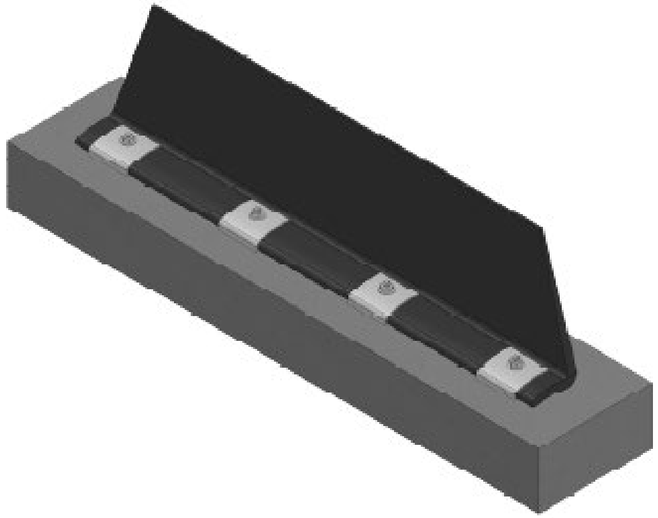
- Self-tapping screws in HDPE, CMP or other polymer

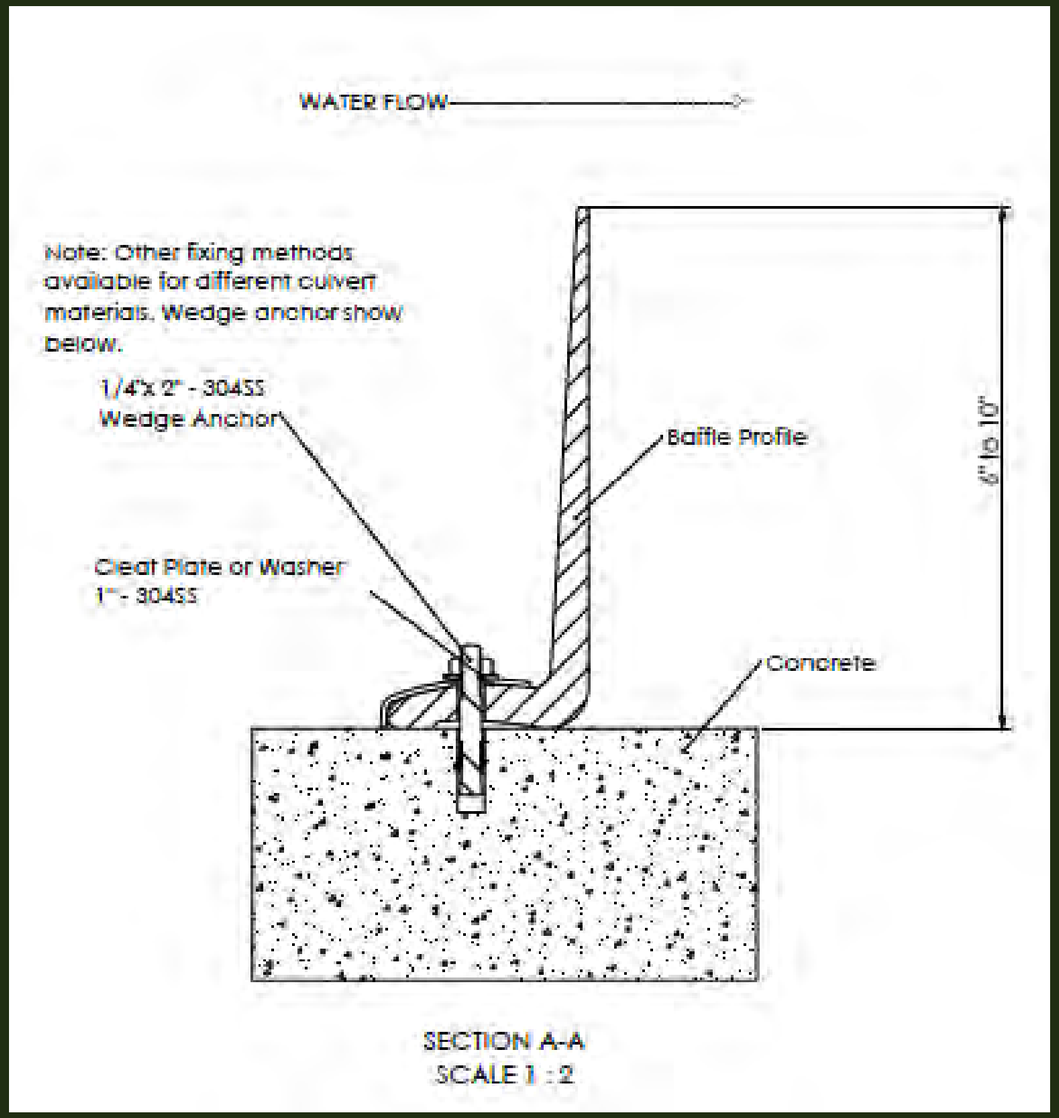
- Wedge anchors in concrete

Flexible Baffles

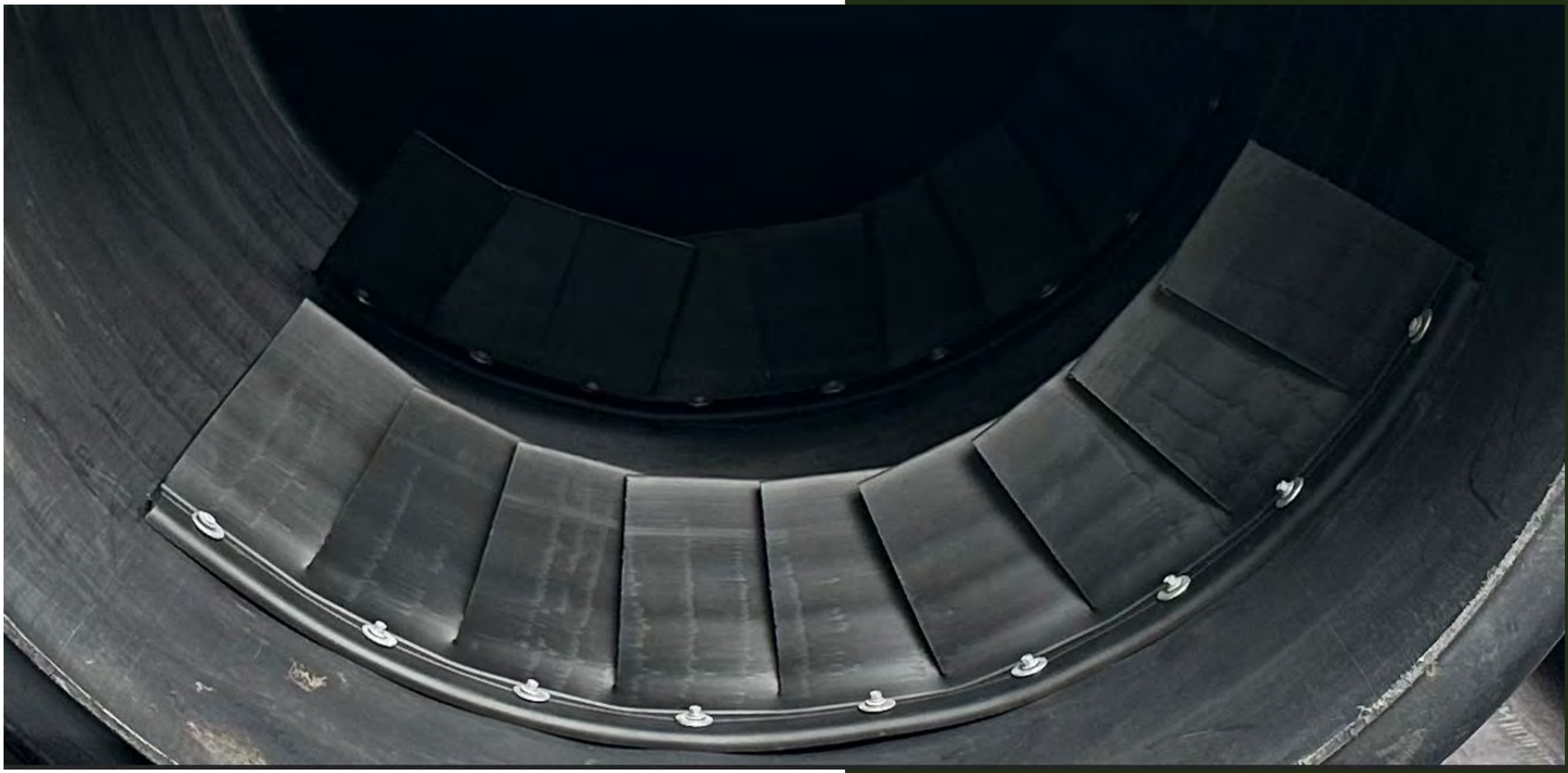
Installation:

- Fixings every 4” to 6”
- 2” from each end





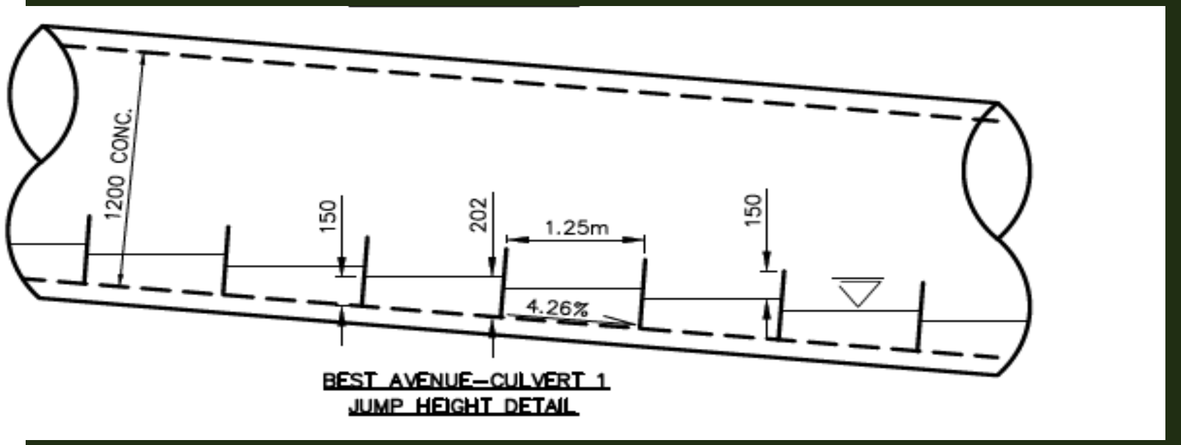
Flexible Baffles



Flexible Baffles

Barrier Prescription:

- Culvert type and configuration
- AOP criteria (i.e., water velocity and depth)
- Recommend Flexi Baffle size and configuration



Flexible Baffles

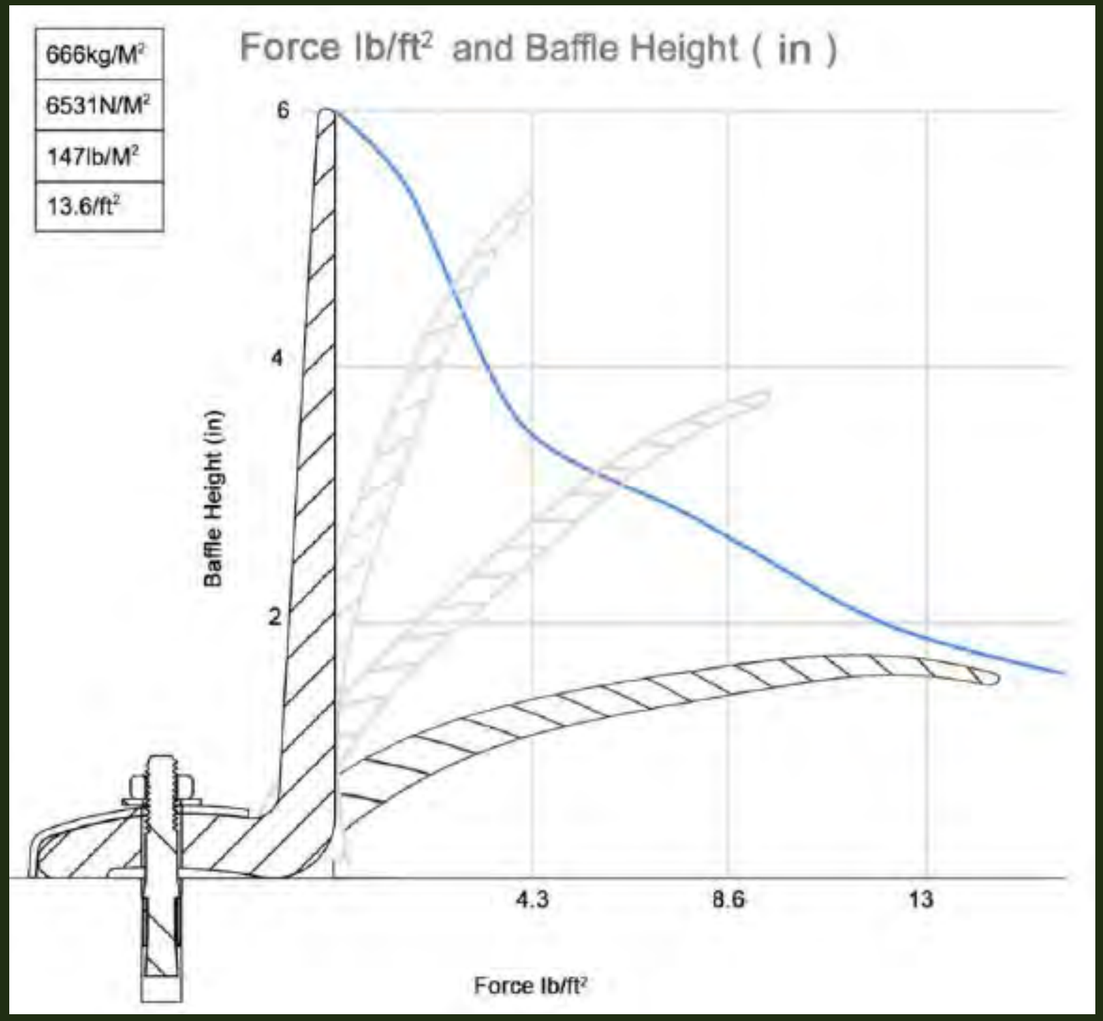
Table 1. Recommended Flexi Baffle Length vs. Culvert Diameter						
Culvert Diameter (in.)	Culvert Diameter (ft.)	Culvert Diameter (mm)	Length (ft.)	Baffle Length (mm)	Spacing (in.)	Cut Spacing (mm)
12	1.0	305	1.0	305	3.0	76
18	1.5	457	1.5	457	3.0	76
24	2.0	610	2.0	610	3.0	76
36	3.0	914	3.0	914	4.0	102
48	4.0	1219	4.0	1219	6.0	152
60	5.0	1524	4.0	1219	6.0	152
66	5.5	1676	6.0	1829	6.0	152
72	6.0	1829	6.0	1829	6.0	152
78	6.5	1981	6.0	1829	6.0	152
84	7.0	2134	6.0	1829	6.0	152
96	8.0	2438	8.0	2438	6.0	152
108	9.0	2743	8.0	2438	6.0	152
120	10.0	3048	10.0	3048	6.0	152
144	12.0	3658	12.0	3658	6.0	152

