Nature Like Fishways:
Modern Perspectives and Techniques
Sessions 3 & 4

A Workshop at the 41st Annual Salmonid Restoration Conference
Santa Rosa, California, March 26-29, 2024

Workshop Coordinators:

- Tyler Kreider, PE, *Kleinschmidt*
- Mike Garello, PE, *HDR, Inc.*
- Mike Love, PE, *Michael Love & Associates*

This instructor-led workshop, organized by the American Fisheries Society–Bioengineering Section, with funding from the Resources Legacy Fund, to presents a two-day-nature-like fishway workshop. This in-person workshop took place over two days and was instructed by several leading practitioners in the field of Nature Like Fishways (NLF) implementation, including representatives from both private and public agencies. The list of speakers includes Michael Garello (HDR), Michael Love (MLA), Jesus Morales (U.S. Fish and Wildlife Service), Tyler Kreider (Kleinschmidt), Bjorn Lake (NOAA Fisheries), Barry Chilibeck (Northwest Hydraulic Consultants), Brian Cluer (NOAA Fisheries), and Marcin Whitman (retired California Department of Fish & Wildlife). The goal of the workshop was to share knowledge of nature-like fishway design and long-term stability observations among practitioners, regulators, and operators to improve the collective awareness of contemporary NLF science and design methodologies to ultimately provide more effective and sustainable passage for fish. This workshop included the following topics:

- History and state of nature-like fishways
- Application of NLFs to natural and built environments
- Site reconnaissance, project assessment, project development
- Identifying data and modeling needs and necessary in-field data collection
- Example design methods, practices, constraints, and uncertainties—also highlight current/ forthcoming design guidance documents
- Construction methods and oversight
- Monitoring
- Lessons learned from previously constructed NLFs
- Risk evaluation in NLF Design
- Getting the right rocks and placing them for long-term stability

Presentations

Pre-Design for Fish Passage Projects

Nature-like Fishways:
Modern Perspectives and Techniques

Michael Love P.E.

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March 26, 2024

California Department of Fish & Wildlife

California Salmonid Stream Habitat Restoration Manual

Part XII: Fish Passage Design and Implementation (2009)

Available at:

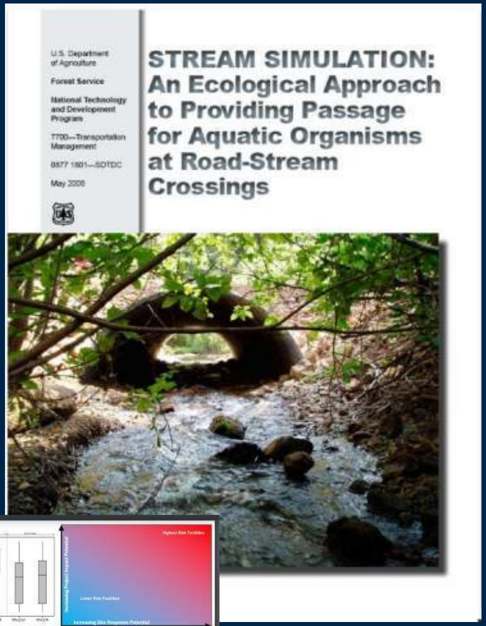
http://www.dfg.ca.gov/fish/resources/habitatmanual.asp

Primary Authors:

Michael Love P.E.
Michael Love & Associates, Inc.

Kozmo Bates P.E.
Olympia, WA

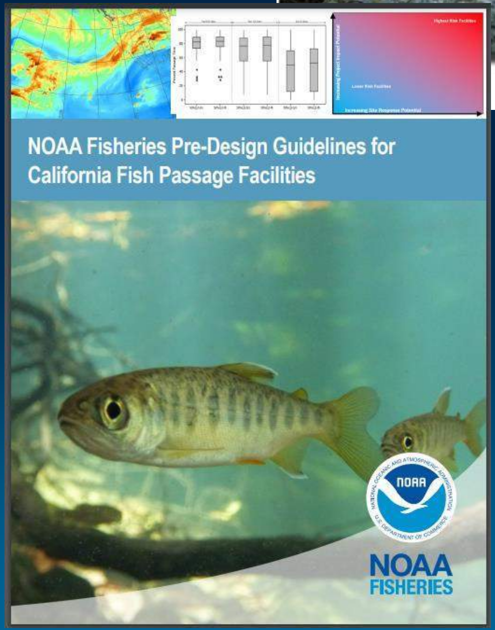
Other Primary Sources for Pre-Design of Fish Passage



US Forest Service, 2008

Stream Simulation: An Ecological Approach to Providing Passage for Aquatic Organisms at Road-Stream Crossings

https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fsm91_054564.pdf



NOAA Fisheries

Pre-Design Guidelines for California Fish Passage Facilities - 2022

https://media.fisheries.noaa.gov/2023-02/pre-design-guidelines-ca.pdf

Conceptual Iterative Design Process

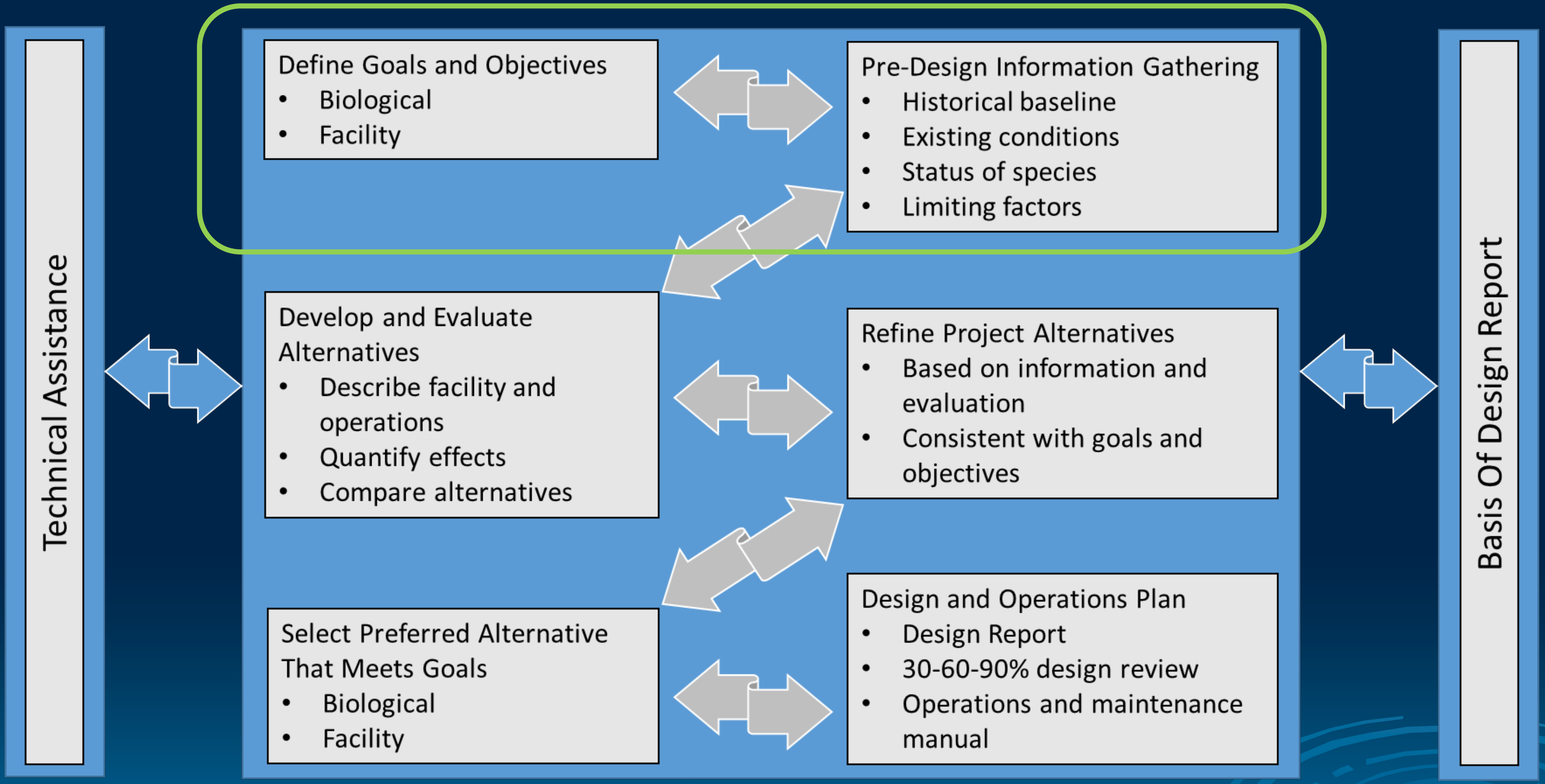
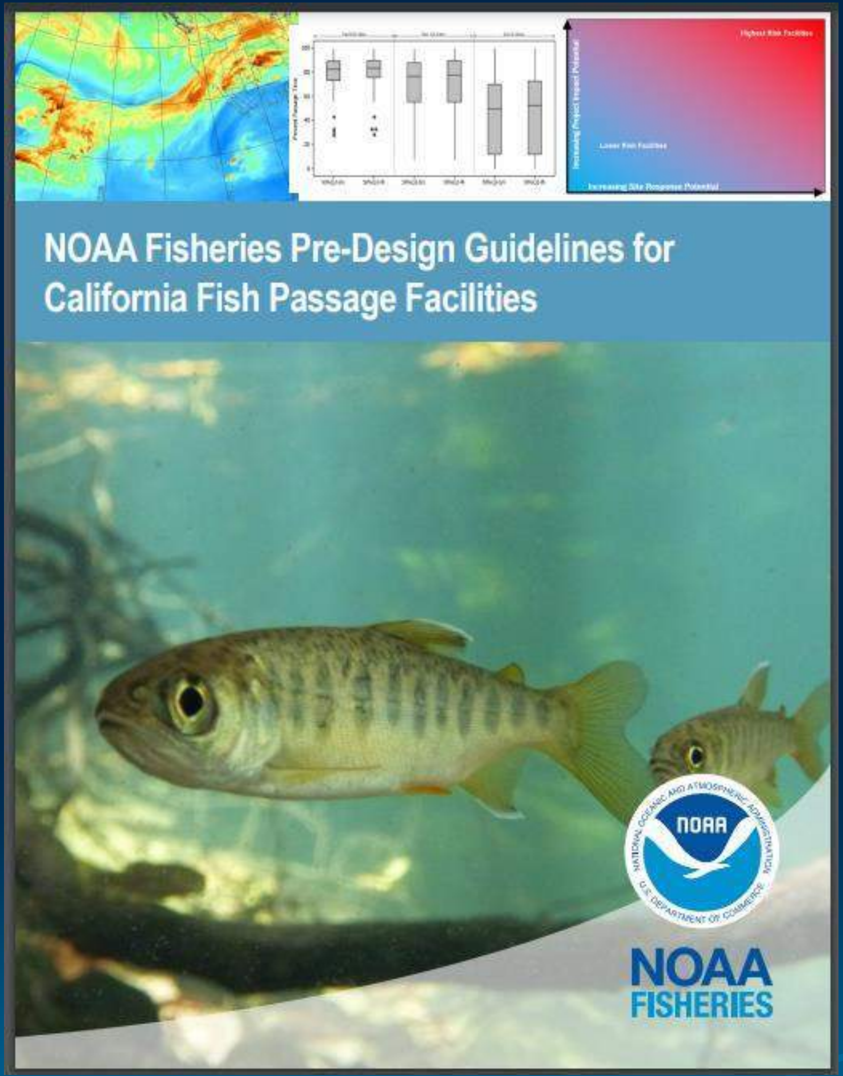


Figure 10 from NOAA Fisheries 2023

Watershed Condition



Regional Variability in Hydrology

Figure 1. Study site location map (prepared by Charleen Gavette and Emily Rose, NMFS).

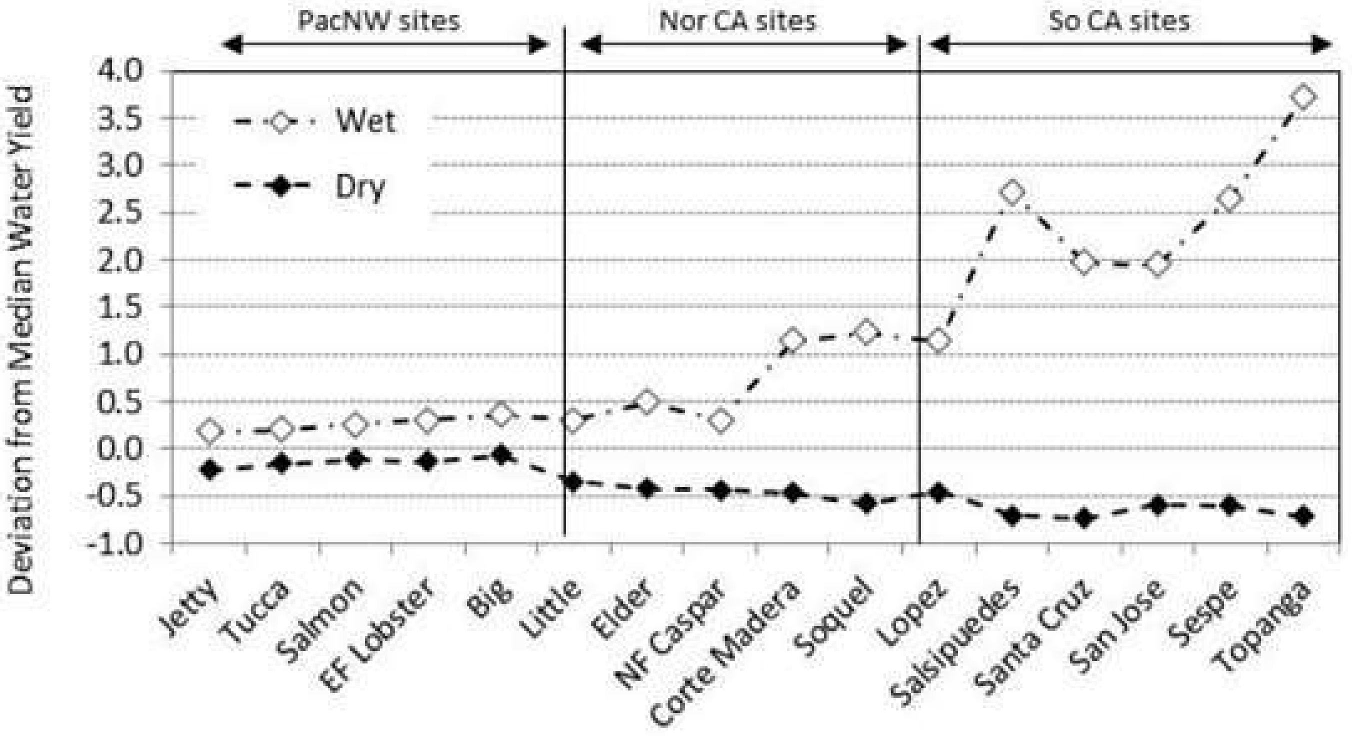
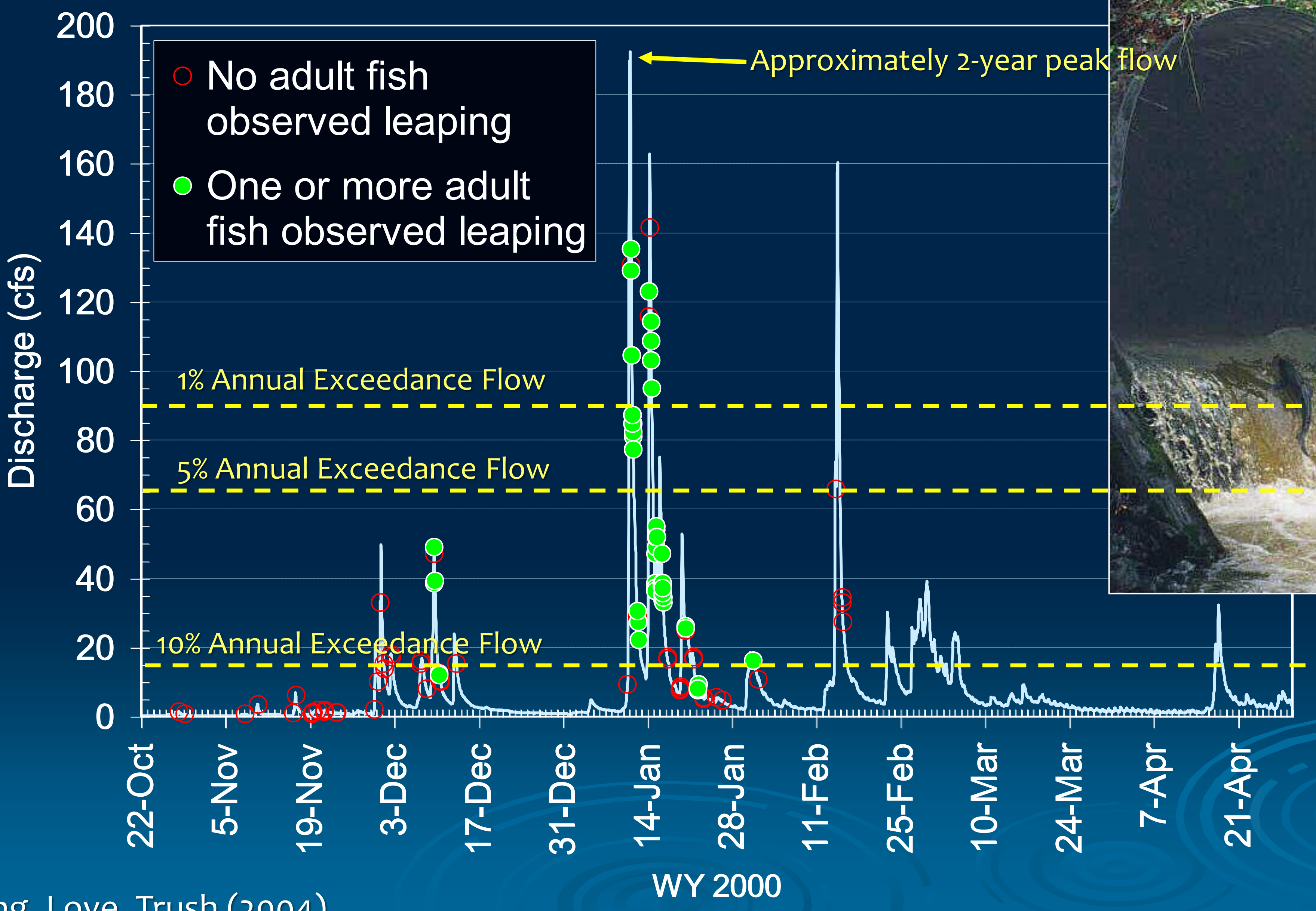
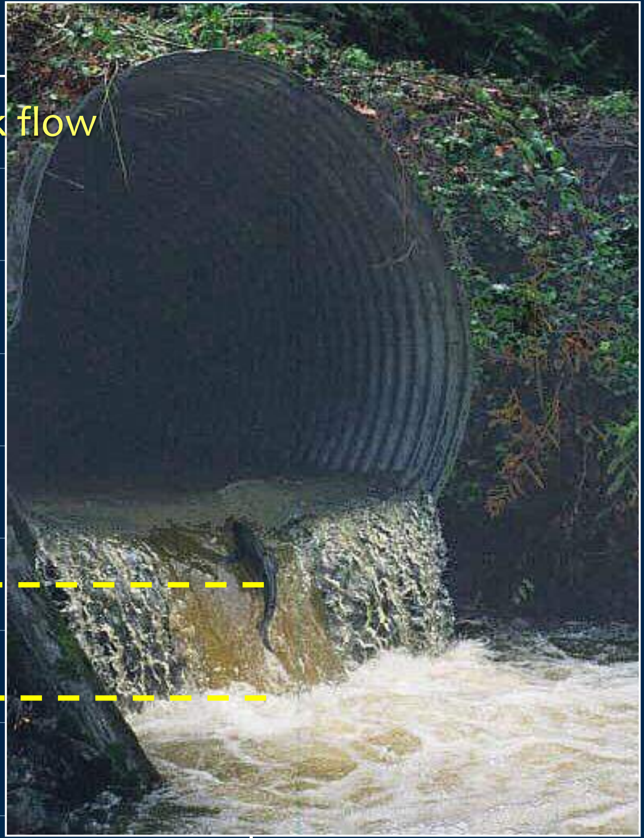


Figure 6. Deviation from median annual water yield indicating climatic and hydrologic variation along the west coast from Oregon to Southern California. Comparison of the upper 20th-percentile water yield (lower boundary of Wet year yields) and the lower 20th-percentile water yield (upper boundary of Dry year yields) expressed as the deviation from the median annual water yield. Sites are arranged from north to south moving left-to-right along the x-axis. Notice the spread between dry and wet years increases dramatically in the southern direction. Source: Lang and Love, 2014; figure 5.

From Lang & Love, 2014

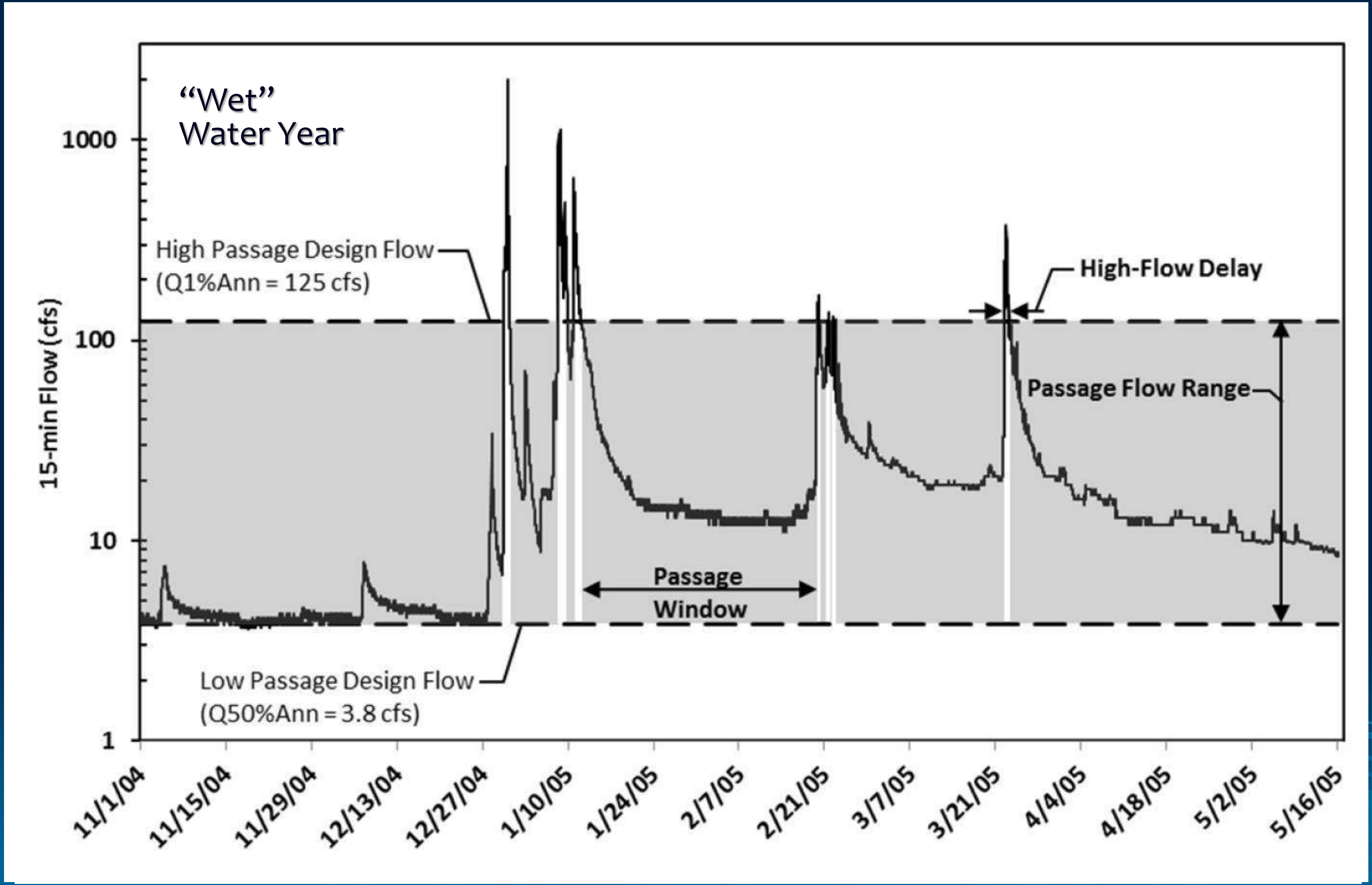
Observations of Adult Salmon Leaps at Sullivan Gulch





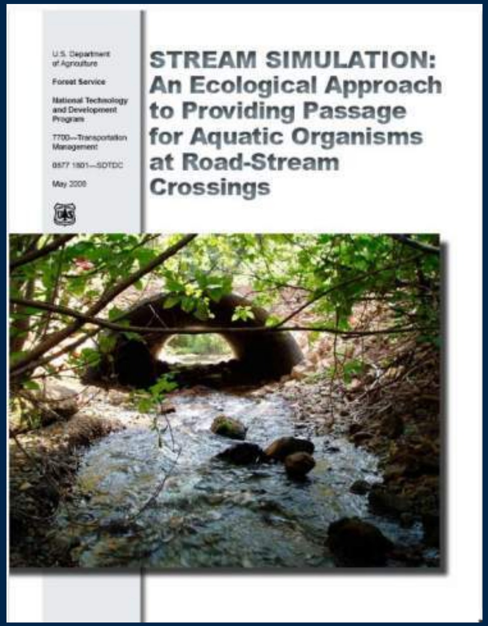
From: Lang, Love, Trush (2004)

Considering Delay when Selecting Fish Passage Design Flows



From: Lang and Love (2014)

Site Assessment



From USFS, 2008 Stream Simulation Manual

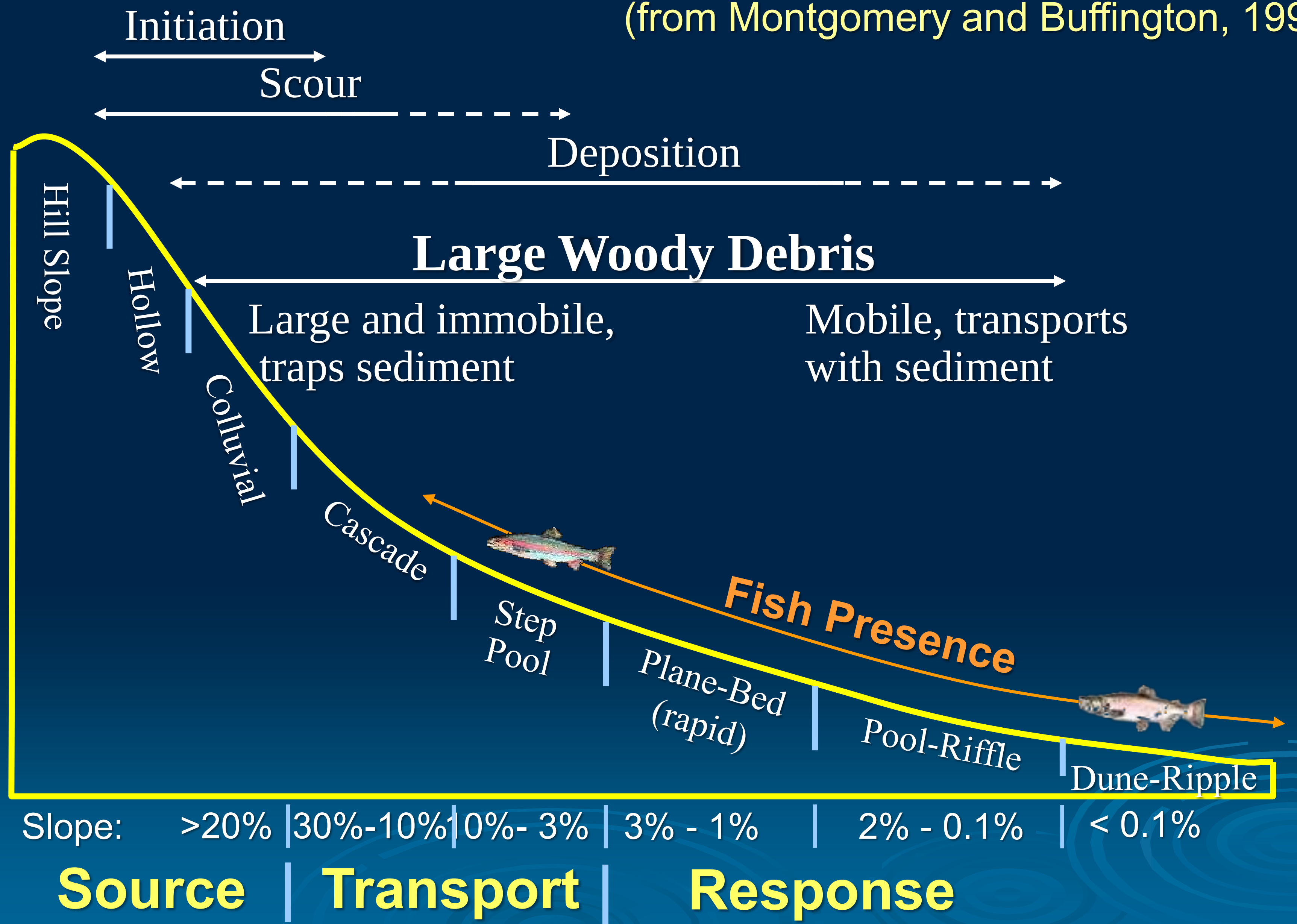
Chapter 5—Site Assessment

Site Assessment Objectives

- Gain an understanding of **channel history, stability**, and **adjustment potential:**
  - Channel type (transport vs. response)
  - Floodplain conveyance
  - Historic channel alternations
  - Bed variability (pool depths)
  - Headcut potential
  - Bank stability
- Characterize Existing Channel:
  - Shape
  - Alignment
  - Bed Controls (embedded wood, large rock, bedrock)
  - Profile
  - Substrate Composition
  - Floodplain Connectivity

Generalized Stream Classification

(from Montgomery and Buffington, 1993)



Longitudinal Channel Profile

- Survey profile along channel thalweg
- Extend survey well past influence of instream structure
  Recommend Min Profile Length = 20 channel widths upstream/downstream of structure influence
- Survey captures bedforms (pool depths, riffles crests)
- Survey "forcing features" controlling grade
  Note long-term stability of each forcing feature
- Survey base and top of features controlling grade
  Bedrock, large colluvium, embedded wood, debris jams, check-dams, culvert inverts, stream confluence…

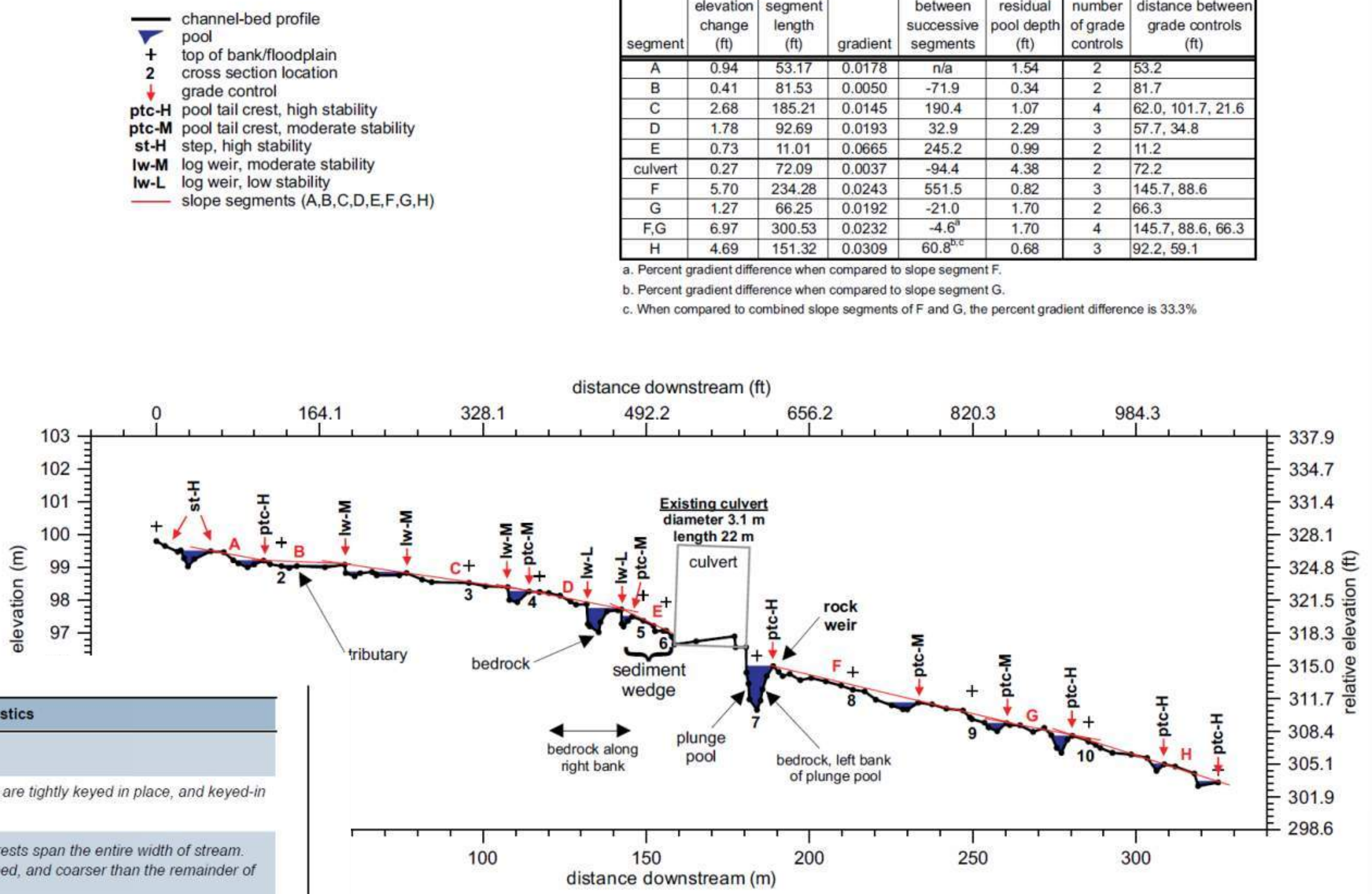
Annotated Longitudinal Profile

segment	elevation change (ft)	segment length (ft)	gradient	% gradient difference between successive segments	maximum residual pool depth (ft)	number of grade controls	distance between grade controls (ft)
A	0.94	53.17	0.0178	n/a	1.54	2	53.2
B	0.41	81.53	0.0050	-71.9	0.34	2	81.7
C	2.68	185.21	0.0145	190.4	1.07	4	62.0, 101.7, 21.6
D	1.78	92.69	0.0193	32.9	2.29	3	57.7, 34.8
E	0.73	11.01	0.0665	245.2	0.99	2	11.2
culvert	0.27	72.09	0.0037	-94.4	4.38	2	72.2
F	5.70	234.28	0.0243	551.5	0.82	3	145.7, 88.6
G	1.27	66.25	0.0192	-21.0	1.70	2	66.3
F,G	6.97	300.53	0.0232	-4.6[a]	1.70	4	145.7, 88.6, 66.3
H	4.69	151.32	0.0309	60.8[b,c]	0.68	3	92.2, 59.1

a. Percent gradient difference when compared to slope segment F.

b. Percent gradient difference when compared to slope segment G.

c. When compared to combined slope segments of F and G, the percent gradient difference is 33.3%



From: USFS 2008 Stream Simulation Design Manual

Stability Rating Table
from USFS 2008 Stream Simulation Manual

Table 5.3—A qualitative method for determining channel-bed structure stability.

Structure composition	Stability Rating	Structure Characteristics
Bedrock	*High*	*Bedrock ledges or falls span entire stream width*
Boulder-cobble steps	*High*	*Boulder-cobble steps span entire width of stream. Rocks are tightly keyed in place, and keyed-in material extends below base of scour pool below step.*
Cobble-boulder or cobble-gravel pool tail crests or riffle crests	*High*	*Cobble-boulder or cobble-gravel pool tail crests or riffle crests span the entire width of stream. Particles are tightly packed, embedded into the channel bed, and coarser than the remainder of the channel bed.*
Log	*High*	*Wood is sound and well anchored, spanning entire stream width.*
Composite log and rock	*High*	*Wood is sound and well anchored, may or may not span entire stream width. Rock pieces are well keyed in place and bridge gaps so that composite structure controls width from bank to bank.*
Boulder-cobble steps, cobble-gravel steps	*Moderate*	*Steps do not span entire width of stream or are loosely keyed in place. Keyed-in rocks may not extend below base of scour pool below step. Alternatively, step key pieces are not in contact with*

Extended Long Profile with LiDAR

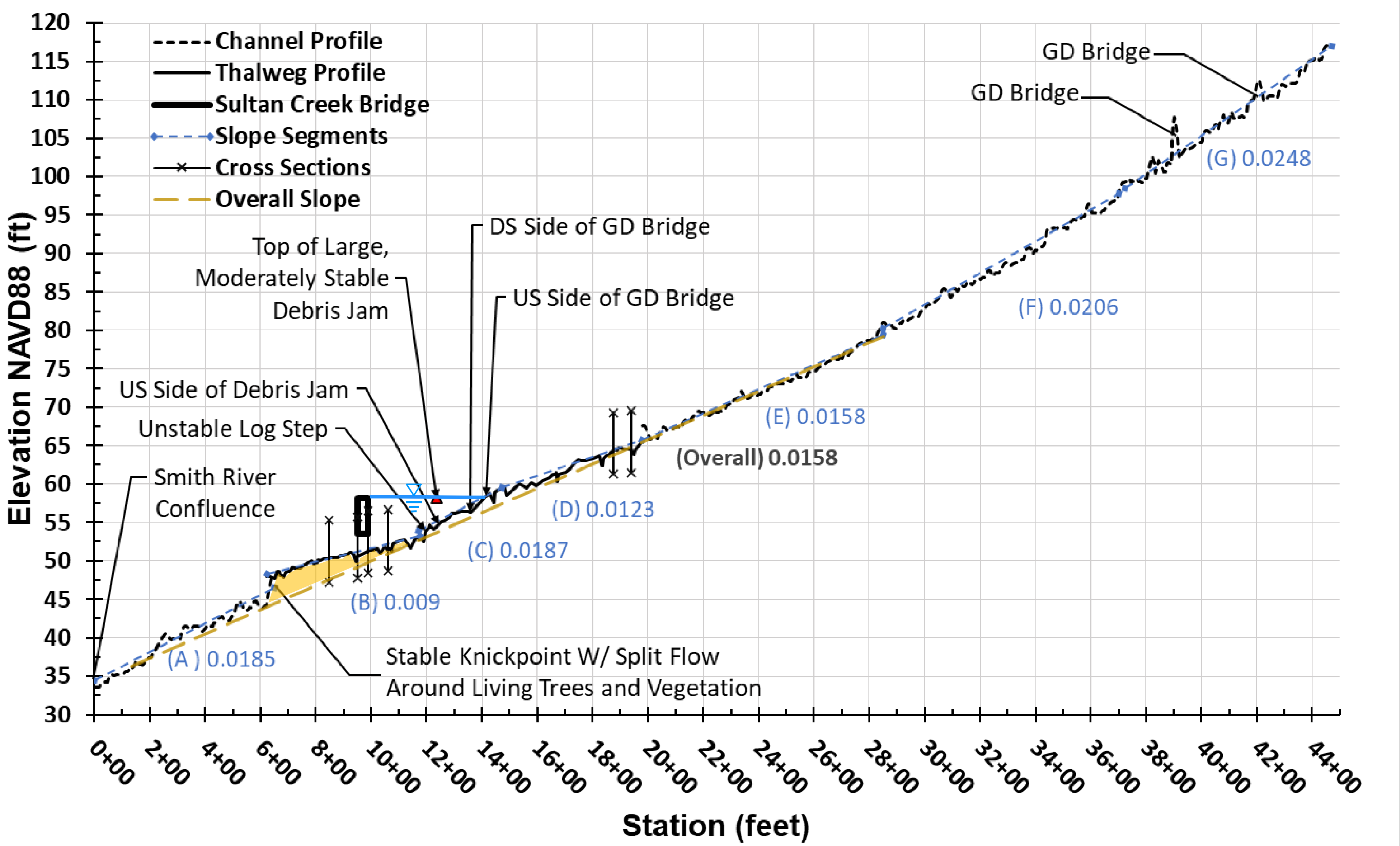
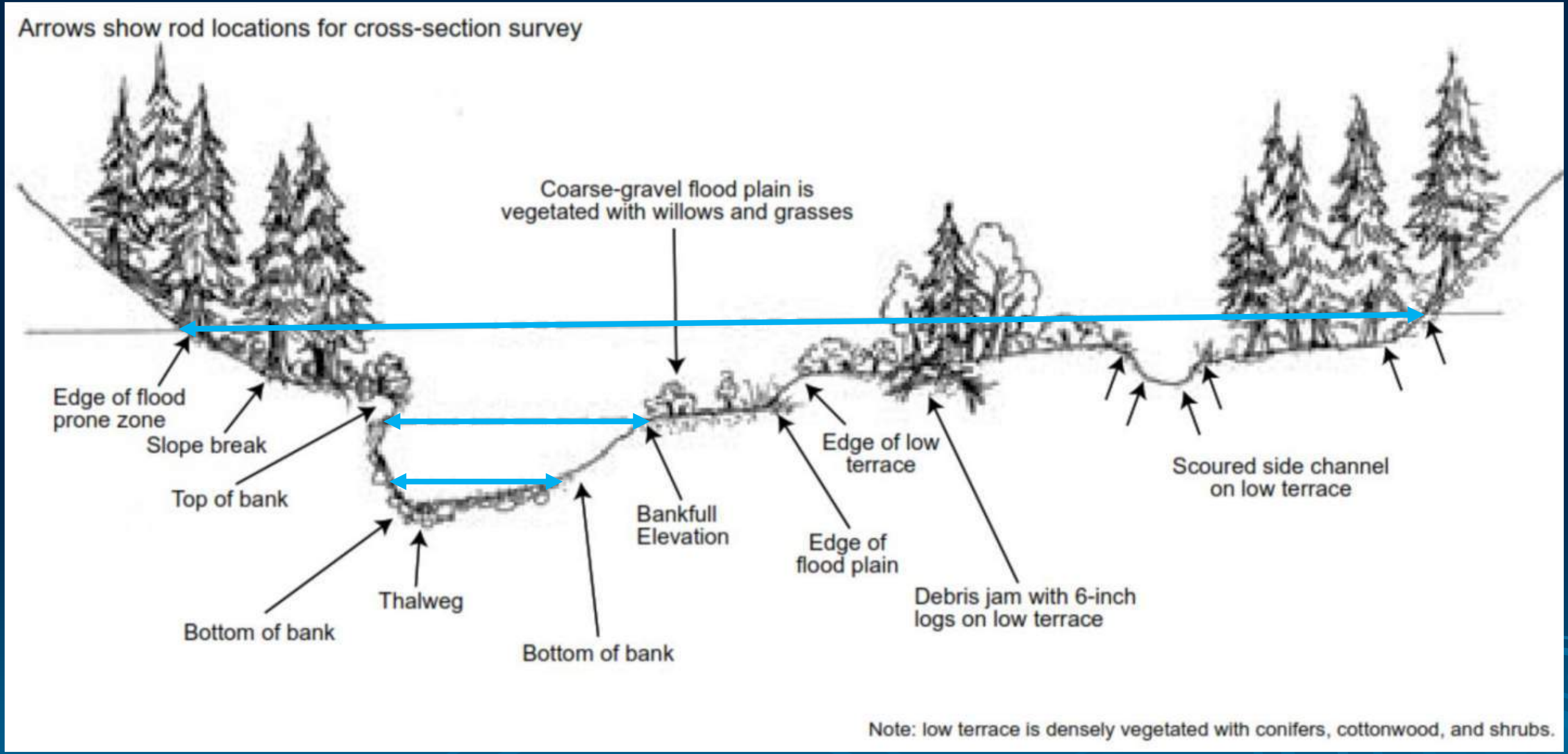


FIGURE 2-3. CHANNEL PROFILE THROUGH PROJECT REACH GENERATED FROM COMBINED LIDAR DEM AND GROUND SURVEY POINTS, WITH CHANNEL SLOPE SEGMENTS DEFINED.

Surveying Channel and Floodplain Features



From: USFS 2008 Stream Simulation Design Manual

Need for Geomorphic Assessments for Fish Passage Projects

- ❑ Post-project assessment of 16 CA State Highway fish passage project
- ❑ Identified common design and performance issues among sites
- ❑ Provided recommended for improving fish passage project outcomes
- ❑ Overarching recommendation was:

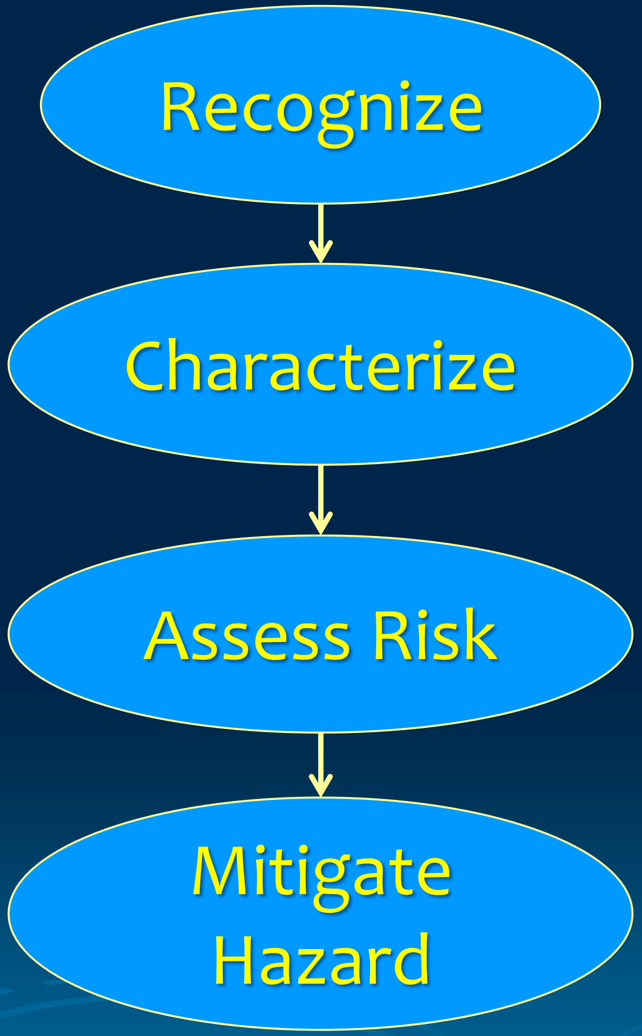
<u>Institute Geomorphic Site Assessments as a Standard Study for Project Development</u>

Includes evaluating geomorphic-based project risks

- ✓ response of project to channel instabilities
- ✓ project influences on stream

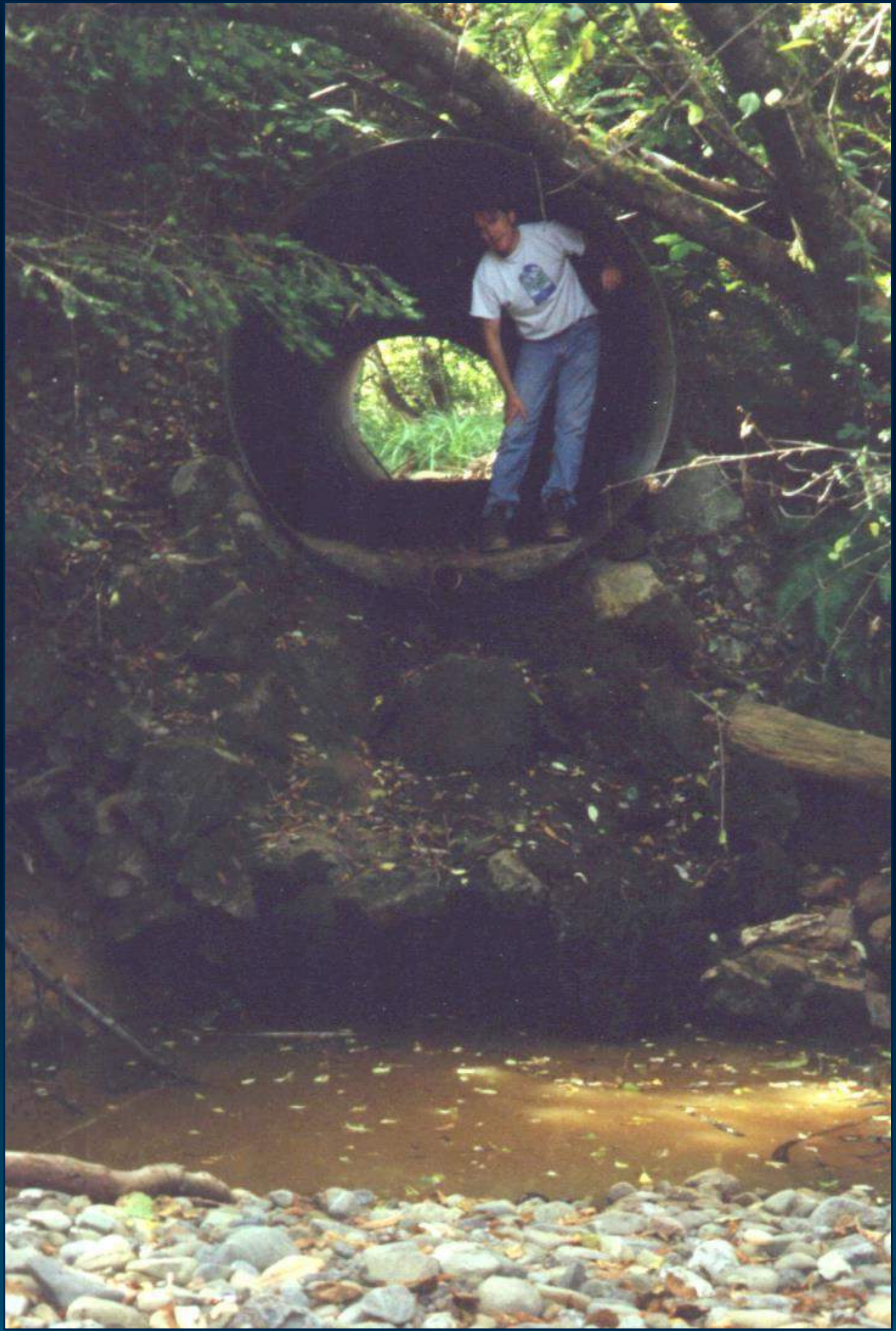
HSU and MLA , 2020. Caltrans Fish Passage Engineering Project Site - Analysis Final Report

Incorporating Geomorphic Risk Assessments into Passage Projects



Resource: Castro, Janine. 2003. *Geomorphic Impacts of Culvert Replacement and Removal: Avoiding Channel Incision*. USFWS

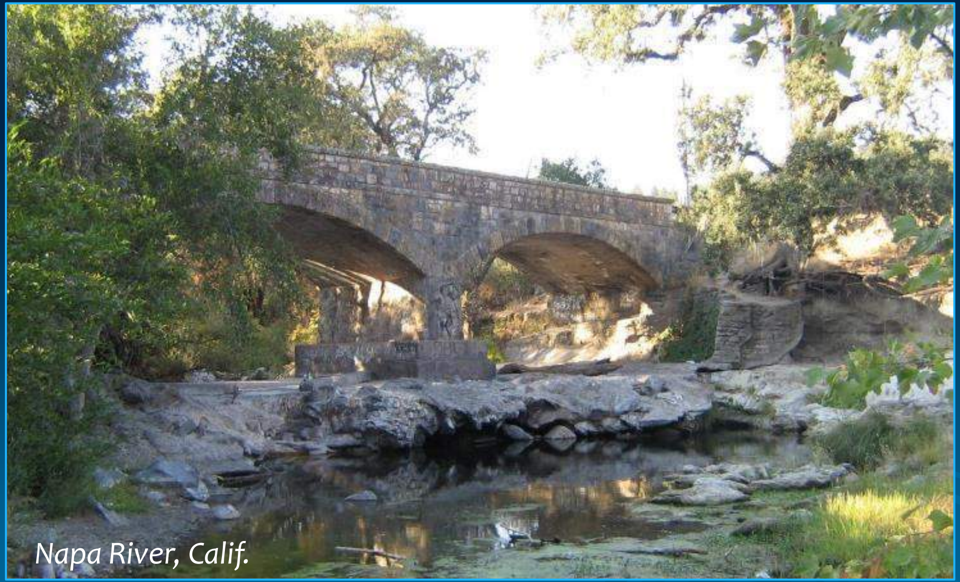
Risk = Hazard Severity x Probability of Occurrence



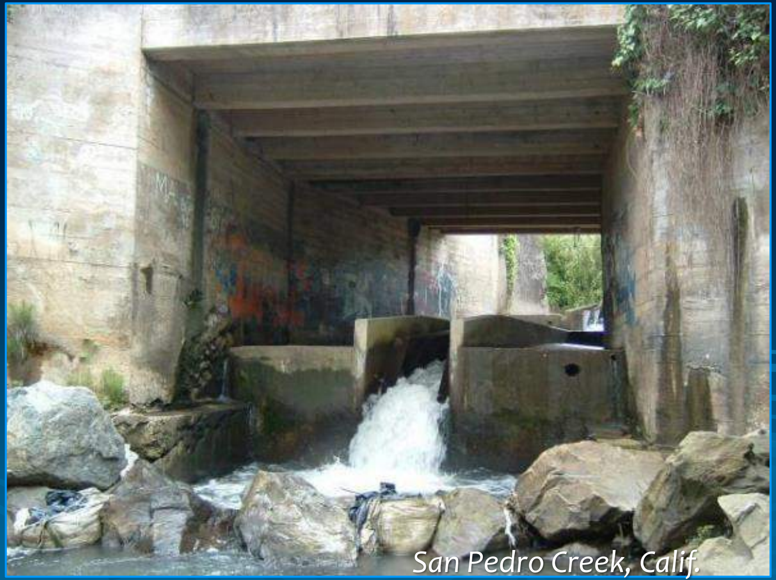
Channel Incision and Anthropogenic Knickpoints

Perched Culverts

Armored Utility Crossings

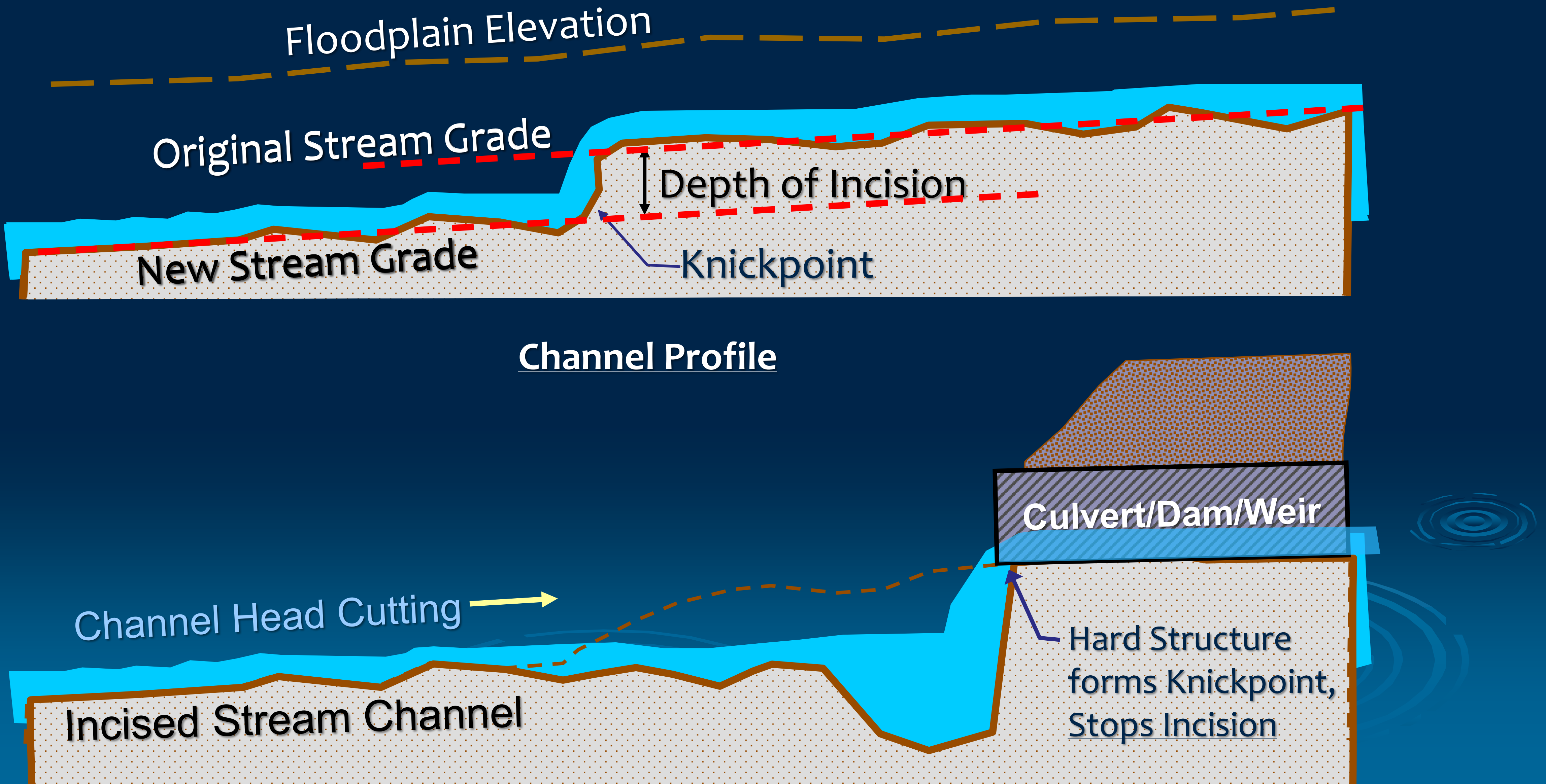


Perched Bridge Aprons



Perched Fishway Entrances

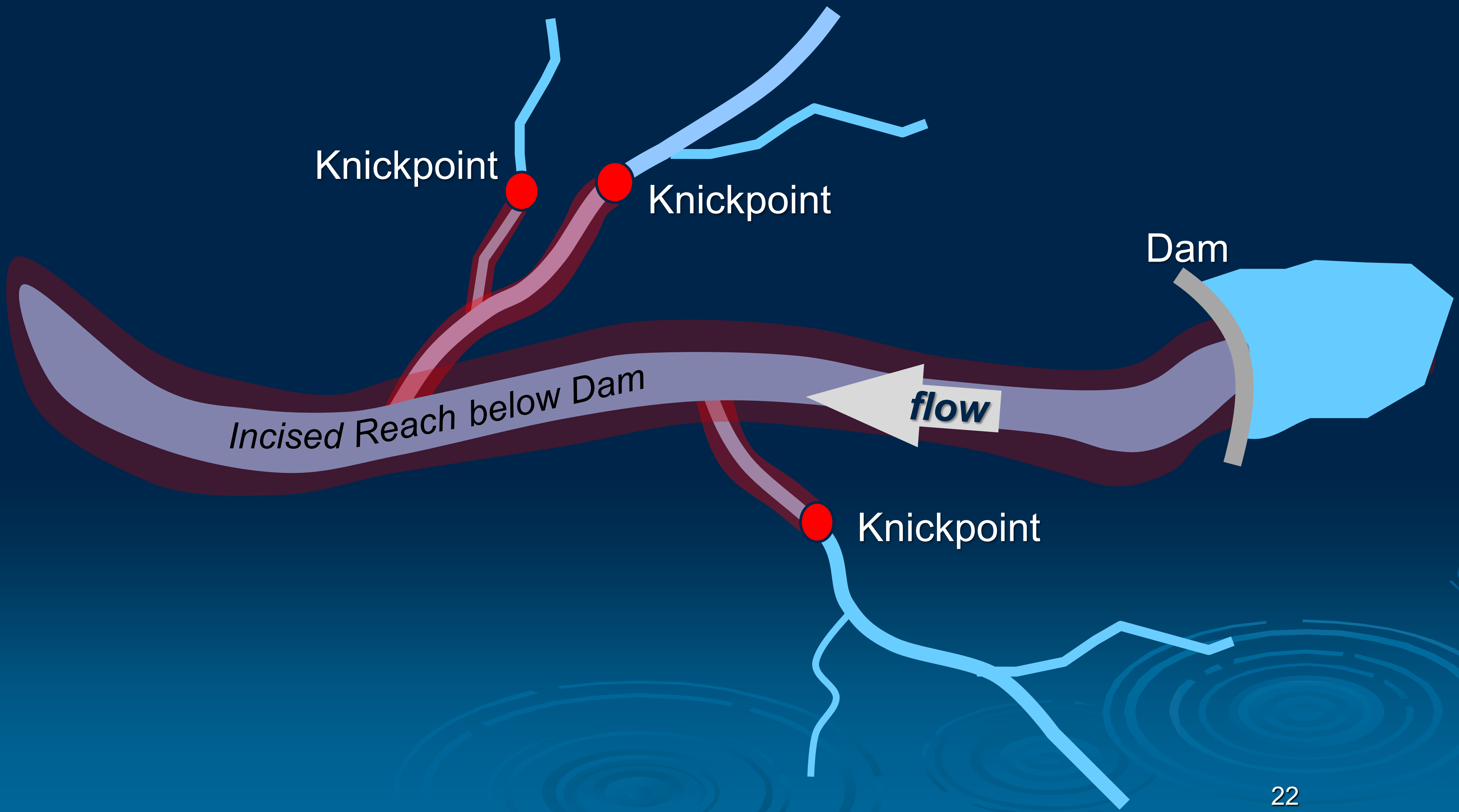
Process of Incision: Headwater Migration



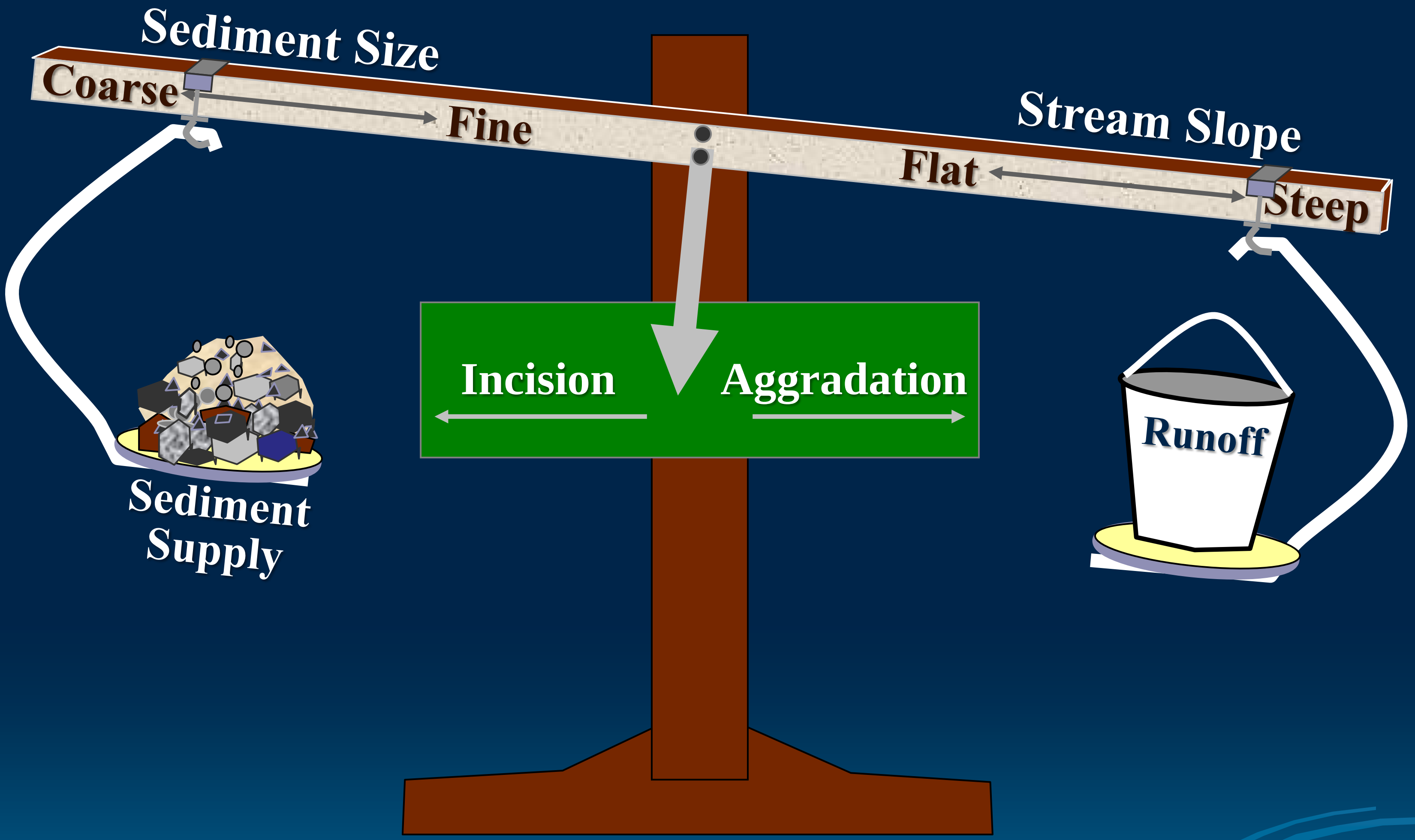
We Initiate of the Incision More often then Not

Photo from US Army Corps of Engineers

Incision Often Moves Headward into Tributaries



Dynamic Equilibrium and Causes of Incision

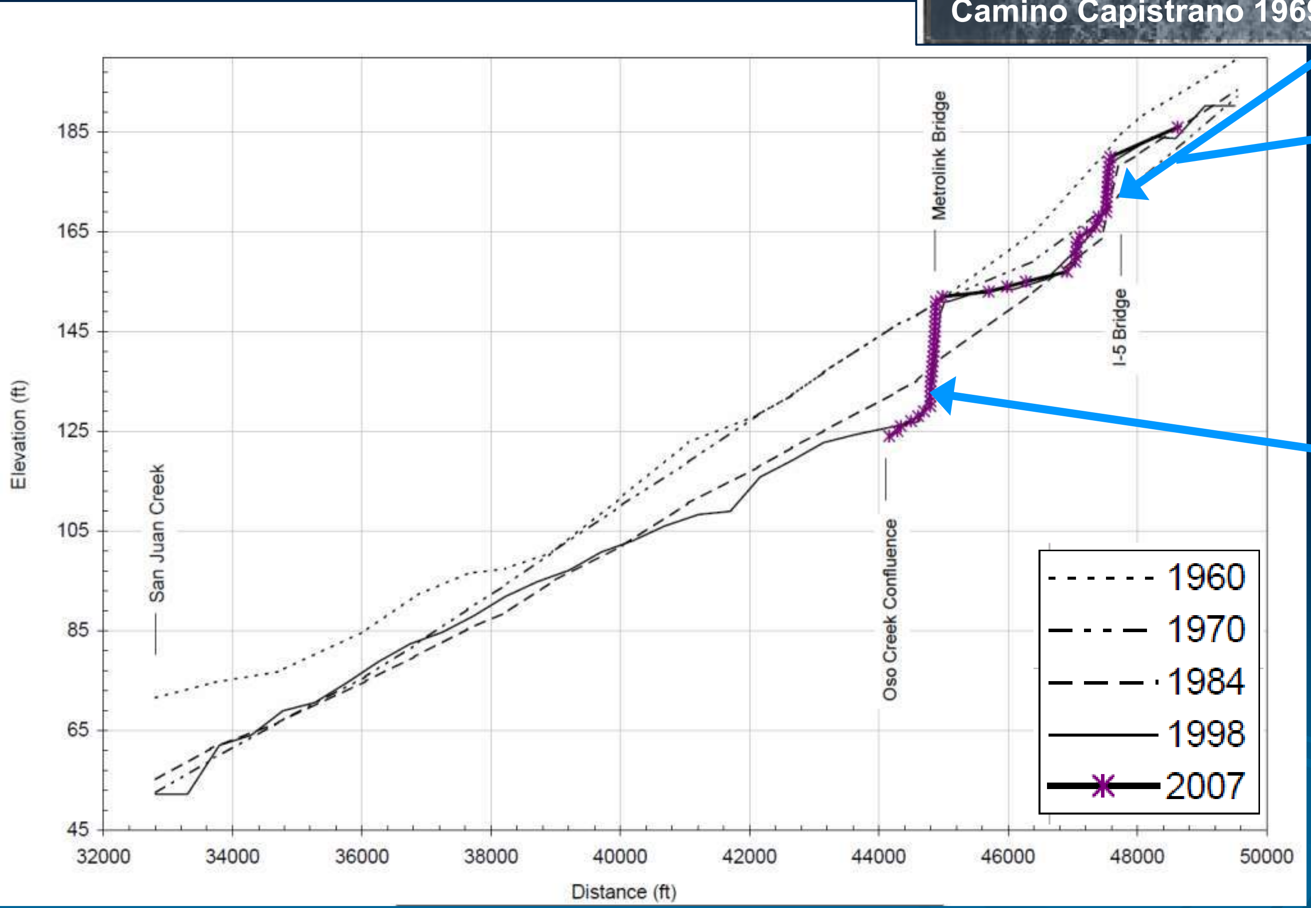


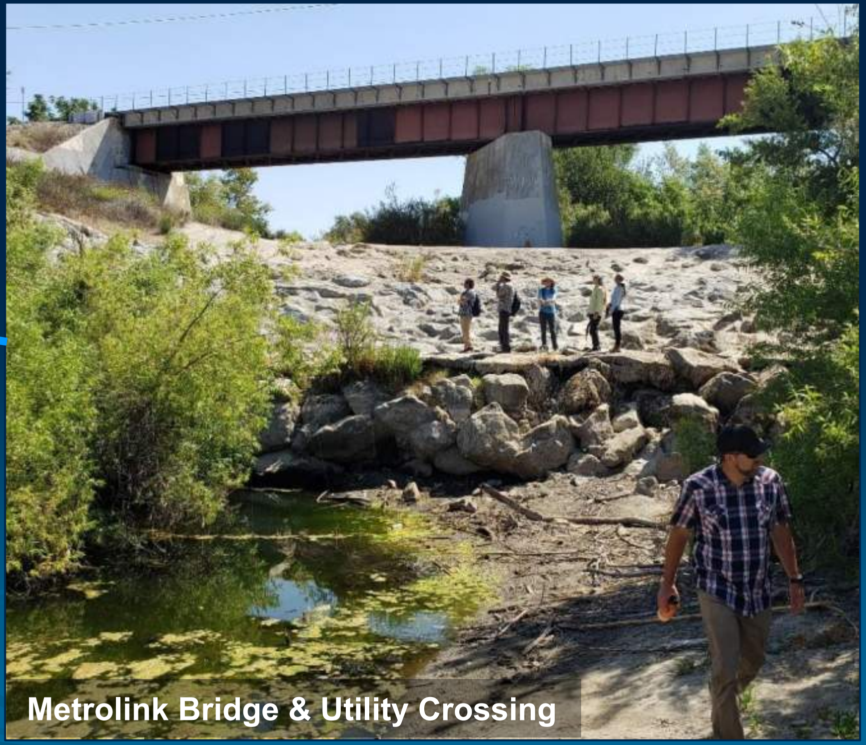
The Lane Relationship (from Lane, 1955)

Trabuco Creek Historical Incision and Knickpoints

Causes of Incision

- ✓ Urban Development (Runoff ⬆)
- ✓ Gravel Mining (Sediment Supply ⬇)
- ✓ Channelization (Channel Slope ⬆)



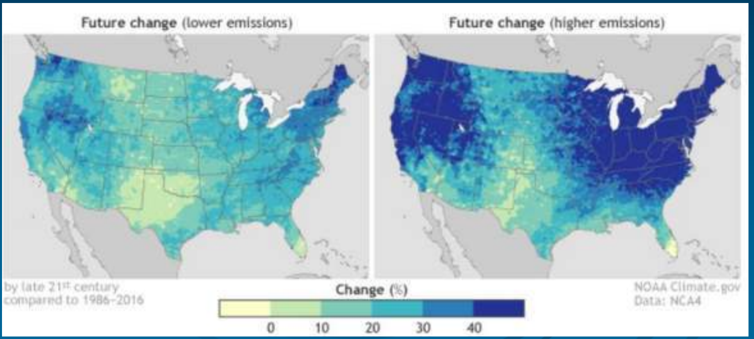


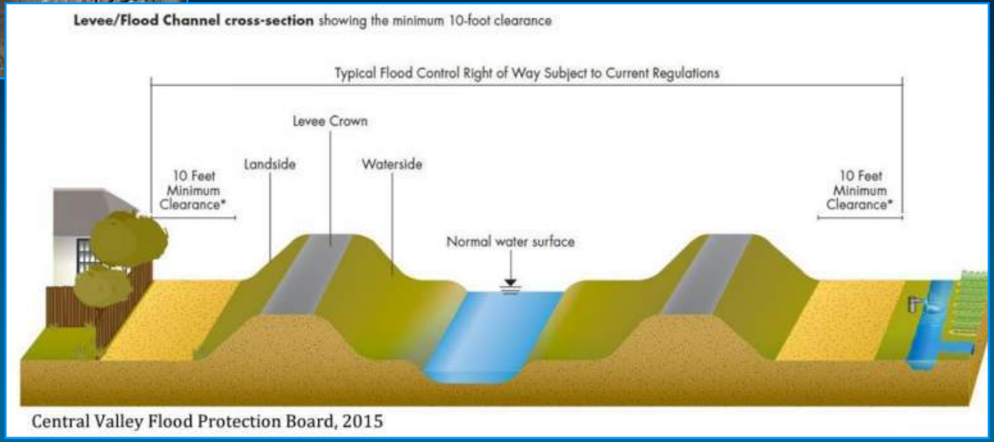
Causes of Channel Incision

- ✓ Decrease in sediment supply
  (dams, gravel extraction, urbanization)
- ✓ Channel encroachment
  (Increase depth of flow, bed & bank shear)
- ✓ Channelization
  (shortening/steepening the channel)
- ✓ Increase in runoff
  (urbanization, agriculture, road density)
- ✓ Loss of wood in streams
  (removal of large wood, beaver dams)
- ✓ Climate change/extreme weather
  (increase in extreme flow events)





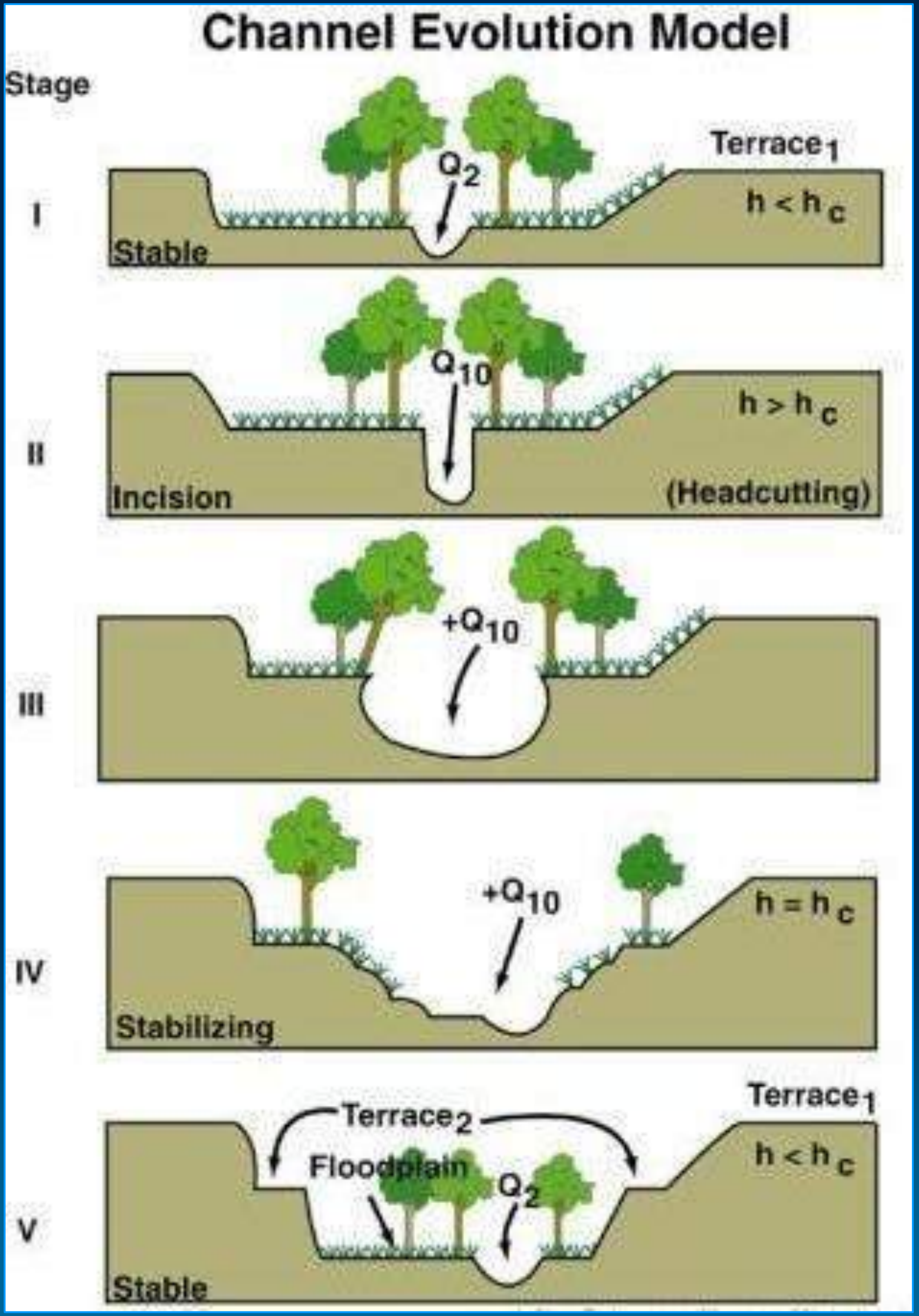




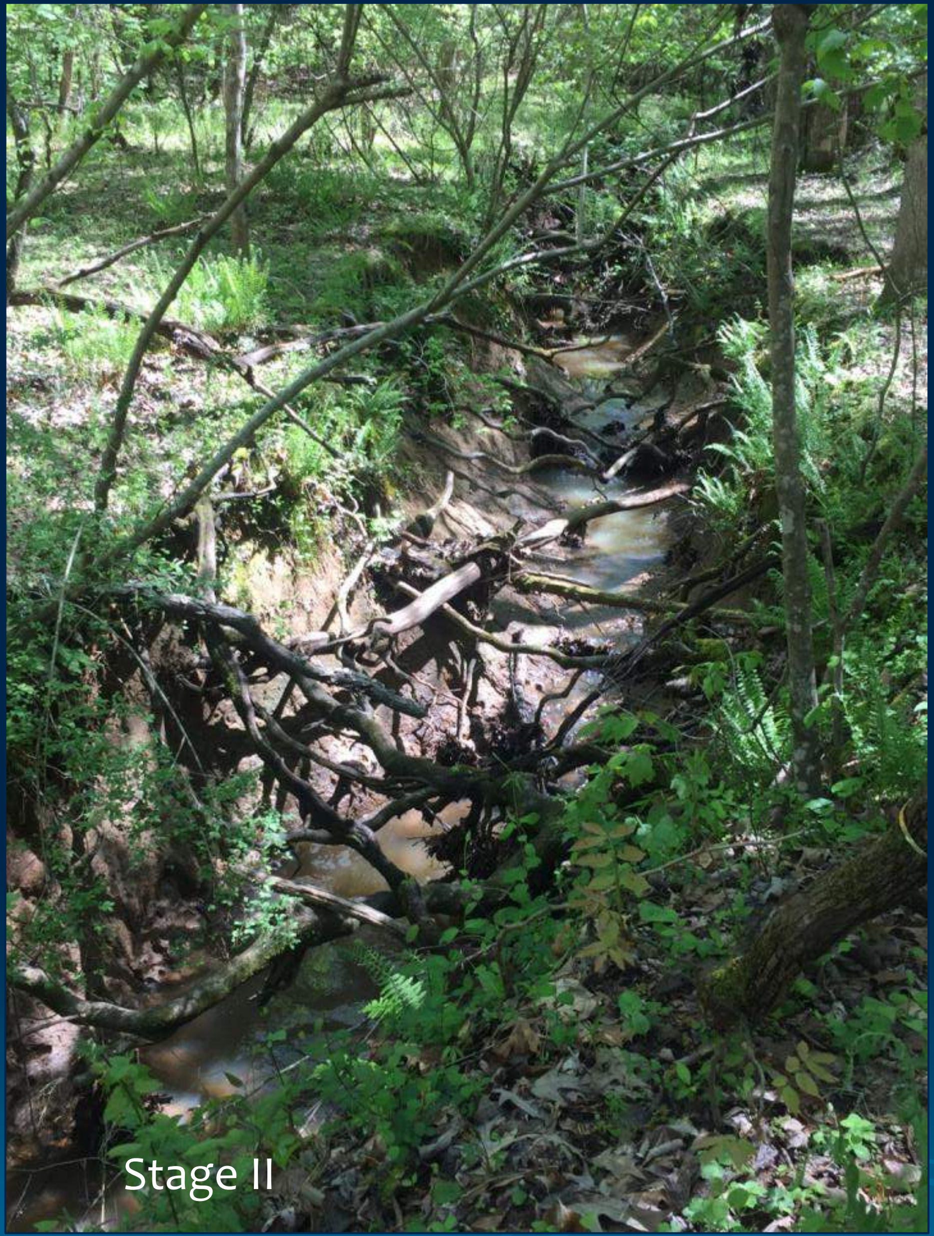
Channel Evolution Model (CEM)

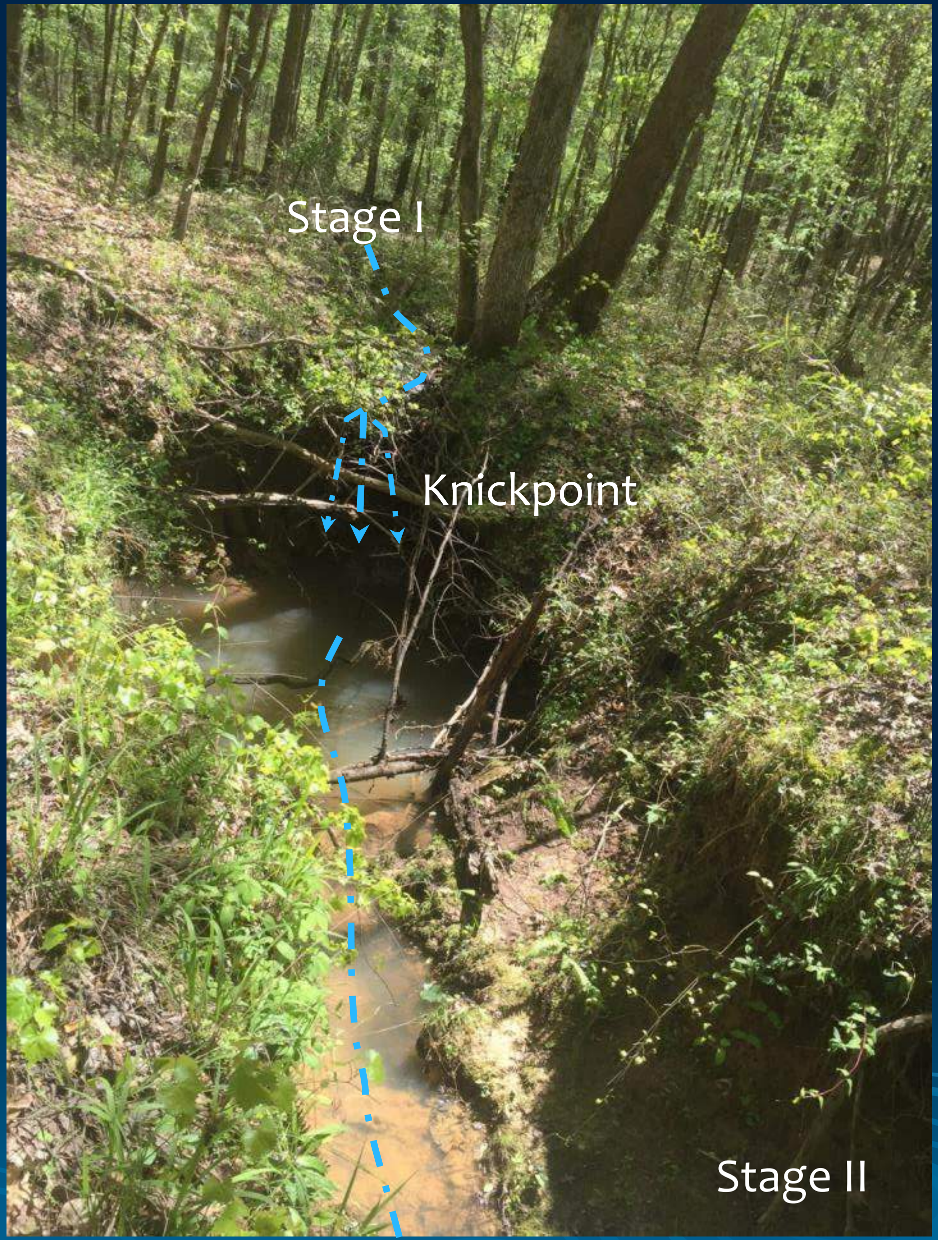
Stage II Incision

Stage III/IV Widening/Stabilizing



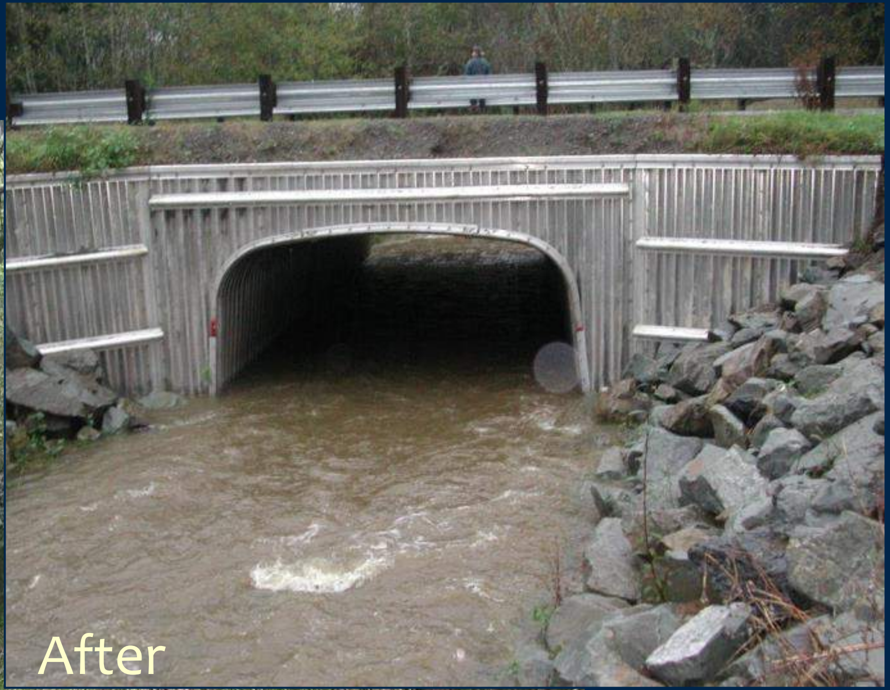
from Schumm, Harvey, and Watson. 1984.





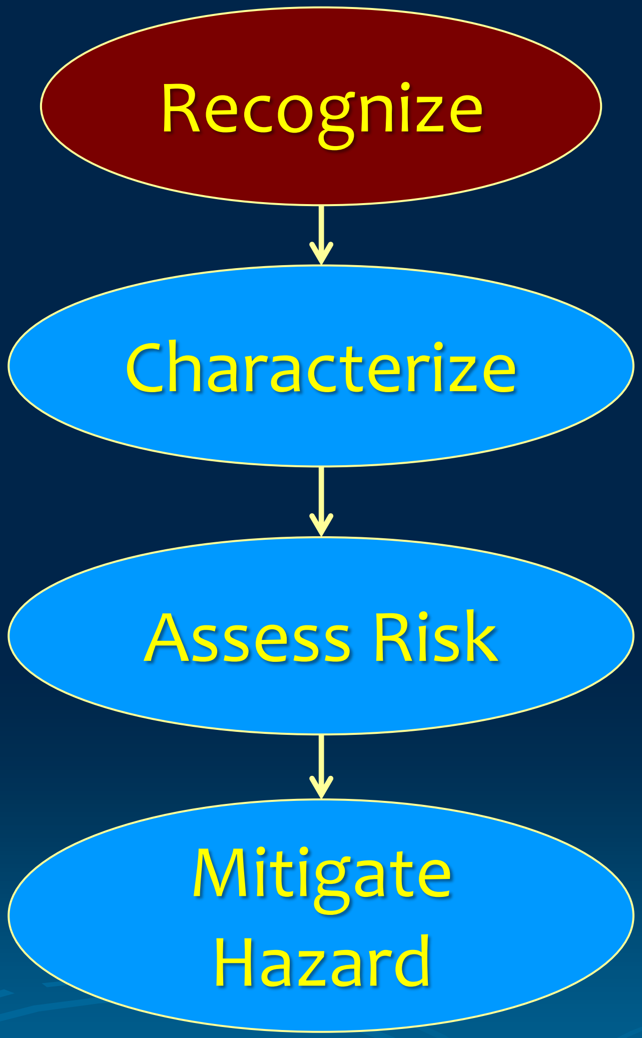
Incising Channel, Toby Tubby Creek Watershed, Mississippi

Allowing Incision to Migrate Upstream without Considering Risk



Jordan Creek at Parkway Drive

Incorporating Geomorphic Risk Assessments into Passage Projects



Resource: Castro, Janine. 2003. *Geomorphic Impacts of Culvert Replacement and Removal: Avoiding Channel Incision*. USFWS

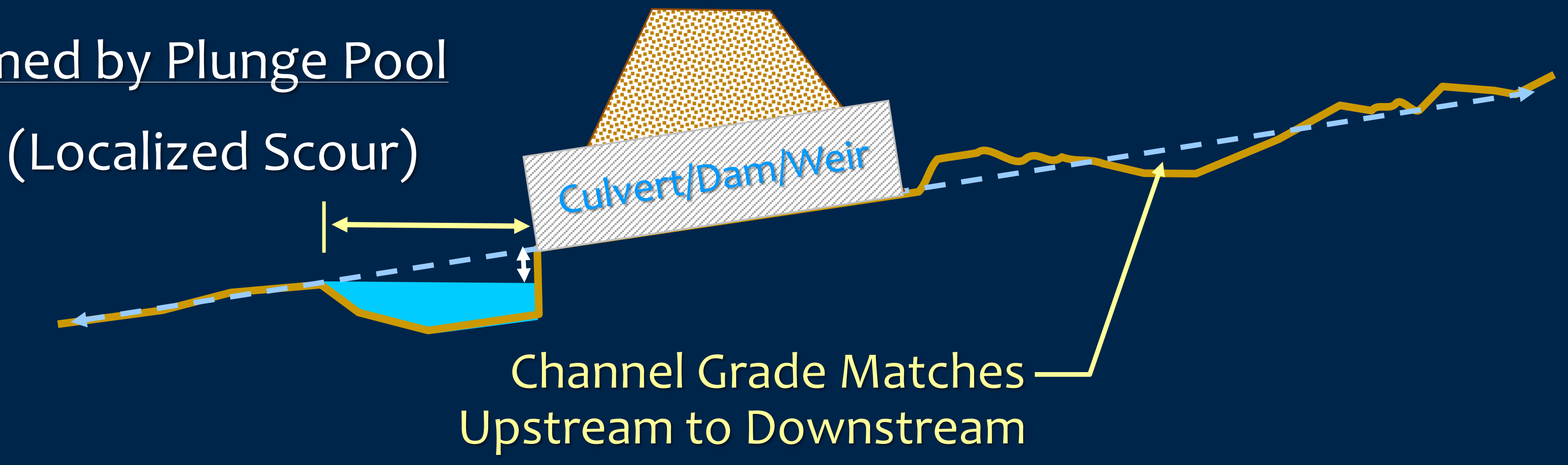
Step 1 - Recognition: Incision or Local Scour?

photo: Kozmo Bates

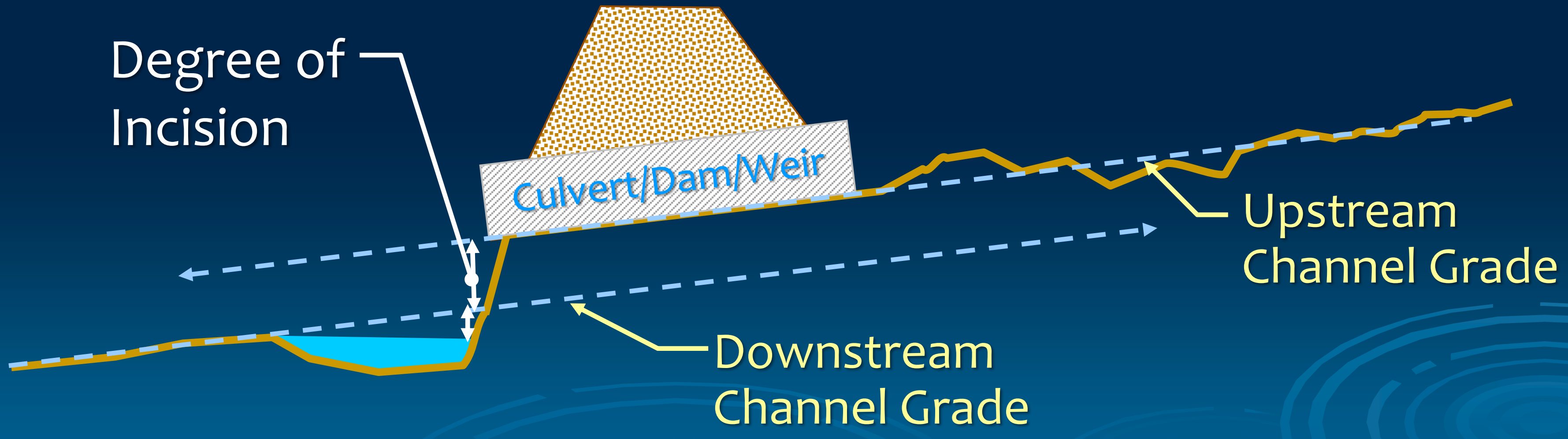
photo: Kozmo Bates

Recognize Local Scour vs. Incision

Drop formed by Plunge Pool

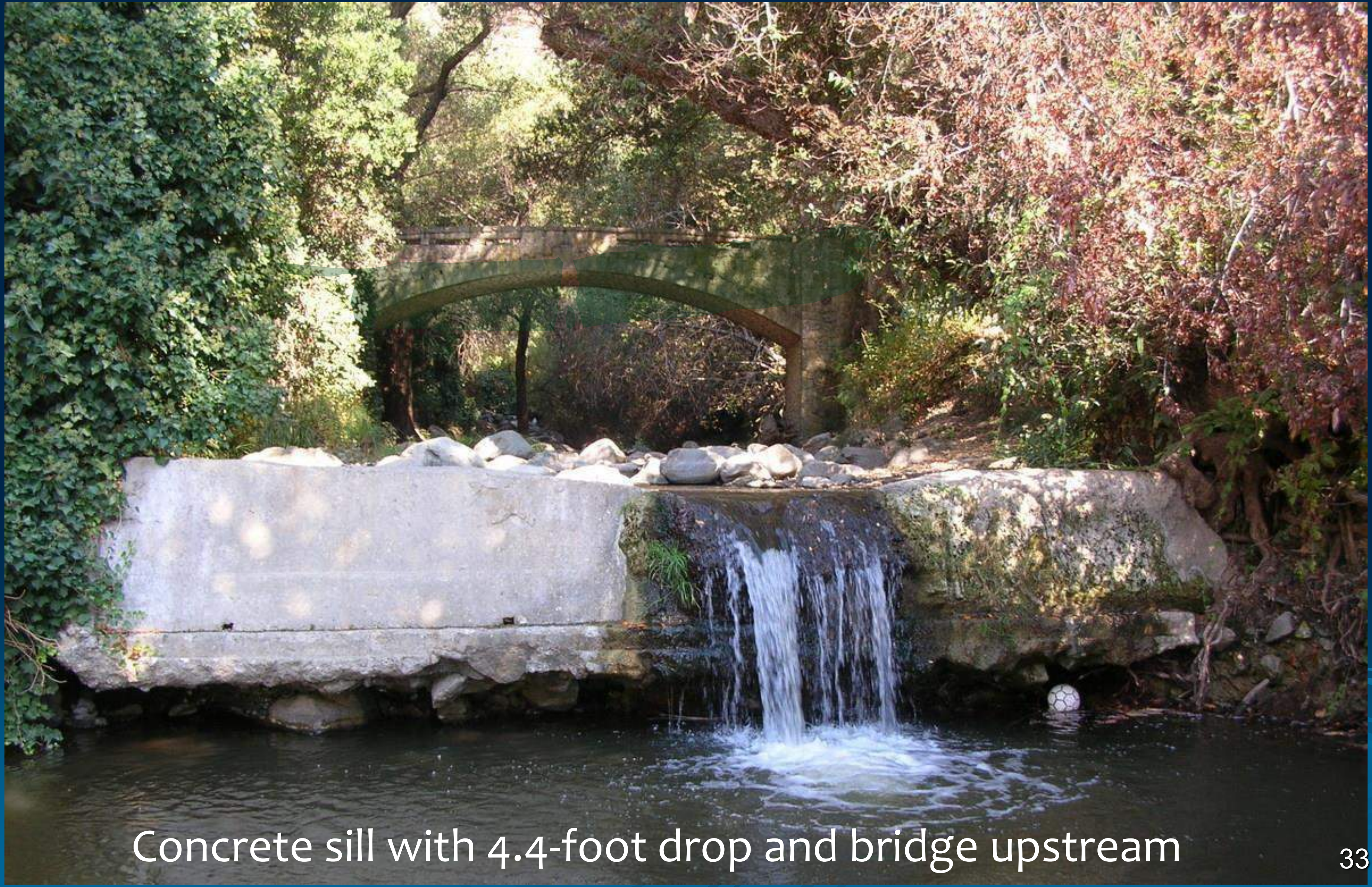


Drop from Channel Incision

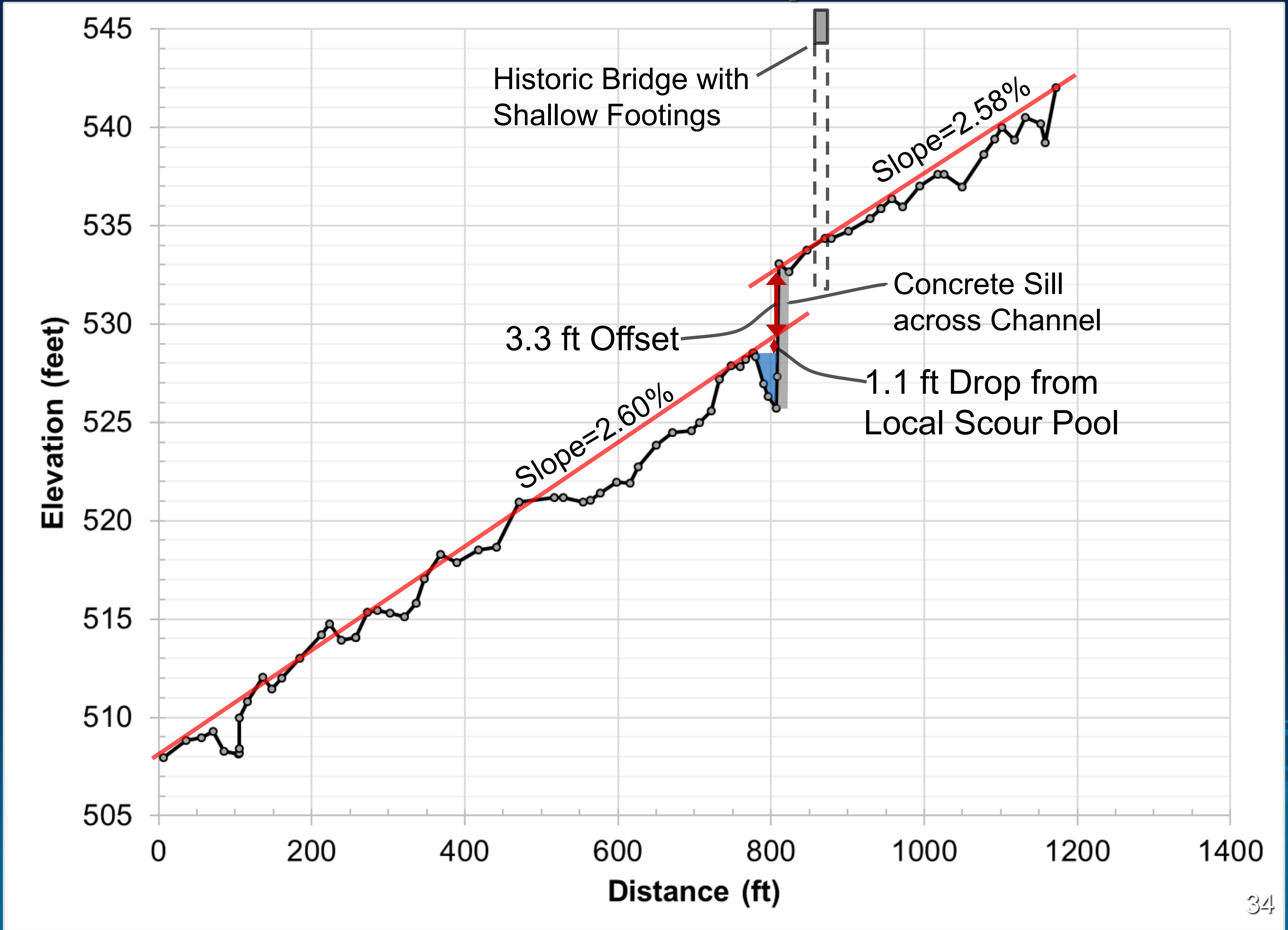


Channel Profile Interpretation

Incision Knickpoint or Not?



Channel Profile Interpretation

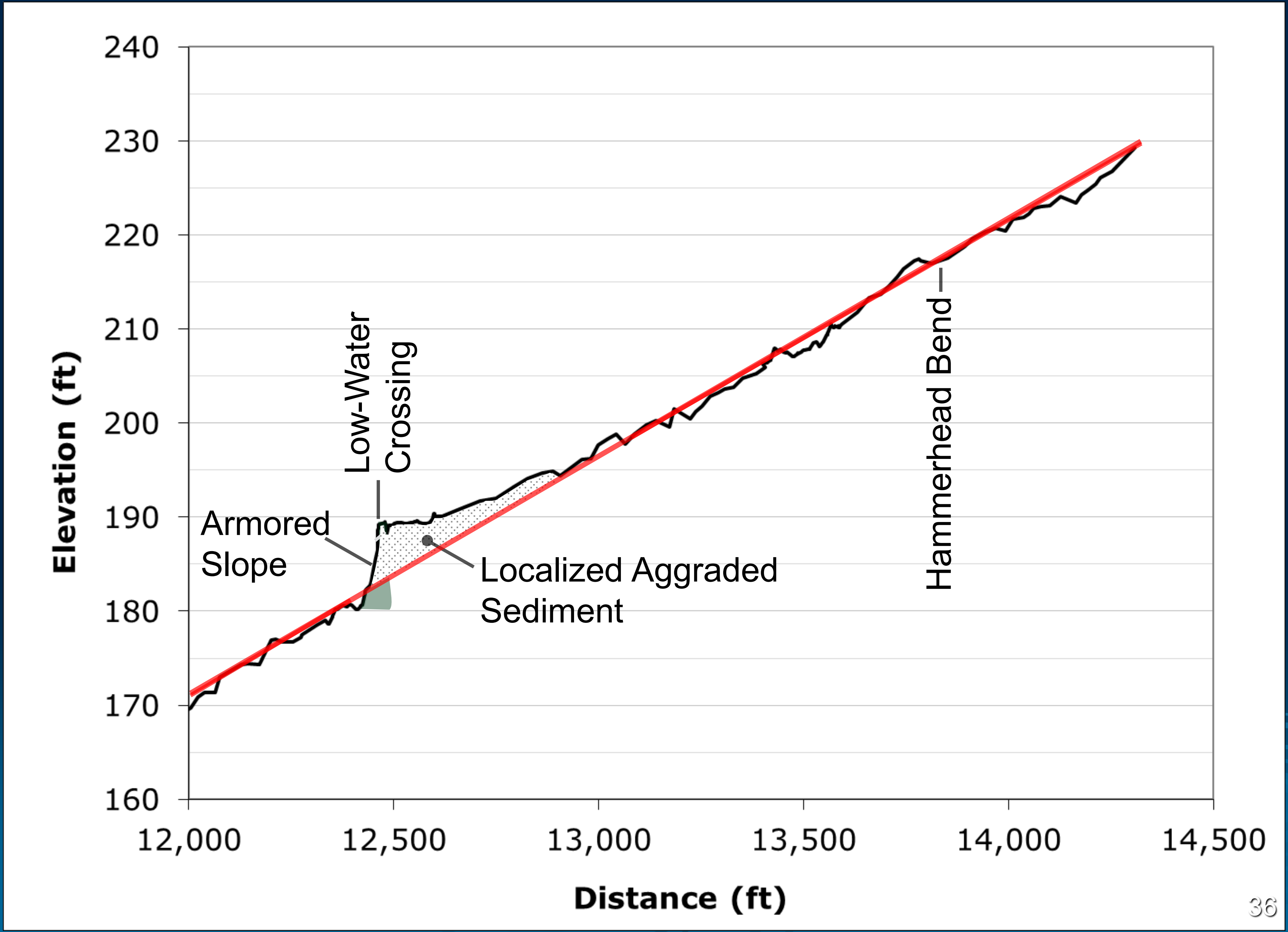


Channel Profile Interpretation

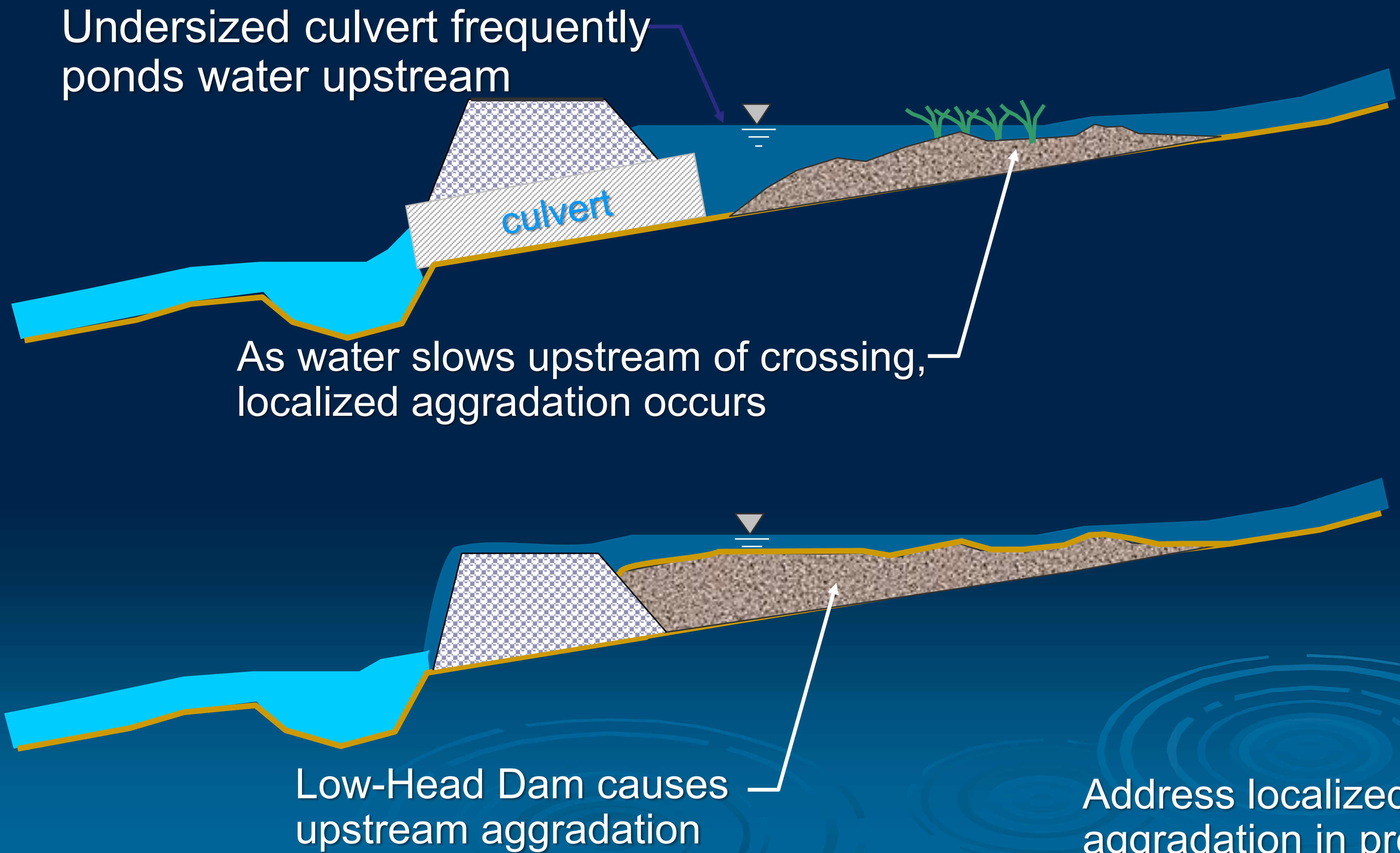
Incision Knickpoint or Not?