Table 2. Recommended Flexi Baffle Spacing vs Culvert Gradient		
Culvert Gradient (% slope)	Baffle Spacing (ft.)	Baffle Spacing (m)
0.0 to 1.0	8.0	2.5
1.0+ to 2.0	5.0	1.5
2.0+ to 3.0	4.0	1.2
3.0+ to 4.0	3.5	1.0
4.0+	3.0	900mm

Flexible Baffles

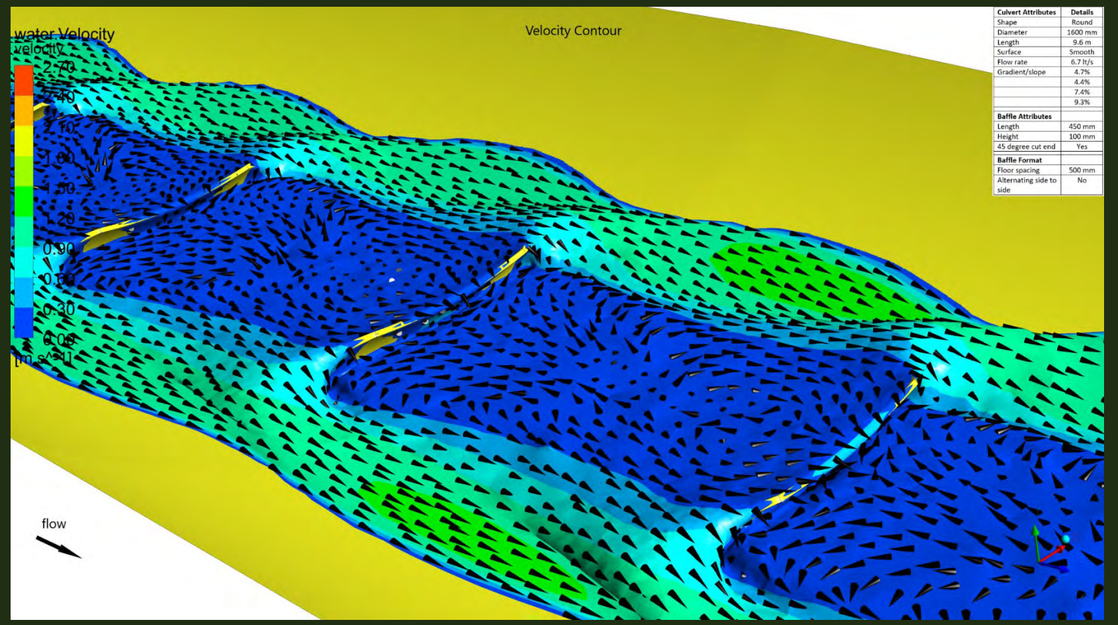
Baffle Forces:

- Force to flatten baffle
  - 13.6 lbs./sq. ft.
- Manning's number (n) = 0.024

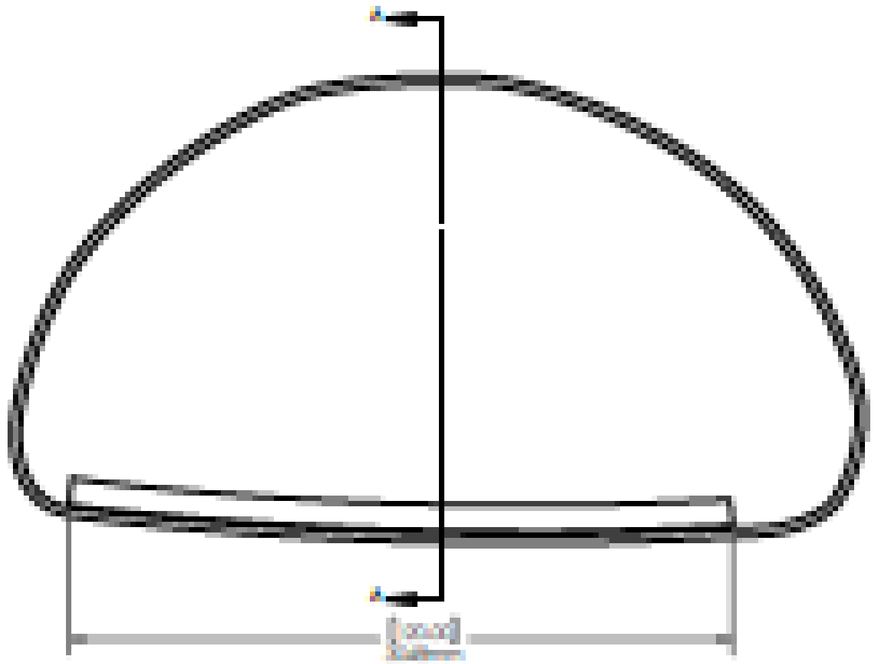


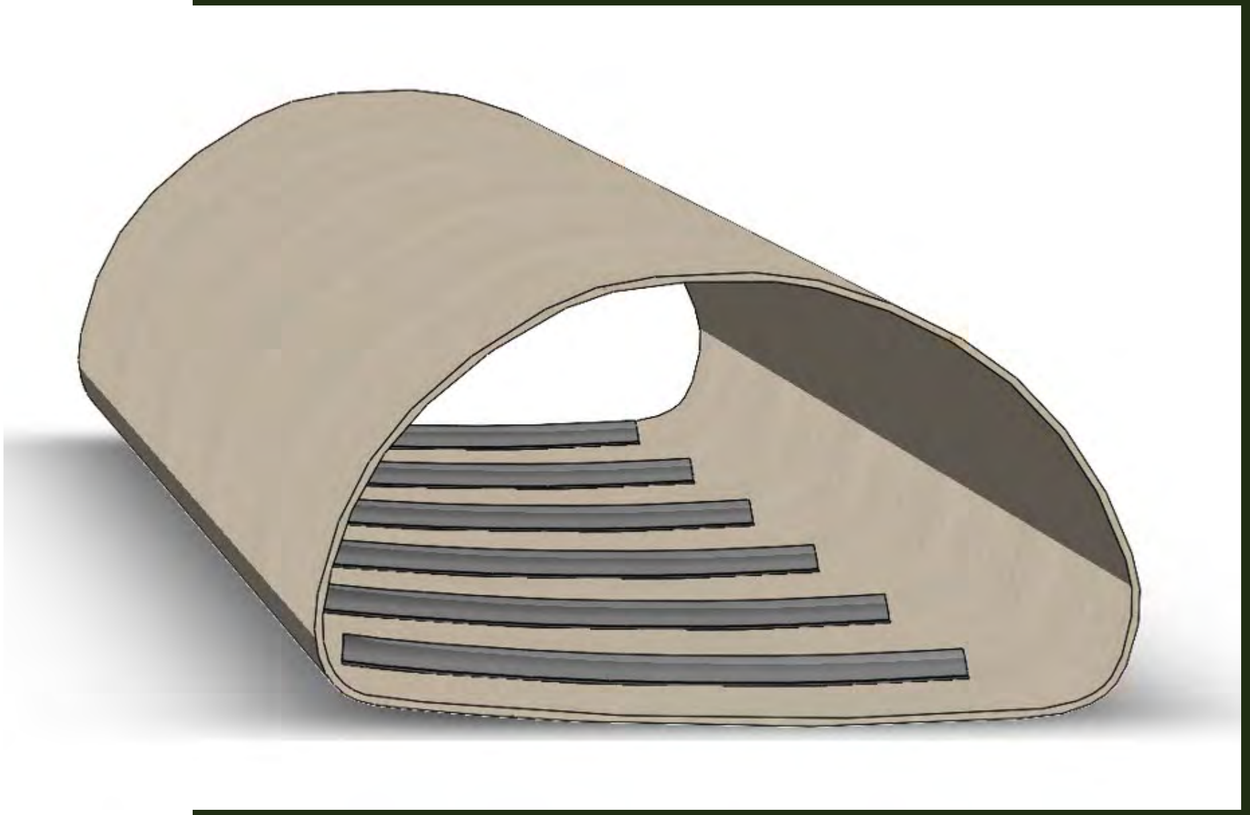
CFD Modeling

CFD (Computational Fluid Dynamics) hydraulic modeling is the simulation and analysis of fluid flow and behavior within hydraulic systems using numerical methods to solve complex equations governing fluid dynamics, often used to optimize designs and predict system performance.