Vented low-water crossing (ford) with 8.7 feet of drop.

Channel Profile Interpretation



Recognize Localized Aggradation



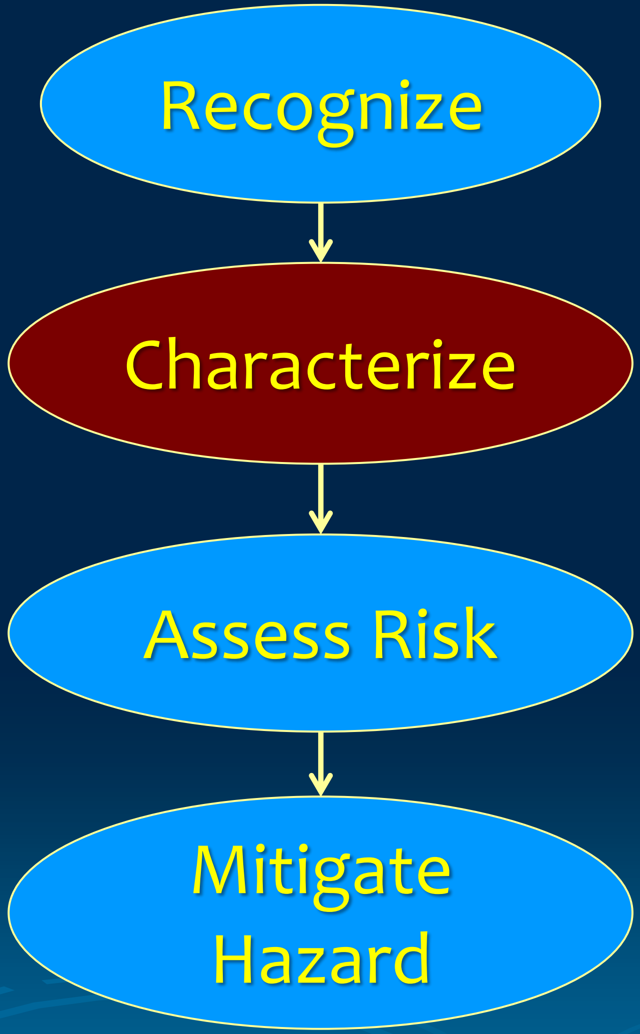
Address localized aggradation in project

Other Channel Incision Indicators

- **Toe of Bank is Vertical**
  Exposed roots, lack of sediment layering at streambed-banks interface
- **Actively Widening (Stage III)**
  Active bank failures, low depositional bars
- **Infrastructure/Cultural Features Exposed**
  Perched culverts or exposed bridge footings, aprons, and pipelines
- **Lack of Sediment Deposition**
  Erosion of channel bed down to bedrock or other resistant soil layers
- **Lack of Pools**
  Long reaches of riffles/runs without pools

List adapted from J. Castro, 2003

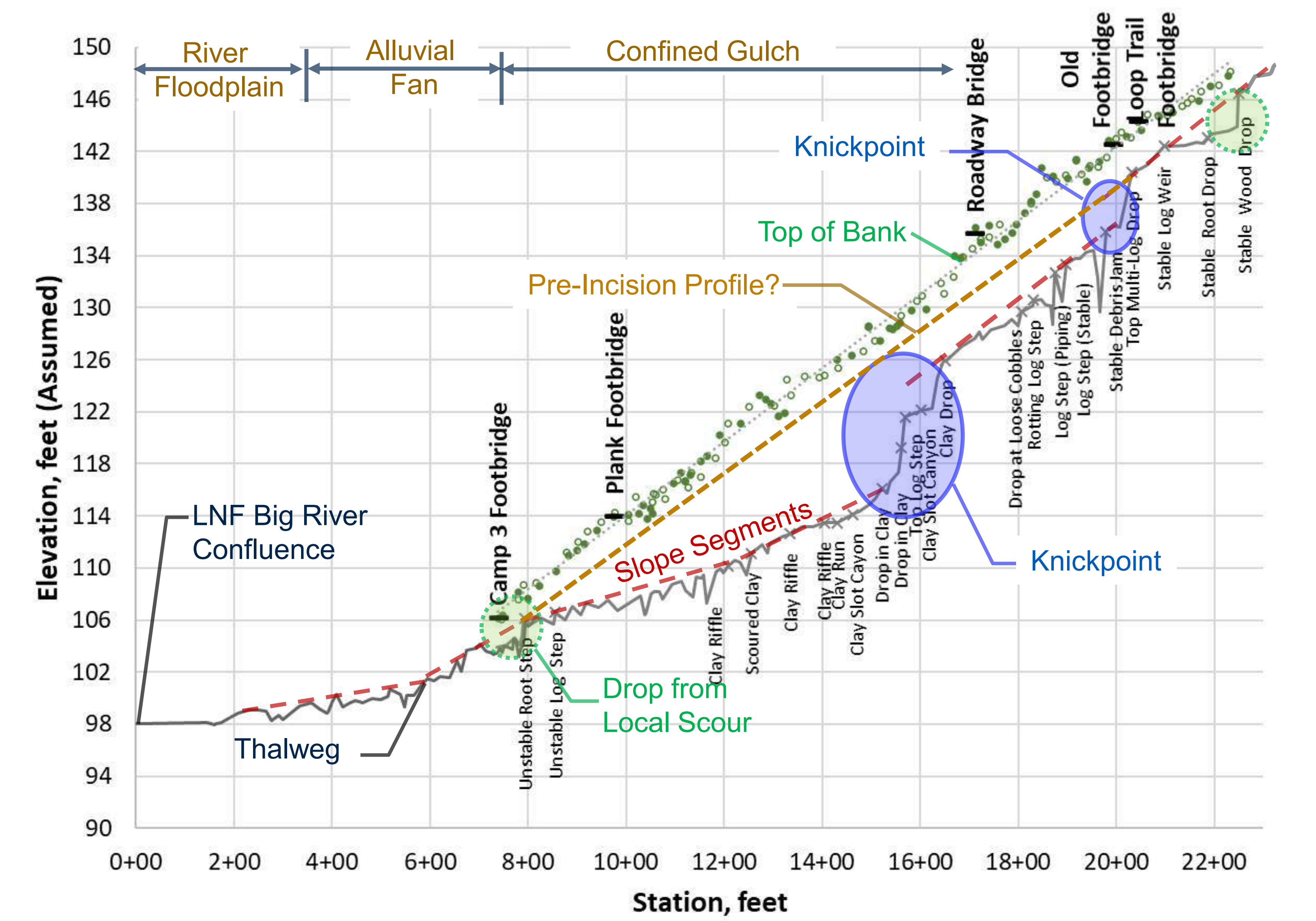
Incorporating Geomorphic Risk Assessments into Passage Projects



Resource: Castro, Janine. 2003. *Geomorphic Impacts of Culvert Replacement and Removal: Avoiding Channel Incision*. USFWS

Channel Profile Interpretation

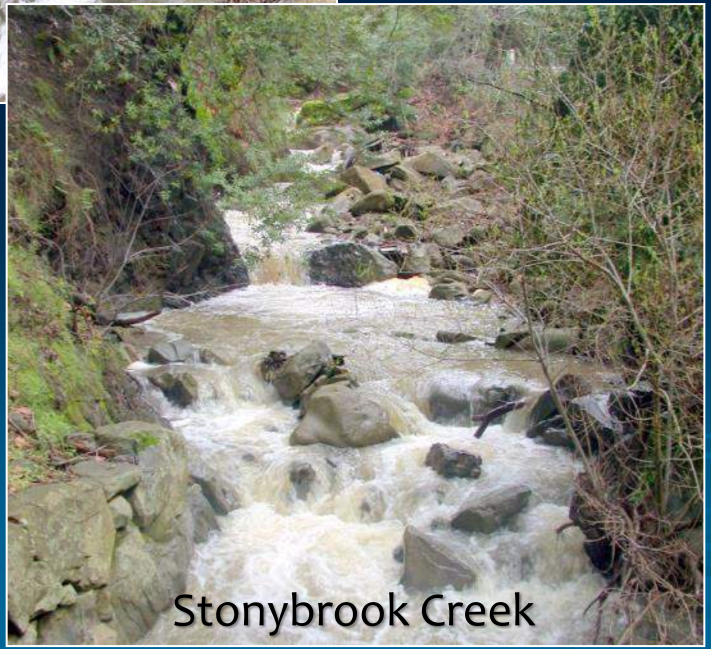
Slope Segments and Multiple Knickpoints



Characterize Rate of Headward Incision

More mobile the bed material, more rapid the channel incises

Boulder Channel



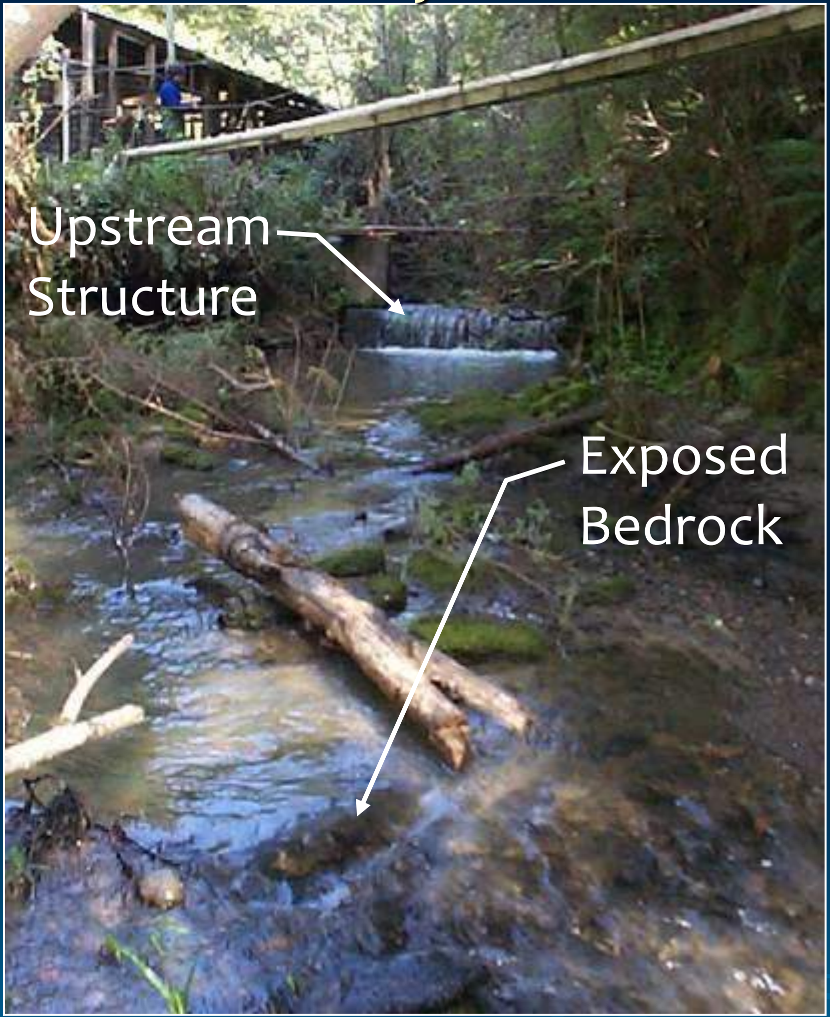
Stonybrook Creek

Fine Grain Bed and Banks

Auburn Ravine

Risk Assessment - Extend of Uncontrolled Regrade

McCready Gulch



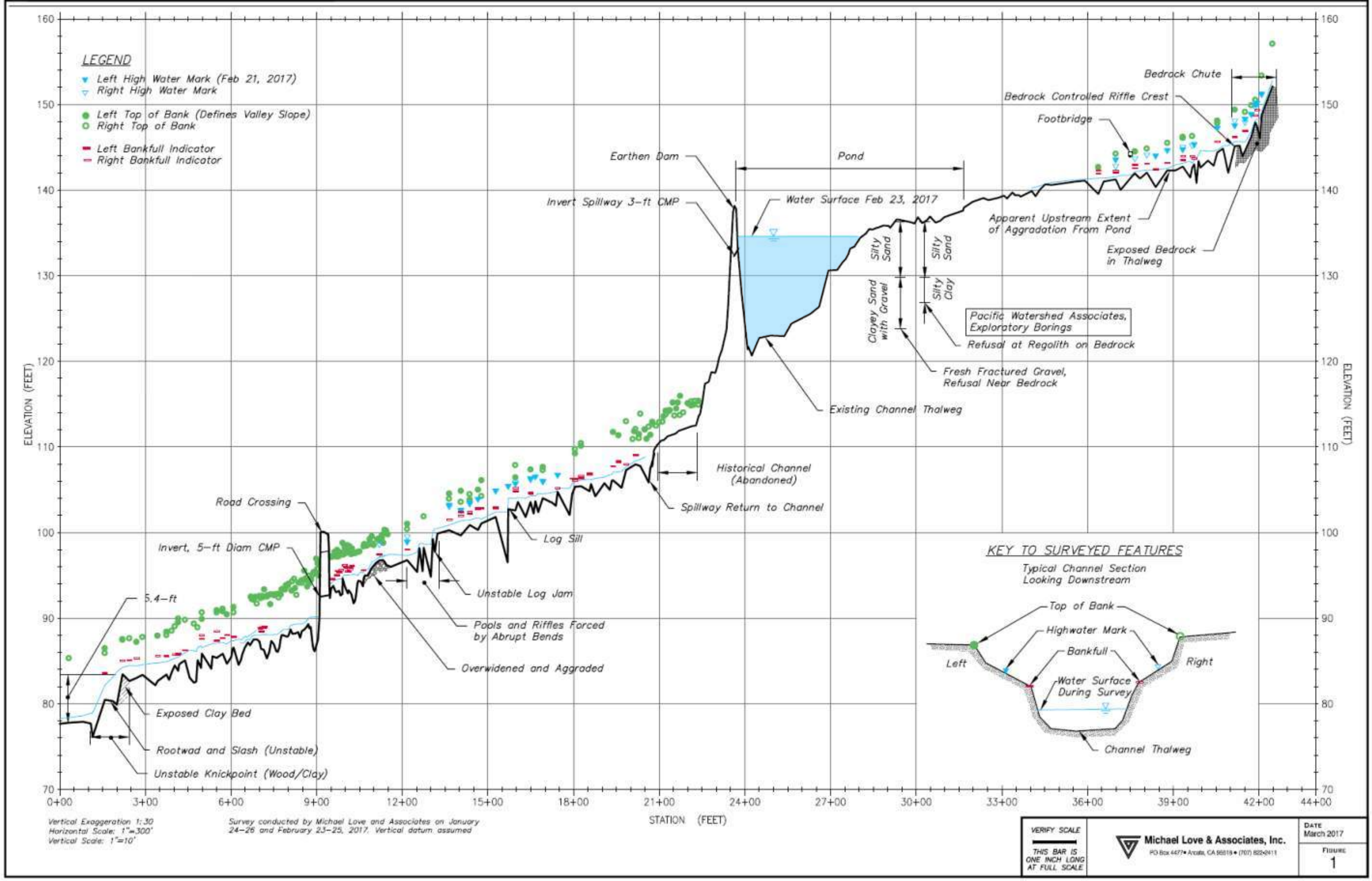
Upstream of perched culvert, prior to removal

Morrison Gulch

Channel upstream of culvert replacement and incision

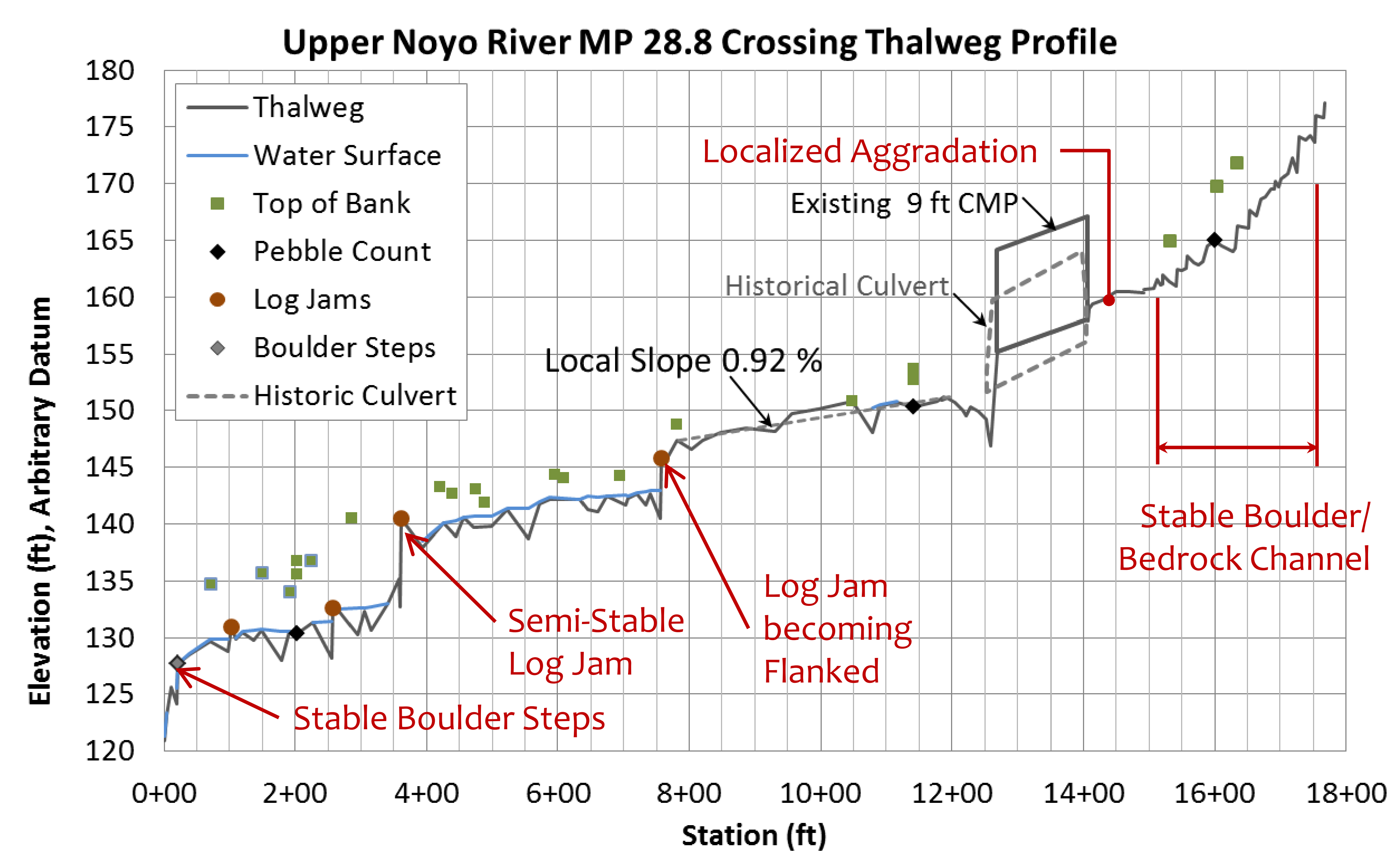
Neefus Gulch Profile Analysis Part I

Group Exercise

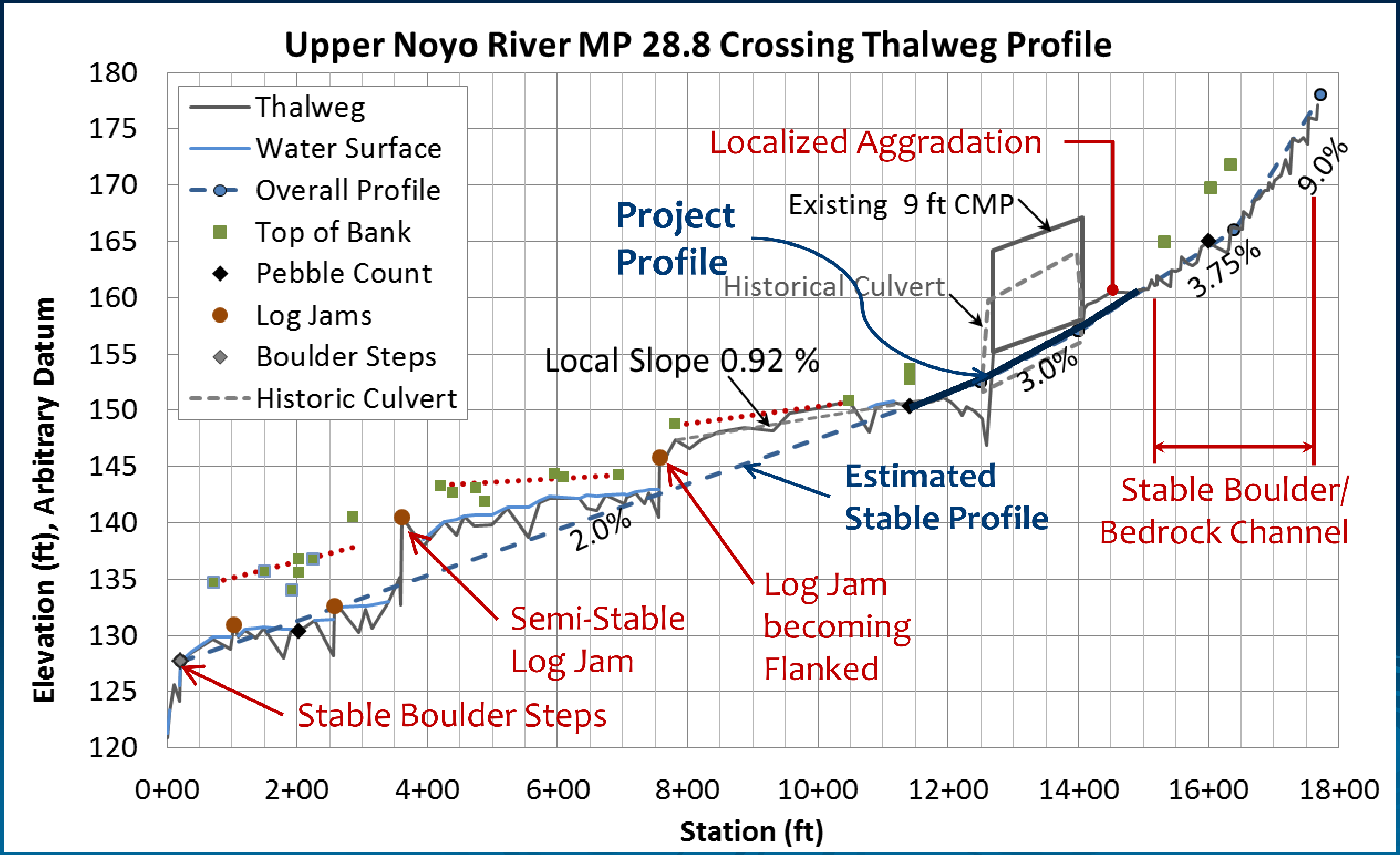


1. Identify slope segments
2. Identify knickpoints
3. Estimate historical channel profile through pond

Establishing Channel's Vertical Adjustment Potential (VAP)

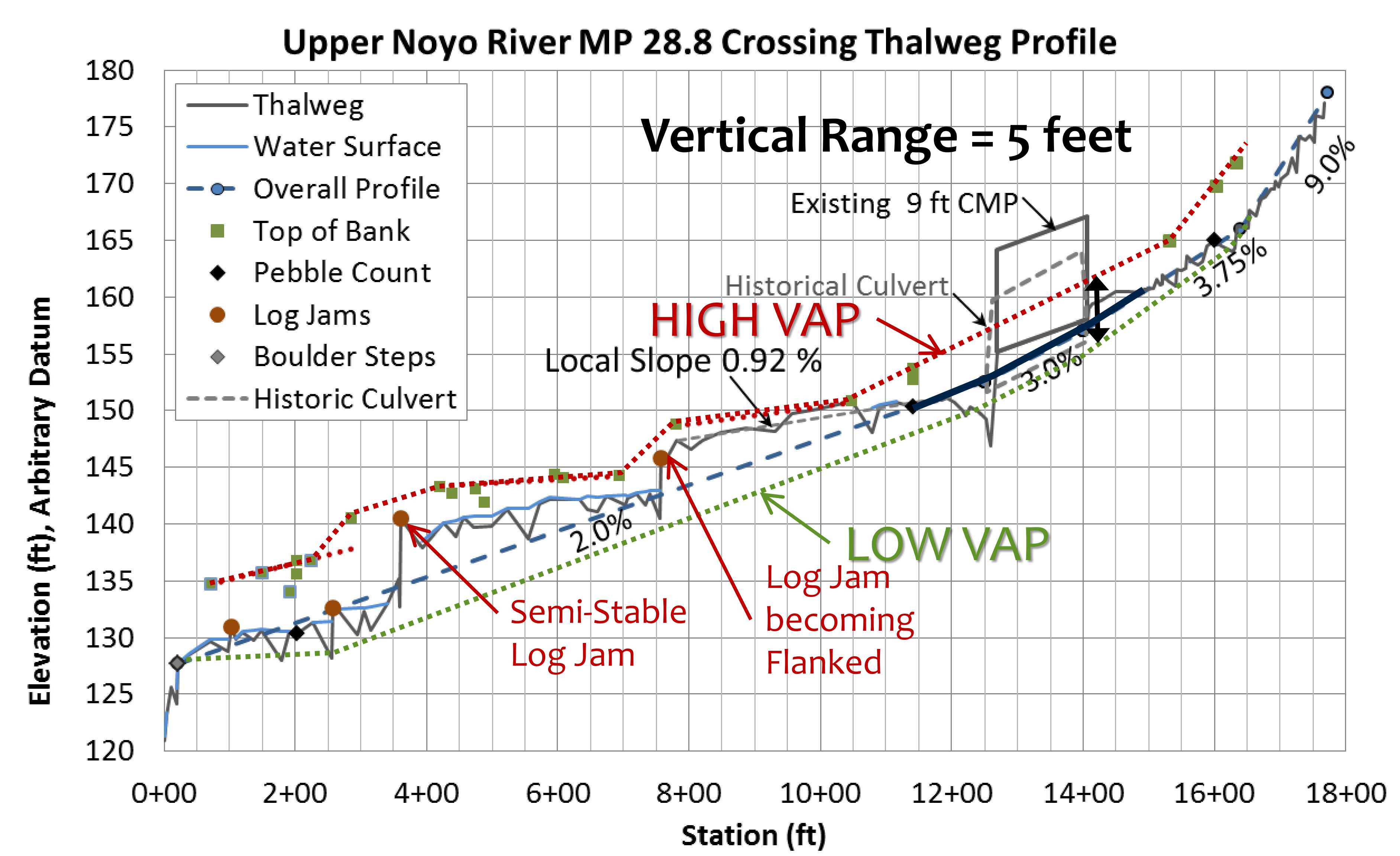


Establishing Channel's Vertical Adjustment Potential (VAP)



Vertical Adjustment Potential (VAP) Profiles

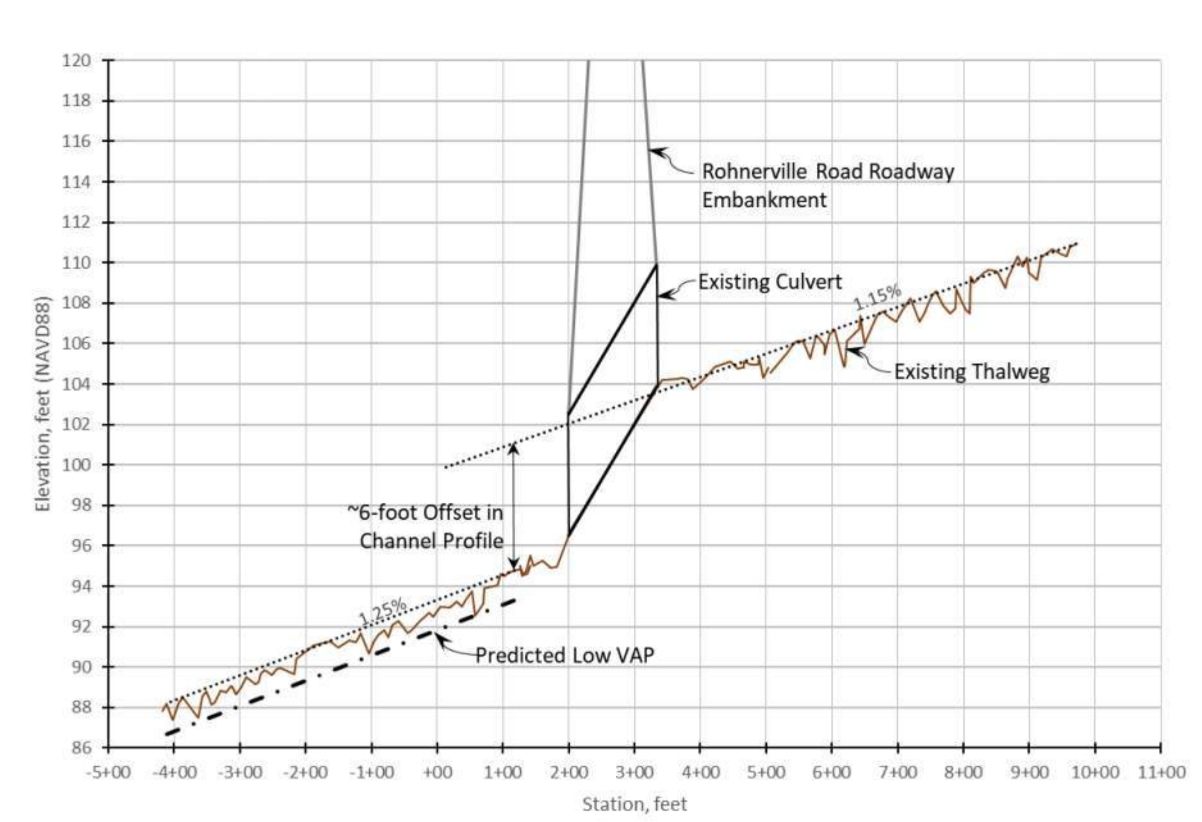
Estimates the range of possible channel profiles for life of project



Establishing the Vertical Adjustment Potential (VAP)

Develop VAP with long profile and field investigations:

- ✓ Channel slopes
- ✓ Stability/mobility of channel type/material
- ✓ Channel controls and anticipated longevity
  [bedrock, large wood, colluvium, hard infrastructure]
- ✓ Knickpoints, evidence of active incision (downcutting) or aggradation
- ✓ Current stage and future projecting in Channel Evolution Model (I, II, III, IV, V)
- ✓ Pool scour depths (low VAP)
- ✓ Bankfull and floodplain elevations (high VAP)
- ✓ Historical information
  (existing invert elev. and slope)



Application of Low and High Vertical Adjustment Potential (VAP)

Low VAP Profile

- Set downstream project profile to accommodate Low VAP
- Set fishway entrances based on Low VAP
- Set elevation of structural elements (i.e. footings) based on Low VAP

High VAP Profile

- Provide adequate hydraulic capacity to convey flows/debris at High VAP
- Mitigate lateral migration/ flanking at High VAP

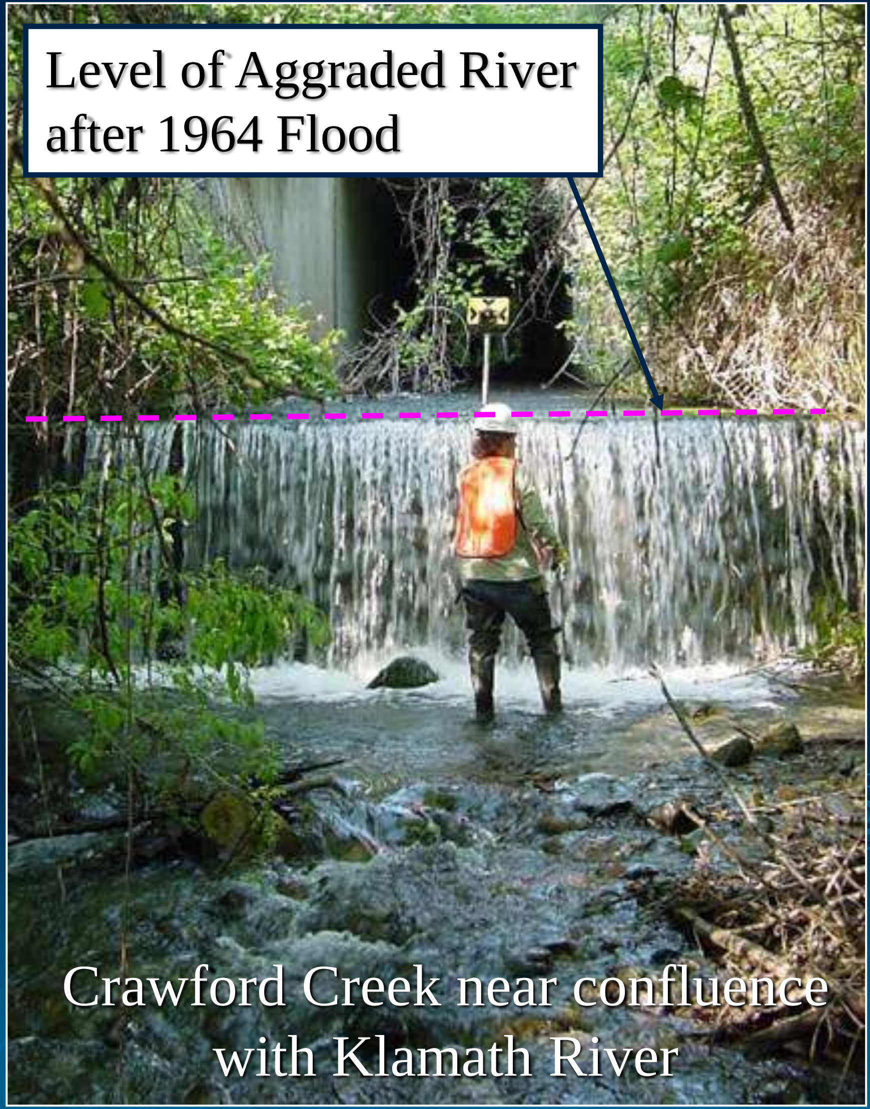
Channel Aggradation and High VAP

Increased sediment loads combined with large flood can cause entire streams and rivers to aggrade.

Channel Aggradation and Fish Passage

Culvert replacements after flood events have added complexity and risk:

- ❑ Anticipating future regrade.
- ❑ Determining vertical placement of culvert invert or arch-footings.
- ❑ Providing enough flood capacity in aggraded state.



Consider Backwater Influences when Setting High VAP

Sultan Creek Bridge
Influenced by River Backwatering

Little Mill Creek Bridge
Depositional Bar from River Backwatering

Potential for Channel Lateral Migration

Fishway Entrance at River Confluence

Vertical Adjustment Potential

Fluctuating Levels of Beach Bars and Mouths of Coastal Lagoons

Solstice Creek Outlet
Discharging onto Beach

Vertical Adjustment Potential

Fluctuating Coastal Lagoons

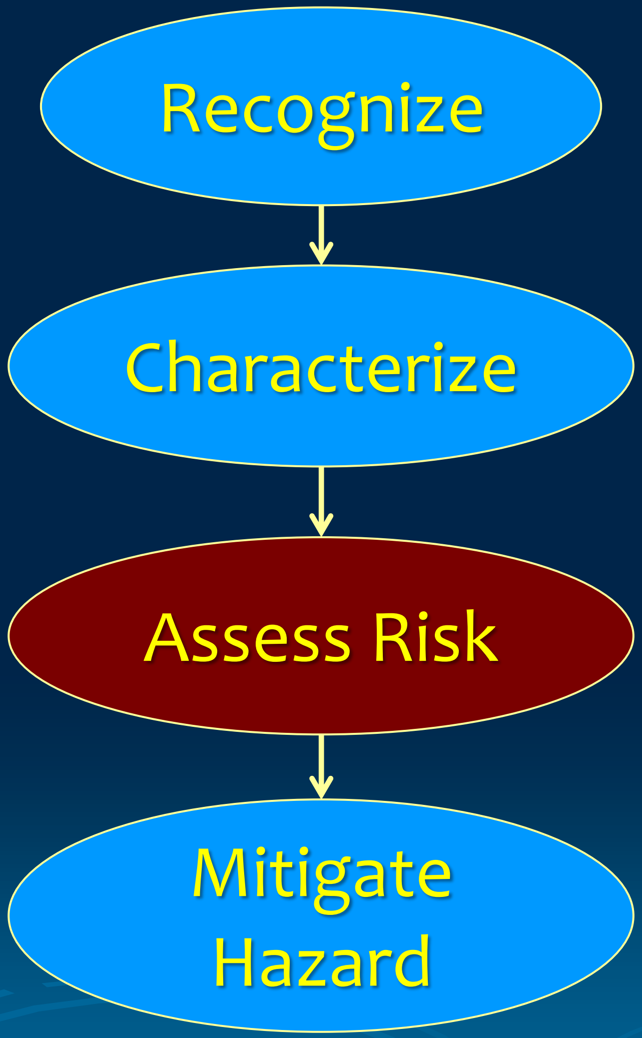
Before Project: Coastal Lagoon Mouth Closed

Lagoon Opens and Water Level Drop

Fishway Entrance not backwatered when Lagoon Opened

Photos from Questa Engineering

Incorporating Geomorphic Risk Assessments into Passage Projects



Resource: Castro, Janine. 2003. *Geomorphic Impacts of Culvert Replacement and Removal: Avoiding Channel Incision*. USFWS

Alteration of Hydrology
Mimic natural hydrographs — Altered timing, duration, frequency of flows

Facility Location
Minor Tributary — Major Tributary — Main Stem River

Type of Facility
Run-of-River — Small Storage Dams — Large Storage Dams
High Flow Diversion — Low Flow Diversions

Potential to Create Limiting Conditions
Low — Moderate — High

Monitoring & Maintenance Plan
Adaptive Management — Monitoring only — None

Highest Risk Facilities

Increasing Site Response Potential

Increasing Project In

Stream Sensitivity / Stream Type
Source (>10% slope) — Transport (3—10%) — Response (<3%)
Bedrock — Colluvial — Alluvial — Incised Channel / Alluvial Fan

Sediment Regime
Steady, moderate inter-annual variation — ENSO cycles — Wildfire cycles

Bank Erosion Potential
Naturally Non-erodible — Erosion Resistant — Highly Erodible, or Revetted

Bed Scour Potential)
Boulder/clay bed (low) — Gravel/cobble bed (moderate) — Sand/silt bed (high)

Dominant Hydrologic Regime
Spring-fed — Snowmelt — Rain — Rain-on-Snow — Atmospheric River

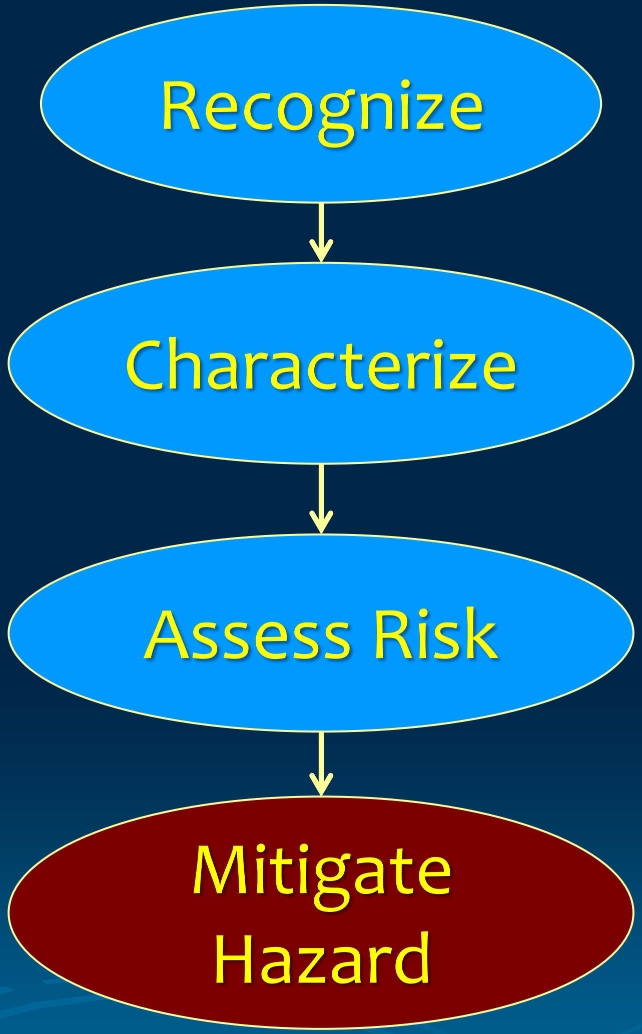
Gene
Proje
Scree
Matri

From: NOAA Fisheries 2022 Pre-Design Guidelines & RiverRAT, 2011

Risk Assessment Check List for Addressing Knickpoints in Incised Channels

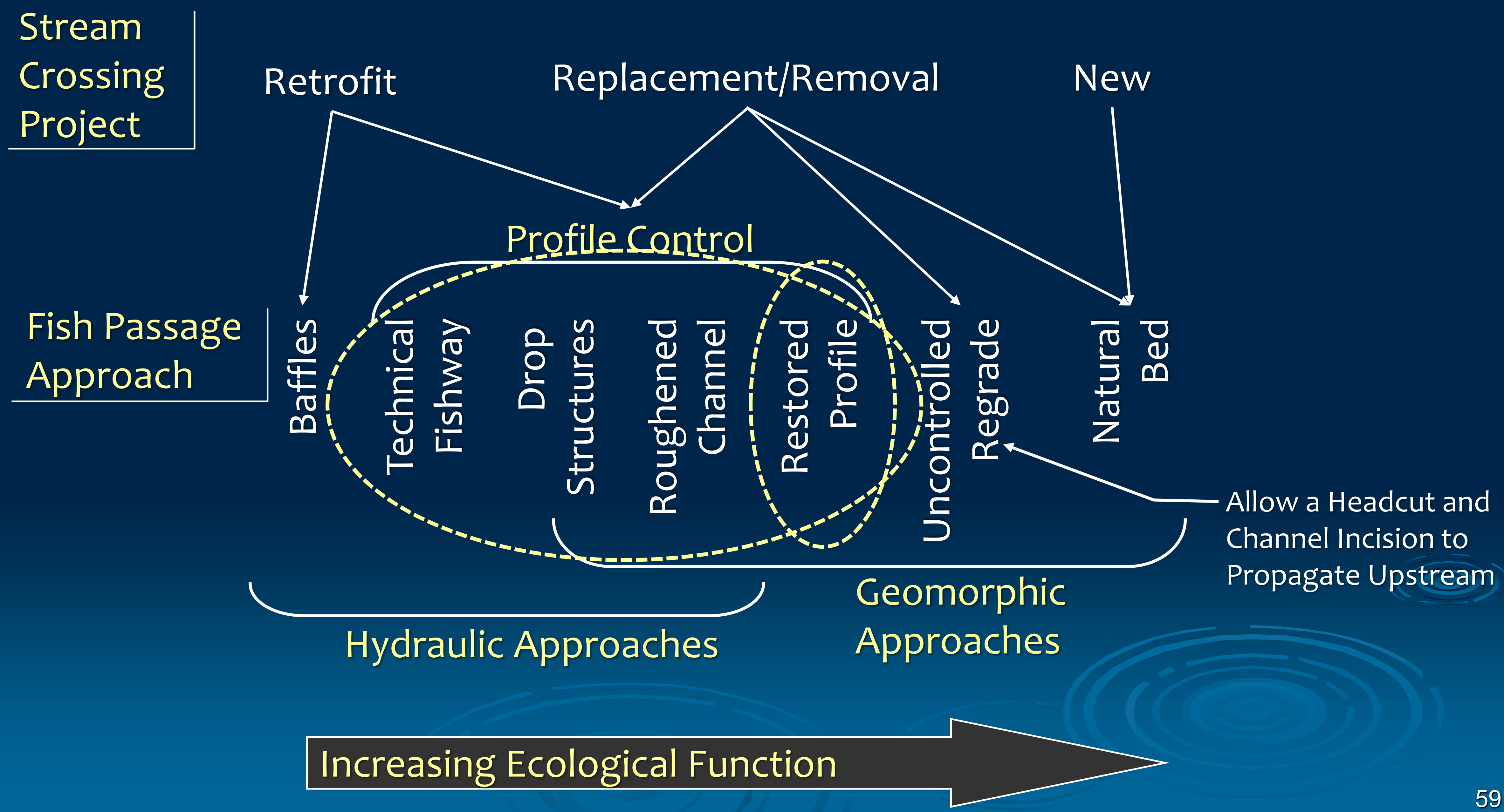
- ❑ Anticipated magnitude and extent
  Depth of incision and length of channel at risk
- ❑ Rate of incision, bank widening, and sediment release
  Mobility of bed, erosivity if banks, wood controls, bedrock
- ❑ Risk to upstream property and infrastructure
- ❑ Impact to existing riparian/wetland vegetation
  Will water table lower with incision and rootzone become dry?
- ❑ Change in connectivity to side-channels and floodplain
- ❑ Ability of channel to recover
  Will bank material and land-use permit channel evolution (widening)?