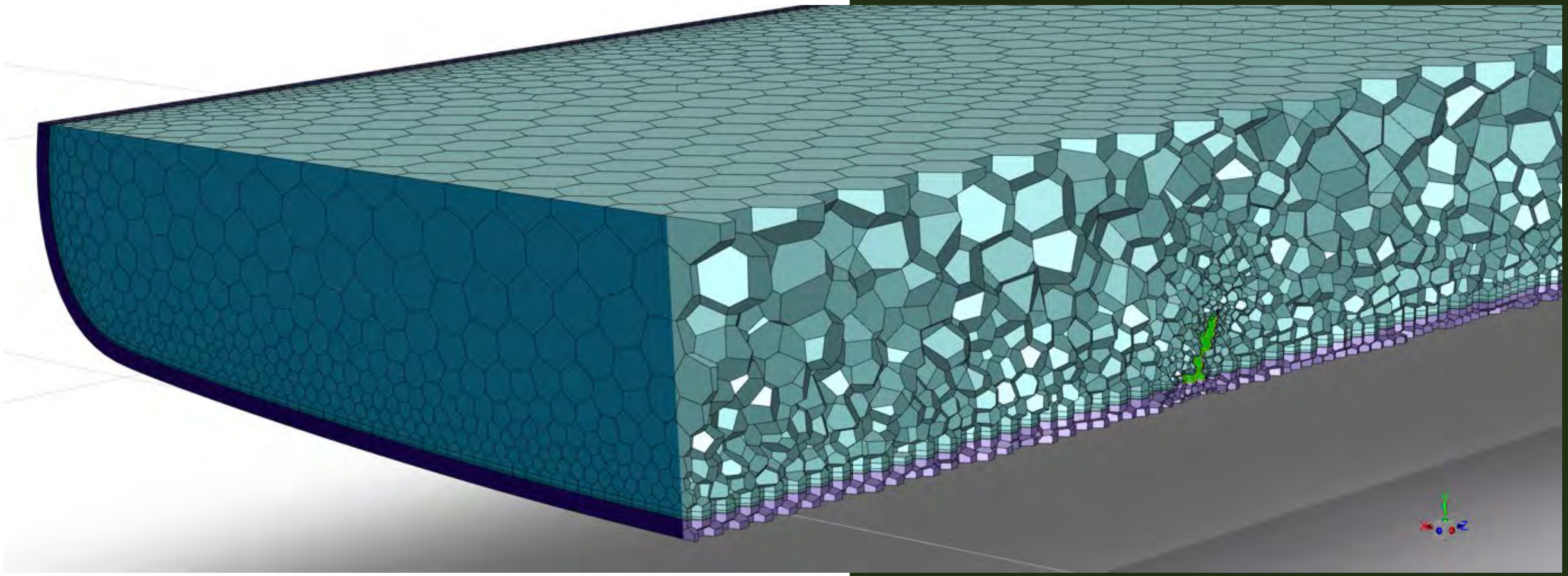


CFD Modeling





CFD Modeling

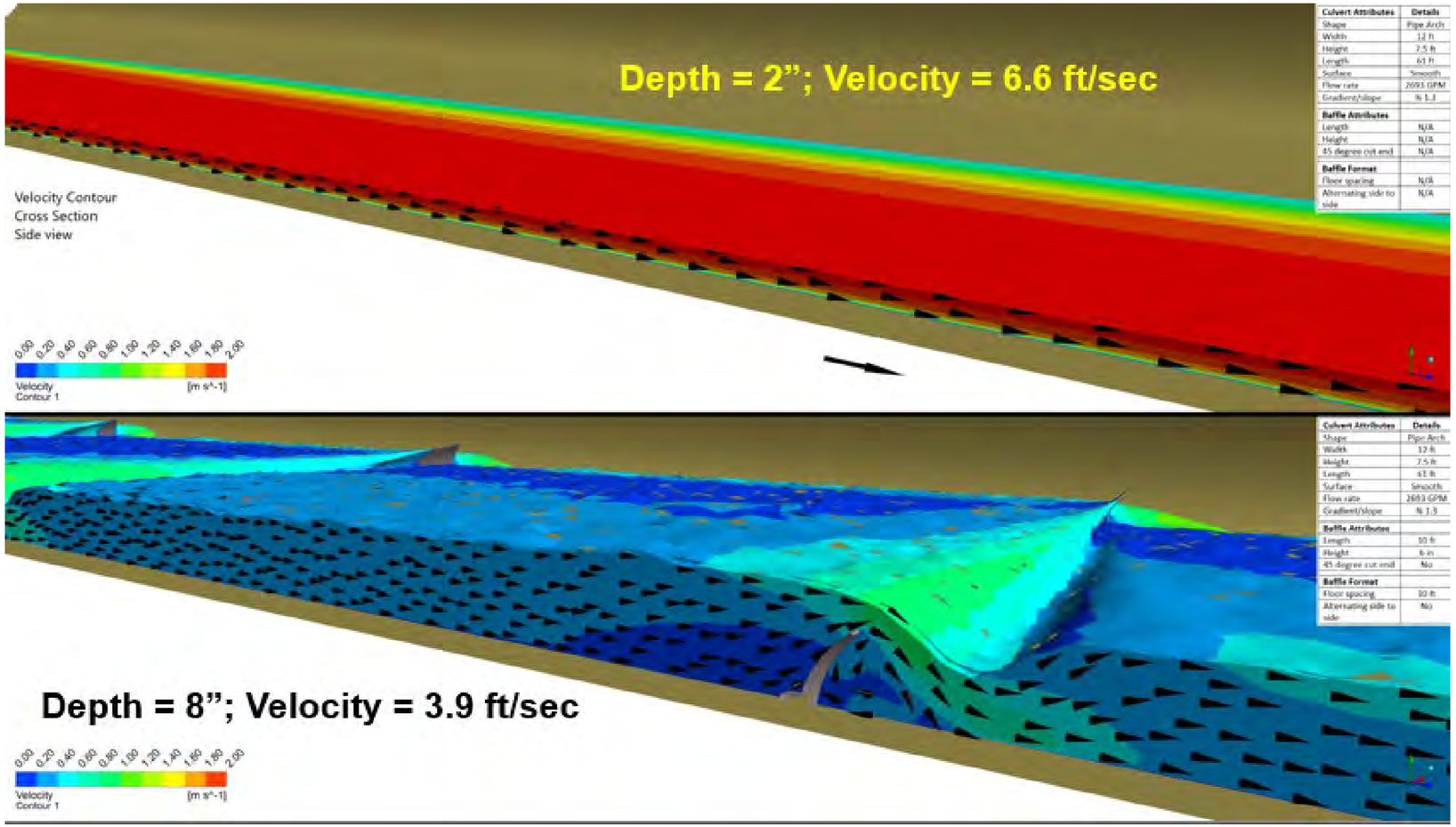


CFD Modeling

- 12’ x 8’ Squashed CMP culvert
- 475’ long
- Water Flow Range = 6.0 to 92.3 cfs
- Target Maximum Water Velocity = 4.0 fps (1.2m/s)

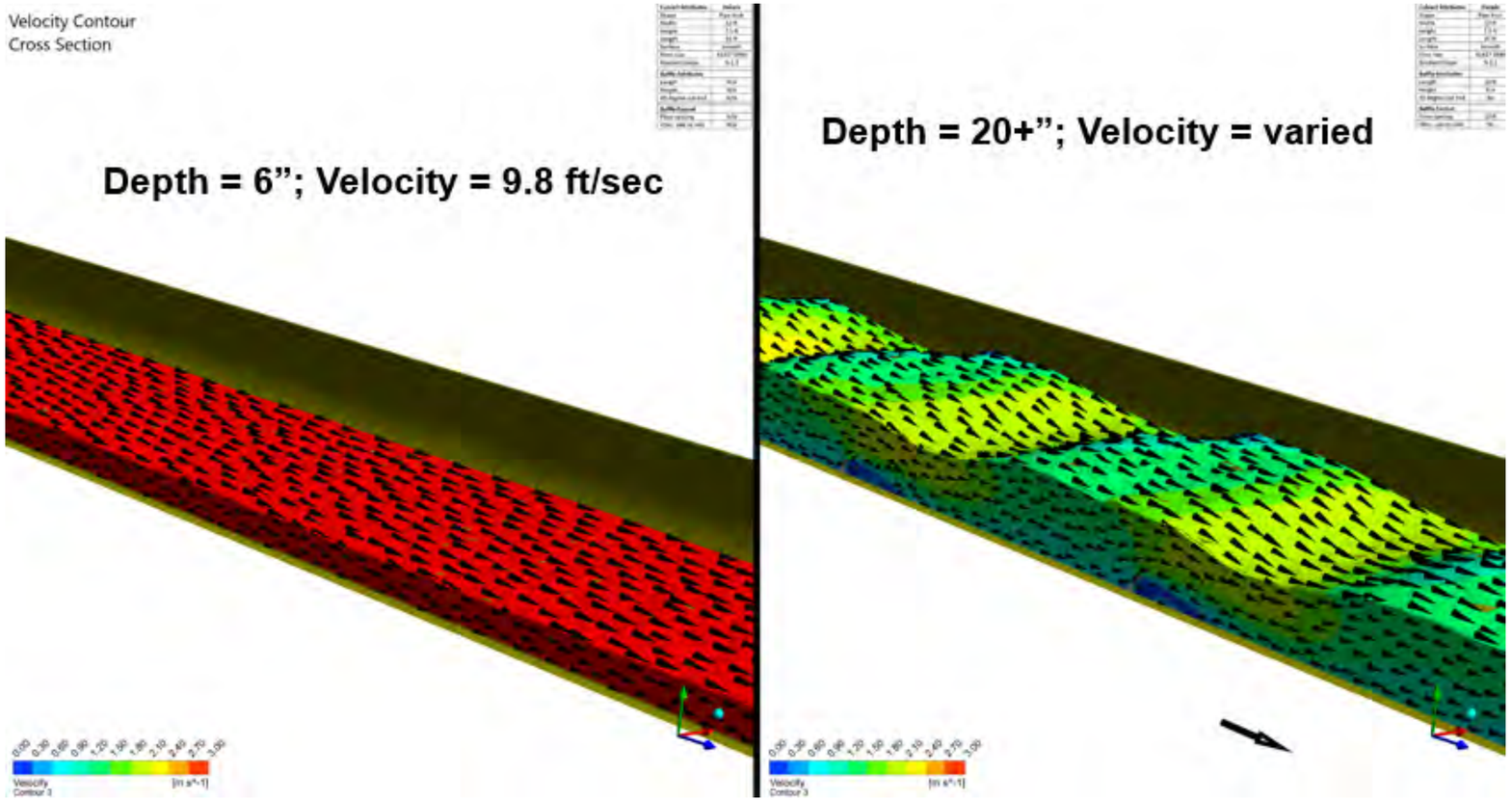
- Add Flexi Baffles to improve fish passage