Incorporating Geomorphic Risk Assessments into Passage Projects

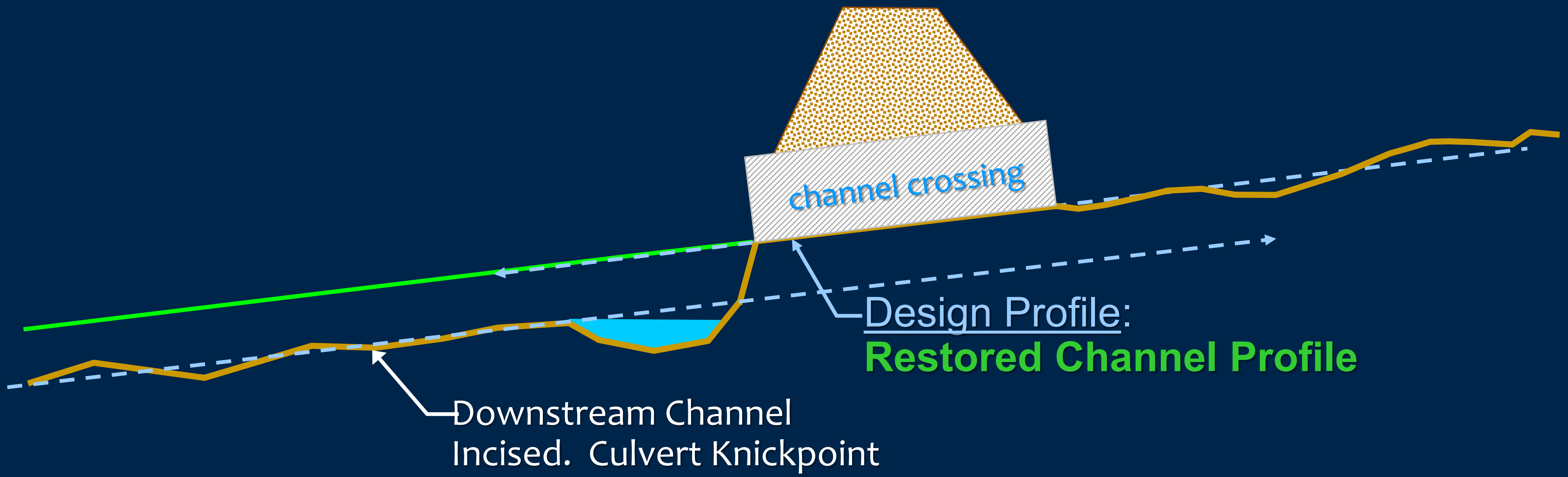


Resource: Castro, Janine. 2003. *Geomorphic Impacts of Culvert Replacement and Removal: Avoiding Channel Incision*. USFWS

Design Approaches for Aquatic Organism Passage



Restored Profile Option



Restoring Incised Channels and Connectivity

Placing Wood - Profile Restoration

Baker Creek
photos: Sam Flanagan, BLM

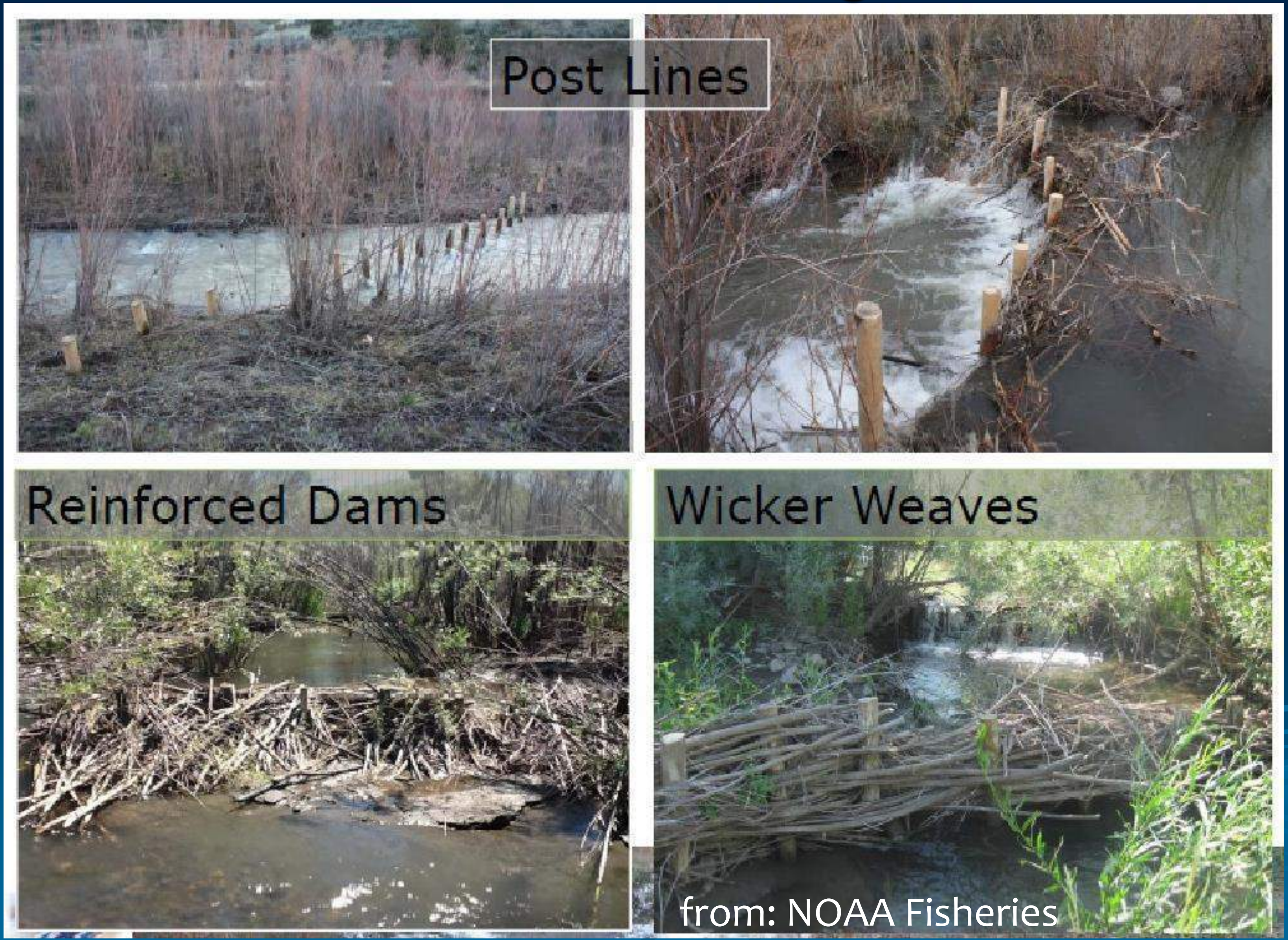
Restoring Incised Channels and Connectivity

Placing Wood - Profile Restoration

Large wood placed to restore incised channel profile
Neefus Gulch, North Fork Navarro River

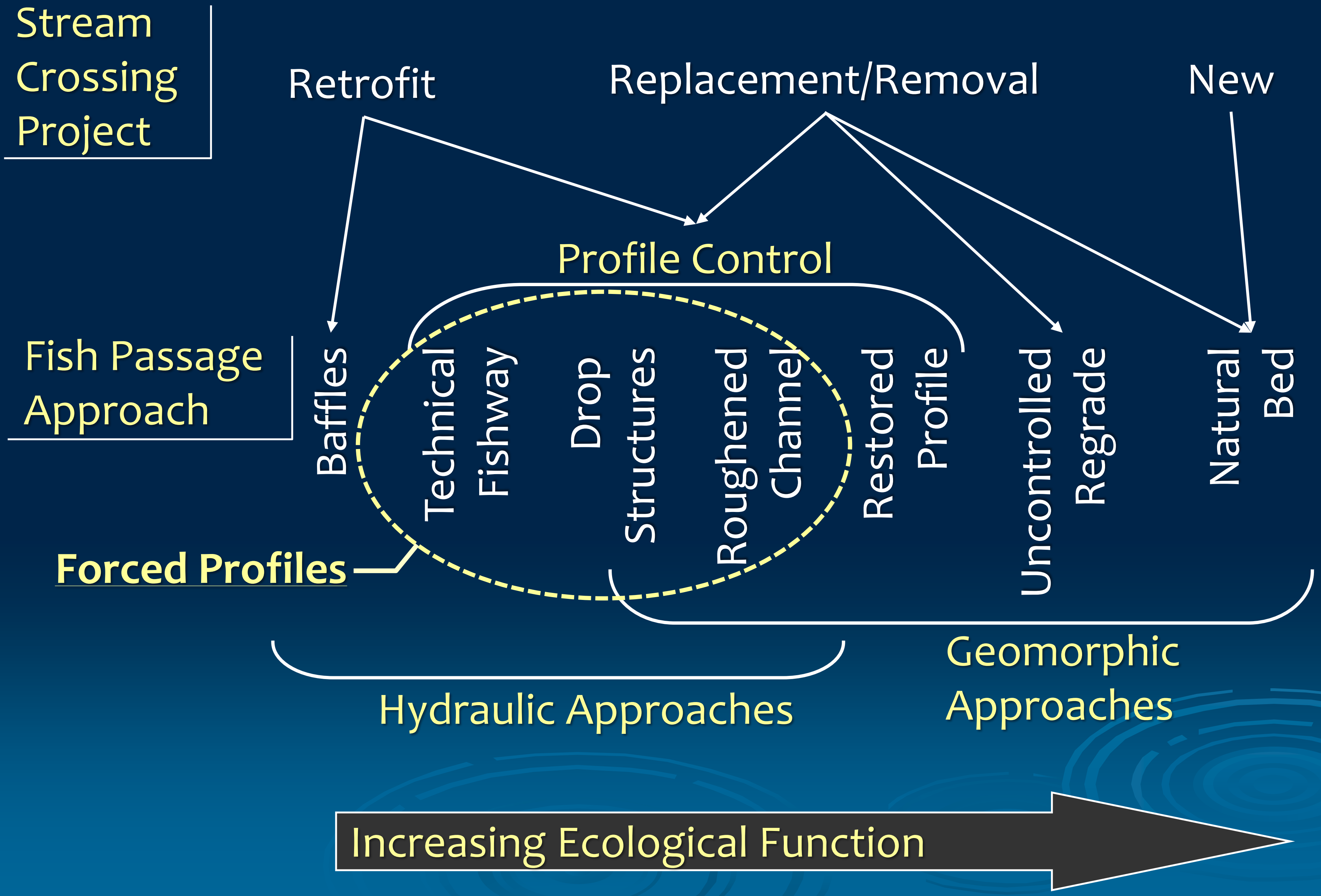
Restoring Incised Channels and Connectivity

Beaver Dam Analogs

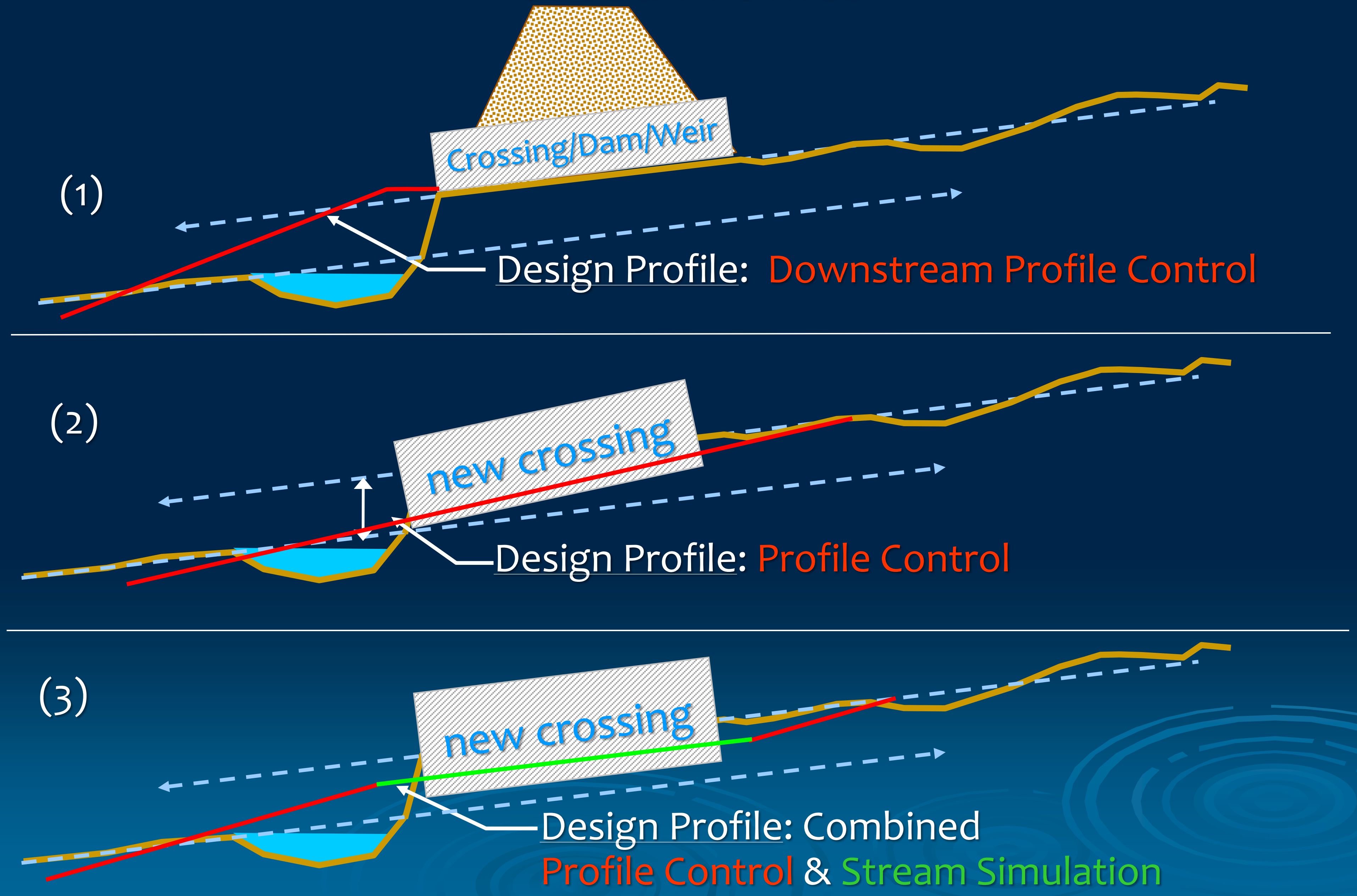


from: NOAA Fisheries

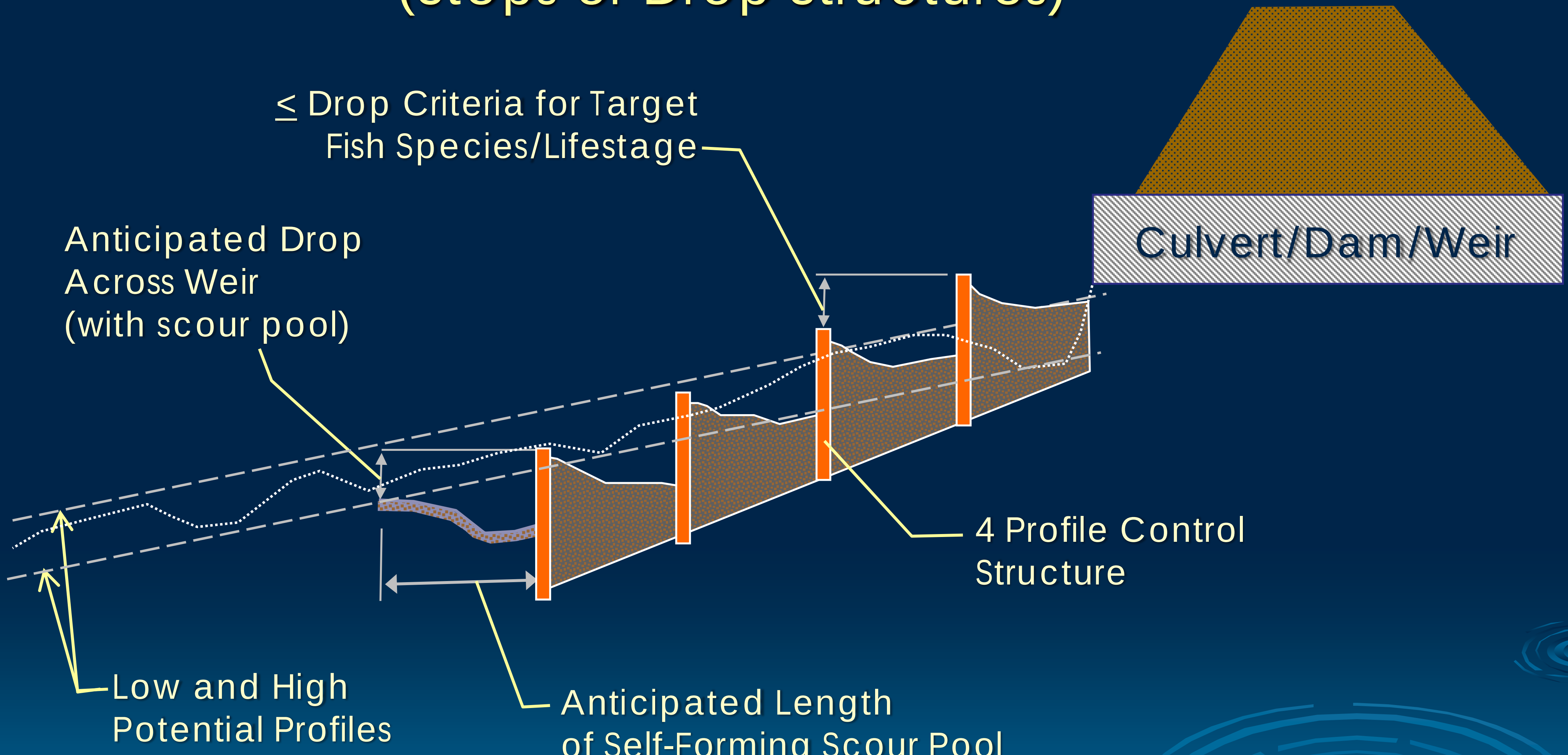
Design Approaches for Aquatic Organism Passage



Forced Profiles



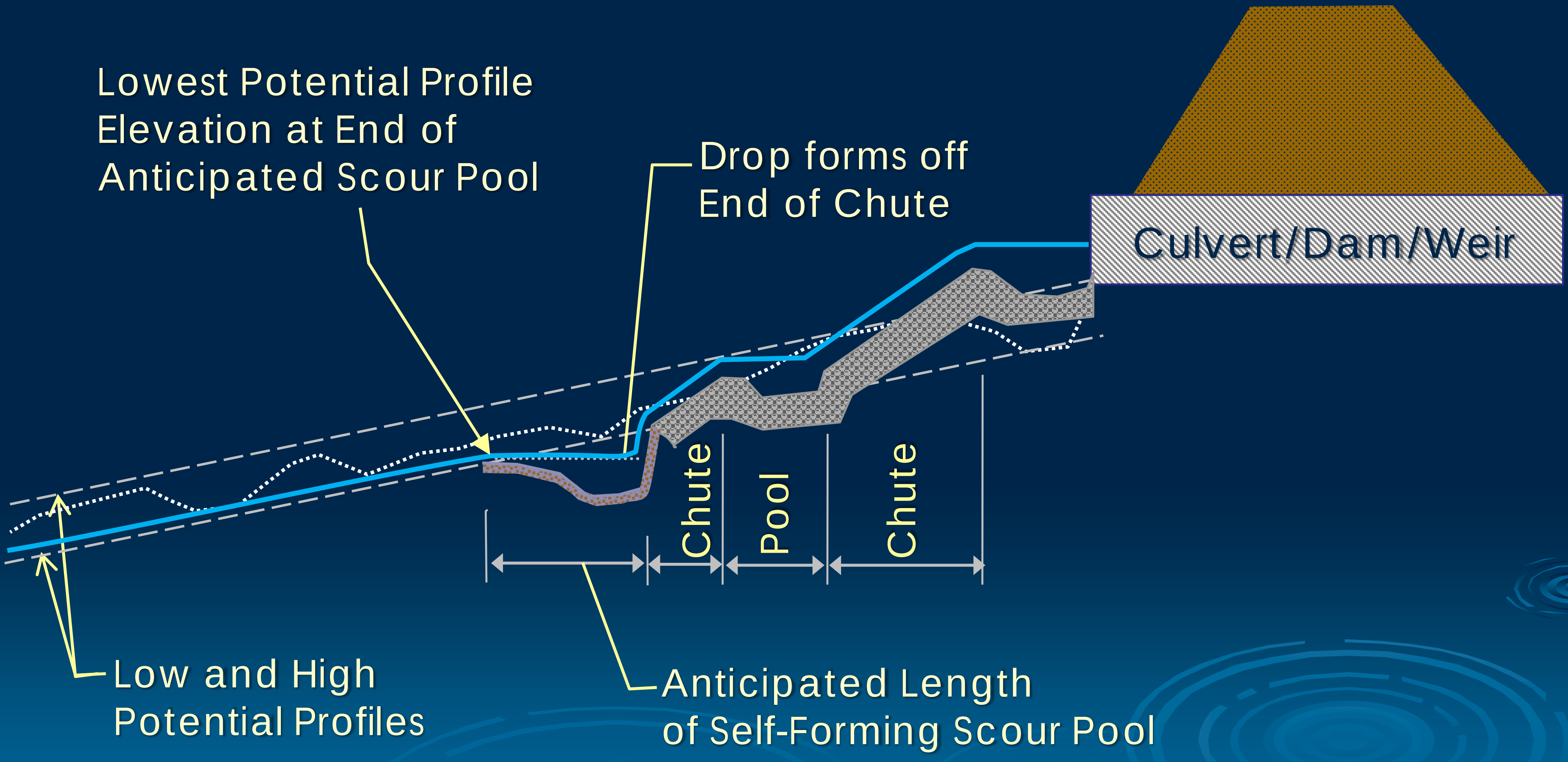
Setting Fishway Entrance based on Low VAP (Steps or Drop Structures)



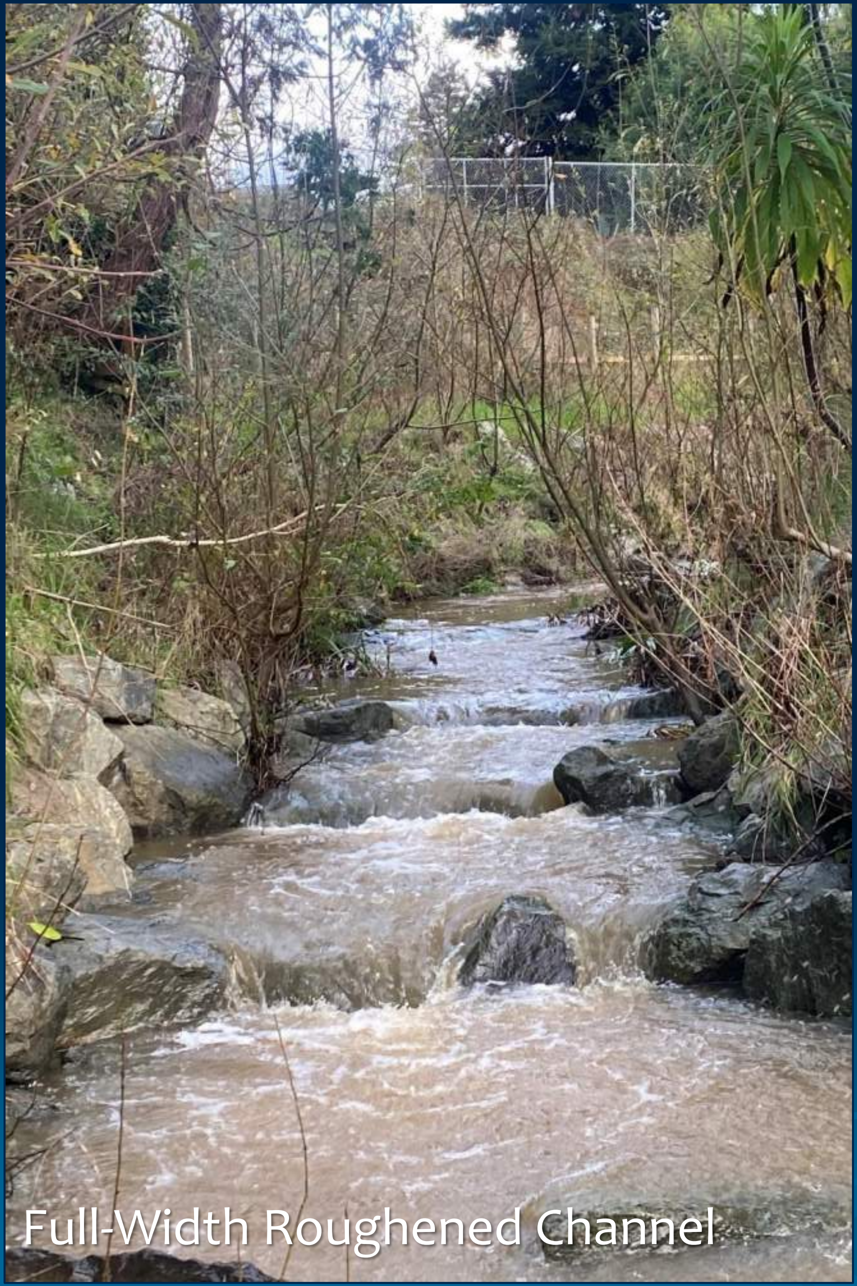
Place End of Profile Control based on Low Potential Profile with Anticipated Scour Pool

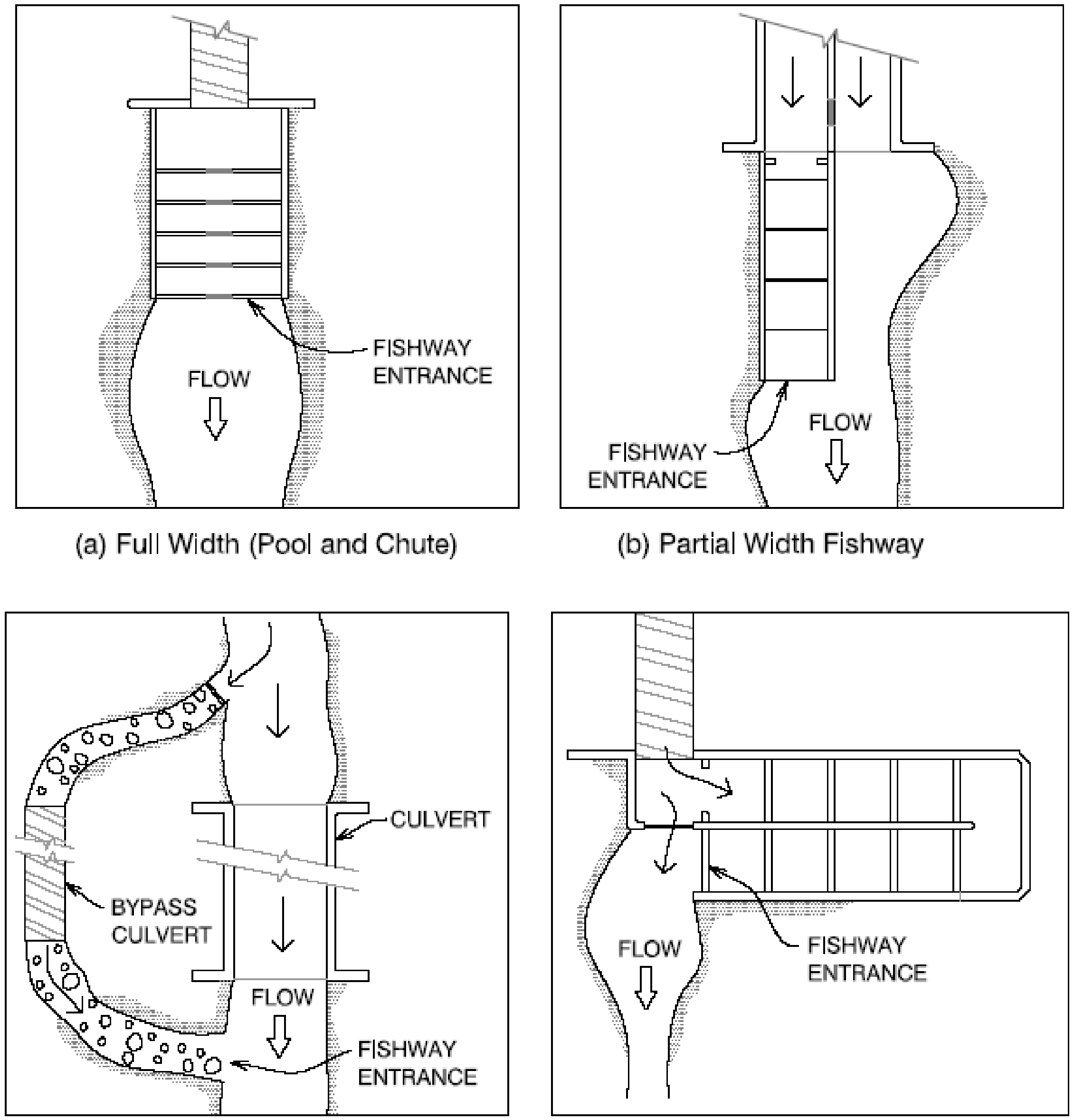
66

Setting Fishway Entrance based on Low VAP
(Chutes & Pools Roughened Channel)



Develop Profile in Conjunction with Plan Layout





(a) Full Width (Pool and Chute)

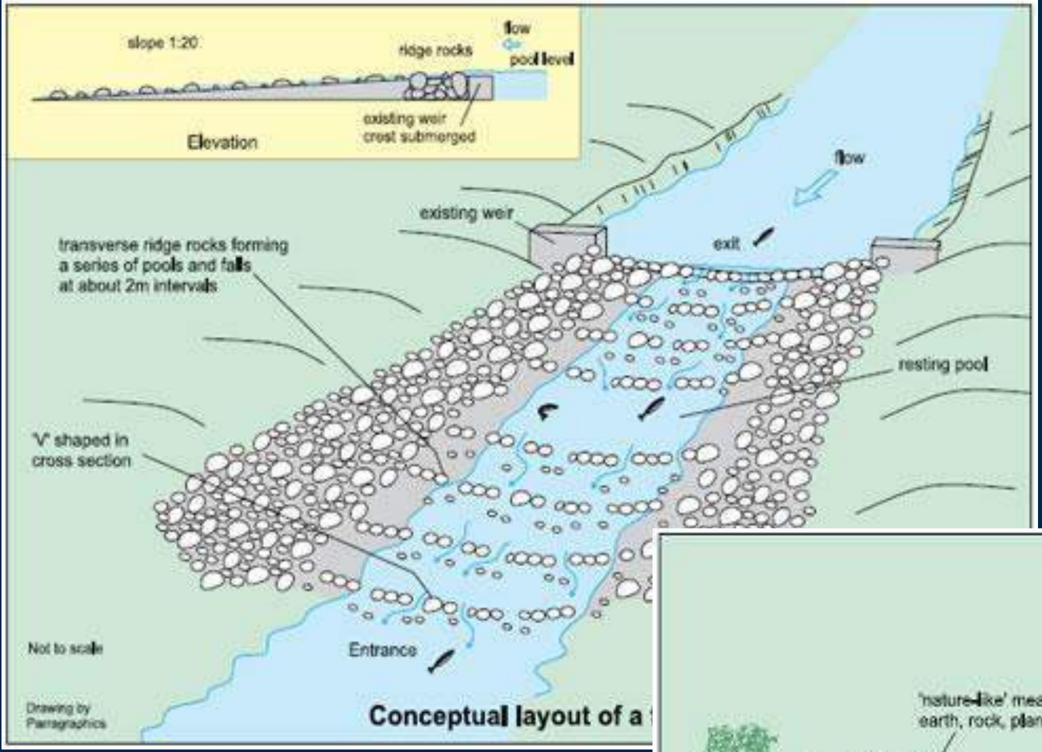
(b) Partial Width Fishway

(c) Bypass Roughened Channel

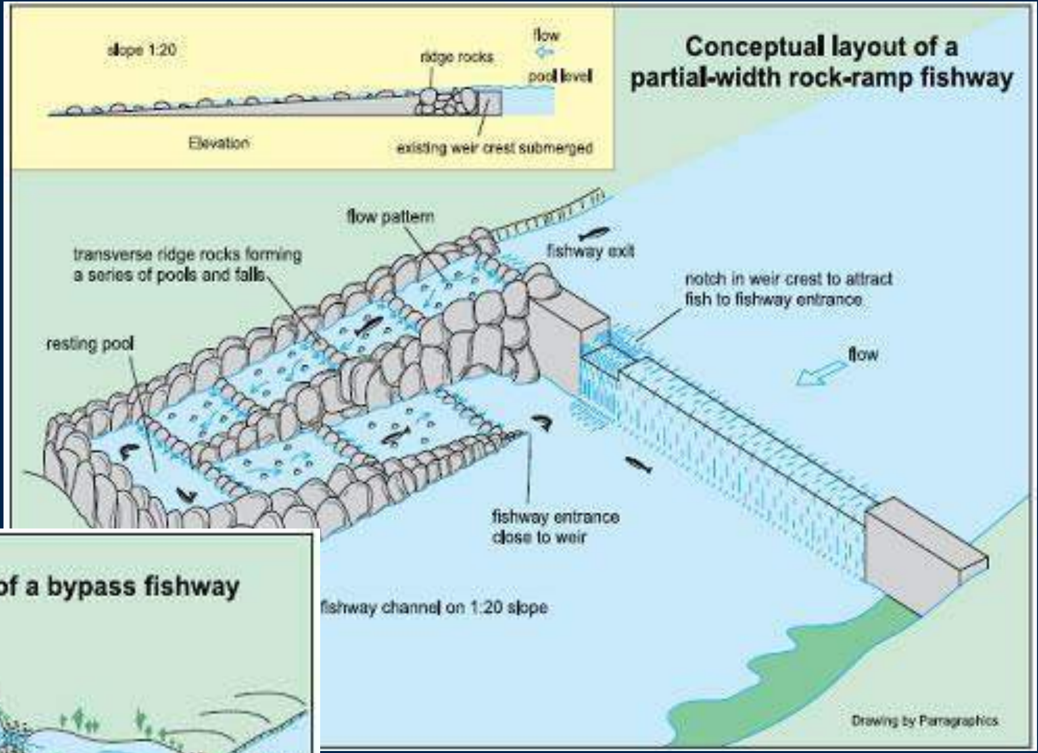
(d) Bypass Pool and Weir

NLF Layouts

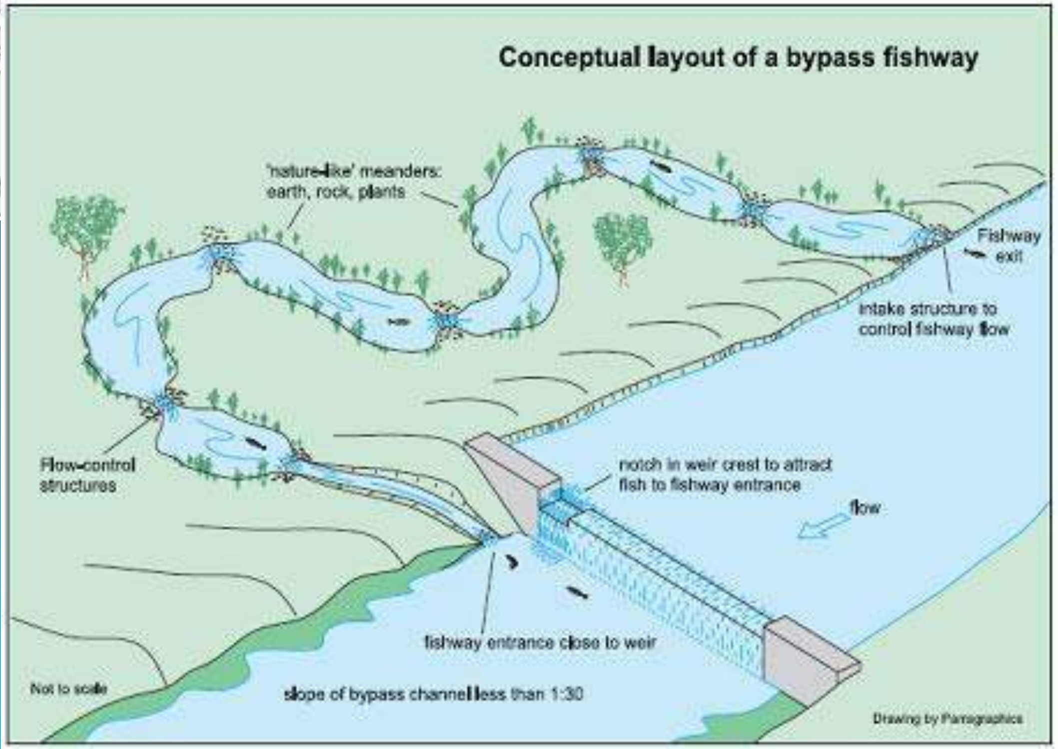
Full Span



Partial Span

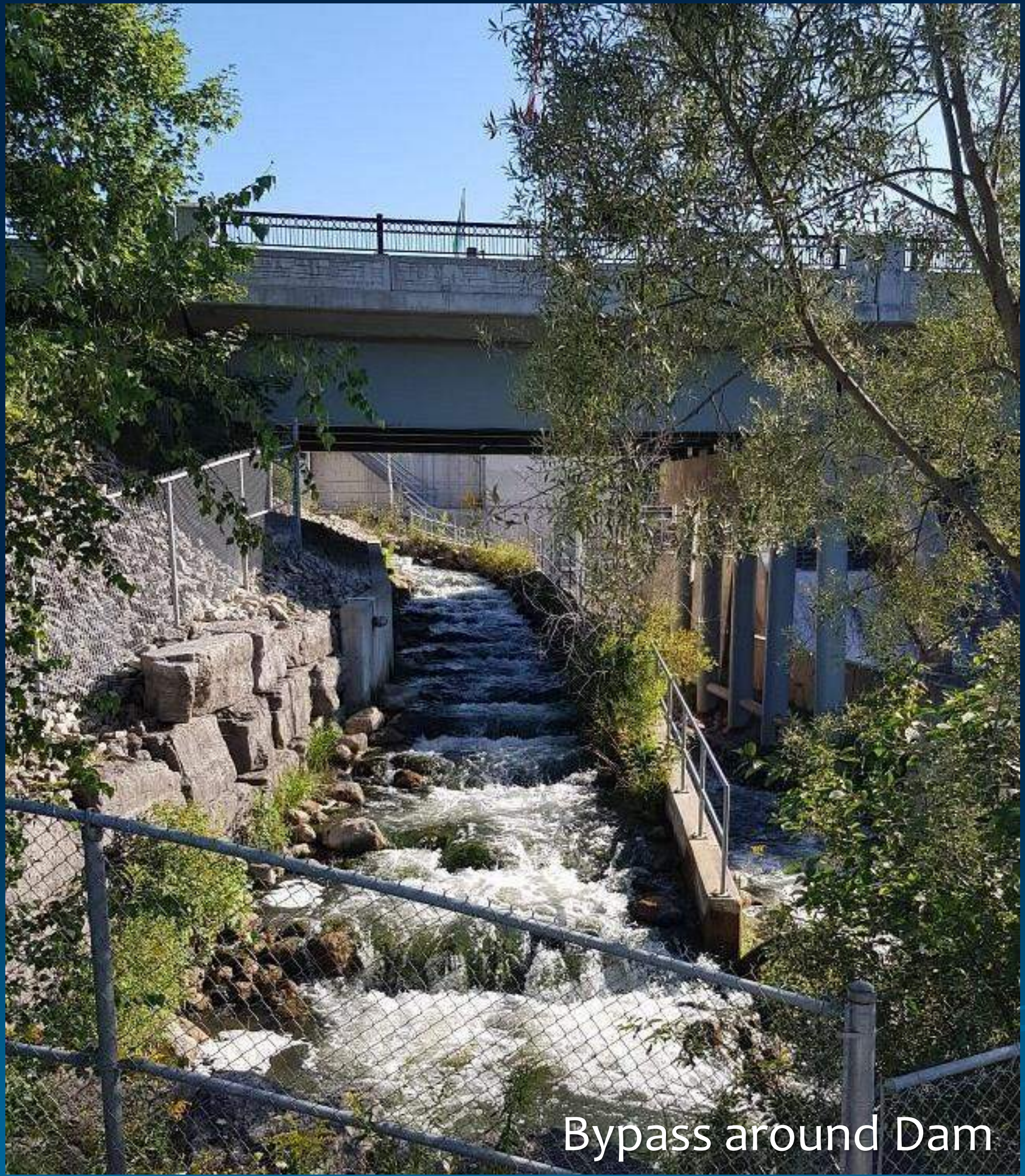


Bypass

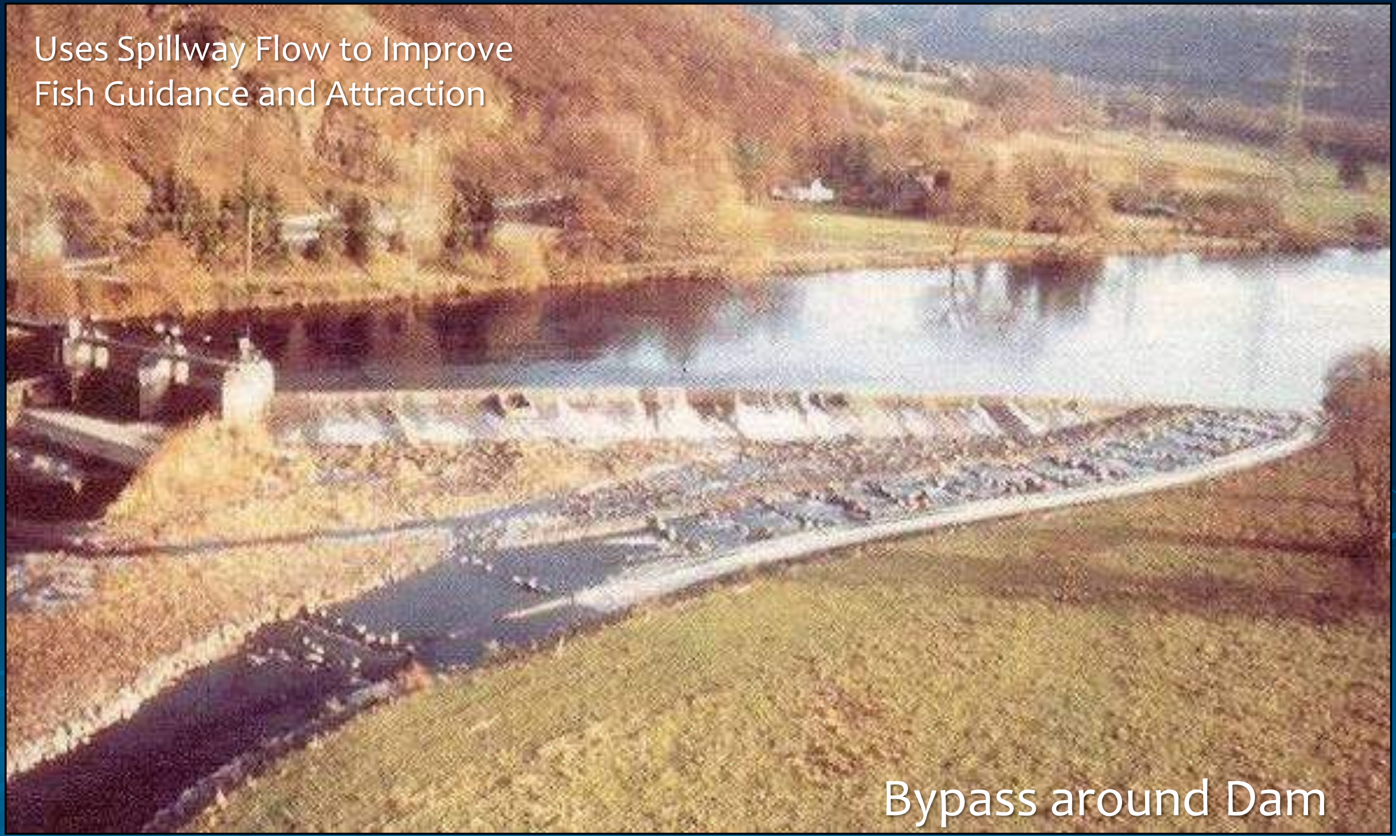


From Thorncraft and Harris, 2000

NLF Layouts



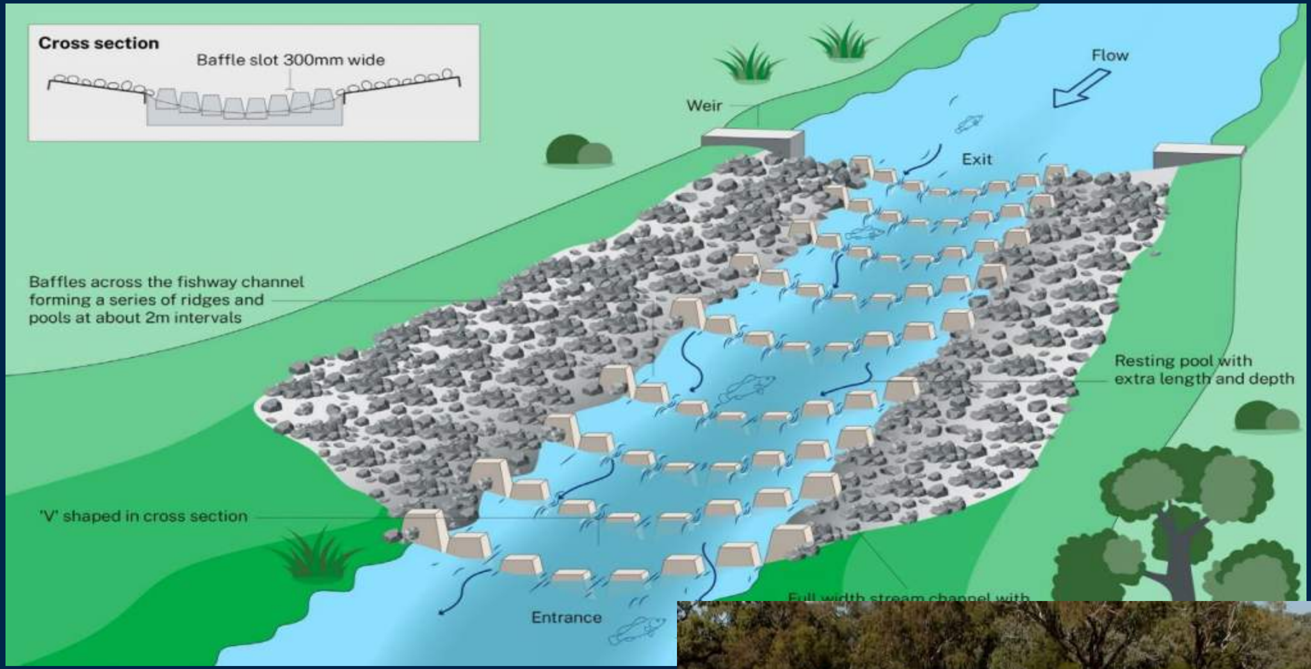
Thornbury, Lake Huron Tributary, Ontario



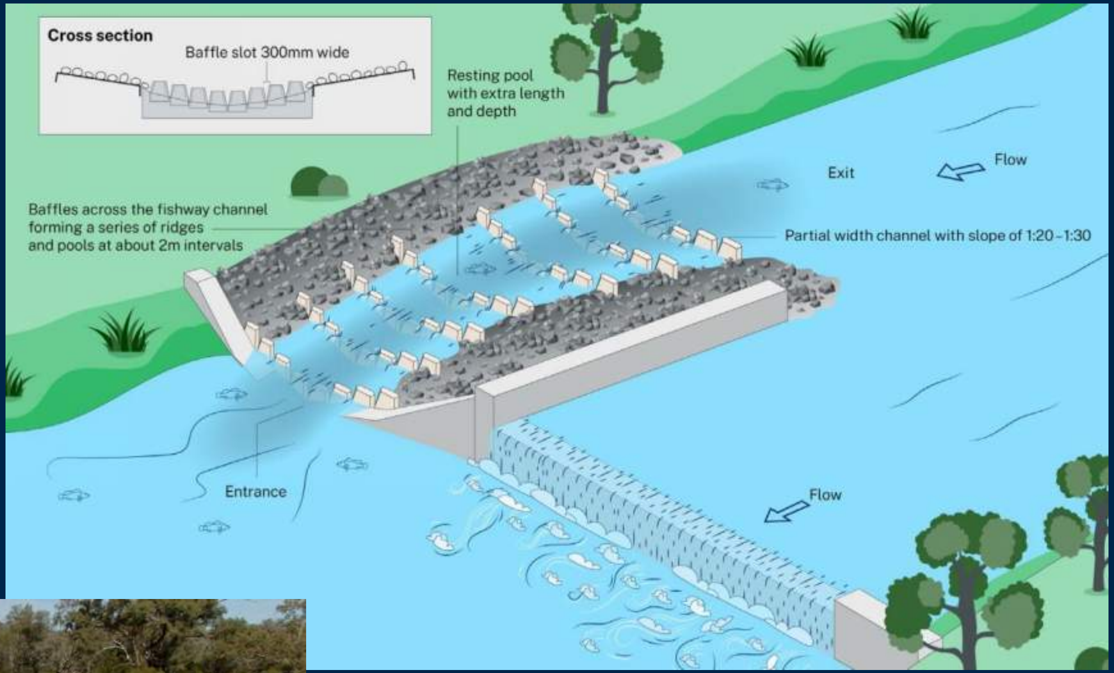
From DVWK 1996

NLF Configurations

Full Span

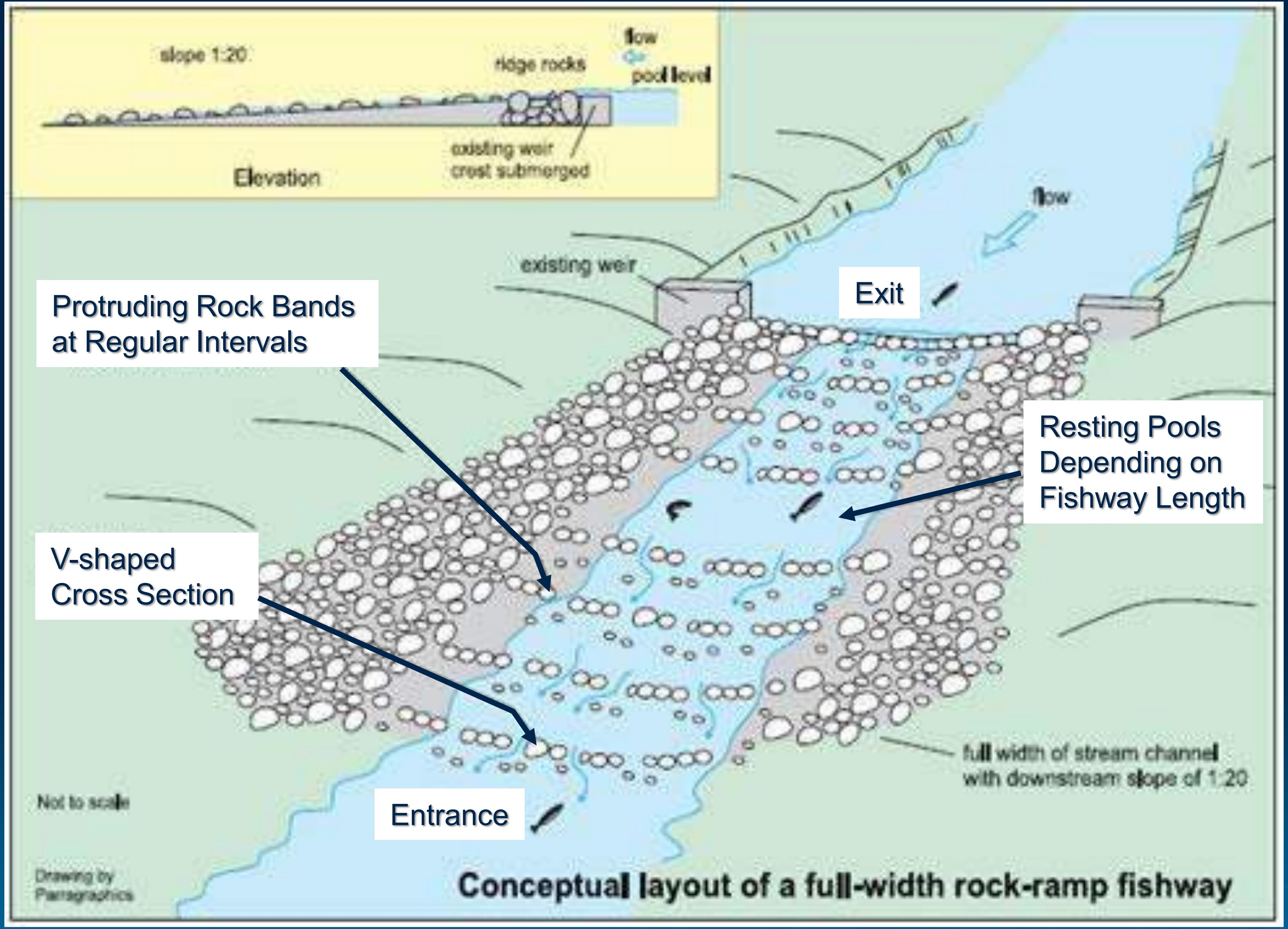


Partial Span



From New South Wales, Australia

Channel Spanning NLF Configuration



Pros

- Excellent attraction (100% of flow)
- Fish able to find entrance with ease
- Less susceptible to sediment and debris

Cons

- Fishway conveys entire flood flow (rock more likely to become destabilized)
- Larger footprint/higher cost than other configurations

Image from Thorncraft and Harris, 2000

Partial Spanning NLF Configuration

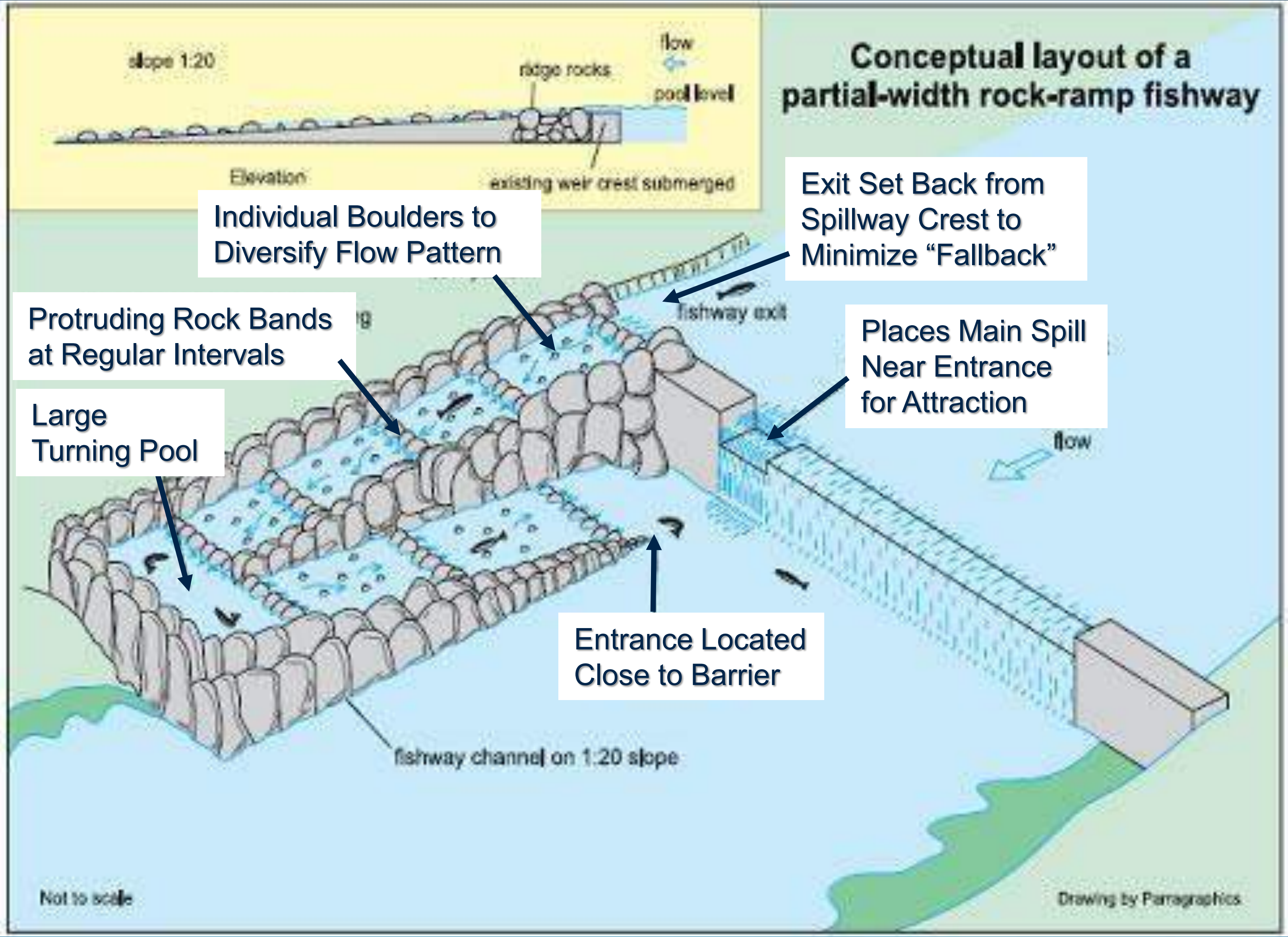


Image from Thorncraft and Harris, 2000

Pros

- Smaller footprint/lower cost
- Conveys only portion of total flow
  - Provide passage over wider range of streamflow
  - More stable at flood flows
- Can regulate (constrict) flood flows entering fishway to improve rock stability

Cons

- More susceptible to debris plugging and sedimentation/lack of scouring
- Lack of attraction velocity
- Barrier flow can create nuisance attraction
- Wide channel relatively small to small entrance

Bypass NLF Configuration

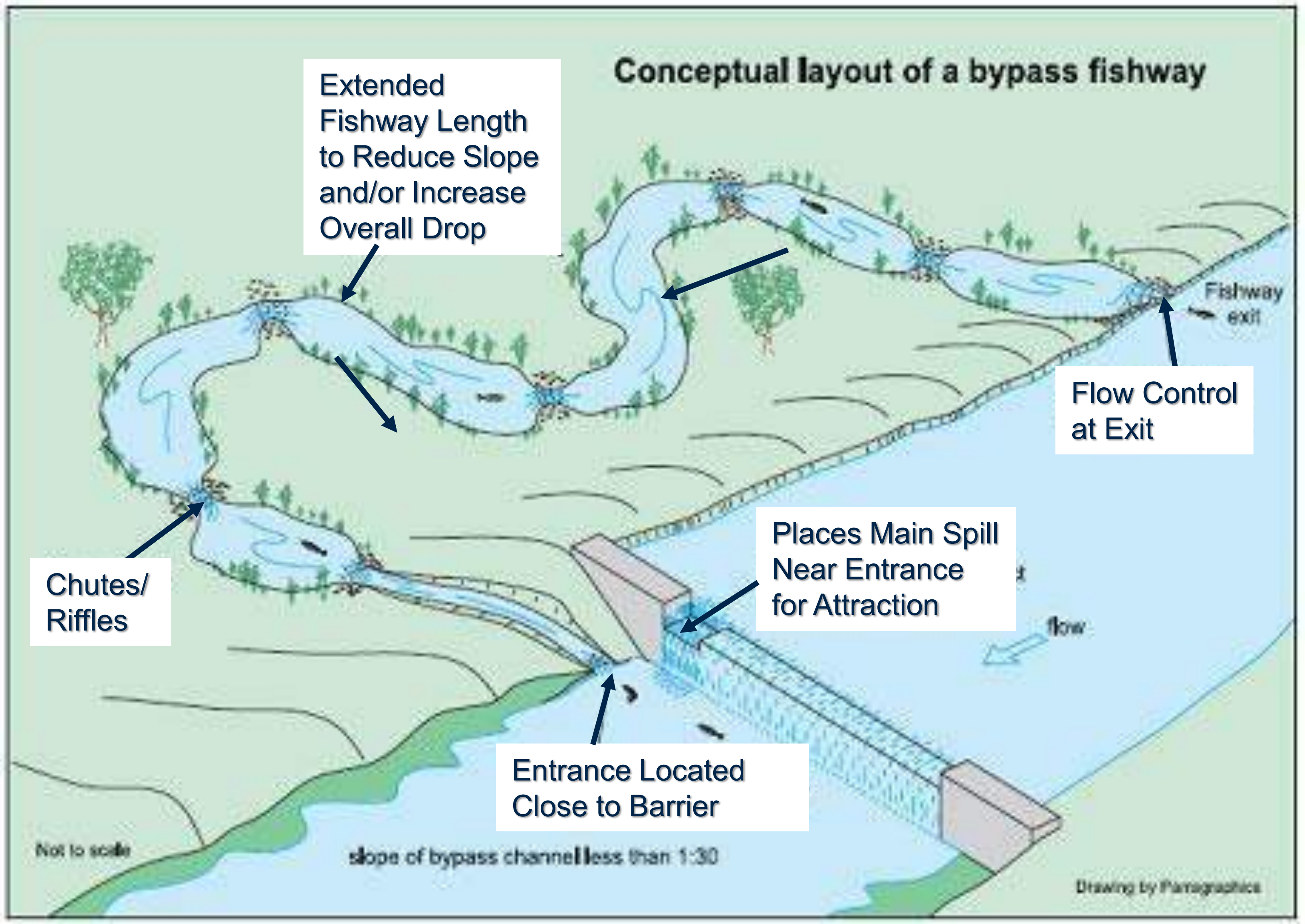


Image from Thorncraft and Harris, 2000

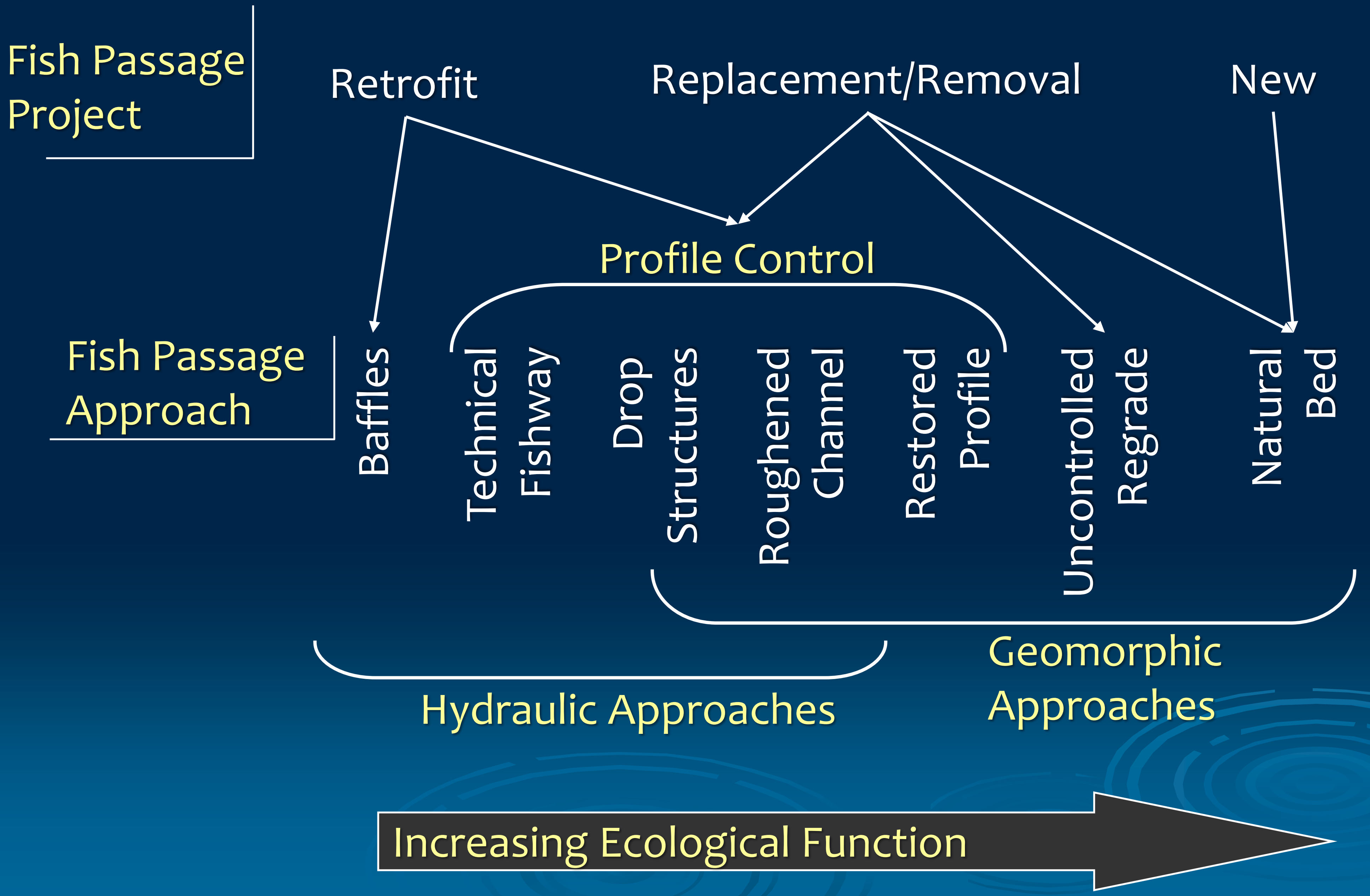
Pros

- Can place most of fishway away from flood flows (more stable)
- Allows for extended length/bypass around larger barriers
- Provide passage over wider flow range
- May have smaller footprint/lower cost
- Fishway can provide habitat/holding/ riparian shade

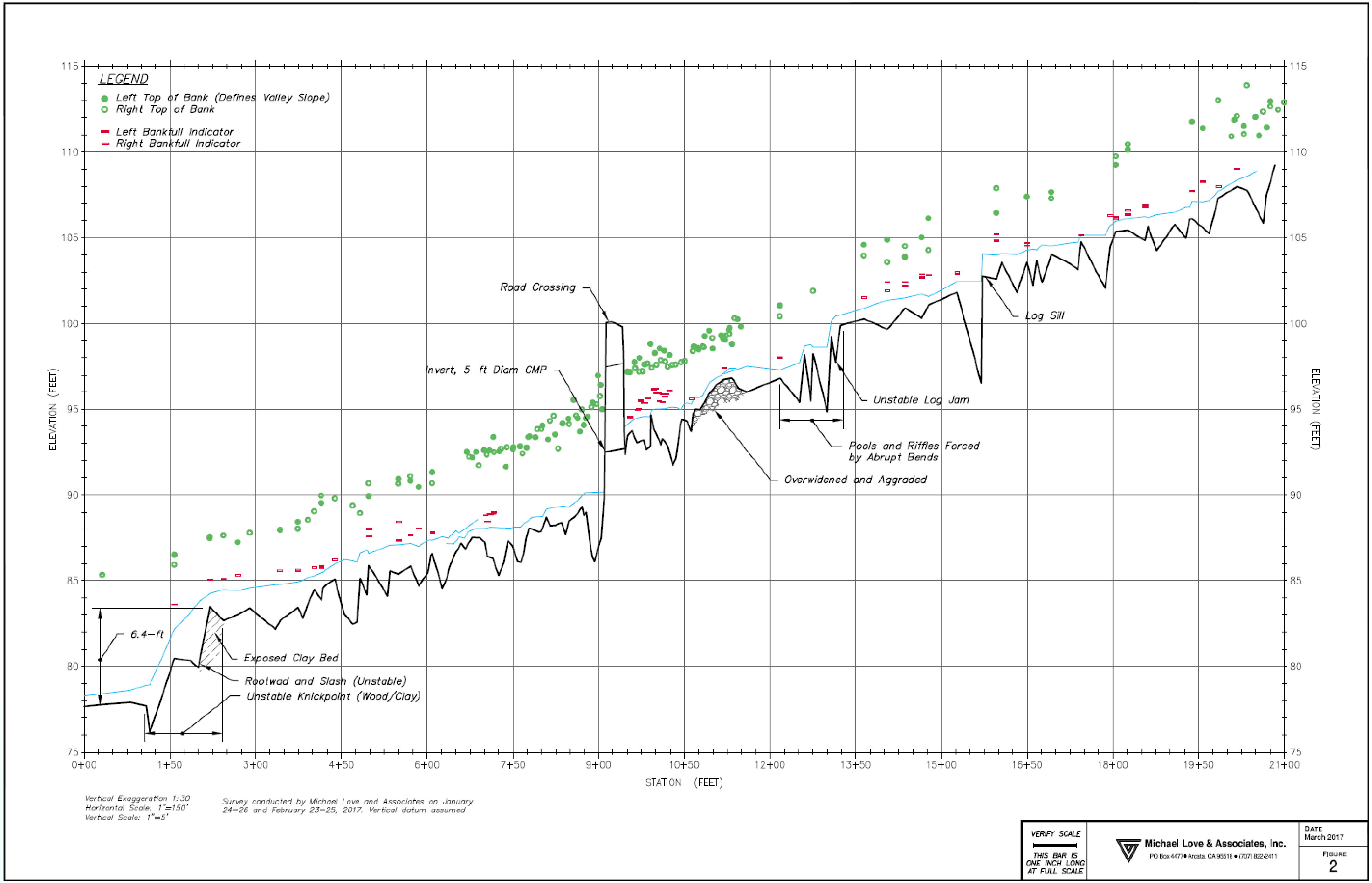
Cons

- More susceptible to debris plugging and sedimentation/lack of scouring
- Lack of attraction velocity
- Barrier flow can create nuisance attraction
- Wide channel relatively small to small entrance

Design Approaches for Aquatic Organism Passage



Neefus Gulch Profile Analysis Part II



Group Exercise

Session 3-3
Primer for Risk and Risk Management during NLF Projects

Mike Garello, PE

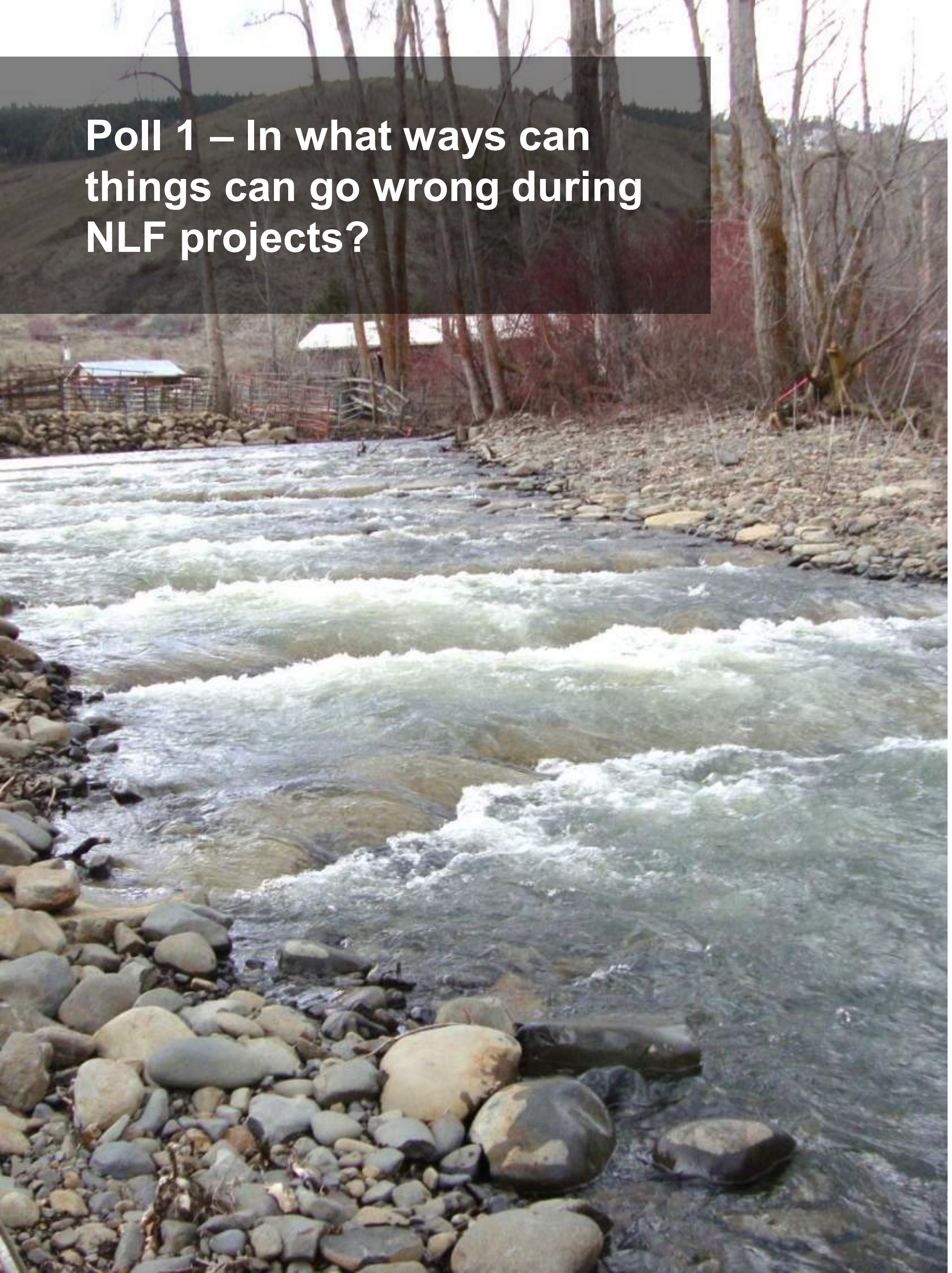
3/26/2024

What is Risk….?

"A probability or threat of a damage, injury, liability, loss, or other negative occurrence that is caused by external or internal vulnerabilities, and that may be neutralized through preemptive action."

www.businessdictionary.com

Poll 1 – In what ways can things can go wrong during NLF projects?



Keach-Jensen Diversion NLF, Manastash Creek, Ellensburg, WA

Nelson Dam Removal, Naches River, Yakima, WA

Risk includes any factor which may negatively impact a NLF project – which could result in a true or perceived failure and put the project, engineer/consultant, owner, or public in jeopardy.

Risk Exposure and Management during NLF Projects

Exposure to Risk

01 **Likelihood**
How likely or frequent is the event going to happen?

02 **Severity**
What is the magnitude of impact?

03 **Severity vs. Likelihood**
When combined, which pose the greatest threat to the project?

04 **Cumulative Impacts**
Are there combinations of risks that have cumulative impact?

05 **Prioritization**
Prioritize risks and identify those that require the greatest attention.

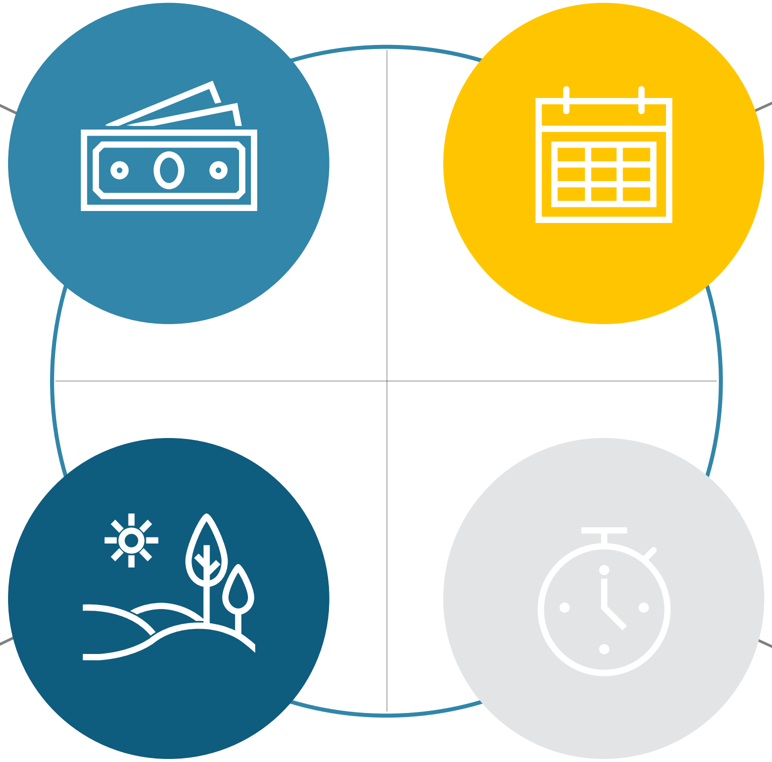

Poll 2 – What risks are the greatest source of project challenges or failures?

Risk Exposure and Management during NLF Projects

Types of Risk

Financial
Magnitude of project cost
Time-value of money
Funding availability
Volatility

Schedule
Project length
Time constraints
Time-value of money
Volatility

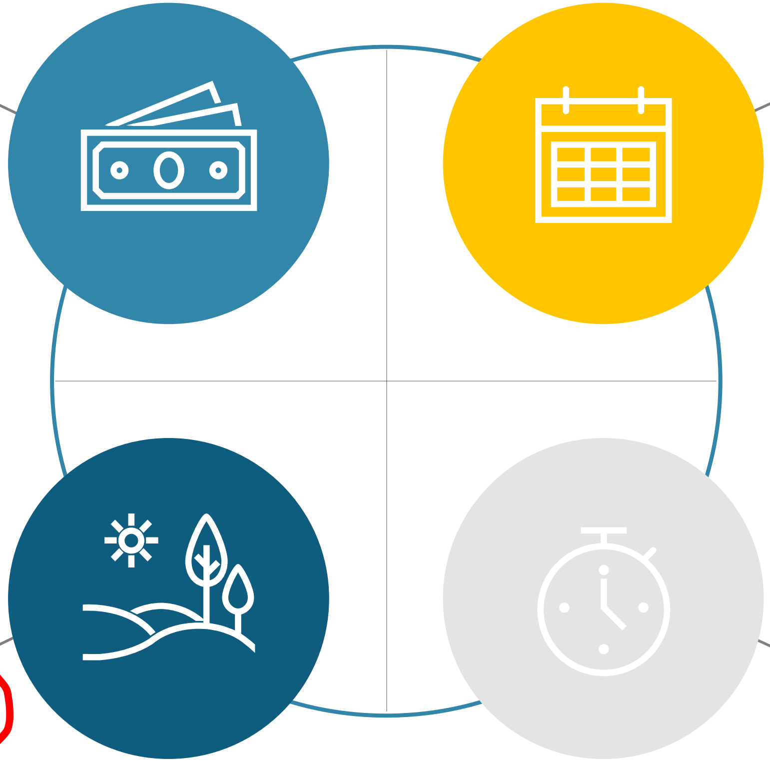


Performance
Physical
Environmental / Biological / Ecological
Public Safety
Complexity / Uncertainty

Longevity/Resilience
Certainty of performance over time
Maintenance expectations
Unforeseen conditions / adaptability
Climate change or variability

Risk Exposure and Management during NLF Projects

Types of Risk - Example



Financial

Magnitude of project cost
Time-value of money
Funding availability
Volatility

Schedule

Project length
Time constraints
Time-value of money
Volatility

Performance

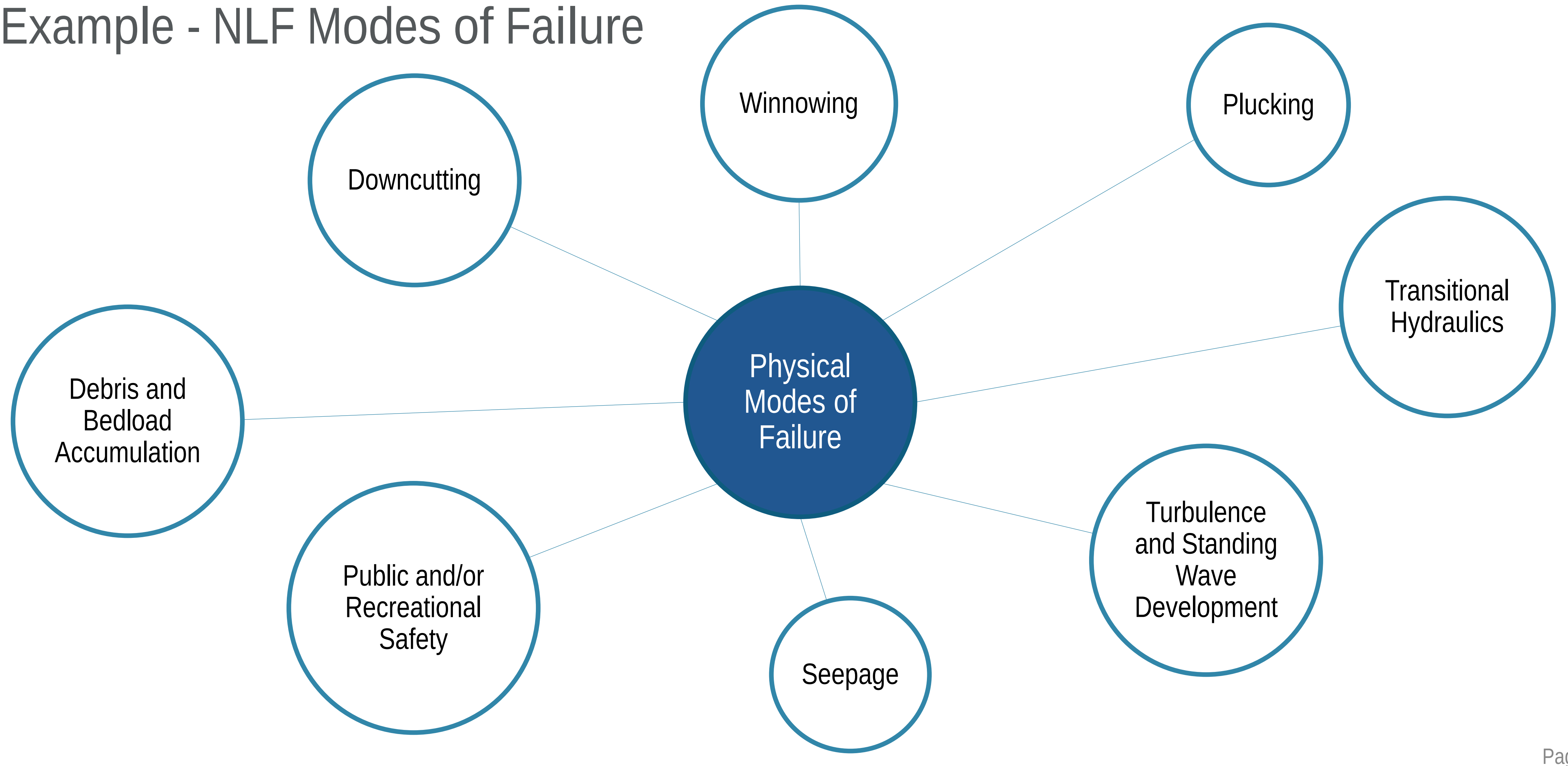
Physical
Environmental / Biological / Ecological
Public Safety
Complexity / Uncertainty

Longevity/Resilience

Certainty of performance over time
Maintenance expectations
Unforeseen conditions / adaptability
Climate change or variability

Risk Exposure and Management during NLF Projects

Example - NLF Modes of Failure



Risk Exposure and Management during NLF Projects

Exposure to Risk

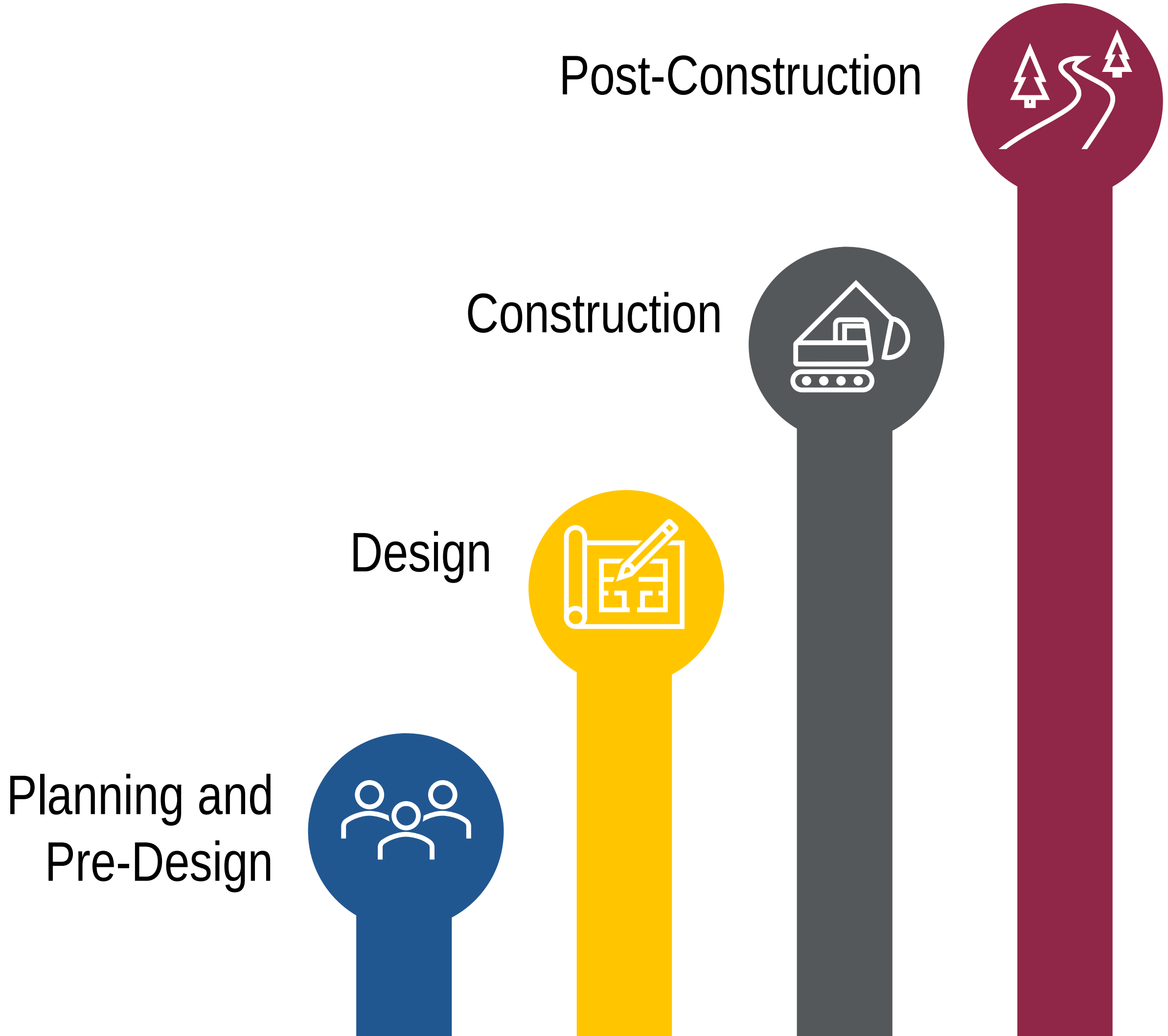
SEVERITY / LIKELIHOOD	MINOR	UNLIKELY	POSSIBLE	LIKELY	ALMOST CERTAIN
CRITICAL	SERIOUS	MAJOR	MAJOR	CRITICAL	CRITICAL
MAJOR	MODERATE	SERIOUS	MAJOR	MAJOR	CRITICAL
SERIOUS	MODERATE	MODERATE	SERIOUS	SERIOUS	MAJOR
MODERATE	MODERATE	MODERATE	MODERATE	SERIOUS	SERIOUS
MINOR	MINOR	MINOR	MODERATE	MODERATE	SERIOUS


Poll 3 – When can you most effectively mitigate NLF project risks?

Risk Exposure and Management during NLF Projects

Identifying and Managing Risks at All Levels of Project Implementation

- Risk management and the mitigation of potential modes of failure must be proactive rather than reactive.
- Identifying, evaluating, and managing risks throughout all phases of implementation are core components of a successful NLF project.



Risk Exposure and Management during NLF Projects

Identifying and Managing Risk at the Pre-design Level

A few places to start….

- *Fish Passage Project Checklists -*
  - *Profile Control Feasibility*
  - *Profile Control Scope of Work*

https://units.fisheries.org/fishpassagejointcommittee/resources/fishpassagetrainingportal/

- *2016 Technical Memorandum – Federal Interagency Nature-Like Fishway Passage Design Guidelines for Atlantic Coast Diadromous Fishes*
- *NOAA – 2022 WCR Anadromous Salmonid Design Manual*
- *NOAA – 2022 Pre-Design Guidelines for California Fish Passage Facilities*
- *Stream Simulation: an ecological approach to Providing Passage for aquatic organisms at road-Stream Crossings*

Risk Exposure and Management during NLF Projects

Identifying and Managing Risk at the Pre-design Level

Risk Exposure and Management during NLF Projects

Identifying and Managing Risk at the Pre-design Level - Example

Pre-Design

Performance

- Establish performance goals, expectations, and constraints
    - Ownership, Infrastructure, Public Use and Safety, and Access
    - Agency, cultural, and stakeholder participation
    - Regulatory setting (FEMA, USACE, ESA, Etc.)
    - Fish species, phenology (life history), and periodicity
    - Timescales – design, construction, regulatory, longevity
    - Risk tolerance, adaptive management
    - Development of design and performance objectives and criteria
- Design strategy to test and address objectives
    - Range of design conditions
    - Modeling tool selection
    - Modeling scenarios
    - Application of model results to inform design
    - Decision framework for NLF Composition, hybridization, and anatomy
    - Decision framework for material selection and assessment of availability
- Data Collection, Field Investigations, and Synthesis
    - Topographic and hydrographic surveys
    - Geomorphic context. Local and reach based processes.
    - Geotechnical and/or geophysical investigations

Risk Exposure and Management during NLF Projects

Open Discussion…

Successes and failures at the pre-design level?

NLF Project Spotlight:

Nelson Dam Removal Project
Naches River, Yakima, WA
Mike Garello, PE

3/262024

Nelson Dam Removal Project

Key Features

- Replaced dam with nature-like fishway at surface water diversion intake
- Channel-spanning rock crest with 350-foot-long roughened channel
- 400 ft wide, 350 ft long, 2.5 percent gradient
- Multi-level cross-section – low flow channel, two secondary channels
- Hydraulic scale and unit discharge characteristics
  - 0.5 APE (2-year) unit discharge 25 to 50 cfs/ft (river flow of 6,520 cfs)
  - 0.01 APE (100-year) unit discharge 100 to150 cfs/ft (river flow of 27,000 cfs)
- Regionally significant project with over a decade of stakeholder engagement

Project Benefits

Overall reduction in WSELs, resulting in less frequent flood-induced infrastructure damage

Increased stability of bridge piers and roadway embankments

Opportunity for sediment continuity through and past the Project reach

Greater reliability of water supply systems

Decreased level of effort associated with facility maintenance

Creation of fish passage corridors to allow volitional upstream and downstream migration

Increased habitat potential for rearing and spawning fish


Pre-Project Conditions
February 2020

Key Considerations, Challenges, and Risks

- *Four example key challenges and risks*

01 Performance Objectives - Longevity

- Structure failure or damage
- Loss of water supply and loss of fish passage
- Damage to existing roadway infrastructure
- Costly and or frequent short-term maintenance
- Costly long-term repairs after flood events

02 Construction - Material Procurement and Quality Control

- Lack of high quality, hard, durable rock availability
- Massive quantity of rock required in during in-water work windows
- Numerous ranges of size classes 3” to 72” required at different stages of construction
- Complex project requiring a skilled contractor with similar experience.

03 Construction Area Isolation - Dewatering

- High level of river flow variability within in-water work windows
- Substantial amount of in-water work constrained within in-water work windows
- Porous granular cobbles with high infiltration rates – high levels of nuisance water

04 Funding

- Larger, more complex nature-like fishway project requiring $10s of millions.
- Multiple funding sources requires long term funding plan.
- Cost risk during construction - Low bid environment – complex project requiring a skilled contractor with similar experience.

Risk Based Performance Objectives

Example Risk 1 - Performance Objectives and Longevity

Stability & Longevity

Ecohydraulic

Public Safety

Risk Based Performance Objectives

Example Risk 1 - Performance Objectives and Longevity

Stability & Longevity | Ecohydraulic | Public Safety

- The structures (weir, channels, and high flow sections) will be designed to withstand flood events up to the 50-year flood event with no damage

  The structure will be designed to withstand flood events up to the 100-year flood event with limited damage

- Limited damage will not impede the ability to achieve fish passage or surface water withdrawal

  Damage will be associated with surface scour of rock matrix, including fine materials creating volume loss, and minor degradation of tailwater control

- Plucking of large structural rocks will be limited to small areas where storm events create conditions that cause isolated areas of instability

  There will be no damage to the seepage wall or the structural matrix just downstream of the weir

- Erosion and scour will not impact existing infrastructure: Powerhouse Road Bridge and North Naches Road

- The rock matrix must withstand debris accumulation and degradation of the downstream channel

  Accumulation, degradation, and distribution of mobile bedload will be transient and will change over time

- The 5-year average maintenance cost will be on the order of $25,000 (2019 $US)

- *Design expectations for the rock structure over time…*

Risk Based Performance Objectives

Example Risk 1 - Performance Objectives and Longevity

Stability & Longevity | **Ecohydraulic** | Public Safety

- Structure configuration and composition will be designed in a manner that meets the fish passage performance objectives.

  Structure shall pass the adult, subadult, and juvenile stages of all native migratory fish.
- The facility will be designed with multiple fish passage pathways so that delay or non-passage periods are reduced over a wide range of hydraulic, environmental, and geomorphic conditions that may occur over the life of the Project
- Fish passage performance objectives of the main roughened channel and secondary channels will be continuous and met throughout the range of anticipated migration flows identified for various target species and life stages.
- Pilot channels and floodplain overbank areas are anticipated to be transitional in nature and performance may vary given observed geomorphic responses to flow events. Access will be maintained to allow monitoring, inspections, and repairs of low flow channel.
- Fall back, false attraction, delays or non-passage periods will be minimized to the extent practicable given the uncertainty inherent with structures of this nature

- *Fish passage performance expectations…*

Risk Based Performance Objectives

Example Risk 1 - Performance Objectives and Longevity

Stability & Longevity | Ecohydraulic | **Public Safety**

Removal of standing waves, rapids, and significant drops of more than 2 feet at flows common to passive boaters and recreationalists

Provide signage upstream of the feature indicating the flow path and designated portage

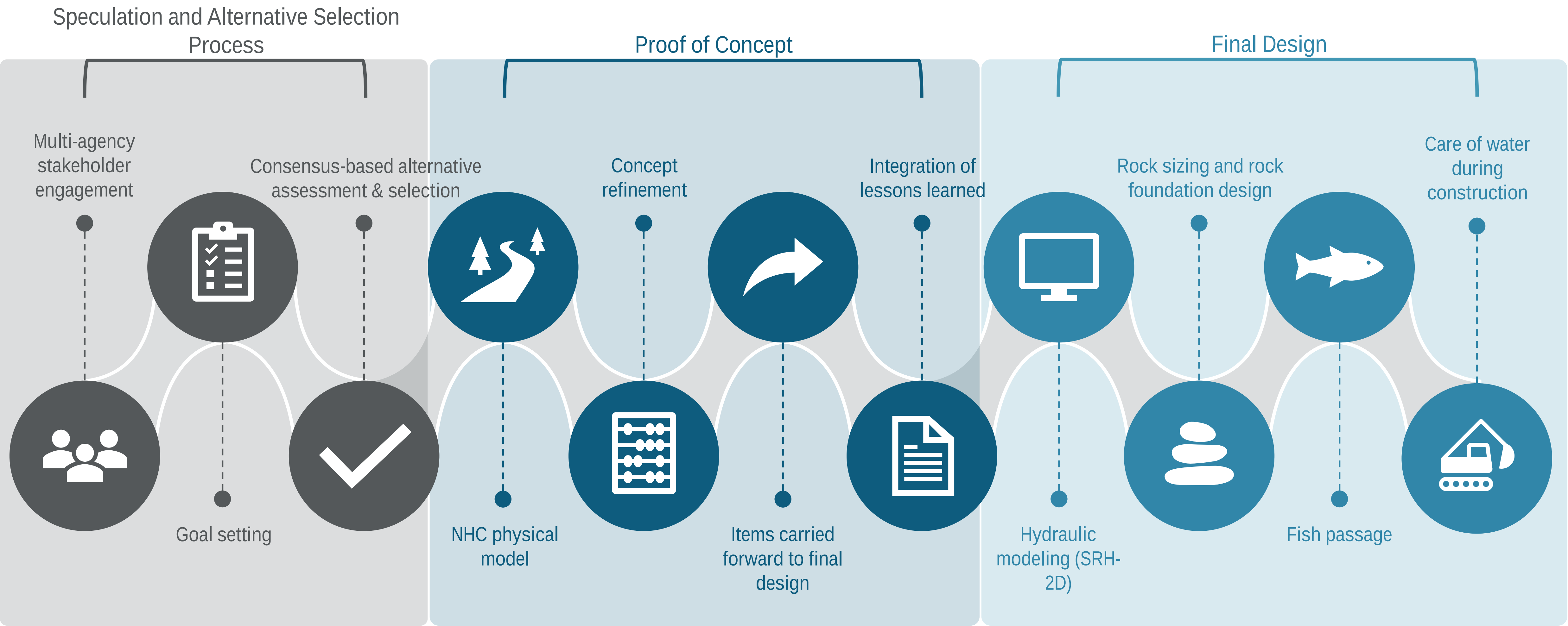
Provide buoys and/or log boom to prevent recreationalist entry into structure

Avoid the following :
- Water flowing under rocks or wood
- Cable, rope, rebar, and sharp rocks
- Drops w/ obstructions immediately downstream
- Anything geomorphically unnatural
- Symmetrical drops

Include the following:
- Separating rapids and drops with deep pools
- Design rapids to have eddies
- Make drop asymmetrical
- Design with historical complexity

- Recreational experience and public *safety*…

Design Strategy Addresses Potential Risks



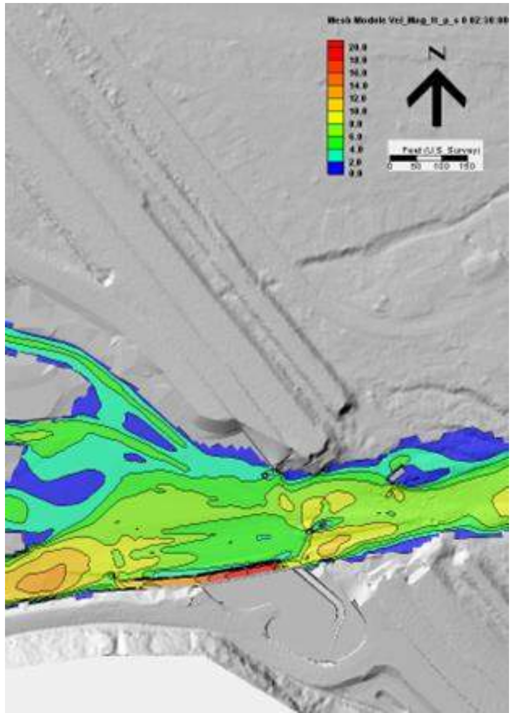
Multi-Model Strategy to Inform Design

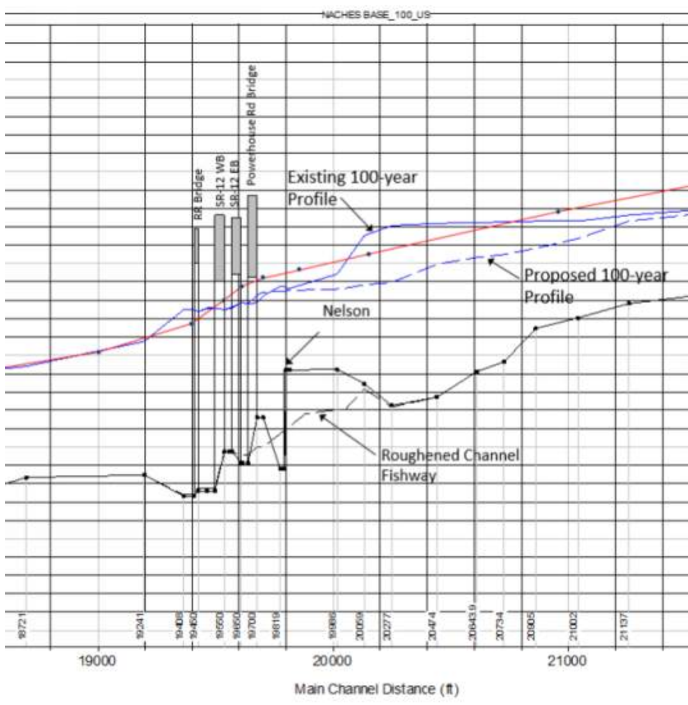
Physical Modeling

- Proof of concept

Numerical Modeling

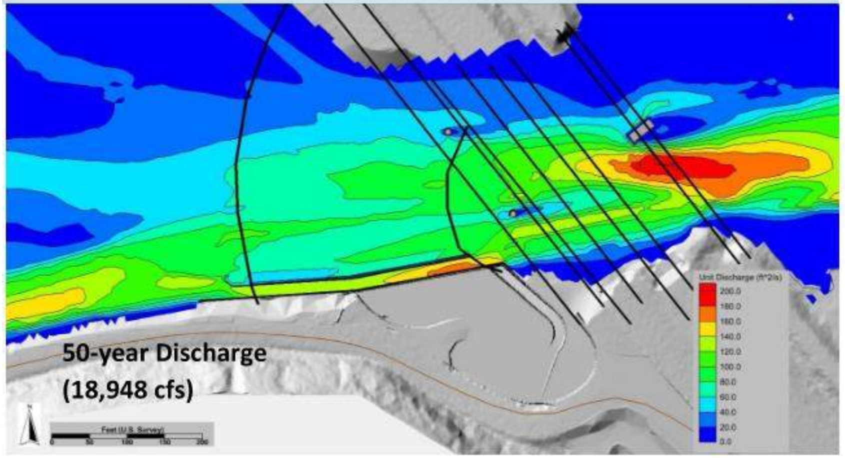
- 1-Dimensional
  - HEC-RAS
  - 2- to 100-year flood profiles
  - Document flood level reduction
- 2-Dimensional
  - SRH-2D
  - Development of hydraulic design parameters for key assessments
  - Risk Scenarios
  - Fish Passage



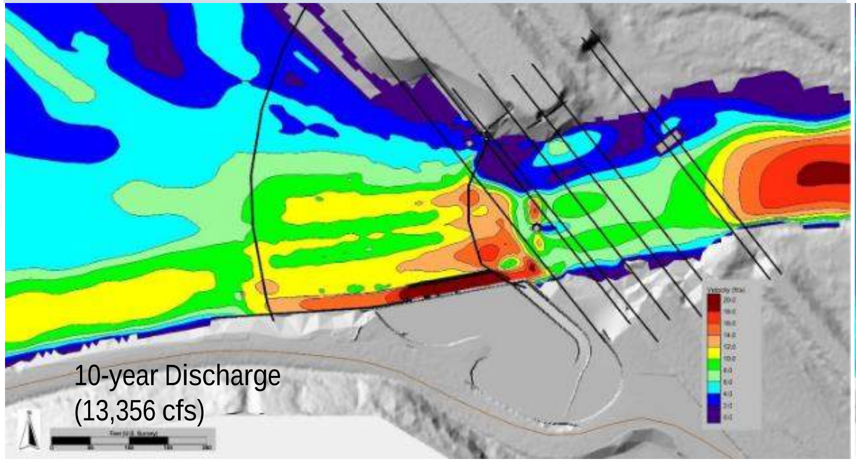


Three Proposed Project Risk Scenarios

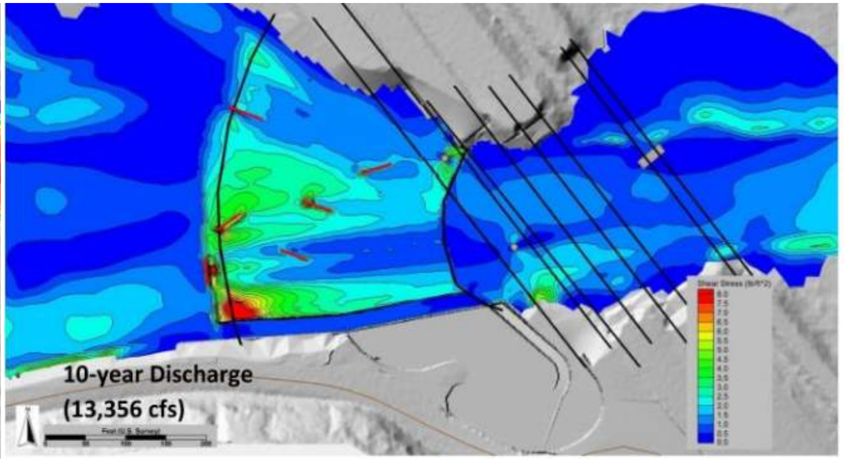
Downstream Bridge Span Widening	Extreme Downstream Scour	Debris Accumulation
• Future widening of Hwy 12 bridge span • Steepening of gradient of energy grade line at higher flood events • Velocity, Shear, Unit Discharge	• Degradation of channel bed downstream of project • Channelization and increase in gradient of energy grade line across all flows • Calculated Velocity, Shear, Unit Discharge	• Accumulation of debris across channel surface • Simulation of elevated localized velocity and shear zones • Calculated Velocity, Shear, Unit Discharge



Unit Discharge, cubic feet per second per foot, (cfs/ft) or square feet per second (ft^2/s)



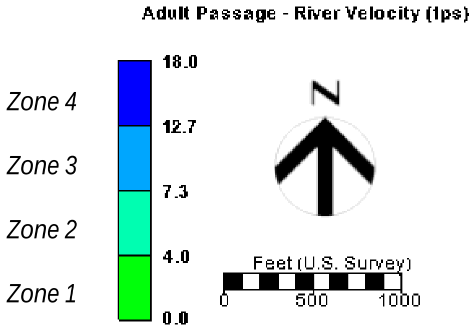
Velocity, feet per second (fps)



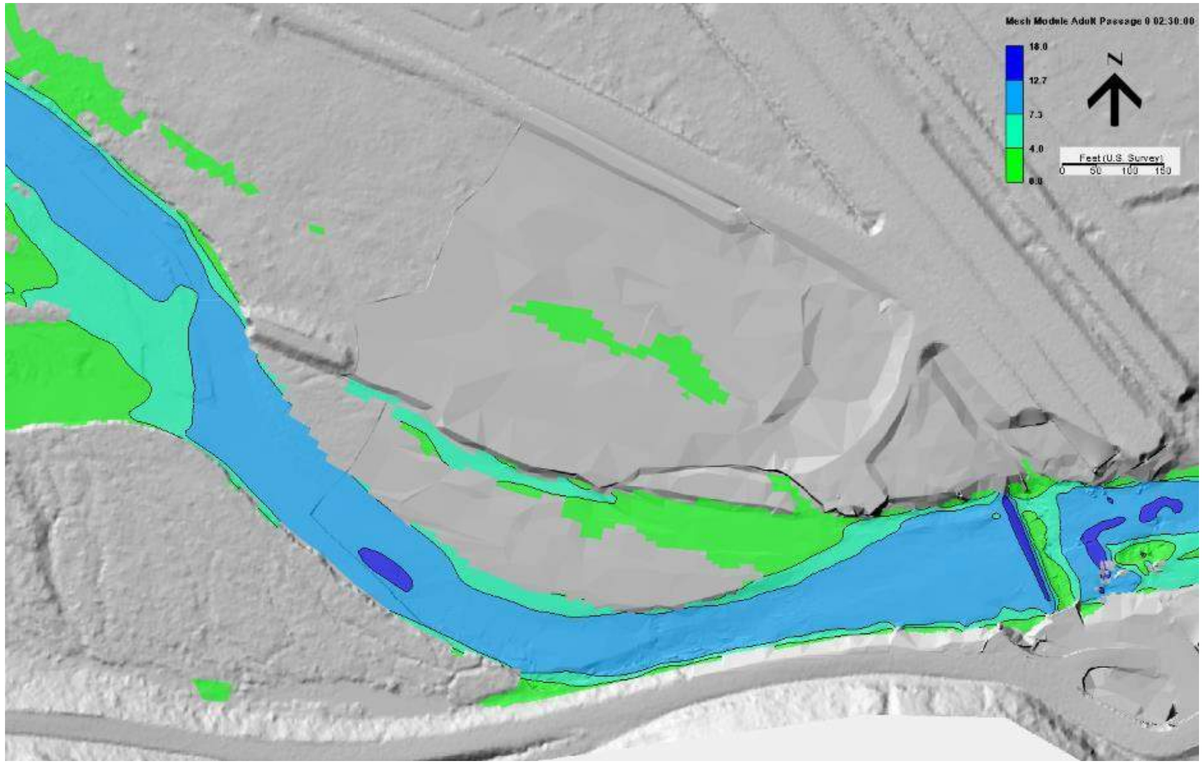
Shear force, pounds per square foot (psf)


As anticipated … debris
accumulation happens

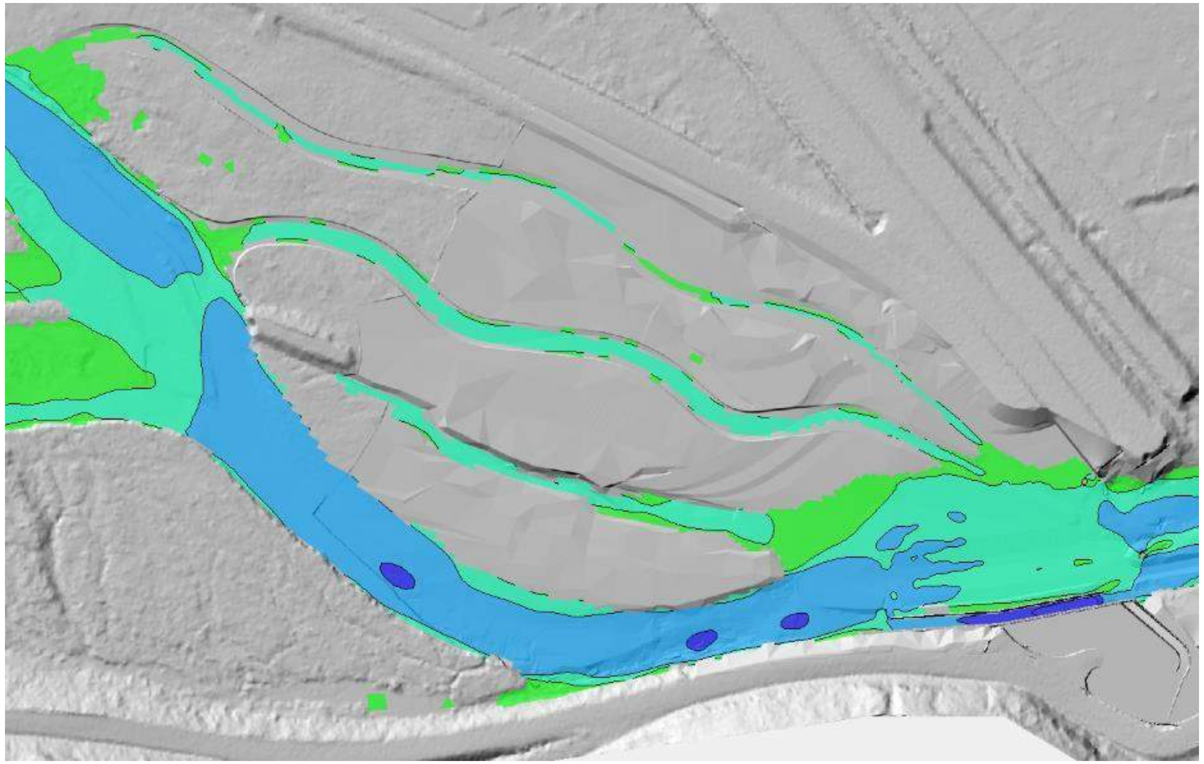
Ecohydraulic Performance - Fish Passage



- Biometric comparison to 2D hydraulic modeling results
- Flow velocity vs. time to exhaustion vs. fish swimming distance adapted from Katopodis and Gervais, 2016
- Example - Adult fish passage at 6,520 cfs, depth 0.9 feet or greater