CFD Modeling



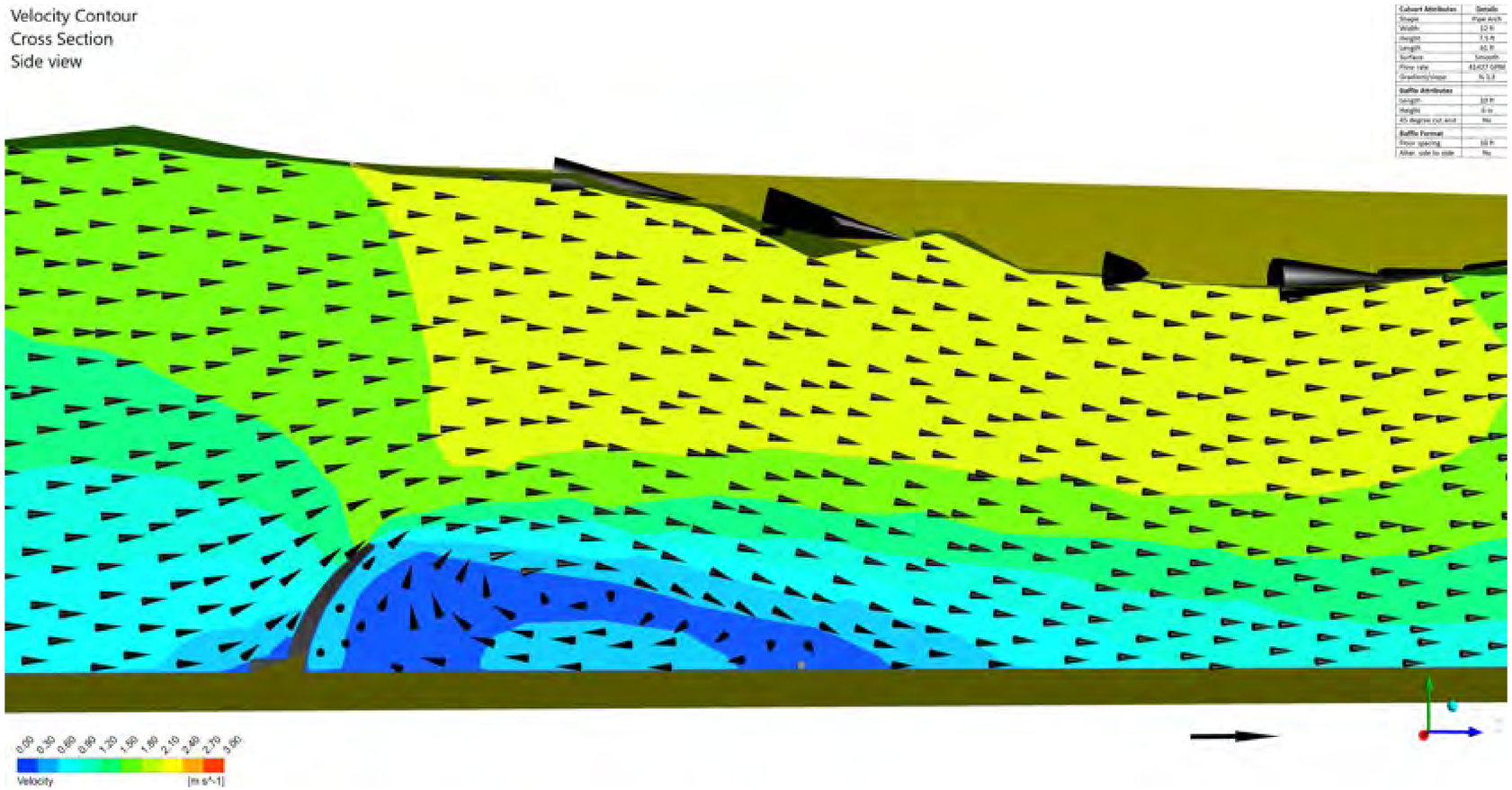
Water Flow = 6.0 cfs
= (0.17 cm/s)

CFD Modeling



Water Flow = 92.3 cfs
= (2.61 cm/s)

CFD Modeling



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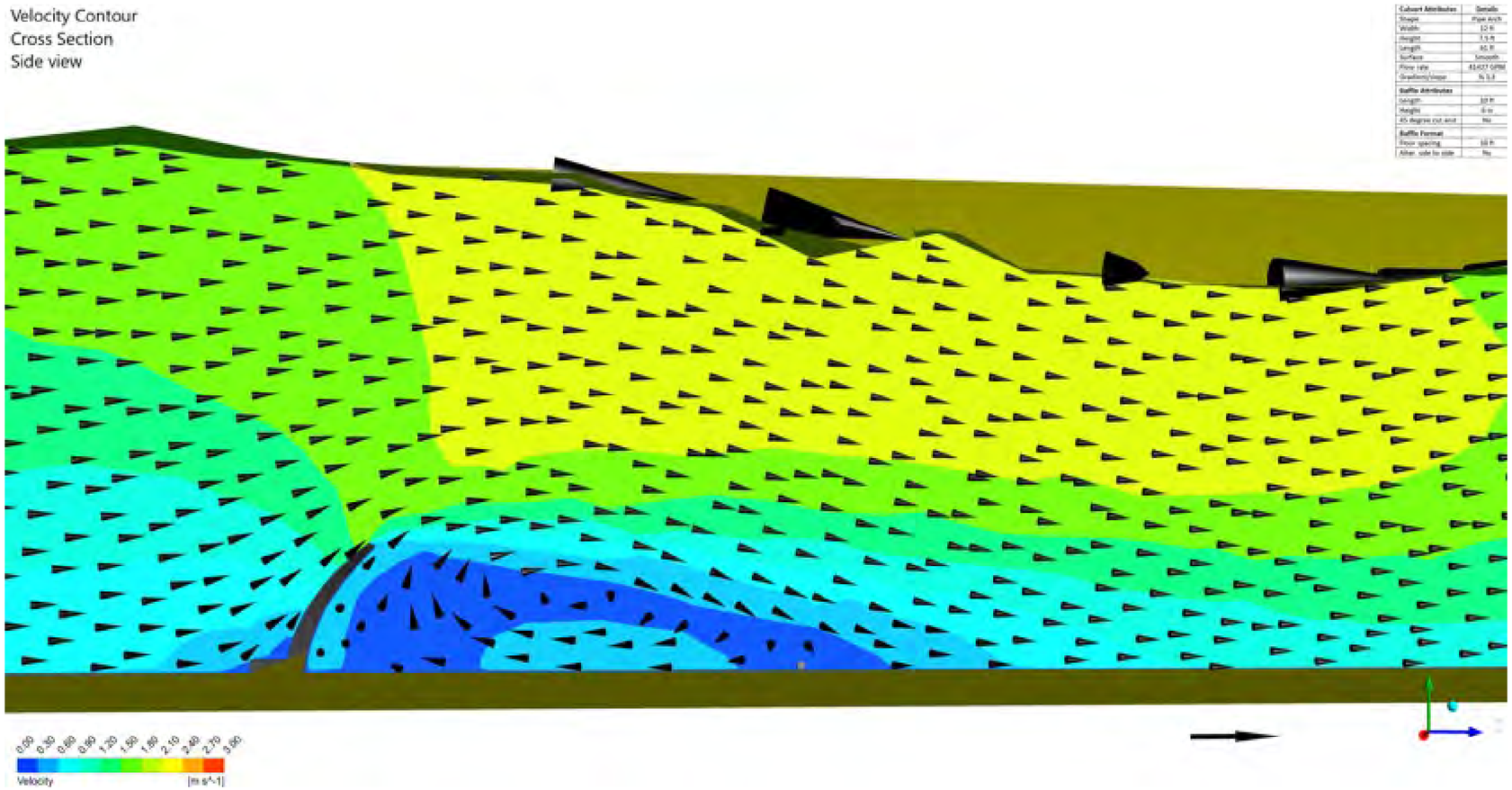
CFD Modeling

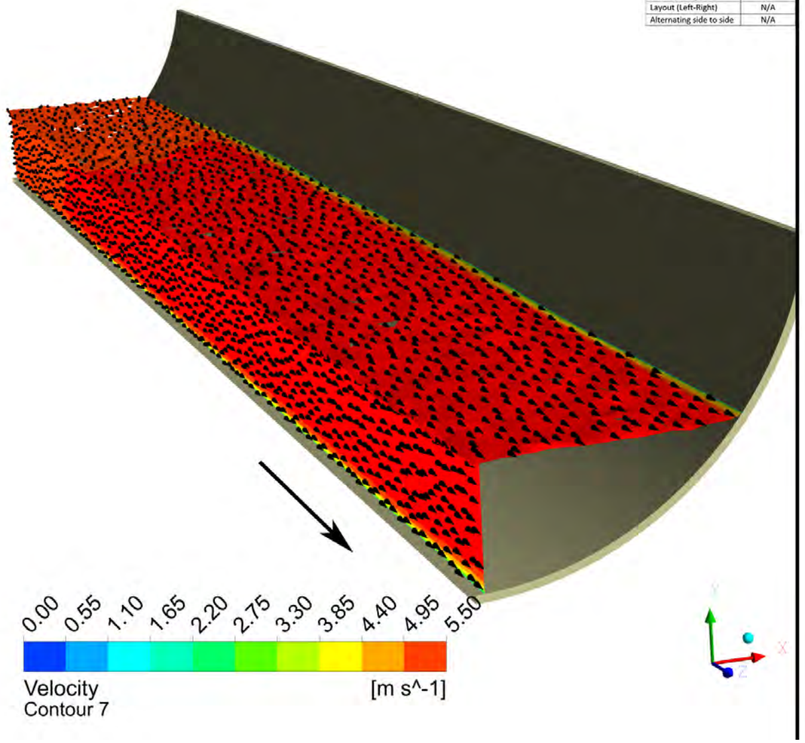


Water Flow = 92.3 cfs
= (2.61 cm/s)

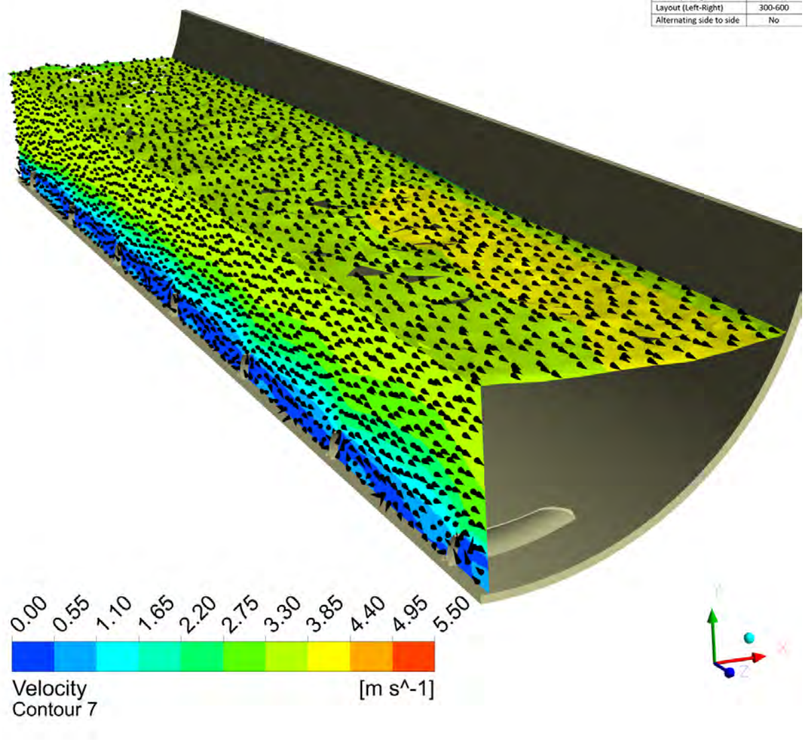
CFD Modeling

Velocity Contour
Cross Section
Side view

Culvert Attributes	Details
Shape	Round
Diameter	1600 mm
Length	5.3 m
Surface	Smooth
Flow rate	1400 lt/s
Gradient/slope	% 6
Baffle Attributes	
Length	N/A
Height	N/A
45 degree cut end	N/A
Baffle Format	
Floor spacing	N/A
Layout (Left-Right)	N/A
Alternating side to side	N/A



Culvert Attributes	Details
Shape	Round
Diameter	1600 mm
Length	5.3 m
Surface	Smooth
Flow rate	1400 lt/s
Gradient/slope	% 6
Baffle Attributes	
Length	900 mm
Height	100 mm
45 degree cut end	Yes
Baffle Format	
Floor spacing	800 mm
Layout (Left-Right)	300-600
Alternating side to side	No



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Height	100 mm
45 degree cut end	Yes
Baffle Format	
Floor spacing	800 mm
Layout (Left-Right)	300-600
Alternating side to side	No

Culvert Retrofit Case Studies

Ketchikan, Alaska

Schoenbar Creek Culvert Rehabilitation

- 12’ x 8’ Squashed CMP culvert
- 475’ long
- Eroded in the bottom
- Repair culvert with concrete
- Water Flow Range = 6.0 to 92.3 cfs
- Target Maximum Water Velocity = 4.0 fps (1.2m/s)

- Add Flexi Baffles to improve fish passage

Ketchikan, Alaska

Schoenbar Creek Culvert Rehabilitation

Ketchikan, Alaska

Schoenbar Creek Culvert Rehabilitation

City of Ketchikan – Public Works

- Culvert was resurfaced with concrete
- 81 x 10-foot Flexi Baffles
- Supply cost of $35k

Ferndale, WA

Terrell Creek Baffle Installation

- 8-foot square cast in place concrete box culvert
- 100’ long

- Add Flexi Baffles to improve fish passage

Ferndale, WA

Terrell Creek Baffle Installation

Nooksack River Enhancement Association

- Installed eight, 8-foot
- Installation took about 4 hours – 5 staff

Ferndale, WA

Terrell Creek Baffle Installation

- Supply cost of $2,300.00

Surrey, British Columbia

Bon Accord Creek Baffle Installation

City of Surrey – Environment Section

- 500 ft x 6 ft Concrete Channel
- Built in the 1950s to reduce flooding
- 1% - 2% Gradient
- Depth and Velocity Passage Barrier
- No Fish Passage Since 1950s

- Add Flexi Baffles to reintroduce salmon

Surrey, British Columbia

Bon Accord Creek Baffle Installation

- Salmon Habitat Restoration Program (SHaRP) Student Volunteers
- Installed sixty, 6-foot baffles every 9 feet
- Installation took about 4 days

Surrey, British Columbia

Bon Accord Creek Baffle Installation

- Supply cost of $18,700.00

Surrey, British Columbia

Bon Accord Creek Baffle Installation - Before

Surrey, British Columbia

Bon Accord Creek Baffle Installation - AFTER

Surrey, British Columbia

Bon Accord Creek Weir Installation – Success!