Pre-Project Conditions

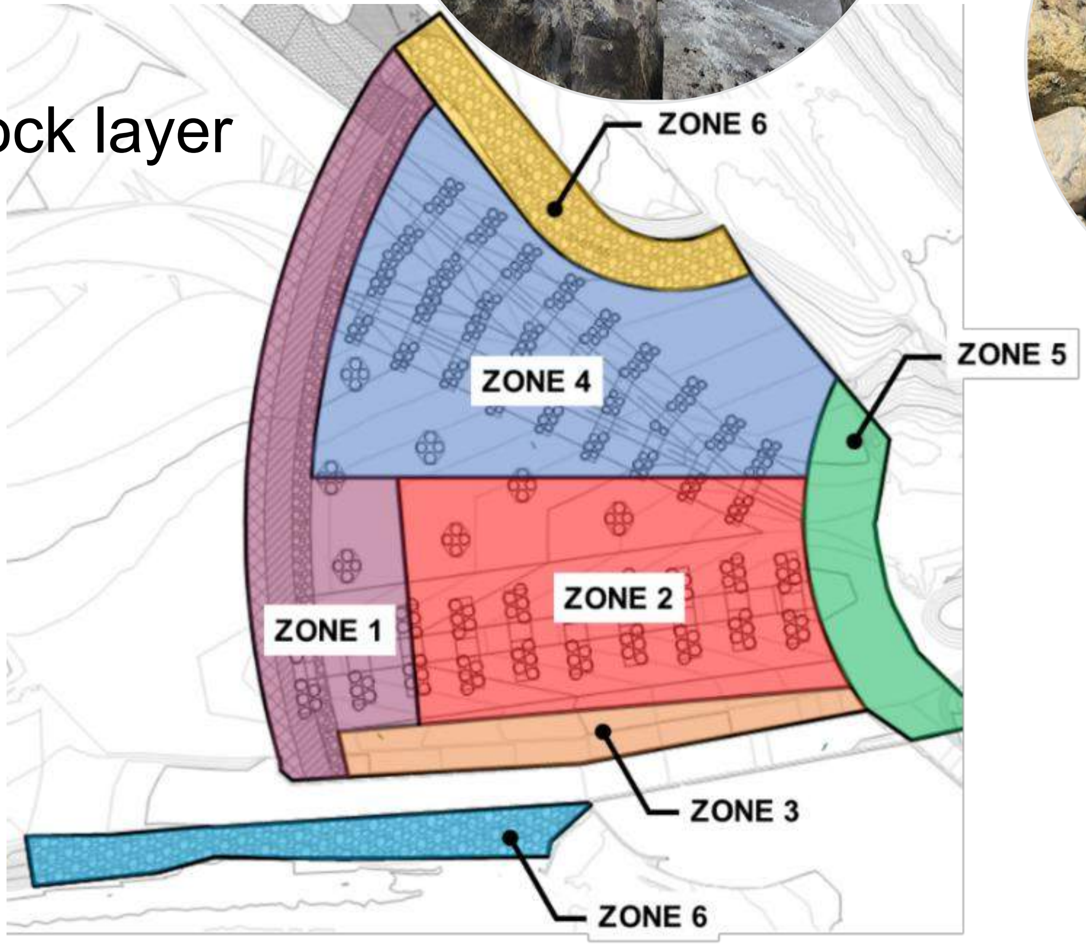


Post-Project Conditions

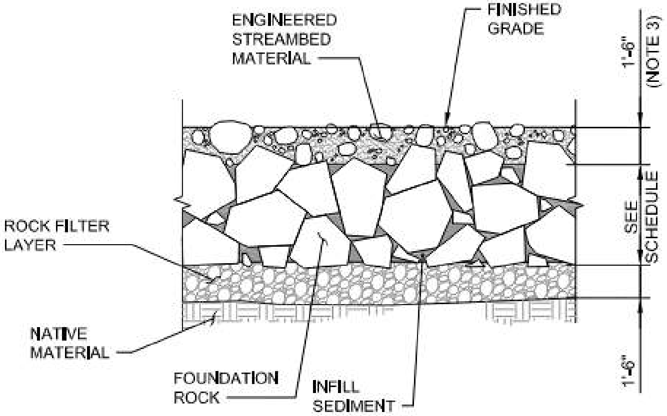

Floodplain connectivity and Multiple Hydraulic Migration Pathways During High Flows

Rock Composition Design and Configuration

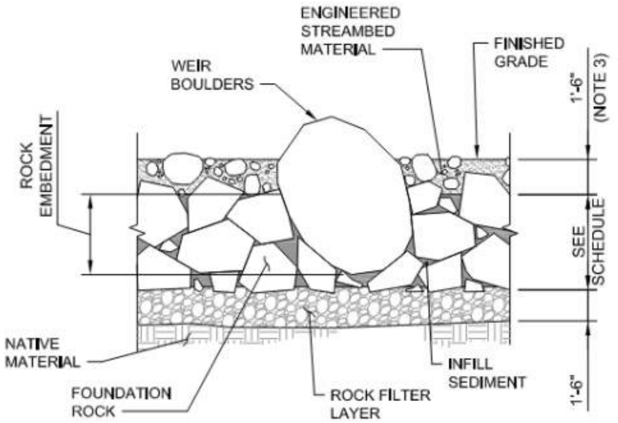
- Sheet-pile seepage wall
- Rock filter layer
- Structural foundation rock layer
- Mobile bed layer



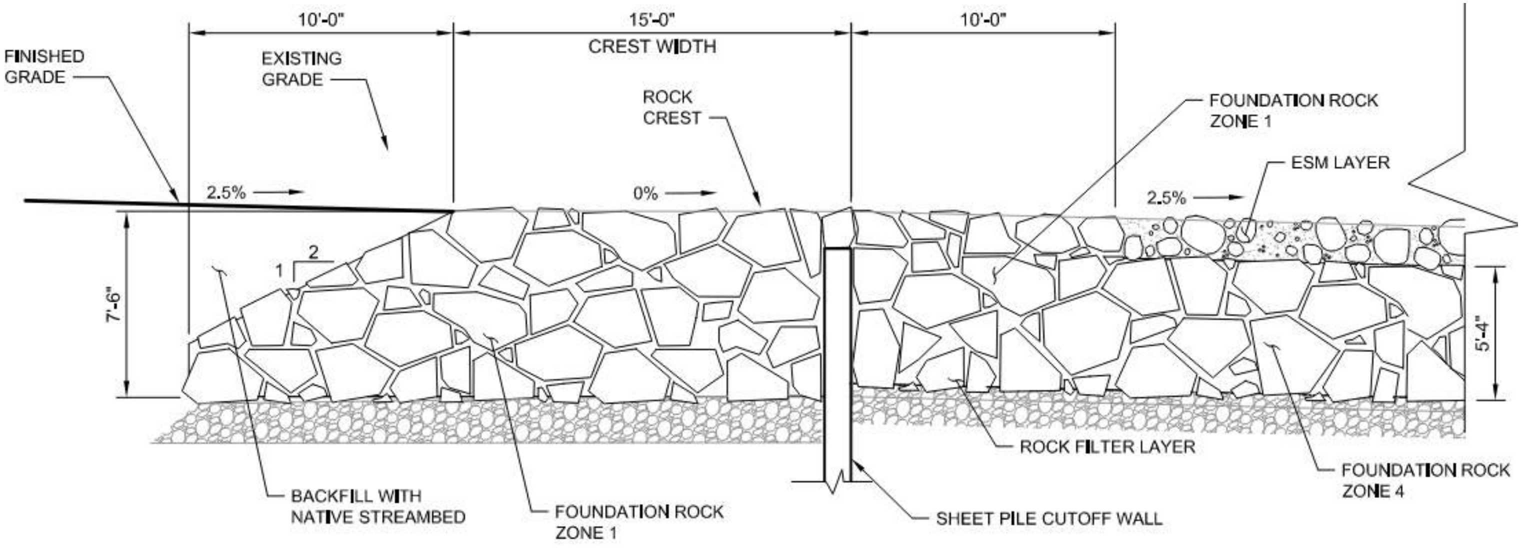
Rock Composition Design and Configuration



PRIMARY FISH CHANNEL DETAIL
SCALE: NTS
4
01R04 01R06



WEIR BOULDER EMBEDMENT DETAIL
SCALE: NTS
3
01R04 01R06



ROUGHENED CHANNEL CREST SECTION
SCALE: NTS
A
01R02 01R06

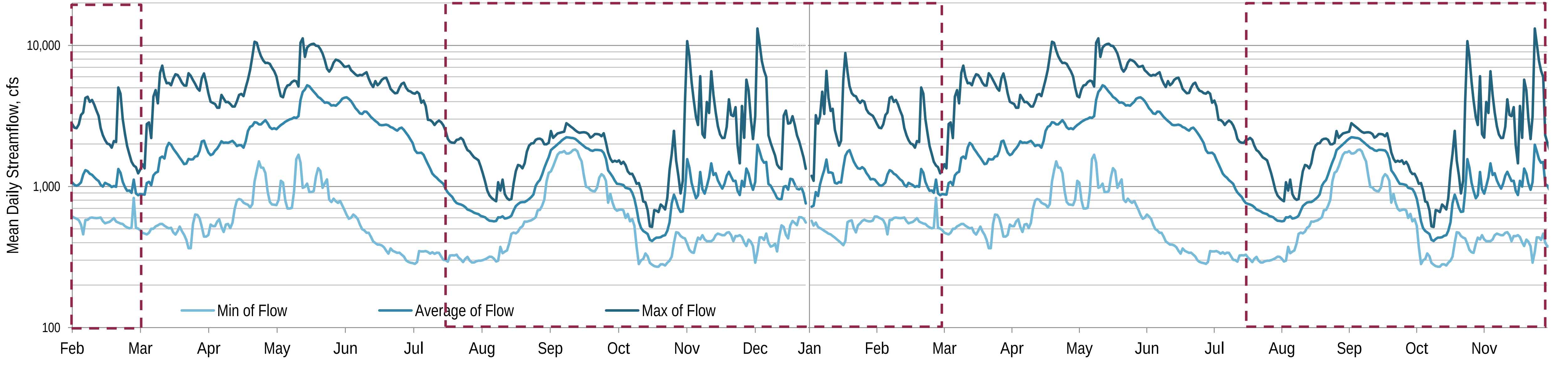
Material Sourcing

- Bid solicitation through City of Yakima Public Works
- Selection of three local quarries to produce material meeting design requirements
- Stockpile select material and deliver as requested by contractor during construction
- Total select rock deliveries to the project site – 39,000 tons

Care of Water During Construction

Summary of Construction Sequencing and Anticipated River Flow Variability

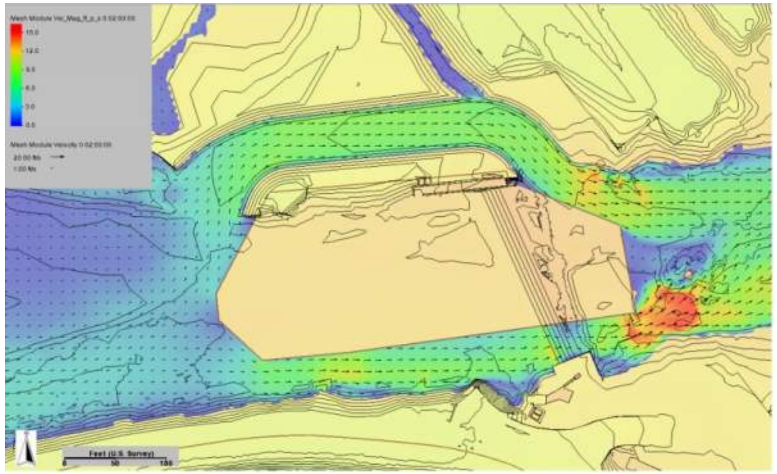
Step	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
1																						
2																						
3																						
4																						



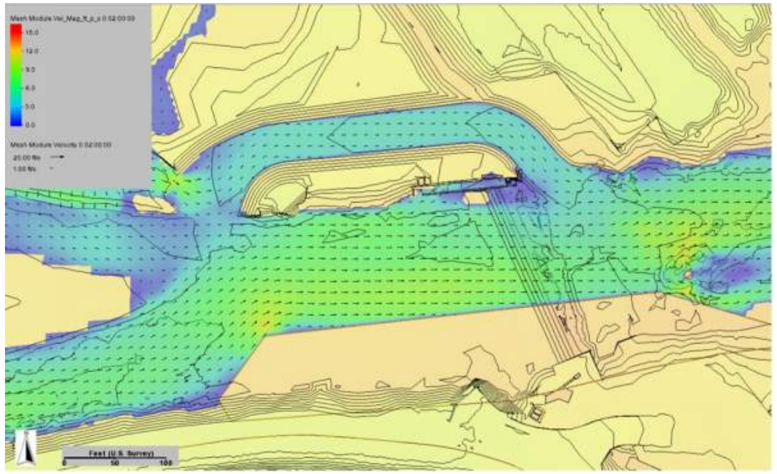
Care of Water During Construction

- Major project component:
  - Cost
  - Risk
- Three phase strategy focused on construction of:
  - Main roughened channel area
  - Sluiceway and intake
  - Pilot channels

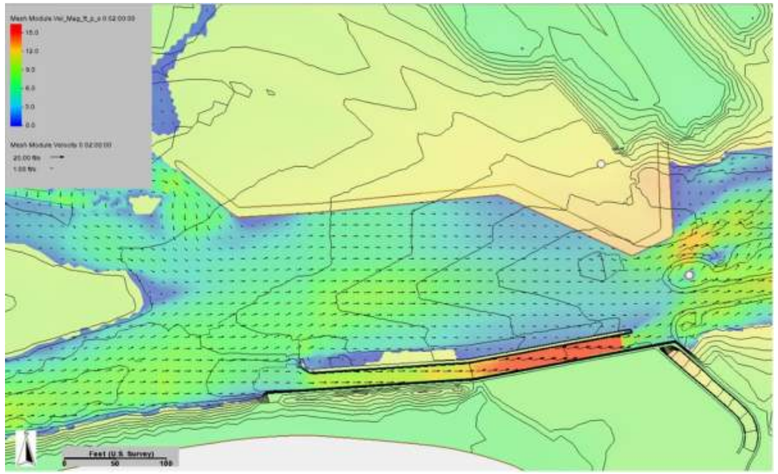
Phase 1



Phase 2



Phase 3



Care of Water During Construction

Phase 1: Care of Water
October 22, 2021

Phase 2: Care of Water
June 9, 2022

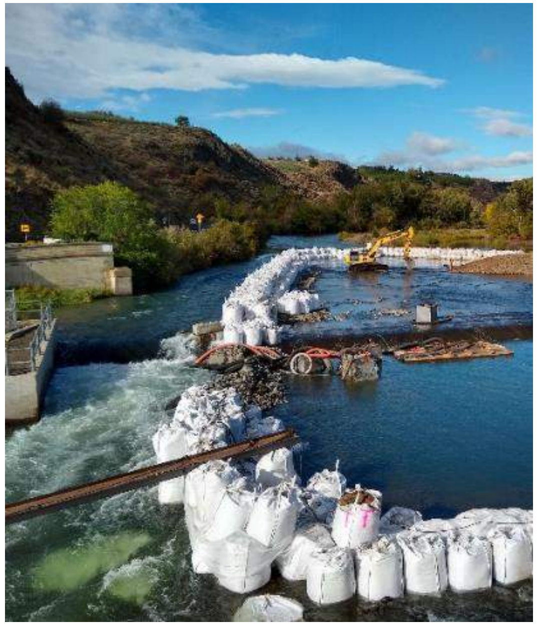
Phase 3: Care of Water
October 24, 2022

Project Completion
April 19, 2023

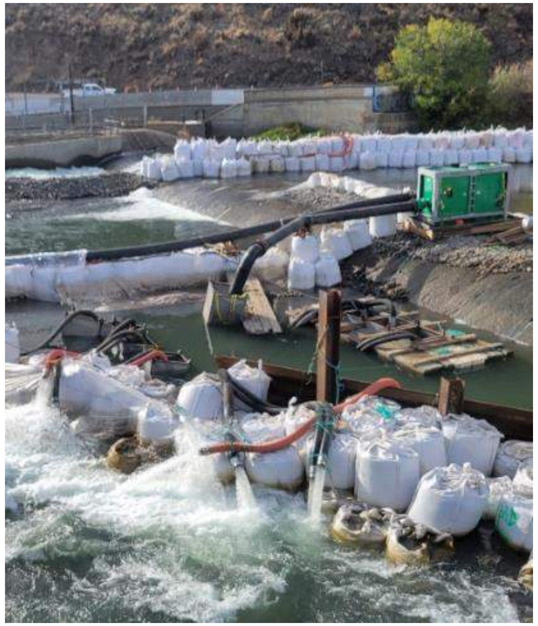
Care of Water During Construction

Over 2,700 supersacks used for cofferdams

Temporary and permanent sheet pile walls



Multiple river diversion strategies



Networks of dewatering pumps, and conveyance techniques

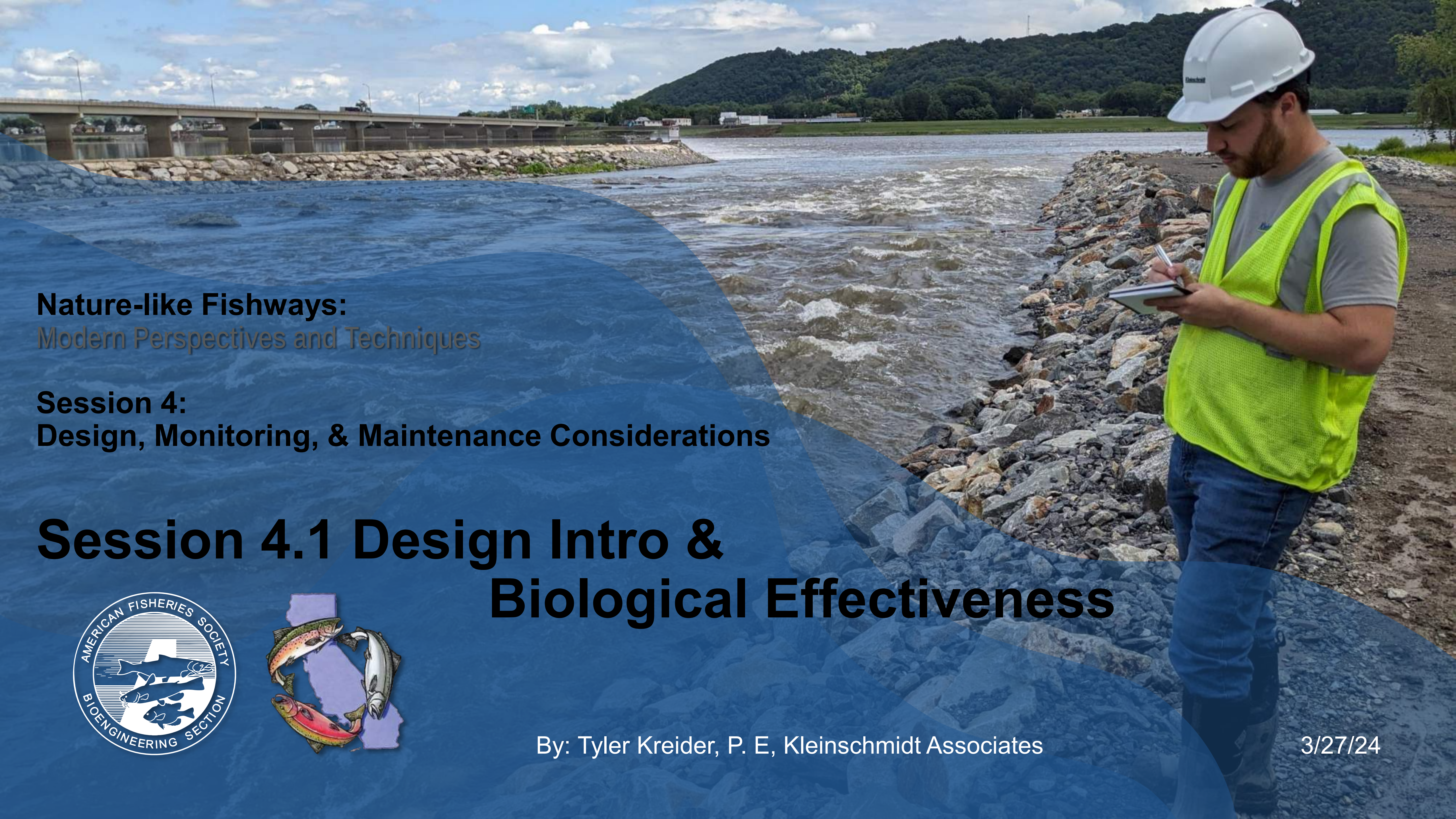
Funding

- Evaluated at each phase of project implementation
- Collaborative effort among numerous funding partners
- Plan for ongoing monitoring and maintenance – reference original risks and design criteria identified during pre-design phase of work


Post-Project Conditions
October 2023

Lessons Learned
Key Successes/Failures

- Risk identification and management begins during the project planning phase and continues throughout every stage of implementation
- Goals, objectives, expectations, and constraints should be communicated often and well documented
- Design, funding, and construction strategies should focus on addressing high priority risks – Risks with severity and likelihood
- Exposure to risk changes throughout the project, evaluating and addressing new risks doesn't end



Nature-like Fishways:
Modern Perspectives and Techniques

Session 4:
Design, Monitoring, & Maintenance Considerations

Session 4.1 Design Intro & Biological Effectiveness

By: Tyler Kreider, P. E, Kleinschmidt Associates

3/27/24

Session 4 AGENDA

01	Design Intro & Biological Effectiveness by Tyler Kreider
02	Hydraulic Modeling by Barry Chilibeck
03	Roughness Design by Barry Chilibeck
04	Other Design Factors by Tyler Kreider
05	Summary of NLF Monitoring Results by Bjorn Lake
06	Monitoring Methods by Barry Chilibeck and Tyler Kreider
07	Maintenance of NLFs by Marcin Whitman
08	Q&A (as time allows) led by Tyler Kreider

Session 4.1 AGENDA

01 Defining “effective passage”

02 Meshing the Biological & Mathematical

Design

Design a fishway

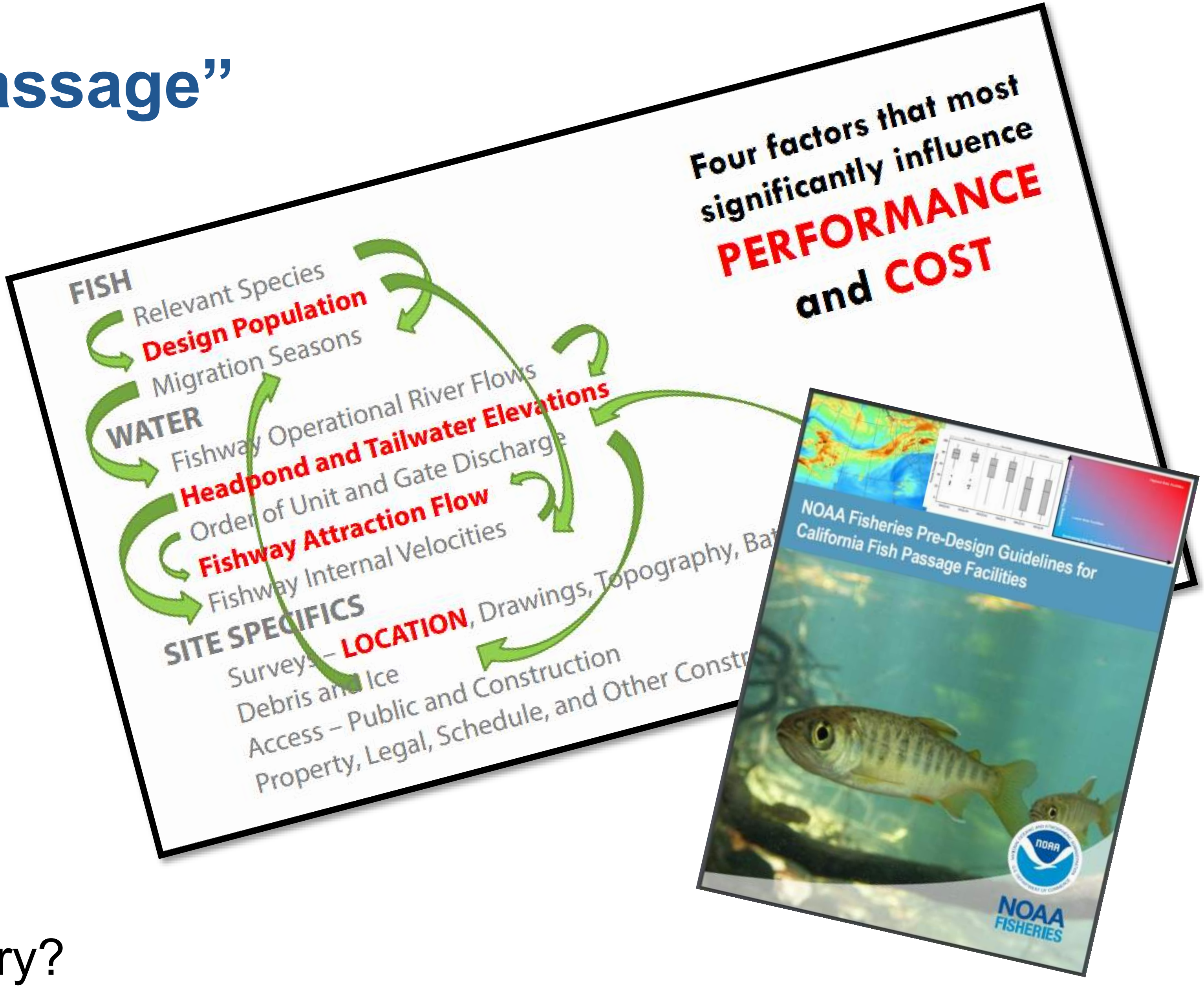
Design a NLF

Design an effective NLF for passage of X,Y, Z species.

- Guidance documents (see Session 1 references)

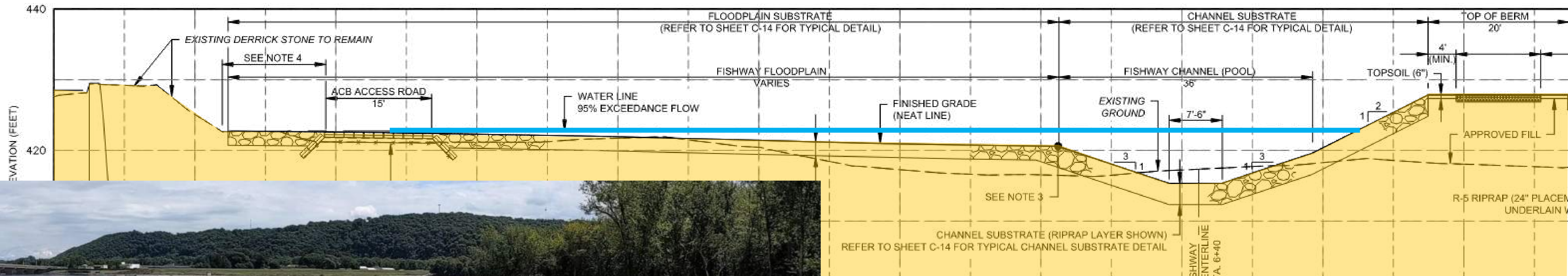
Defining "Effective Passage"

- Project Design Criteria
  - Defining design criteria could be 2-day workshop by itself!
  - NOAA Pre-Design Guidelines for CA Fish Passage Facilities
  - Some mentioned in following slides, but not exhaustive
- Compliance driven?
- Regulatory input
- Get fisheries biologist & engineer input
- Species: Resident? / Migratory? Life Stage(s)?



Defining "Effective Passage"

- NLF type (*see Session 2*)
  - Pool/weir vs. roughened channel vs. hybrid
  - Partial width vs. full-width vs. bypass
  - Attraction flow (% of total river flow)
- Applicability of Regional/National fish passage guidance
  - Specific for NLFs?
  - May vary by NLF type
- One-size-fits all criteria/guidance???
  - Overly conservative vs. not conservative enough for given species?
  - Variability in fish size across region/nation

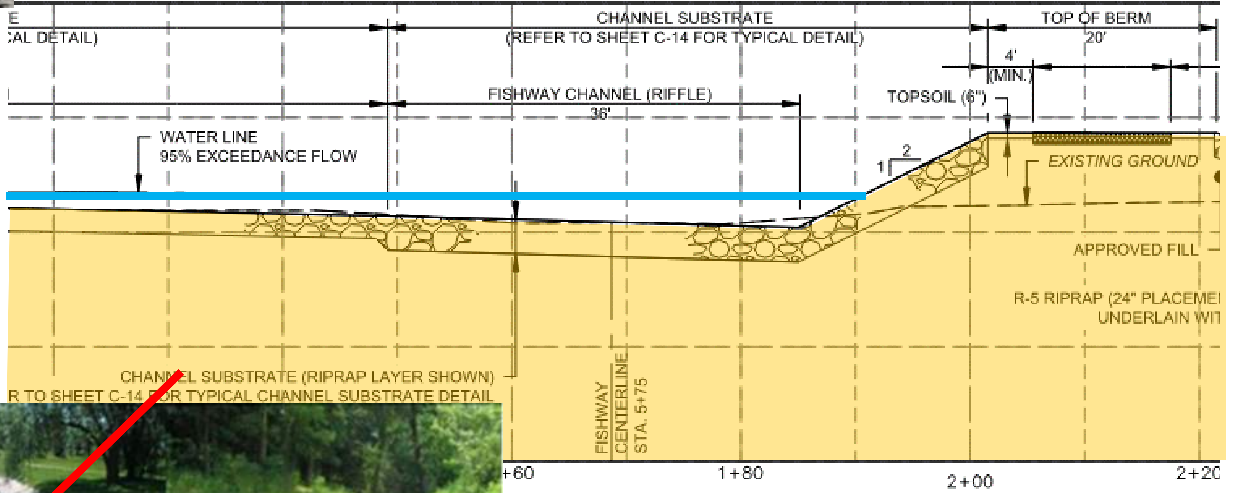


POOL Cross Section

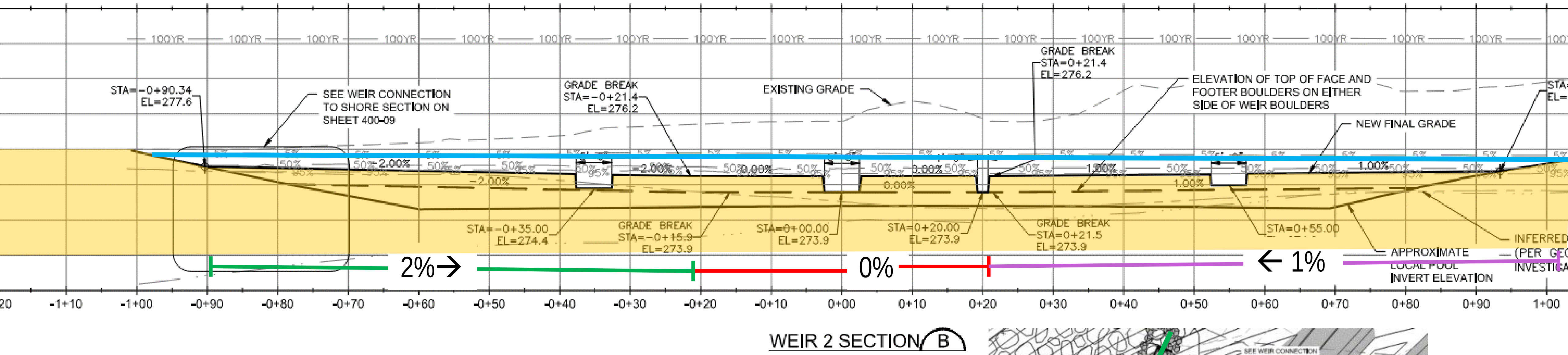
Defining “Effective Passage”

Cross Section matters!

- Pool vs. riffle/weir
- Thalweg/deep zone of passage
  - Width
  - Cross-flow slope?



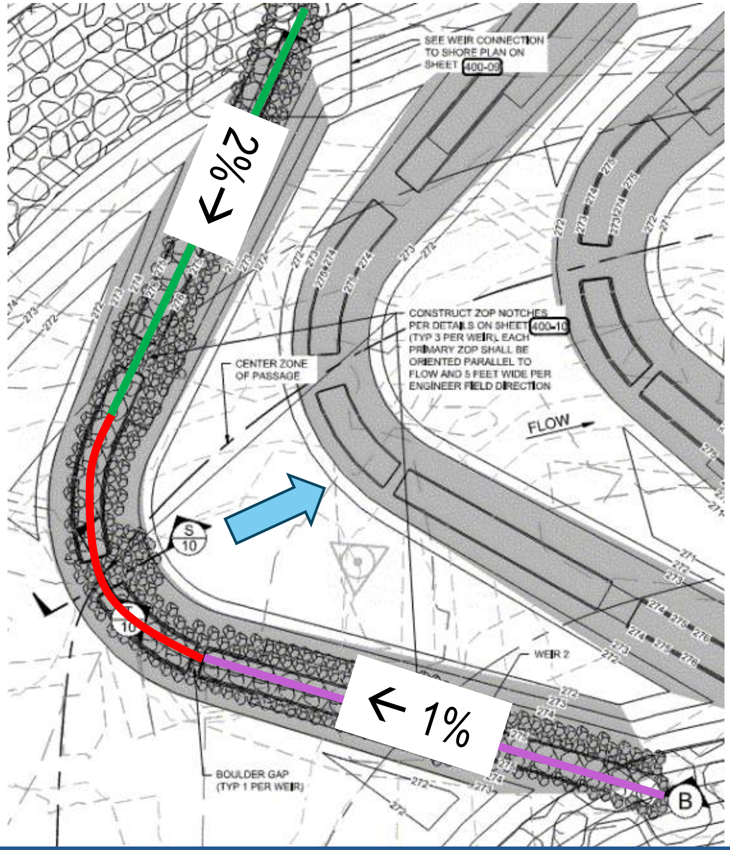
RIFFLE Cross Section

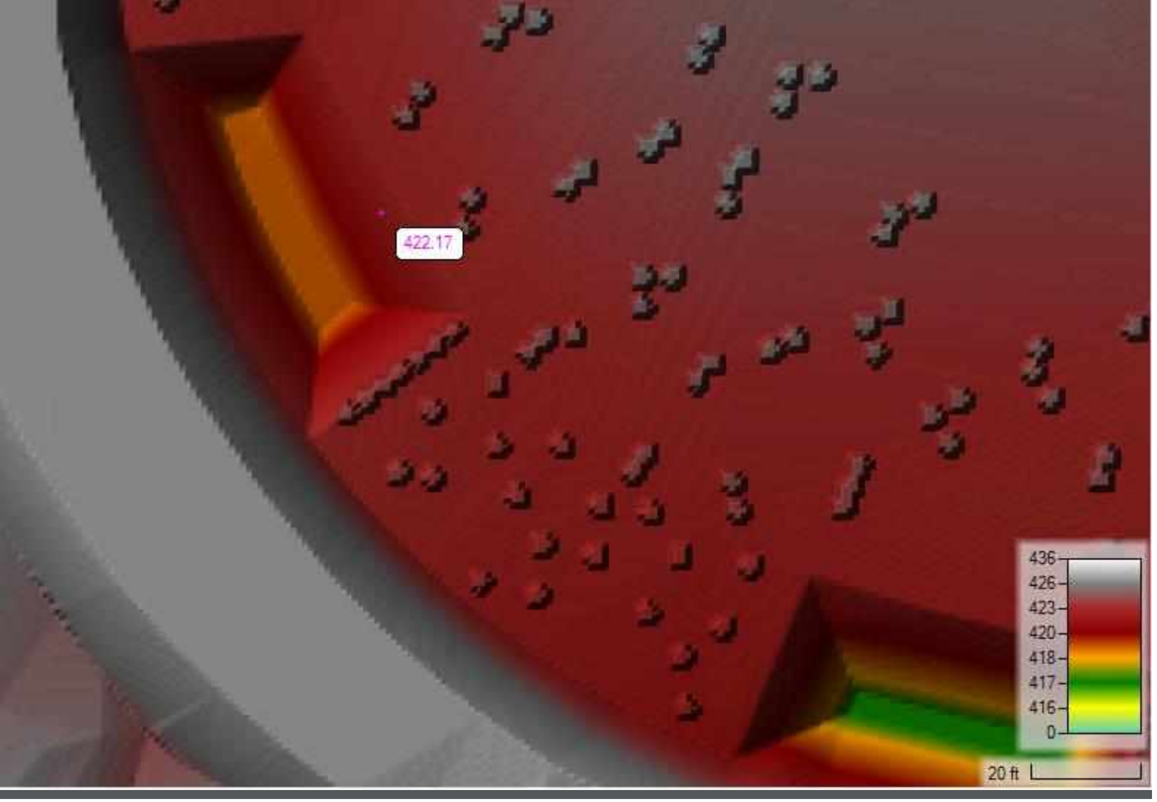


Defining "Effective Passage"

Cross Section matters!

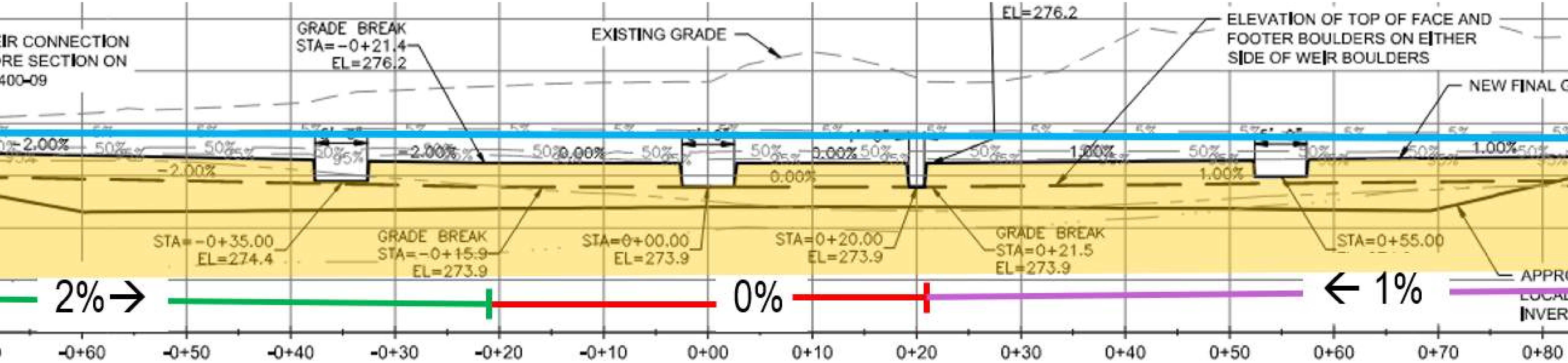
- Boulder weir arm/floodplains
  - Width
  - Cross-flow slope (vary by side?)





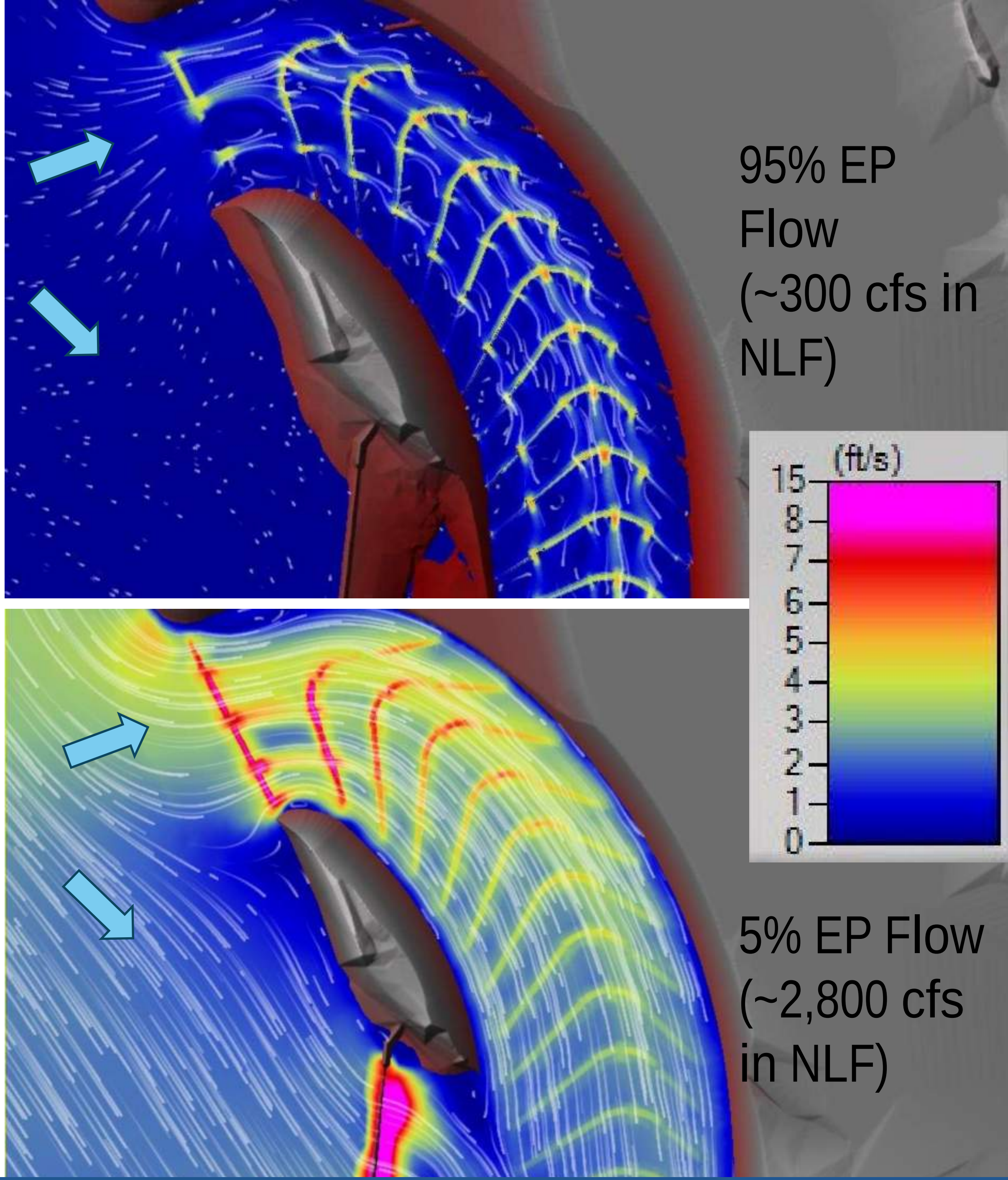
Defining "Effective Passage"

- Cross Section matters!
  - Roughness Elements?
  - Zones of Passage
    - "Random" vs. small/large gapped boulders
    - Refer to design criteria → water depth
    - Variability (in design and construction)



Defining "Effective Passage"

- Effectiveness likely will vary with flow
  - 95% exceedance flow
  - 50% exceedance flow
  - 5% exceedance flow
- Optimize passage for flows that can reasonably be anticipated to occur most often
- Scope/Budget/Schedule limitations



Effective Passage: Desktop vs. Field

- Designer's Goal: is maximum fish passage for minimal design/construction cost
- Need mechanism to evaluate passage effectiveness during design
  - Balance theoretical design effort (desktop) against labor-intensive condition survey of known passable reaches (field)
- Desktop tools: Google Earth/FEMA/hyd. model
- Field benefits:
  - Design to replicate known passable conditions

Meshing the Biological & Mathematical

Methods to consider

- Depth/Velocity Mapping
  - Single species vs. conservative values to cover multiple species

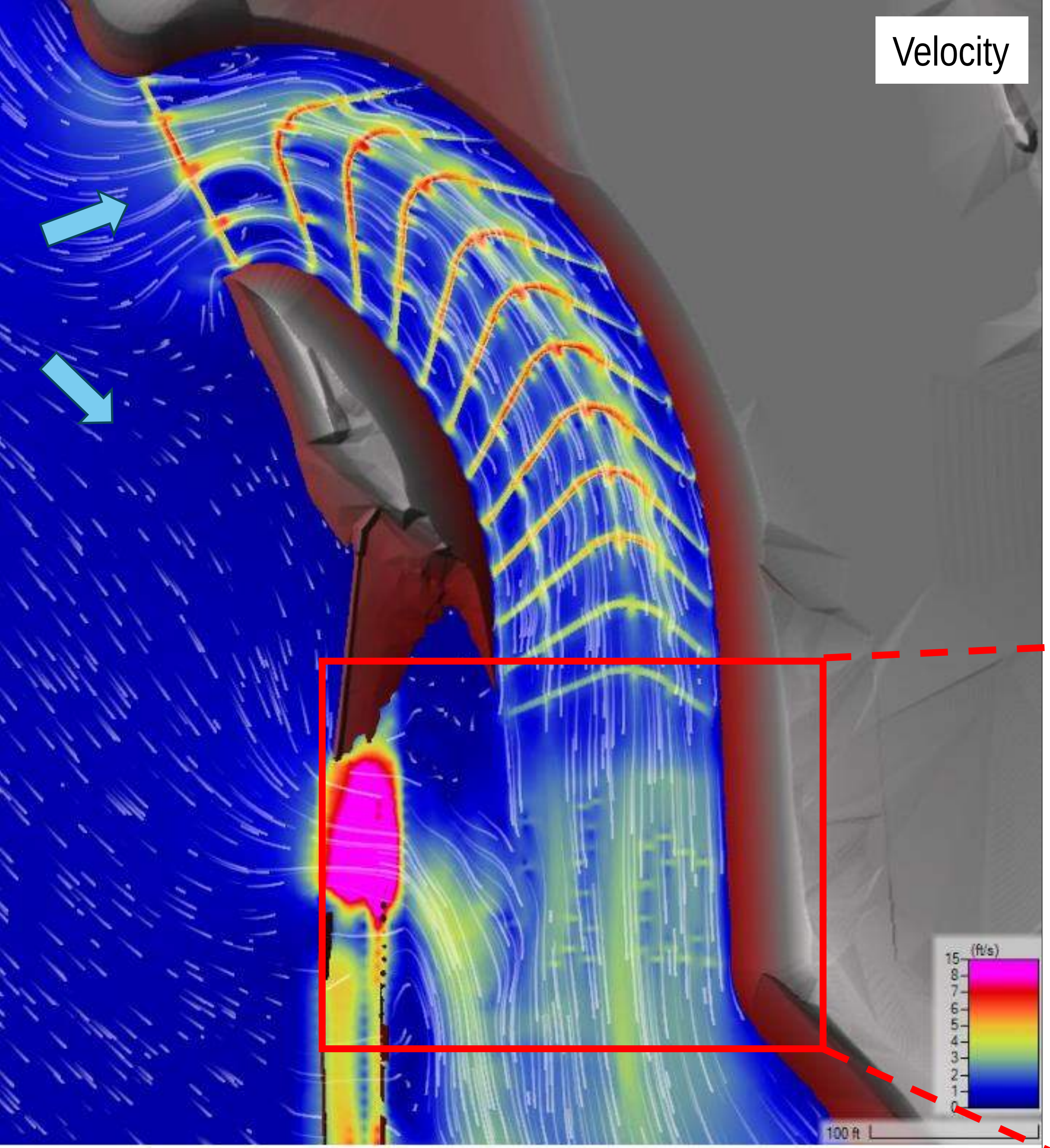
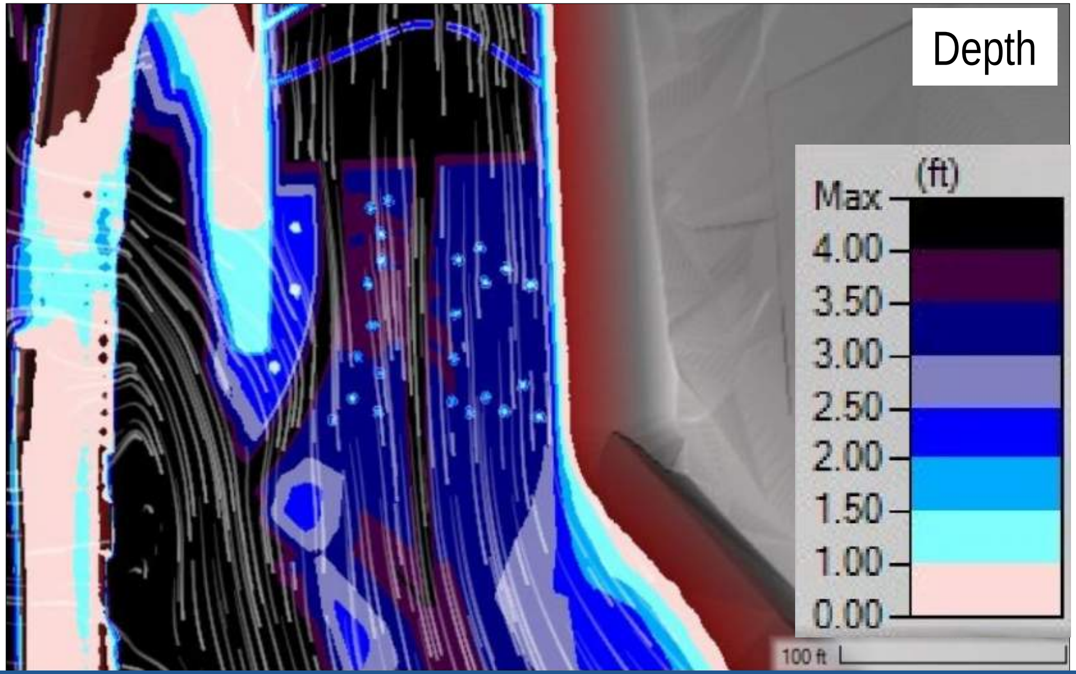


Figure 5-11. **Proposed Inland Nature-like Fishway: Fine Scale Model 50 Percent Exceedance Probability (35,200 cfs) Velocity**



Meshing the Biological & Mathematical

Methods to consider

- Depth/Velocity Mapping
- Species-specific mapping
  - Zones of passage
  - Suitable passage by flow for given species threshold depth & velocity

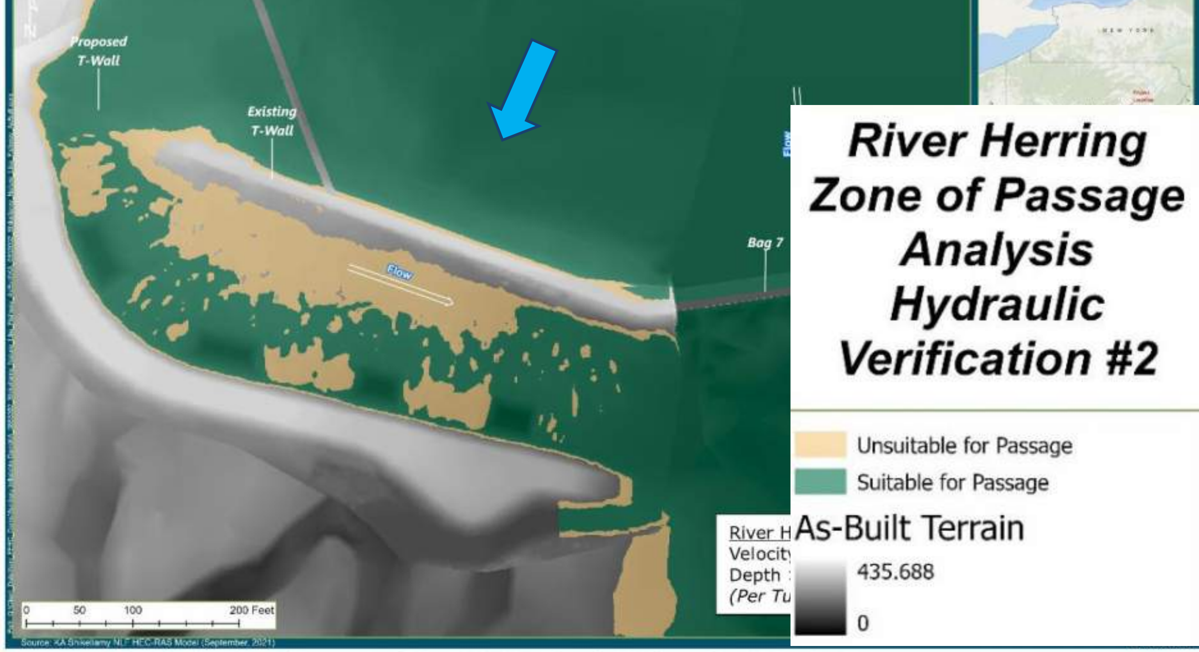


Figure 15. River Herring Zone of Passage Analysis at 428.4′ Headpond WSE (lower than design flow).