Surrey, British Columbia

Bon Accord Creek Weir Installation – Success!

Comparison of Costs

King Co, WA – Little Soos Creek

- 3-foot round concrete culvert
- 60 feet long
- Slope (%): 0.88
- Barrier Type: Water Depth
- Estimate to replace with a bridge:
  - $5,806,000.00

Comparison of Costs

King Co, WA – Little Soos Creek

- Estimate to retrofit with a Flexible Baffles:
  - Eight, 3-foot Flexi Baffles - $1,300.00
  - Less than one day labor for 3 staff

Comparison of Costs

King Co, WA – Harris Creek

- 9’ x 6.5’ Squashed CMP culvert
- 55 feet long
- Slope (%): 2.29
- Barrier Type: Slope
- Estimate to replace with a bridge:
  - $5,319,000.00

Comparison of Costs

King Co, WA – Harris Creek

- Estimate to retrofit with a Flexible Baffles:
  - Nineteen, 9-foot Flexi Baffles - $8,900.00
  - One day labor for 3 staff

http://apps.wdfw.wa.gov/fishpassagephotos/Reports/880003_Report.pdf

Comparison of Costs

King Co, WA – Watercress Creek

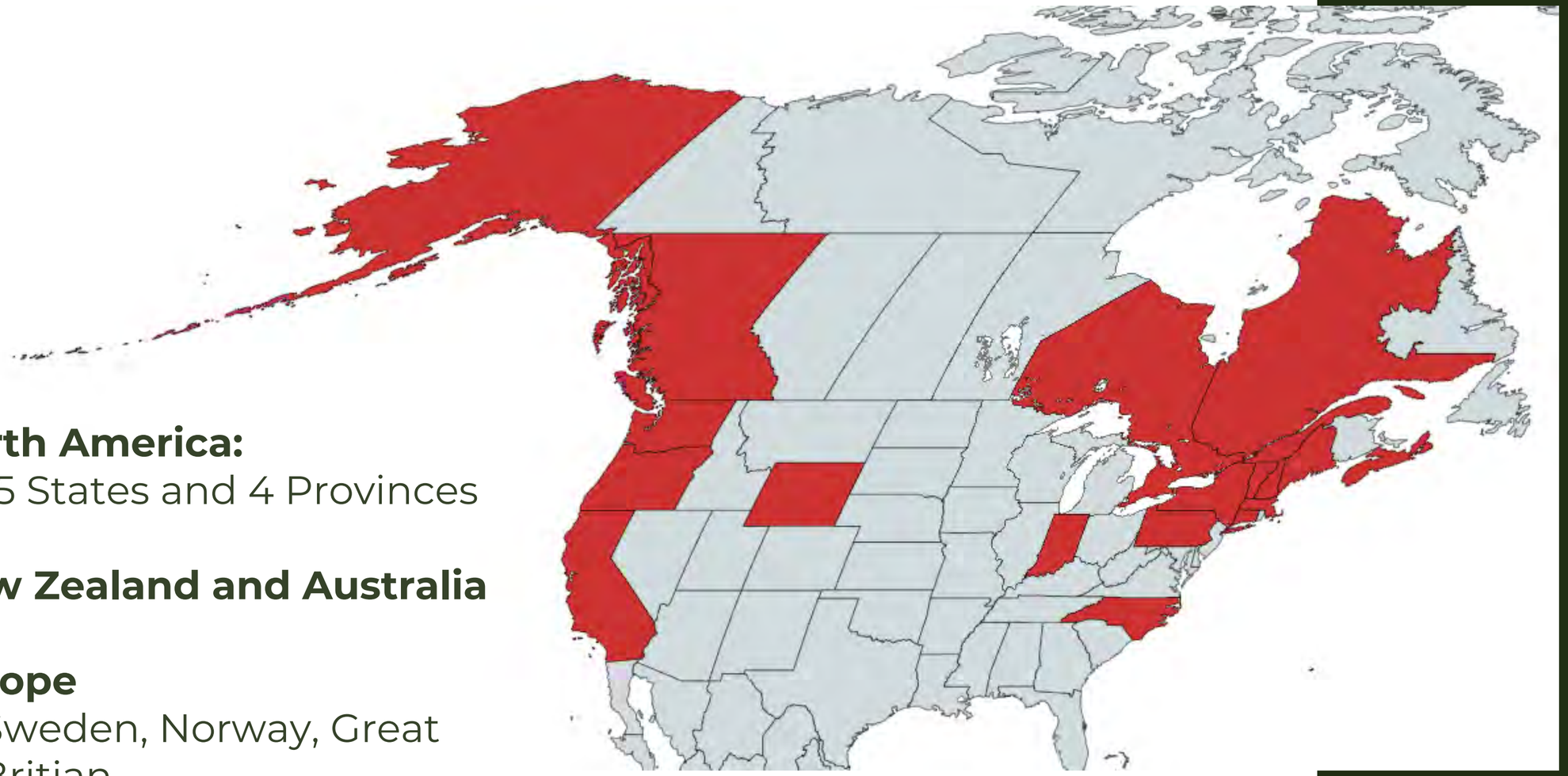
- 4’ round CMP culvert
- 44 feet long
- Slope (%): 2.3
- Barrier Type: Velocity
- Estimate to replace with a bridge:
  - $1,878,000.00

Comparison of Costs

King Co, WA – Harris Creek

- Estimate to retrofit with a Flexible Baffles:
  - Thirty, 4-foot Flexi Baffles - $4,700.00
  - Two days labor for 3 staff

Flexi Baffle Installation to Date



North America:

- 15 States and 4 Provinces

New Zealand and Australia

Europe

- Sweden, Norway, Great Britian

Summary

Culvert Retrofit with Flexible Baffles:

- Low Cost
- Easy to install
- Permanent or Temporary Installations
- Biologically Effective for Improving AOP

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Thank you!


12/21/86
NORM'S SPAWNING SERVICE
"When you gotta get upstream in a hurry"
Larson

Questions?

STORMWATERAWARENESS.ORG

CONTACT US

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Website

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The Problem:

- High Water Velocities
- Shallow Water Depth
- Steep Gradient
- Plunge Height and Distance

= Passage Barrier