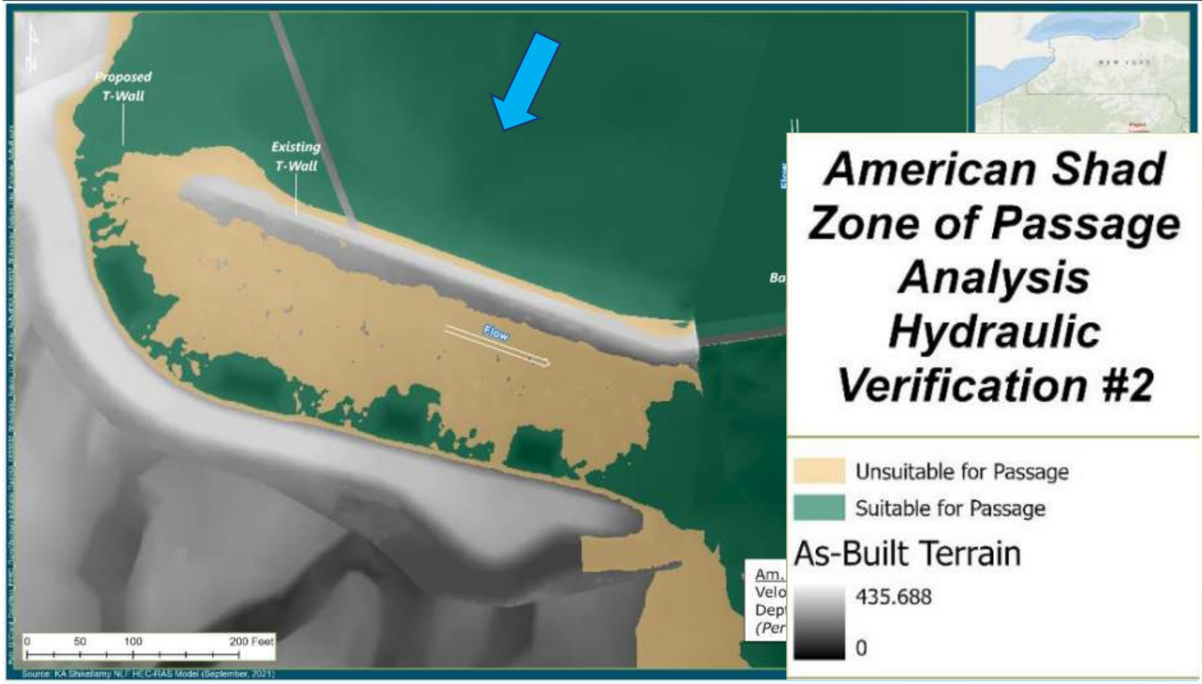


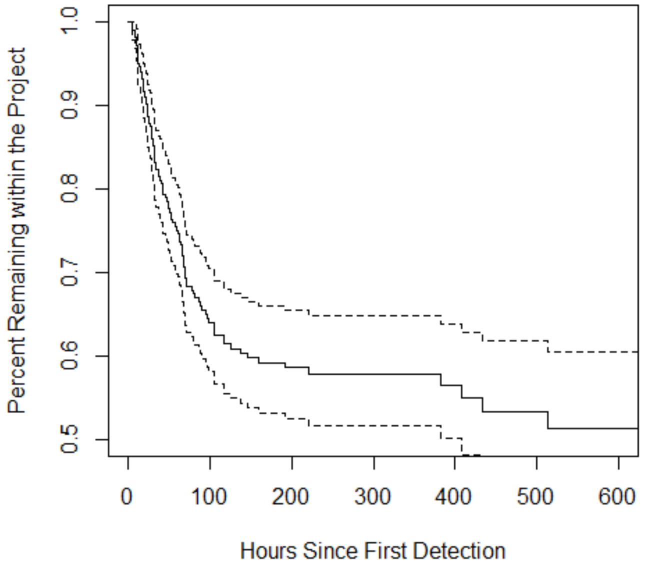
Figure 16. American Shad Zone of Passage Analysis at 428.4′ Headpond WSE (lower than design flow).

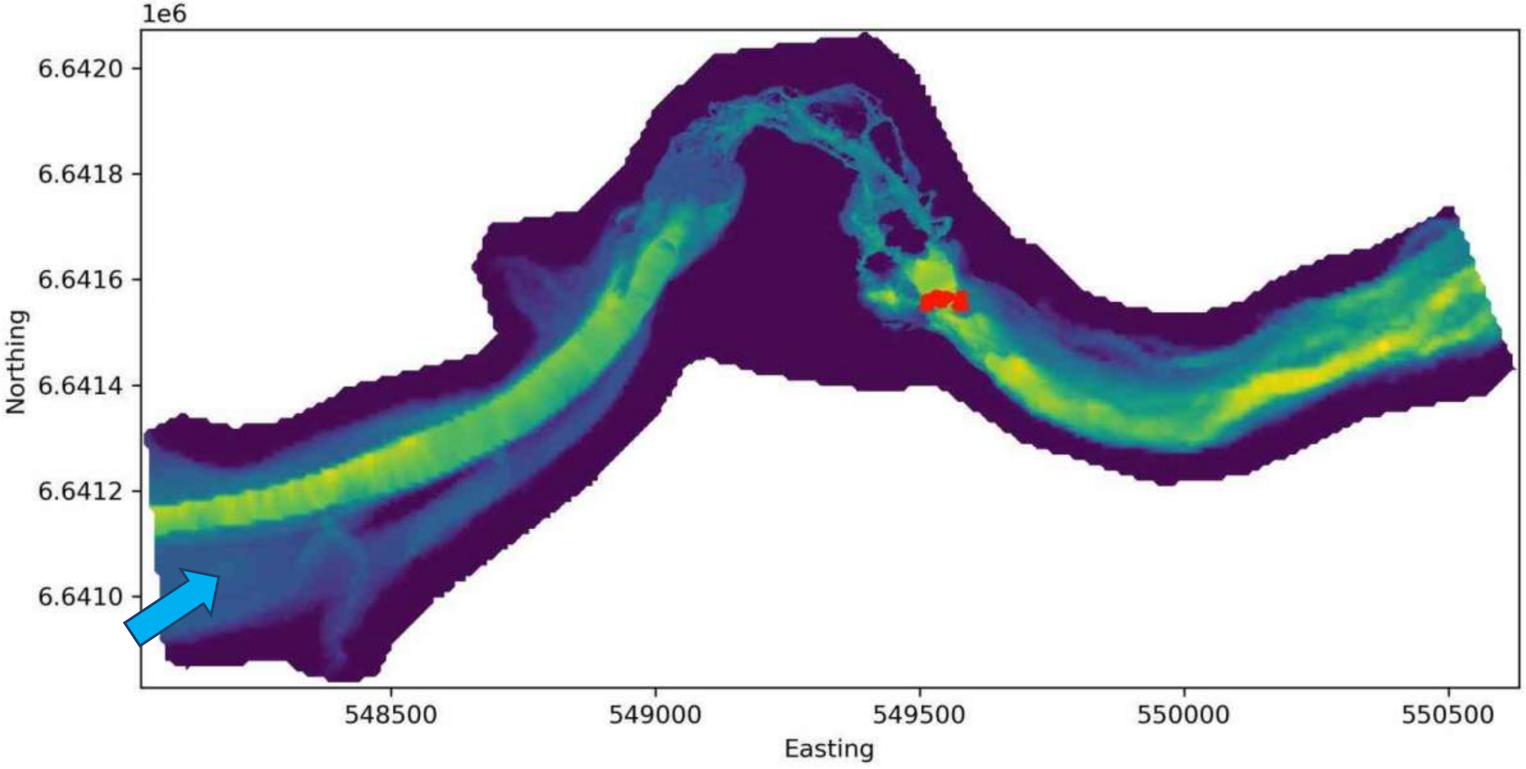
Meshing the Biological & Mathematical

Methods to consider

- Depth/Velocity Mapping
- Species-specific mapping
- Agent-based
  - Each "fish" programmed with depth/velocity preference/range
  - Released into hydraulic model to swim upstream
  - Evaluate passage rate

- Kaplan Meier curve: shows the percent remaining in the initial state at time t
- Cox Proportional Hazards regression → hazard ratio <1?





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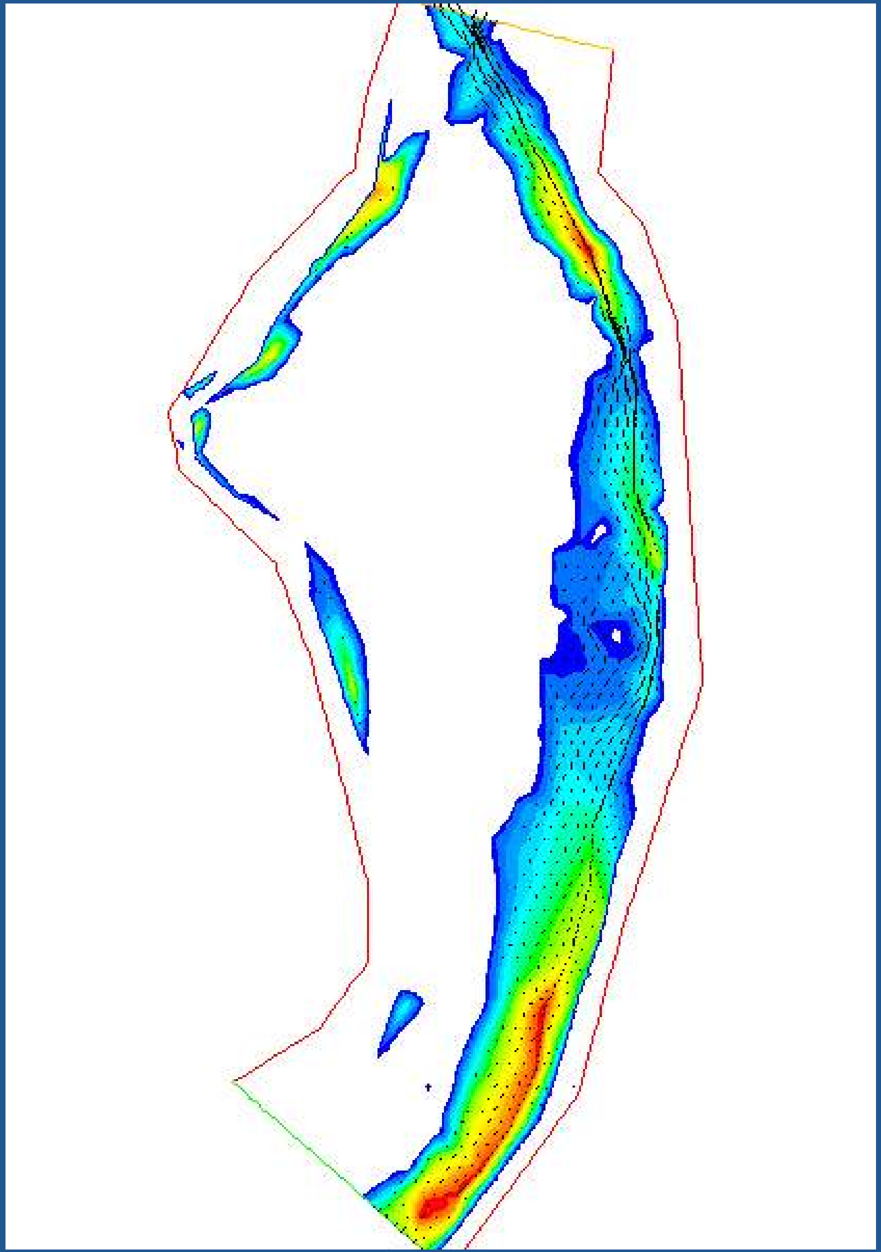
Up Next!

Nature-like Fishways:
Modern Perspectives and Techniques

Session 4:
Design, Monitoring, & Maintenance Considerations

Lead By:
Tyler Kreider &
Barry Chilibeck

March 27, 2024



Discussion Topics

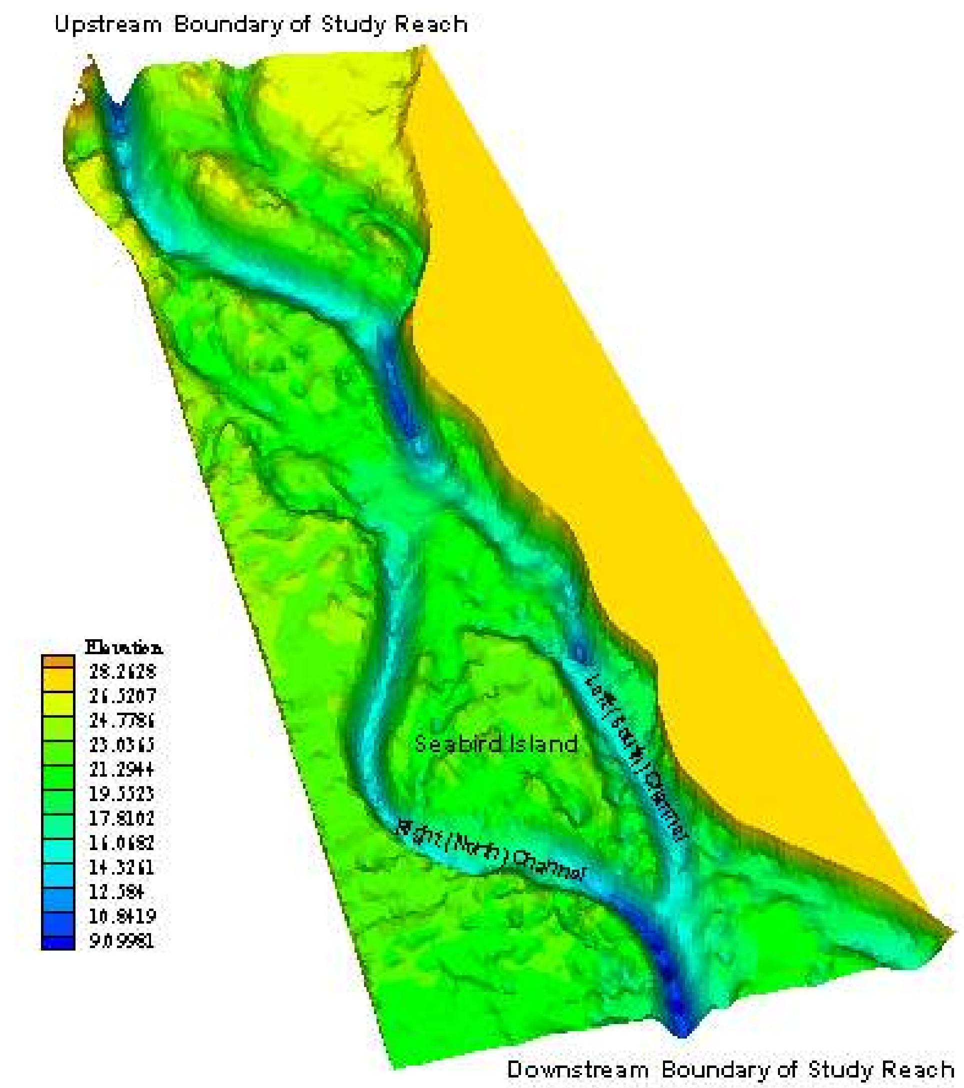
- Types of hydraulic models
- Modeling components and methodology
- Integration of numerical tools into NLF design and assessment
- What to model where and why
- Future of numerical simulations and modeling

the medium is the message

- Marshall McLuhan

Hydraulic Analysis and Simulations

1. Hydraulic calculators
2. 1D hydraulic models
3. 2D hydraulic models
4. 3D and CFD models
5. Physical Models



References

1. Maddock et al. 2013. Ecohydraulics: An Integrated Approach; **Part I, Section 3: Hydraulic Modelling Approaches for Ecohydraulic Studies: 3D, 2D, 1D and Non-Numerical Models**, Daniele Tonina and Klaus Jorde.
2. HEC RAS Hydraulic Reference Manual (web): https://www.hec.usace.army.mil/confluence/rasdocs/ras1dtechref/latest

At-a-section Hydraulics

- Simple hydraulic calculators and spreadsheets are excellent tools in the conceptual design of NLF
- uniform flow, roughness and hydraulics
- These tools can:
  - develop rating curves to analyse flow distribution
  - determine required NLF width – given unit discharge – to determine flows for passage and attraction
  - provide estimate of mean velocity – at a given slope and roughness – to investigate roughness and initial design trade-offs

At-a-section Hydraulics

- using Manning equation and develop solvers
- use survey data or estimates of section and reach properties
- can use rating curves developed in other models (e.g. HECRAS, etc.)
- concept and prototype designs to fail-fast

Solve Depth

Solve Slope

Solve 'n'

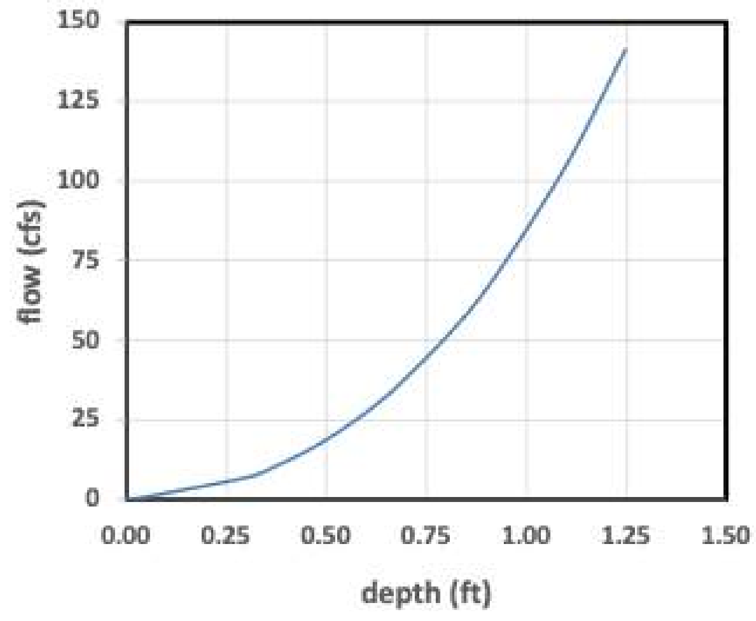
CHANNEL HYDRAULICS			SEDIMENT DATA		
Bottom Width	2.0	m	Size D_{15}	25	mm
Side Slopes	2.0	H:1V	Size D_{50}	150	mm
Bank Height	1.00	m	Size D_{86}	200	mm
Depth	0.06	m	Size D_{100}	300	mm
Mannings n	0.060		Specific Gravity	2.65	
Slope	0.8%				
Discharge	0.03	m^3/s			
			Bray (1979)		
Calculated Discharge	**0.03**	m^3/s	*D_{50}*	150	mm
Average Velocity	**0.21**	m/s	*d*	0.45	m
Average Depth	**0.05**	m	*R*	0.20	m
Flow Area	0.12	m^2	n	0.063	
Perimeter	2.26	m			
Top of Bank Width	6.0	m	***FHA (1975)***		
Wetted Width	2.2	m	*D_{50}*	150	mm
Hydraulic Radius	0.05	m	n	0.035	
Shields Stable Stone Size (0.045)	6	mm	***Strickler (1926)***		
Lane Stable Stone Size	5	mm	*D_{50}*	300	mm
Effective Grain Size (Neill)	0	mm	n	0.039	
Froude Number	0.29				
Shear Velocity	0.07	m/s	***Estimated n for steep slopes***		
Shear Stress	4.2	N/m^2	Roughness of loose rock riprap on steep slopes.		
Stream Power	2	W	Rice. C.E. et al. 1998. Journal of Hydraulic Engineering,		
Unit Stream Power	1	W/m	February 1998. pf 179-185.		
Critical Shear Stress - intiation	109.2	N/m^2			
Critical Shear Stress - full movement	145.6	N/m^2	$0.1<S_0<0.4$	$n=0.029(D_{50}S_0)^{0.147}$	
Density	1000	kg/m^3	D_{50}	0.3	m
Kinematic Viscosity	0.00000179	m^2/s	S_0	0.2	
Gravity	9.806	m/s^2	n	0.019	
Blench:	rock diameter > 2 - 3 x bed material D100				
Miles:	rock diameter > 25 x bed material D50				

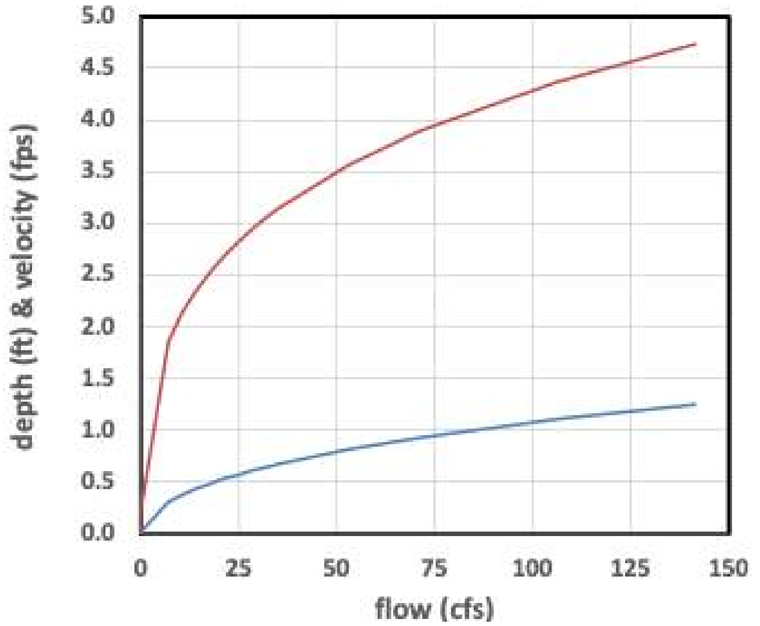
At-a-section Hydraulics

- NLF Section Hydraulics:

Bottom Width	3.0	m	9.8	ft
Side Slopes	4.0	H:1V	4.0	H:1V
Bank Height	1.00	m	3.281	ft
Depth	0.00	m	0.0	ft
Mannings n	0.080		0.08	
Slope	5.0%		5.0%	
Discharge	0.00	m^3/s	0.0	cfs

- look at flows and velocities to see where structure is required



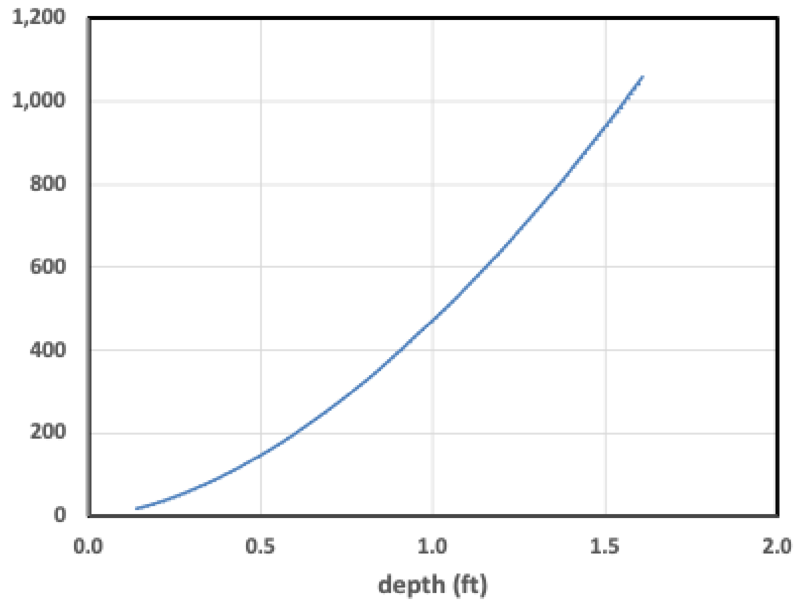


At-a-section Hydraulics

- River Section Hydraulics:

Bottom Width	40.0	m	131.2	ft
Side Slopes	2.0	H:1V	2.0	H:1V
Bank Height	2.00	m	6.562	ft
Depth	0.04	m	0.1	ft
Mannings n	0.030		0.03	
Slope	0.5%		0.5%	
Discharge	0.50	m^3/s	17.7	cfs

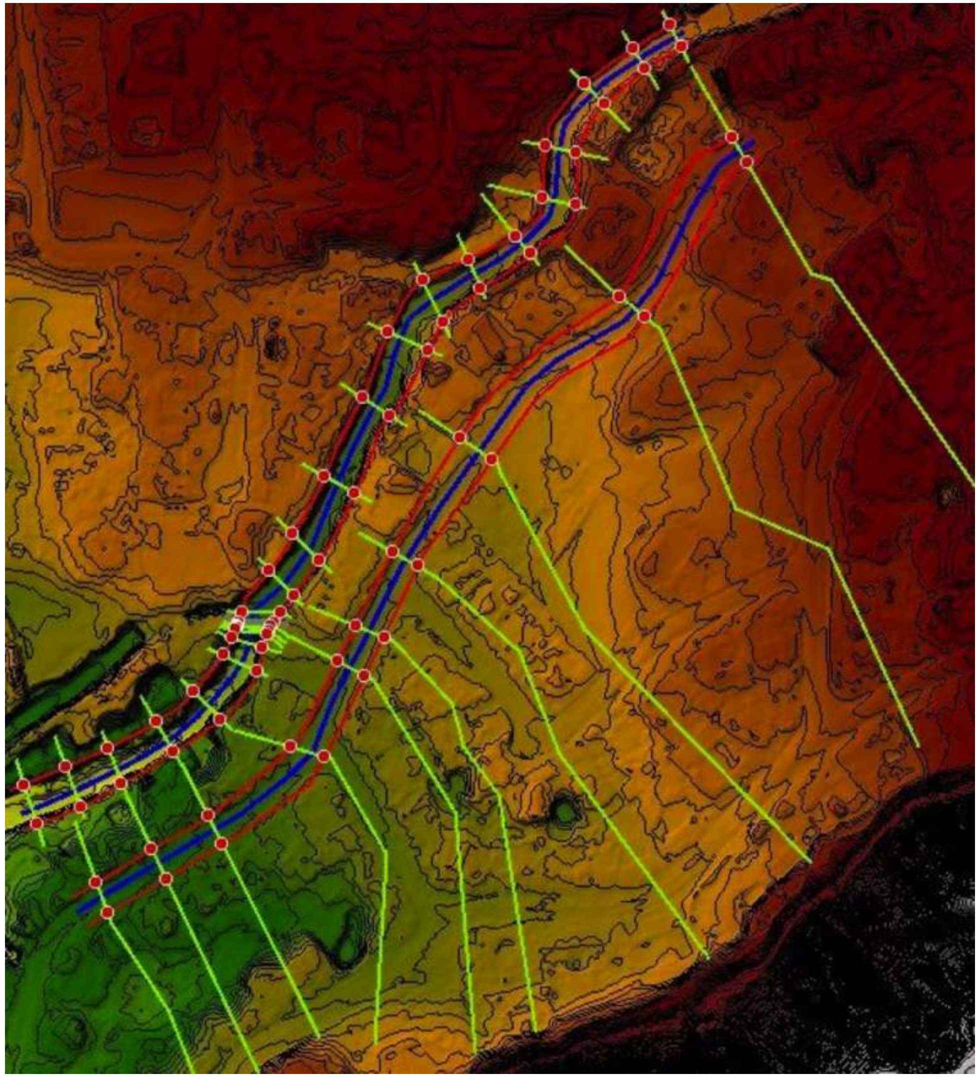
- can compare rating curves and check design invert elevations for operability and flow splits



Depth (ft)	River (cfs)	NLF (cfs)	% Attraction
0.1	10	1	13%
0.2	31	3	12%
0.3	62	7	13%
0.4	100	12	14%
0.5	146	19	15%
0.6	199	28	16%
0.7	258	38	17%
0.8	324	51	19%
0.9	395	67	20%
1.0	**471**	**85**	**22%**
2.0	**1518**	**451**	**42%**
3.0	**3008**	**1285**	**75%**

Hydraulic Analysis and Simulations
1D Modeling

- 1D Hydraulic Models (HEC-RAS, SRH-1D, etc.) used in sediment transport modelling
- 1D is very dependent of section lay-out and assumption at bifurcations and controls
- similar to hydraulic calculators but with momentum and flow conservation
- Provides at-a-section hydraulics and has generally been superseded by 2D modeling

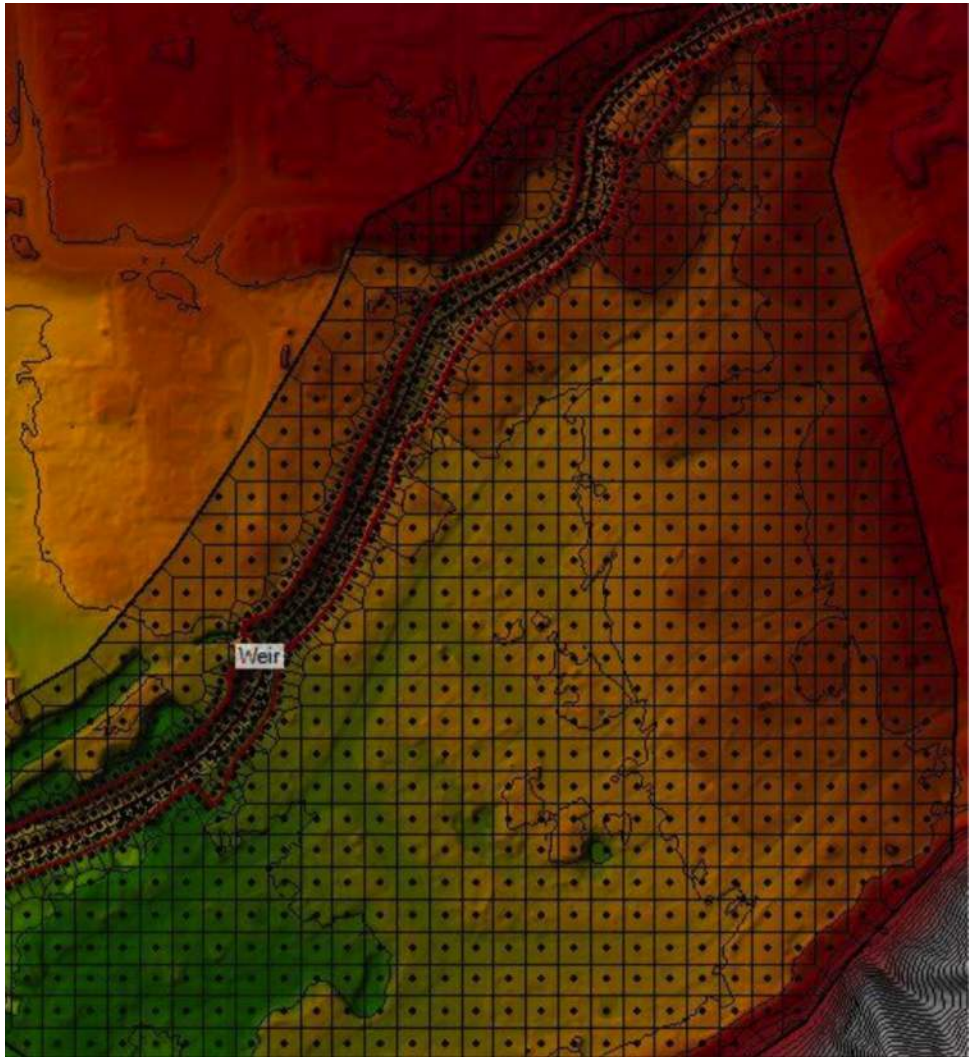


Hydraulic Analysis and Simulations
2D Modeling

- 2D hydraulic modelling (HECRAS, SRH-2D, TELEMAC, River2D, etc.)

Property or Factor	One-Dimensional Modeling	Two-Dimensional Modeling
Flow Direction	Prescribed (streamwise)	Computed
Transverse Velocity and Momentum	Neglected	Computed
Vertical Velocity and Momentum	Neglected	Neglected
Velocity Averaged Over…	Cross Sectional Area	Depth at a Point
Transverse Velocity Distribution	Assumed Proportional to Conveyance	Computed
Transverse Variations in Water Surface	Neglected	Computed
Vertical Variations	Neglected	Neglected
Unsteady Flow Routing	Can Be Included	Can Be Included

- detailed at a point hydraulics can be resolved – ideal for NLF design and assessment

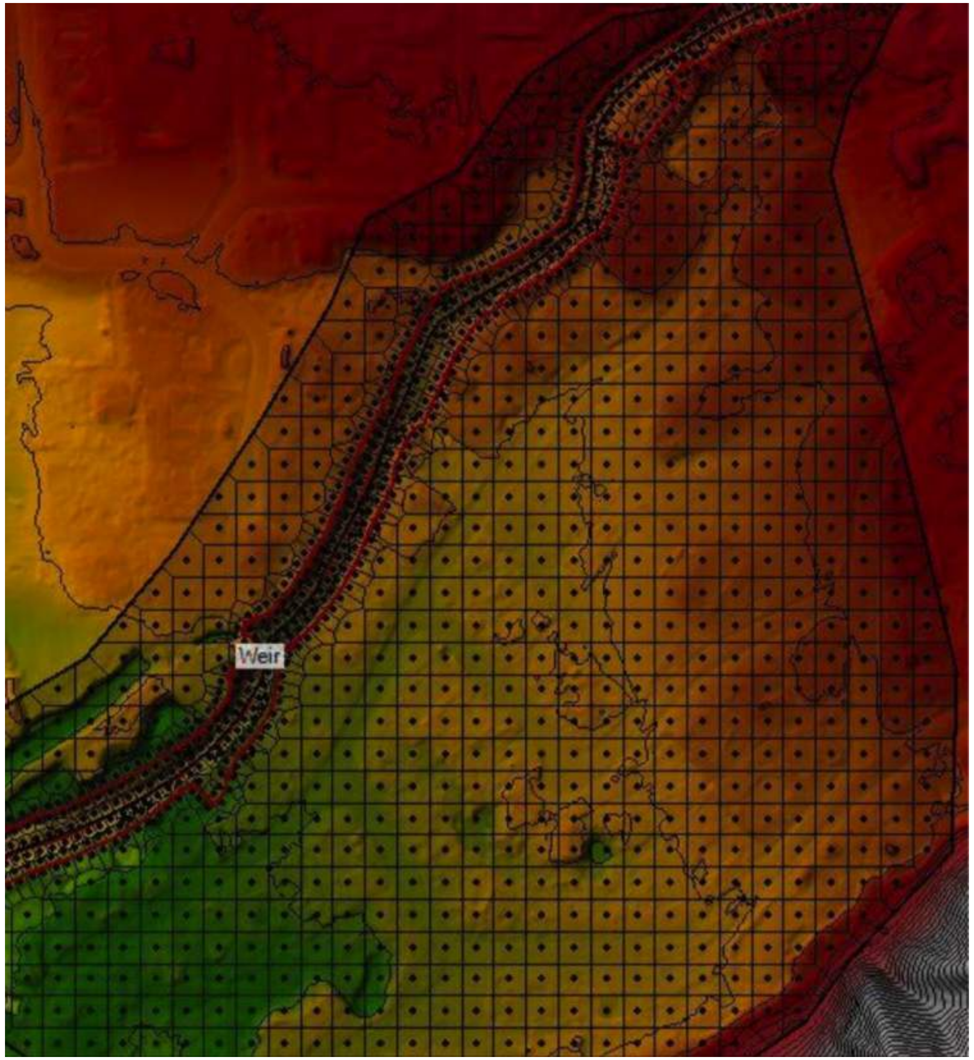


Hydraulic Analysis and Simulations 2D Modeling

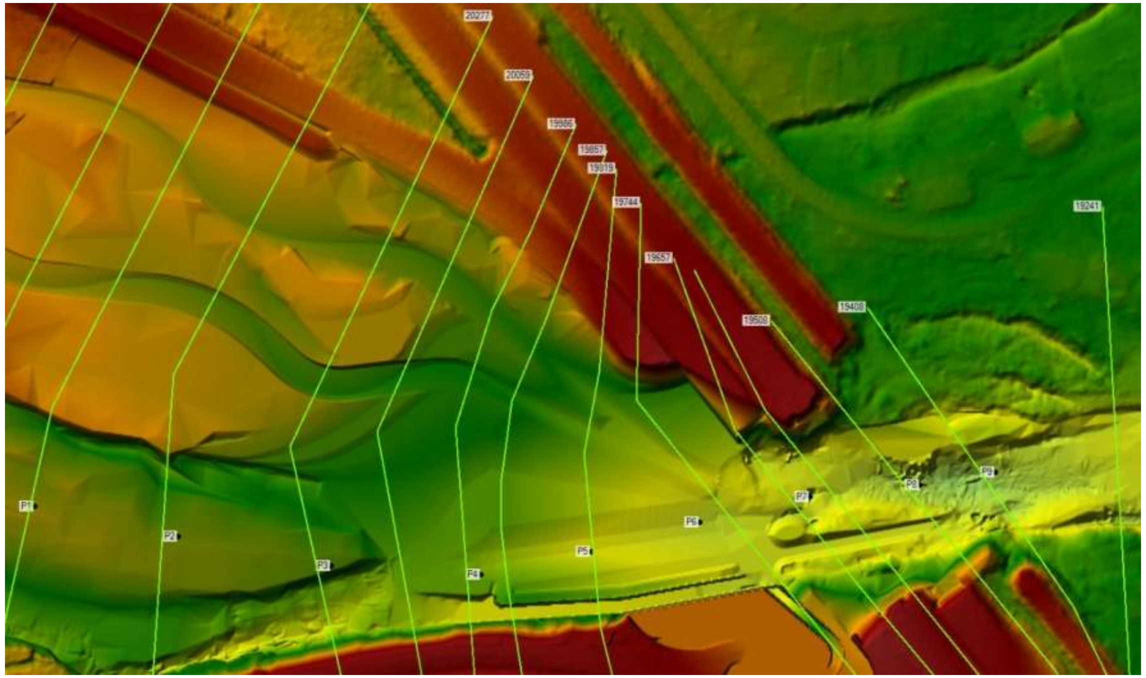
- 2D hydraulic modelling (HECRAS, SRH-2D, TELEMAC, River2D, etc.)

Property or Factor	One-Dimensional Modeling	Two-Dimensional Modeling
Flow Direction	Prescribed (streamwise)	Computed
Transverse Velocity and Momentum	Neglected	Computed
Vertical Velocity and Momentum	Neglected	Neglected
Velocity Averaged Over…	Cross Sectional Area	Depth at a Point
Transverse Velocity Distribution	Assumed Proportional to Conveyance	Computed
Transverse Variations in Water Surface	Neglected	Computed
Vertical Variations	Neglected	Neglected
Unsteady Flow Routing	Can Be Included	Can Be Included

- detailed at a point hydraulics can be resolved – ideal for NLF design and assessment

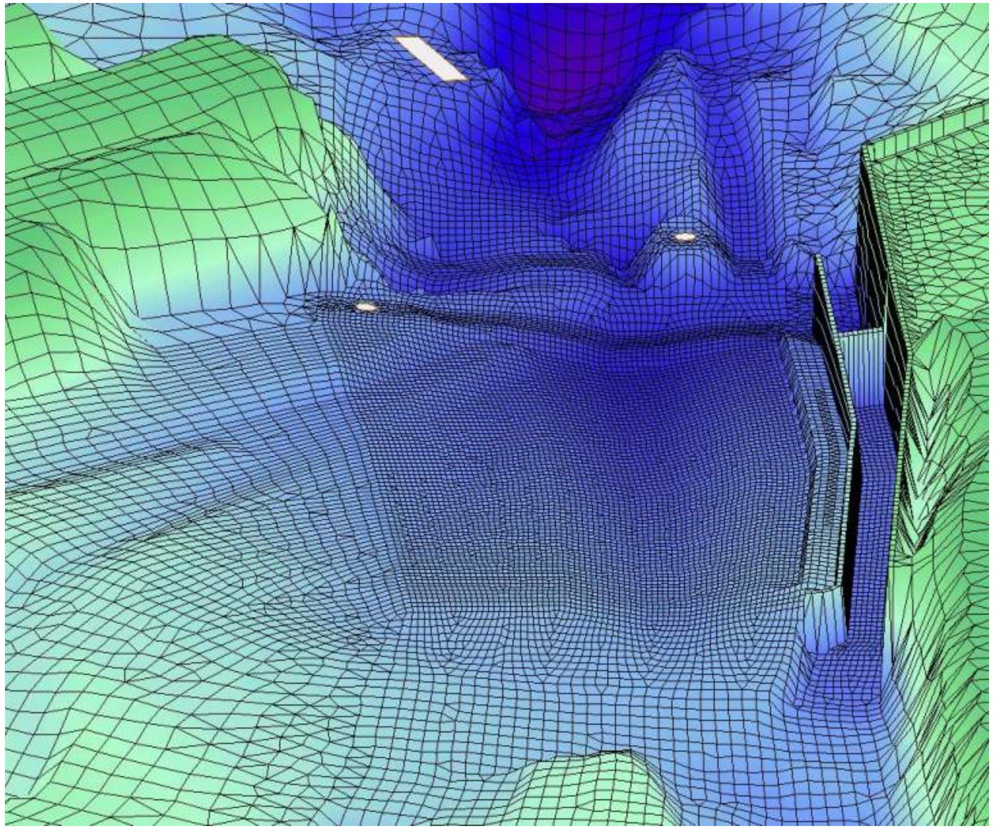


1D FEMA - Nelson Dam



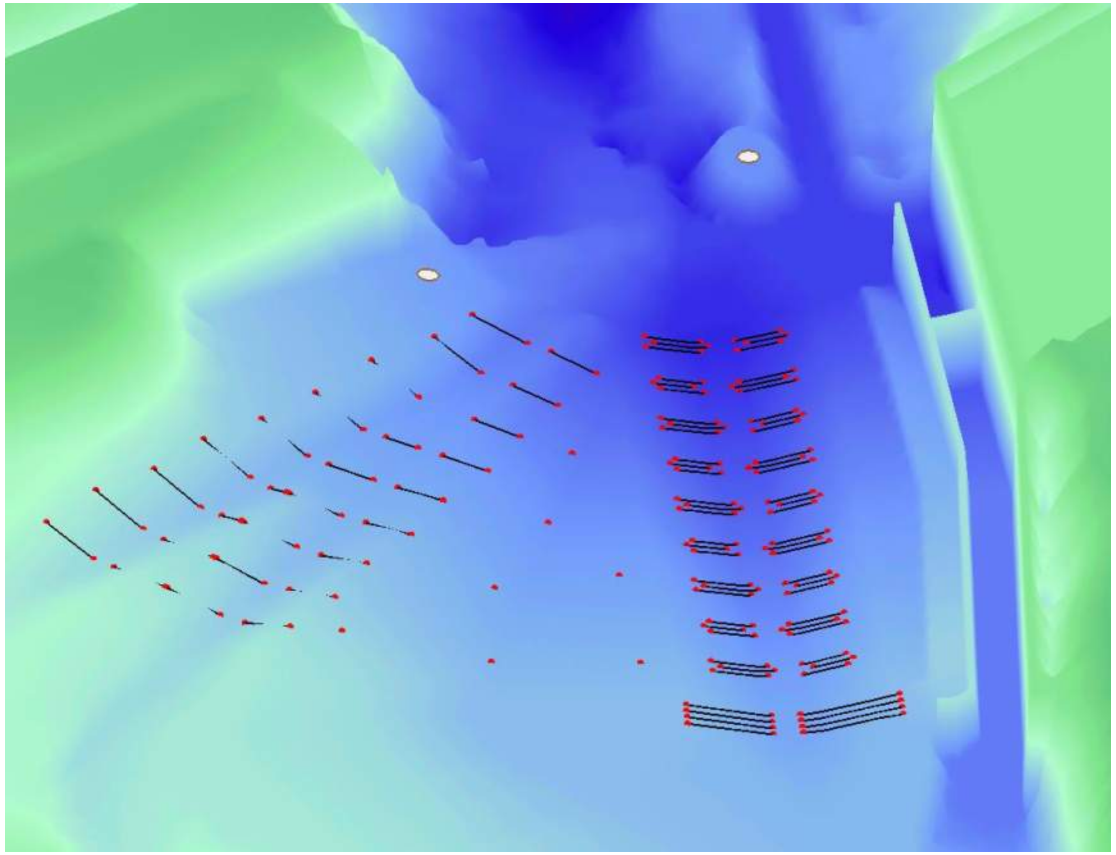
1D limitations? Not going to cut the mustard for fish…

SRH-2D - Nelson Dam

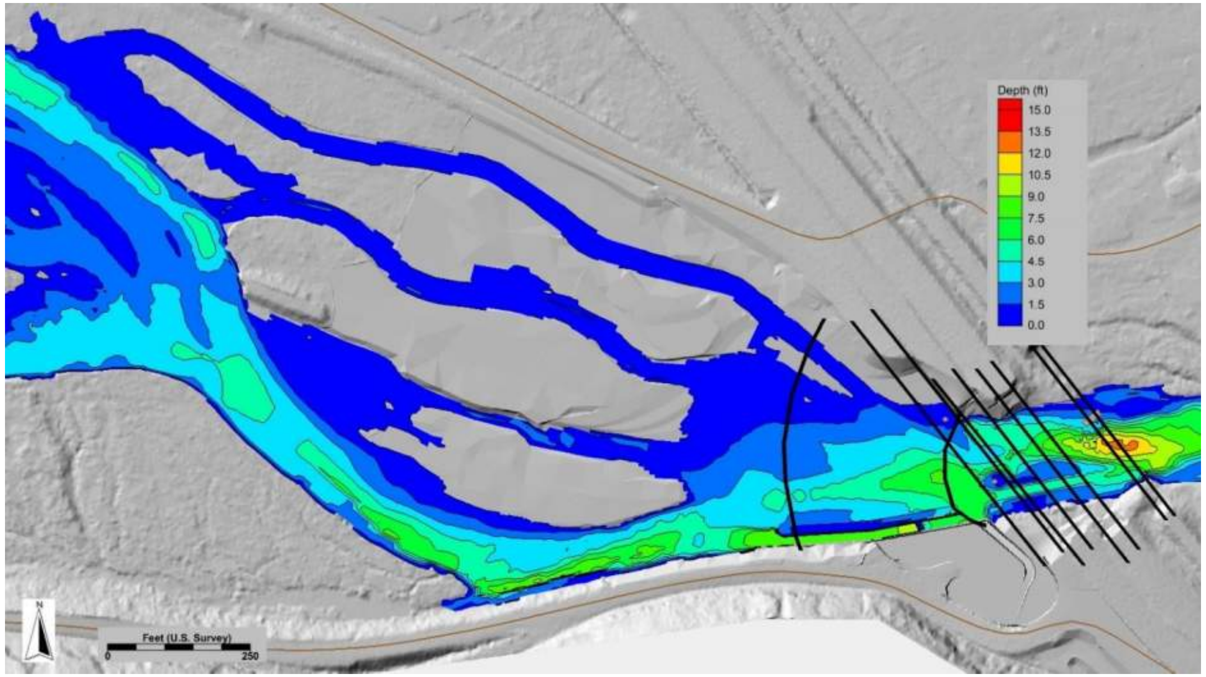


Converging flows, contraction and acceleration?

SRH-2D - Nelson Dam



Roughness Representation

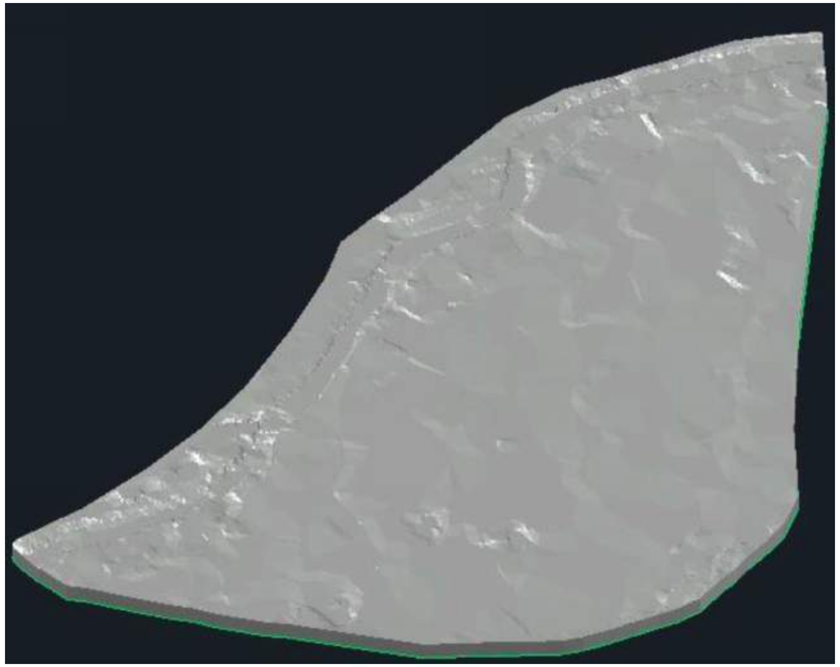


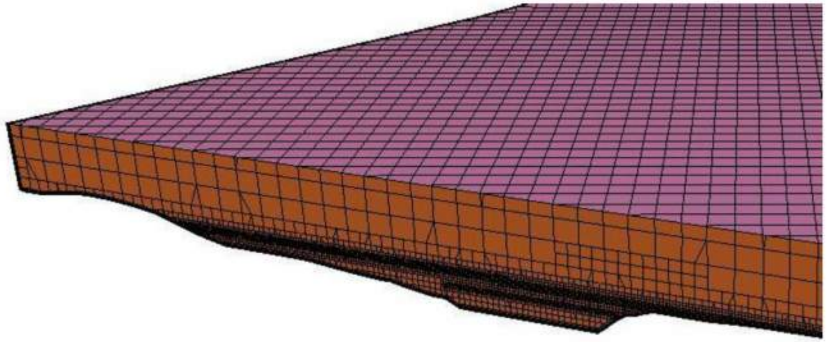
Floodplain Activation

Hydraulic Analysis and Simulations 3D / CFD Modeling

- 3D and CFD models are becoming more commonplace (Delf 3D, Flow-3D, Fluent, openFOAM, TELEMAC 3D)
- 2D surfaces become 3D volumes
- computational meshing and volumes should be scaled appropriately:

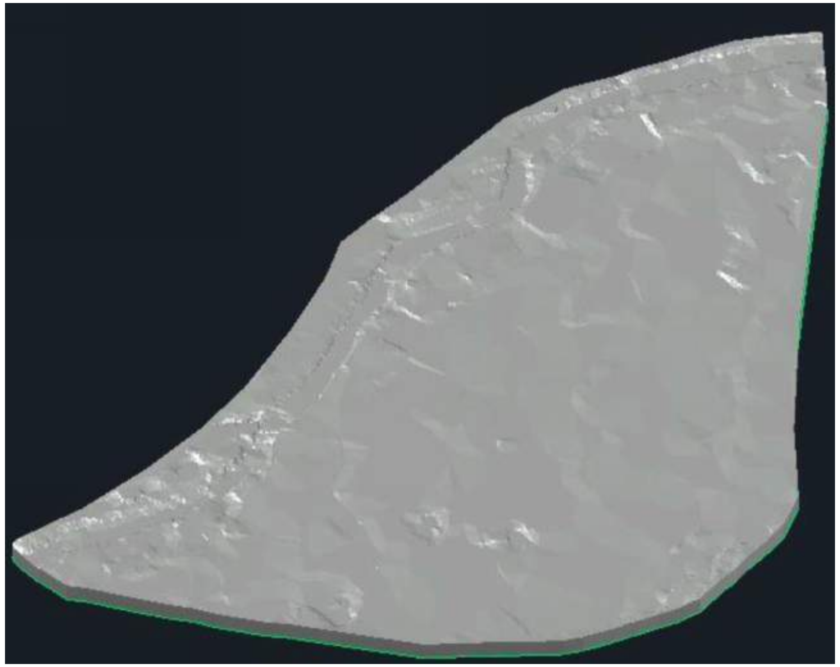
1. scale to the fish scale!
2. scale to the level of model resolution required (e.g. minimum required to derive the correct results in the solver for the application)

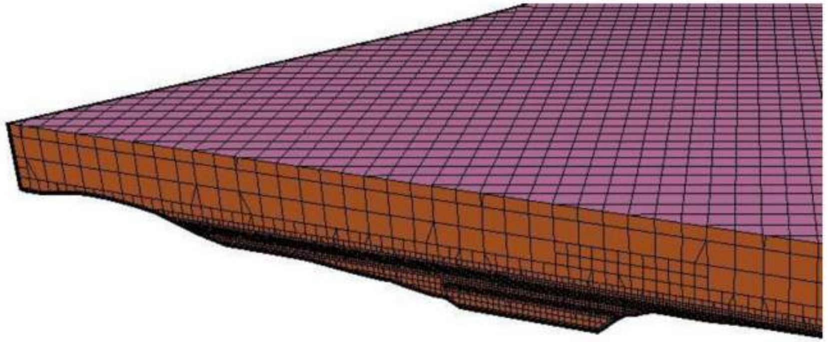




Hydraulic Analysis and Simulations 3D / CFD Modeling

- 3D and CFD models are becoming more commonplace (Delf 3D, Flow-3D, Fluent, openFOAM)
- tend to be data intensive and require post processing to digest the results
- Each CFD model has strengths and weaknesses that have to be assessed against the design objectives:
  - data needs and model assembly
  - solver type
  - computation effort





Hydraulic Analysis and Simulations
3D / CFD Modeling

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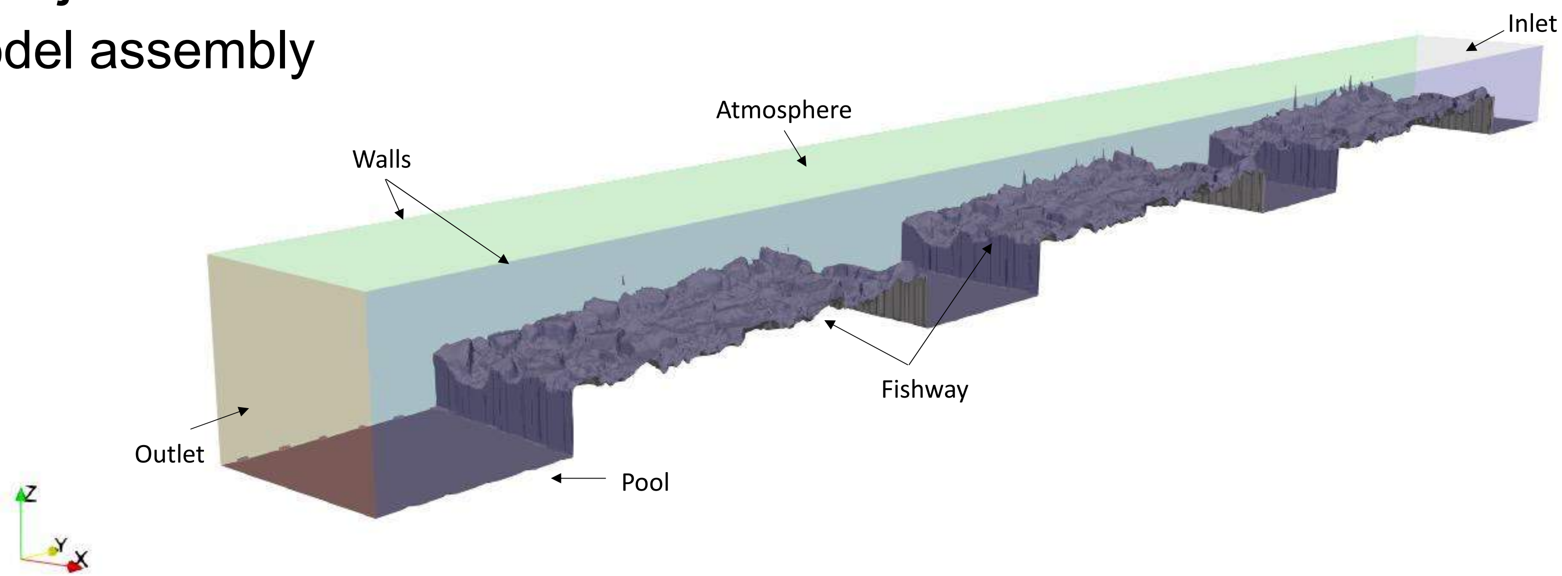
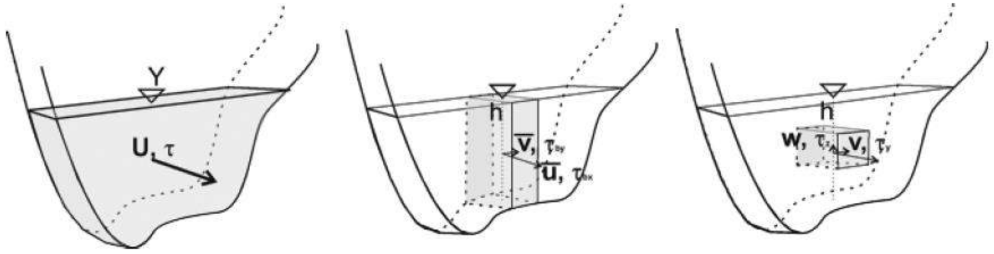
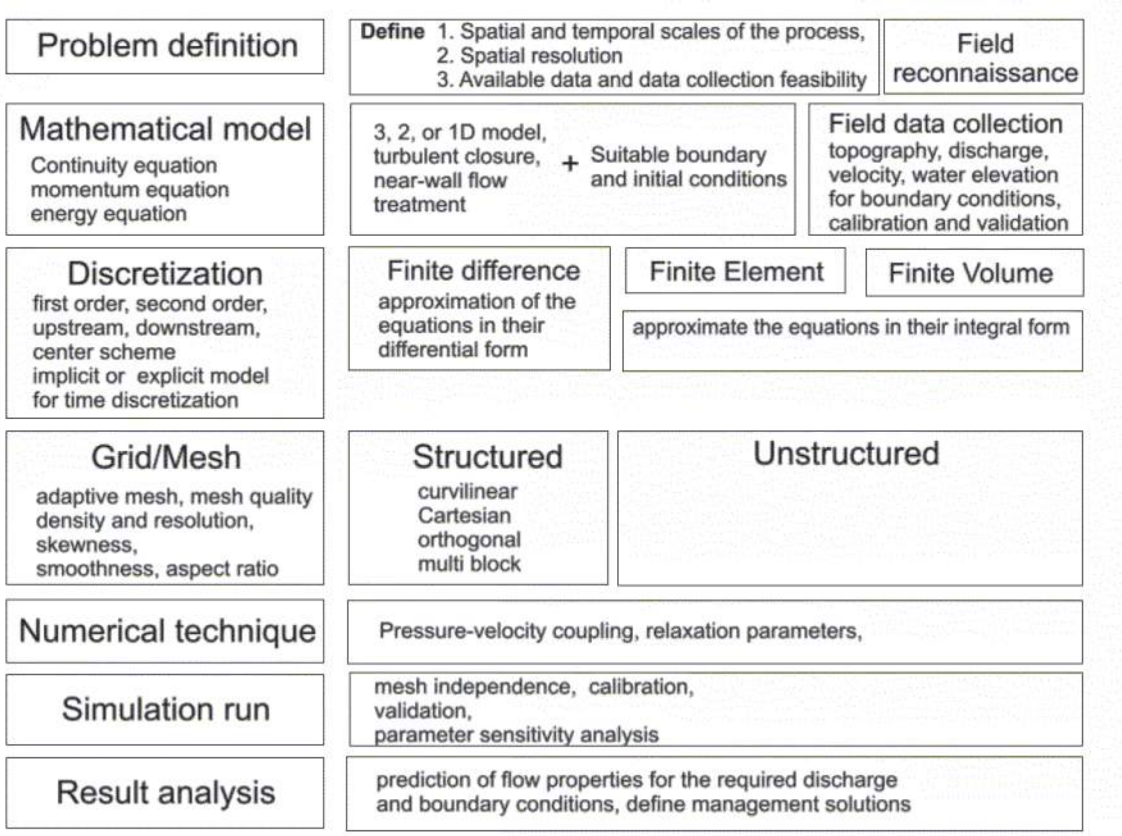


Hydraulic Analysis and Simulations
Spectrum of Numerical Modeling for NLF Design

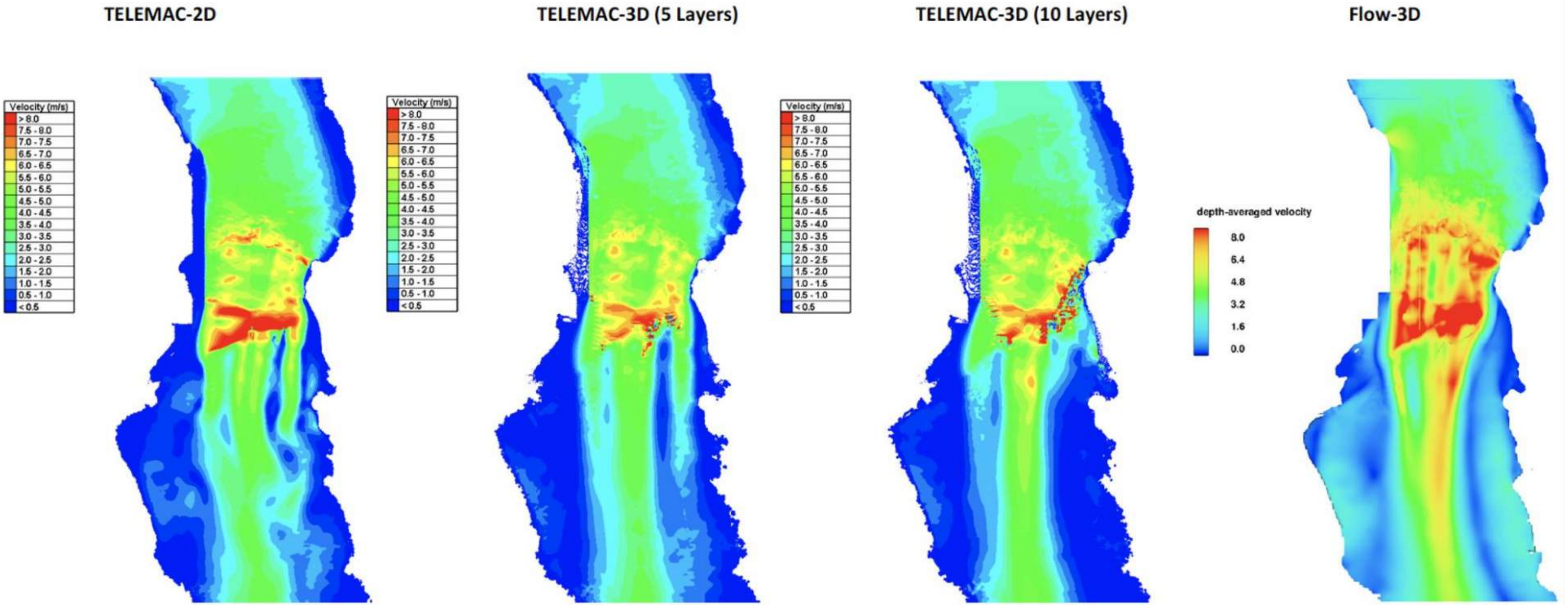


- ecohydraulic perspective is important for assessing fish passage
- hydraulic perspective is critical for NLF channel design, structure and roughness
- 2D modeling tends to satisfy both

meanwhile, behind the scene….



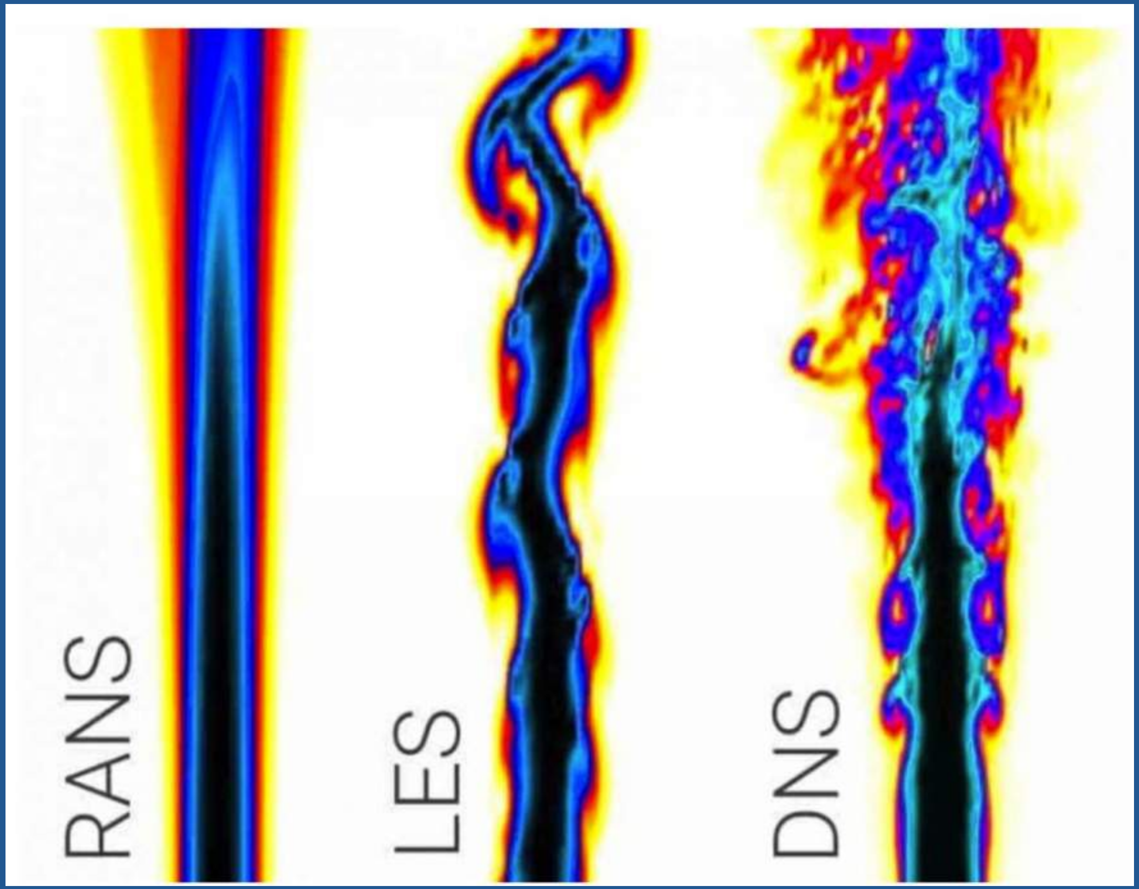
Influence of Numerical Solvers on Results



Influence of Numerical Solver on Results

- Solver effort related to how accurately the numerical solutions resolve turbulence
- More conservative solutions require more solver computation in 2D and CFD

CFD Solvers



Hydraulic Analysis and Simulations Physical Modeling

- Project Complexity
- High risk/uncertainty
- Communications
- Evaluate “what-if” and future scenarios rapidly
- Cost of model vs. savings to overall project
- Best approach is often a hybrid numerical/physical model

Hydraulic Analysis and Simulations Physical Modeling – sediment transport

- Scaled mobile bed physical modeling is relevant where sediment transport factors into the project success or failure
- Model type include comprehensive small-scale models and large-scale section models

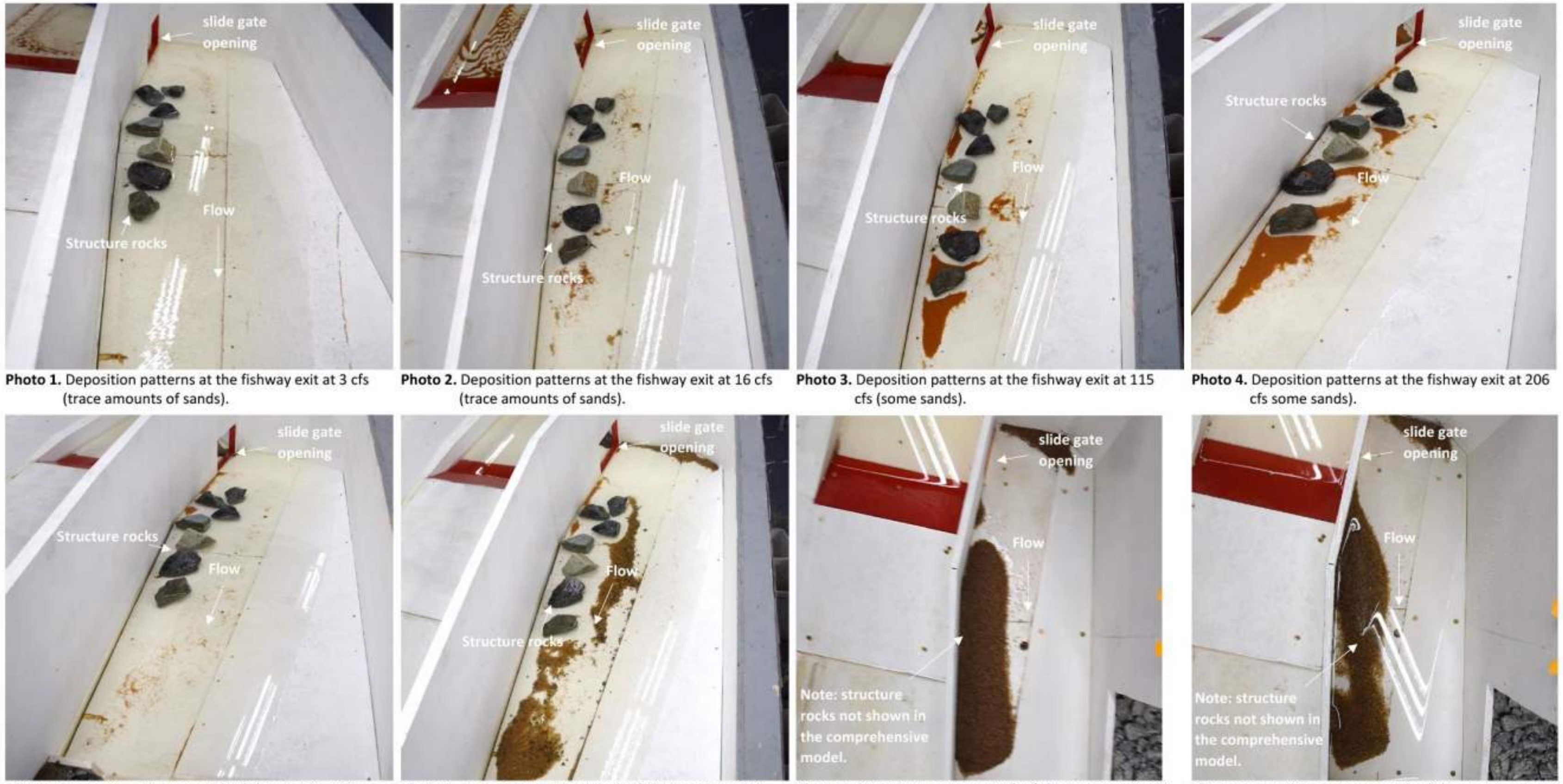


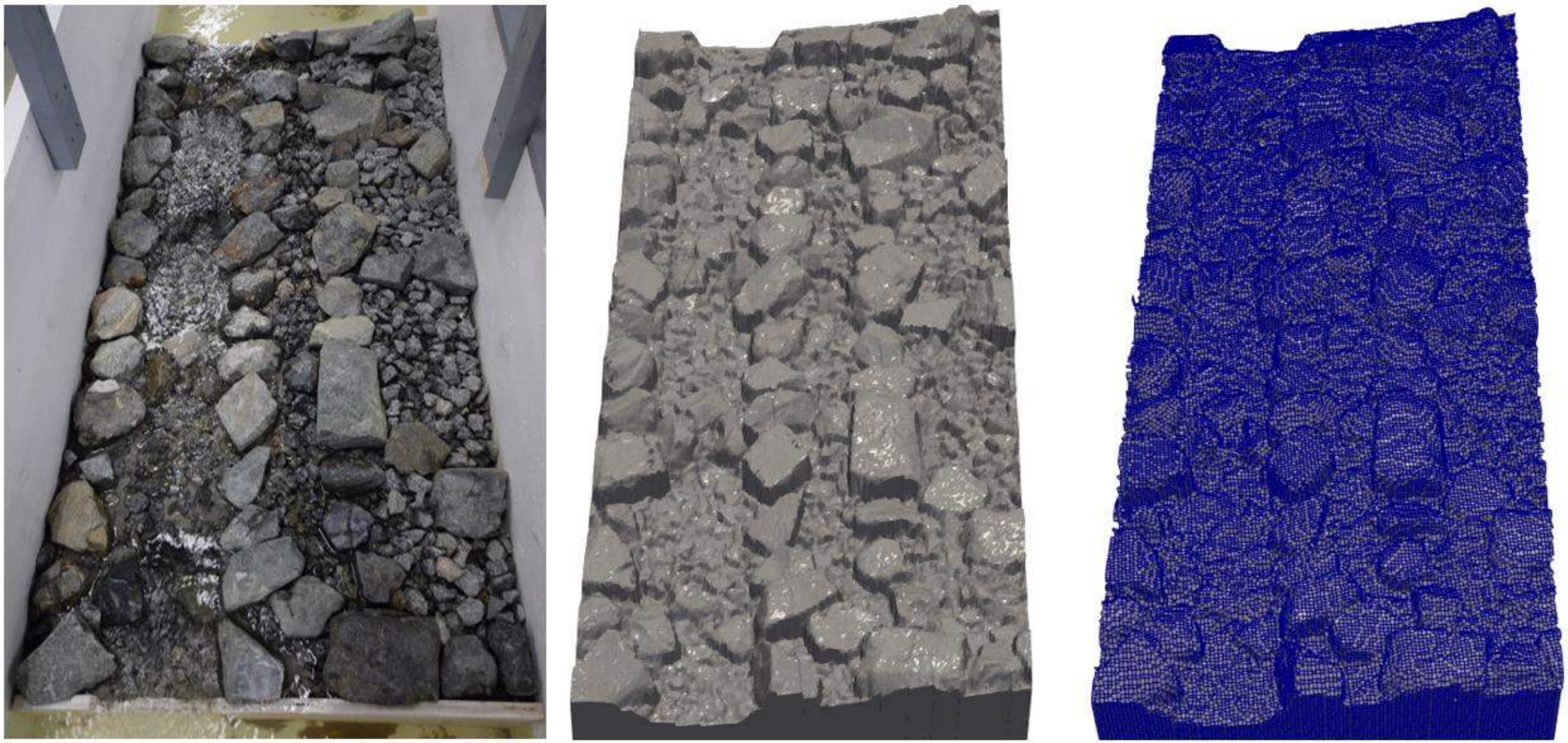
Photo 1. Deposition patterns at the fishway exit at 3 cfs (trace amounts of sands).
Photo 2. Deposition patterns at the fishway exit at 16 cfs (trace amounts of sands).
Photo 3. Deposition patterns at the fishway exit at 115 cfs (some sands).
Photo 4. Deposition patterns at the fishway exit at 206 cfs some sands).
Photo 5. Deposition patterns at the fishway exit at 425 cfs (trace amounts of fine gravels).
Photo 6. Deposition patterns at the fishway exit at 850 cfs (fine gravels with some coarse gravels).
Photo 7. Deposition patterns at the fishway exit at 3,400 cfs (coarse gravels).
Photo 8. Deposition patterns at the fishway exit at 8,500 cfs (coarse gravels).

Hydraulic Analysis and Simulations
Physical Modeling – sedimentation and debris

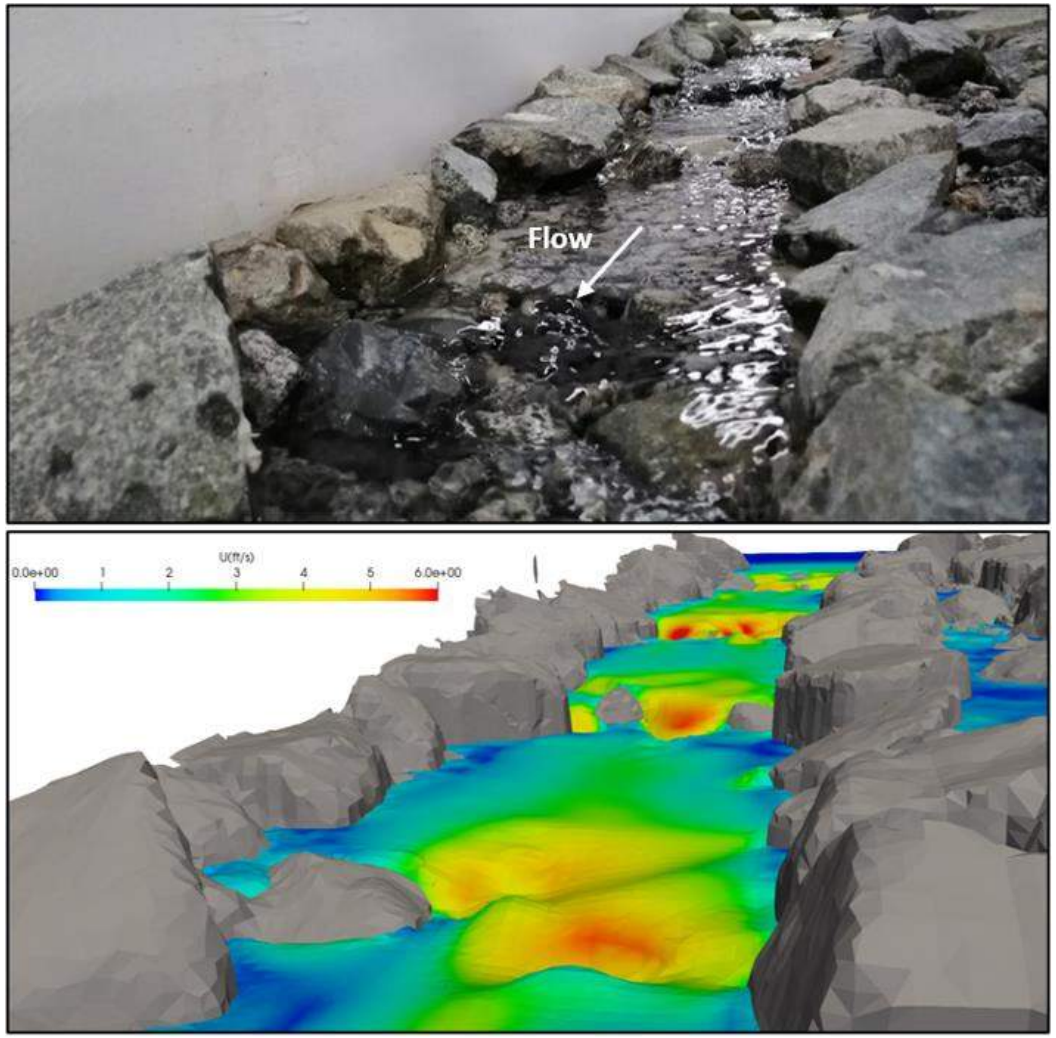
- Physical modeling with scaled sediment allows assessment of sedimentation

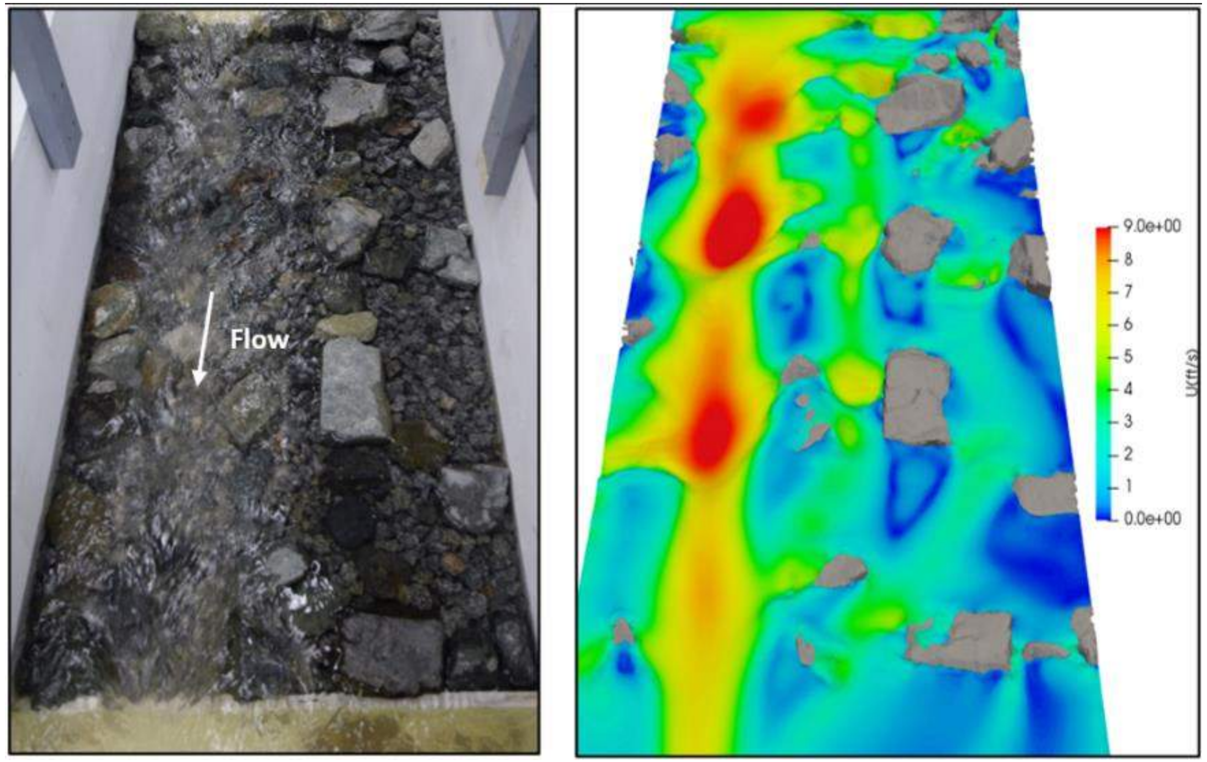
- Interactions with debris and blockages can be assessed to fish passage and hydraulics

Hydraulic Analysis and Simulations
Integrated CFD / Physical Modeling

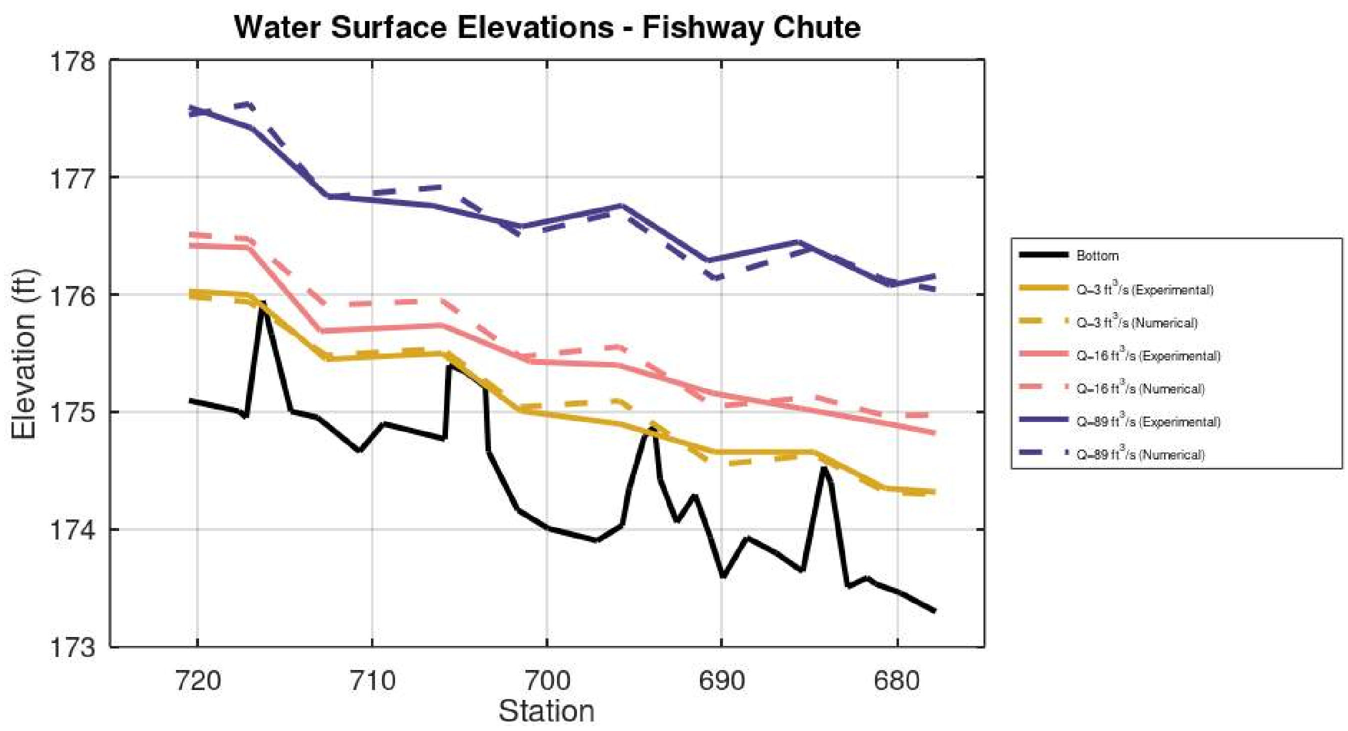


Hydraulic Analysis and Simulations
Integrated CFD / Physical Modeling





Hydraulic Analysis and Simulations
Integrated CFD / Physical Modeling

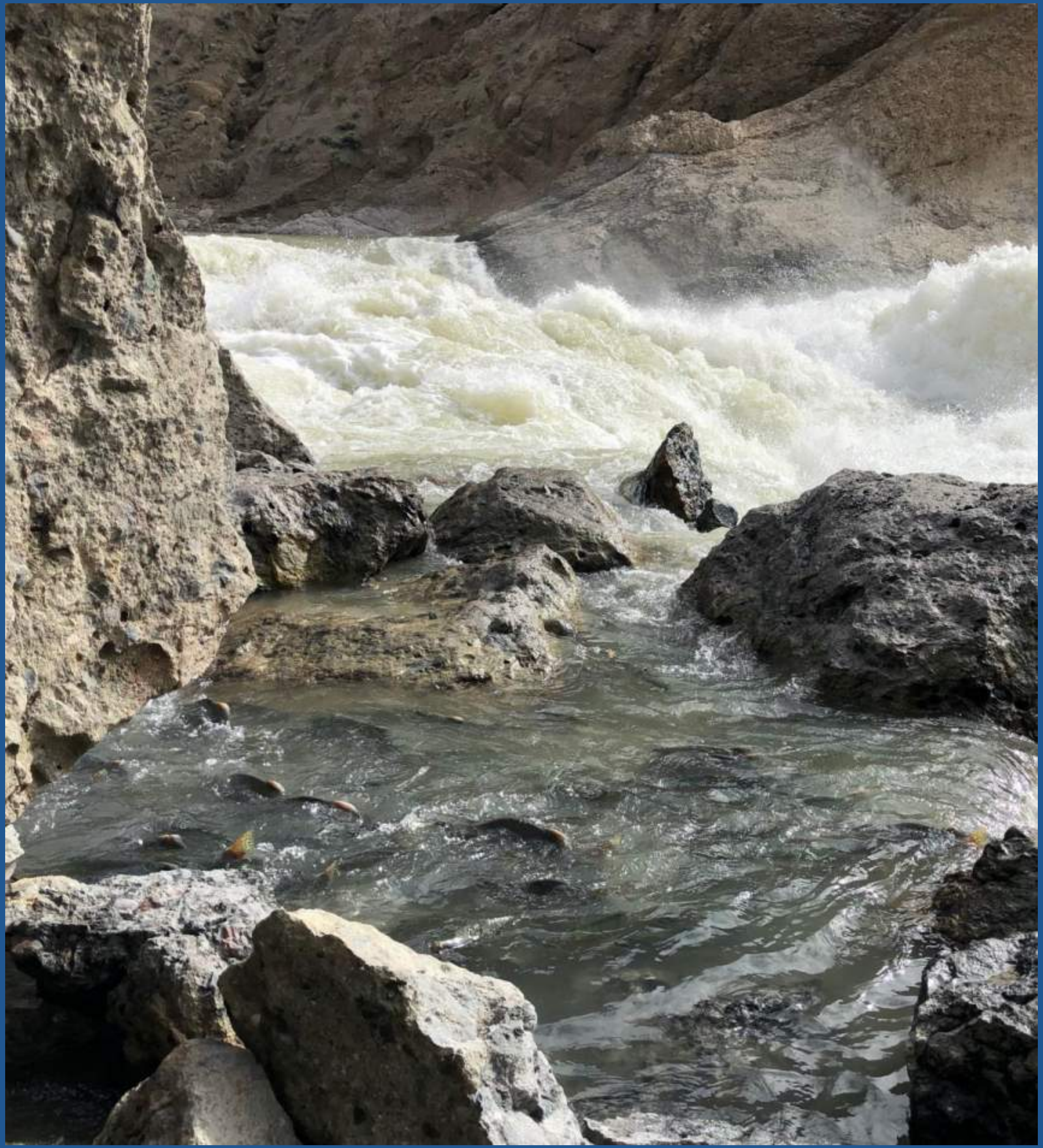


Fishway Flow (cfs)	Location	Physical Model		Numerical model (OpenFOAM)	
		Depth (ft)	Velocity (ft/s)	Depth (ft)	Velocity (ft/s)
3	1	1.0	2.8	1.0	1.2
	2	0.9	3.2	0.8	1.6
	3	0.8	1.9	1.1	1.8
	4	0.9	2.0	0.8	3.8
	5	1.0	2.7	1.2	2.9
	Average	0.9	2.5	1.0	2.2
16	1	1.5	3.4	1.5	2.0
	2	1.1	4.2	1.1	4.6
	3	1.2	4.3	1.6	3.9
	4	1.4	4.0	1.3	5.7
	5	1.7	4.0	1.9	2.5
	Average	1.4	4.0	1.5	3.7
64	1	2.3	4.2	2.3	3.6
	2	2	5.7	1.8	5.3
	3	2.3	6.3	2.5	6.4
	4	2.2	8.0	2.3	7.1
	5	2.6	5.9	2.7	6.2
	Average	2.3	6.0	2.3	5.7
74	1	2.3	4.3	2.4	4.0
	2	2	4.9	1.9	5.9
	3	2.2	6.5	2.6	6.7
	4	2.4	5.8	2.4	7.3
	5	2.6	5.9	2.9	6.3
	Average	2.3	5.5	2.4	6.0
89	1	2.7	4.1	2.6	4.7
	2	2.2	7.0	2.0	6.7
	3	2.4	7.1	2.7	7.5
	4	2.4	9.4	2.5	8.1
	5	2.8	9.1	3.0	6.9
	Average	2.5	7.3	2.5	6.8
119	1	2.8	6.8	2.8	5.4
	2	2	9.0	2.2	7.7
	3	2.5	8.1	2.8	8.5
	4	2.8	8.9	2.6	9.3
	5	2.7	9.2	3.1	7.9
	Average	2.6	8.4	2.7	7.8

How do we interpret model results to assess effective passage or effctively assess passage?

- CFD and 2D modeling generates enormous amounts of data but how do we use them to assess volitional fish movement?

1. Filtering and Blanking:
   HEC RAS 2D and most GUI programs can filter and scale output within the program to help identify area of depth-averaged passage velocities and depths
2. Scripting:
   Python and ArcGIS can be used to post-process CFD output data to render heatmaps and volumes of passage in 3D
3. IBM / ABM:
   Individual or Agent-based models can process steady-state datasets to examine likelihood of passage

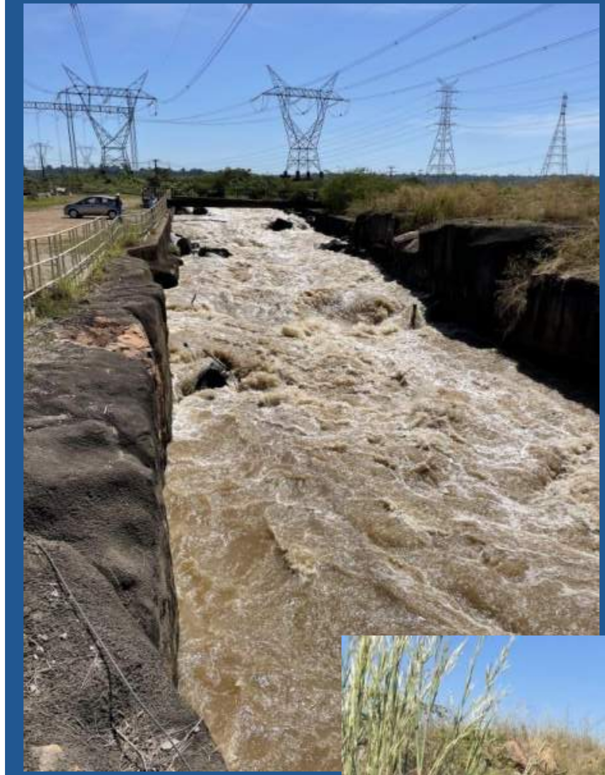


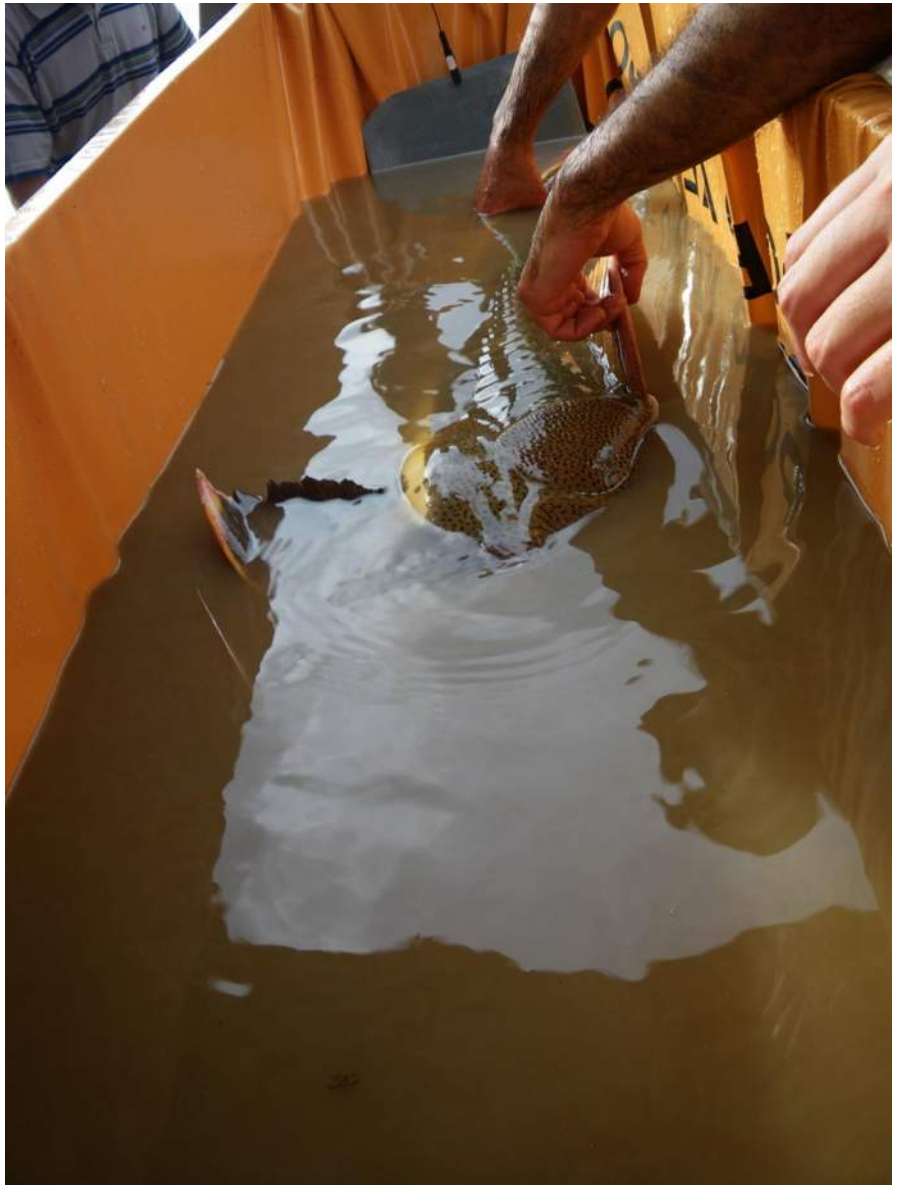
Emerging Trends

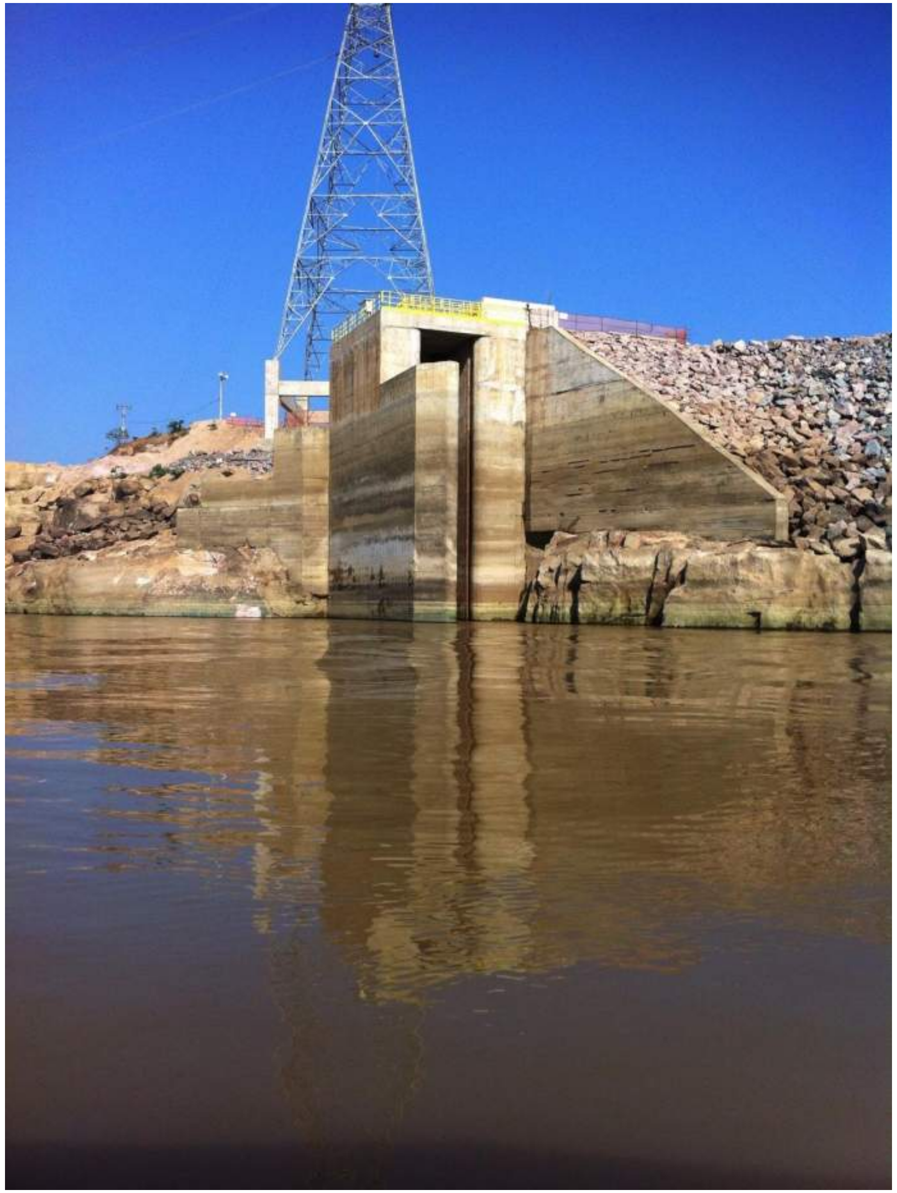
- EDF replacement?
- CFD fish-related parameters:
  - TKE
  - TI
  - Reynolds Shear
  - Vorticity
- Reality or Rabbit Hole?
- Can biology and fisheries sciences keep up with computational and data sciences?

Post-Processing Numerical Model Results
What are we looking for…

- Fighting salmo-centricty!
- Longitudinal hydraulic connectivity
- Multiple opportunities for passage
- Mult-species passage
- Energetics and passage probability
- Testing lines of reasoning to develop weight of evidence approaches to proving volitional passage for fish

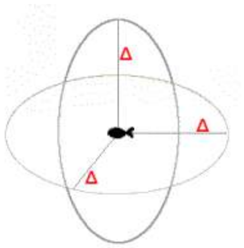


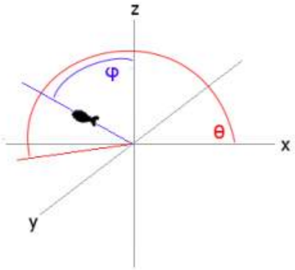


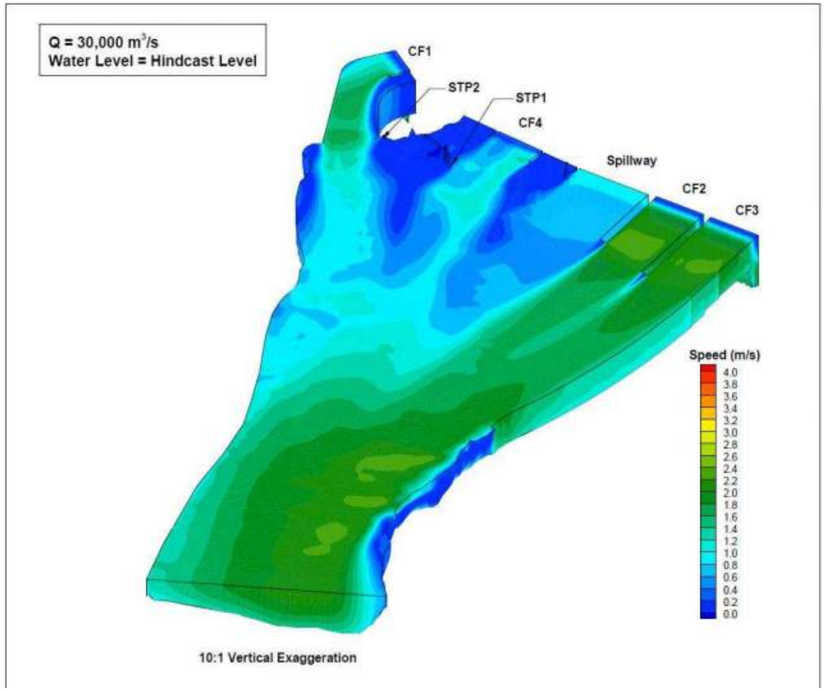


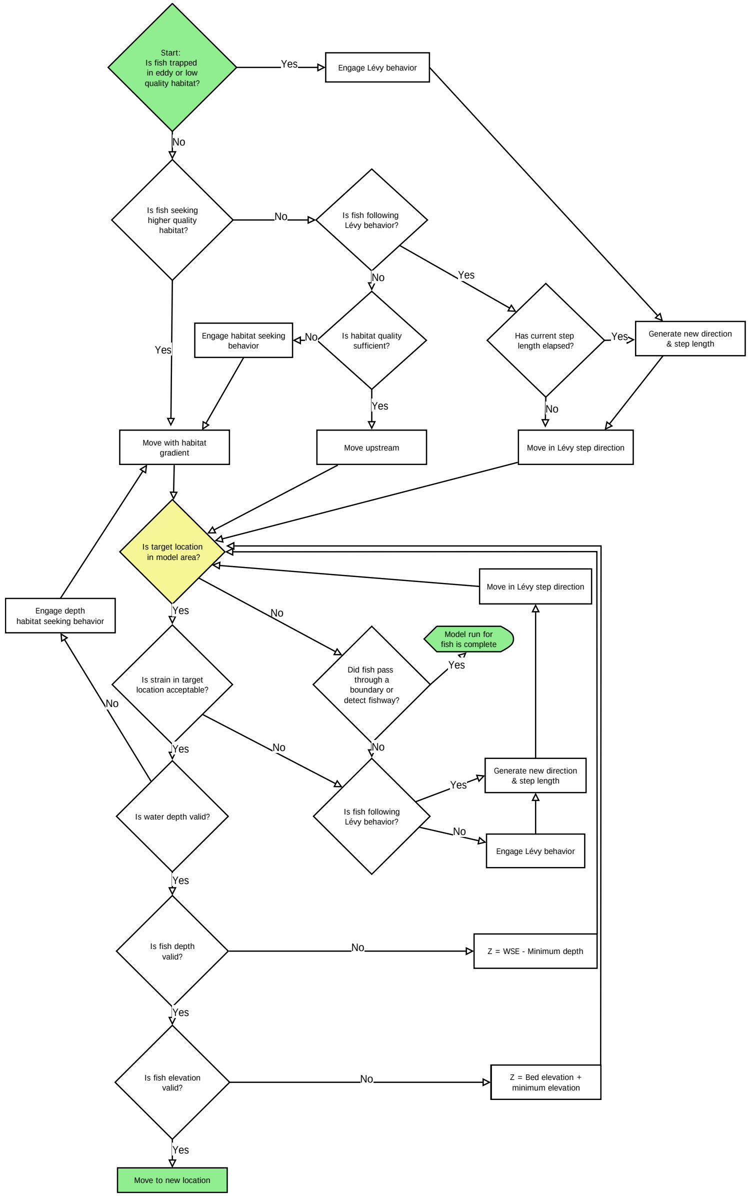
Agent-based Models

Parameter	Value	Unit
Fishway Detection Radius	5.0	m
Swim Speed	3.0	ms^{-1}
Max Time For Consecutive Upstream Movement	1.0	hr
Max Distance for Consecutive Upstream Movement	5.0	km
Minimum Depth	1.0	m
Strain Tolerance	10.0	s^{-1}
Habitat Seeking Behavior Duration	10-20	s
Initial z Position	40-80	% depth
Minimum Water Depth	1.0	m
Minimum Fish Depth	0.25	m
Minimum Fish Elevation	0.25	m
Sensory Radius	1.00	m

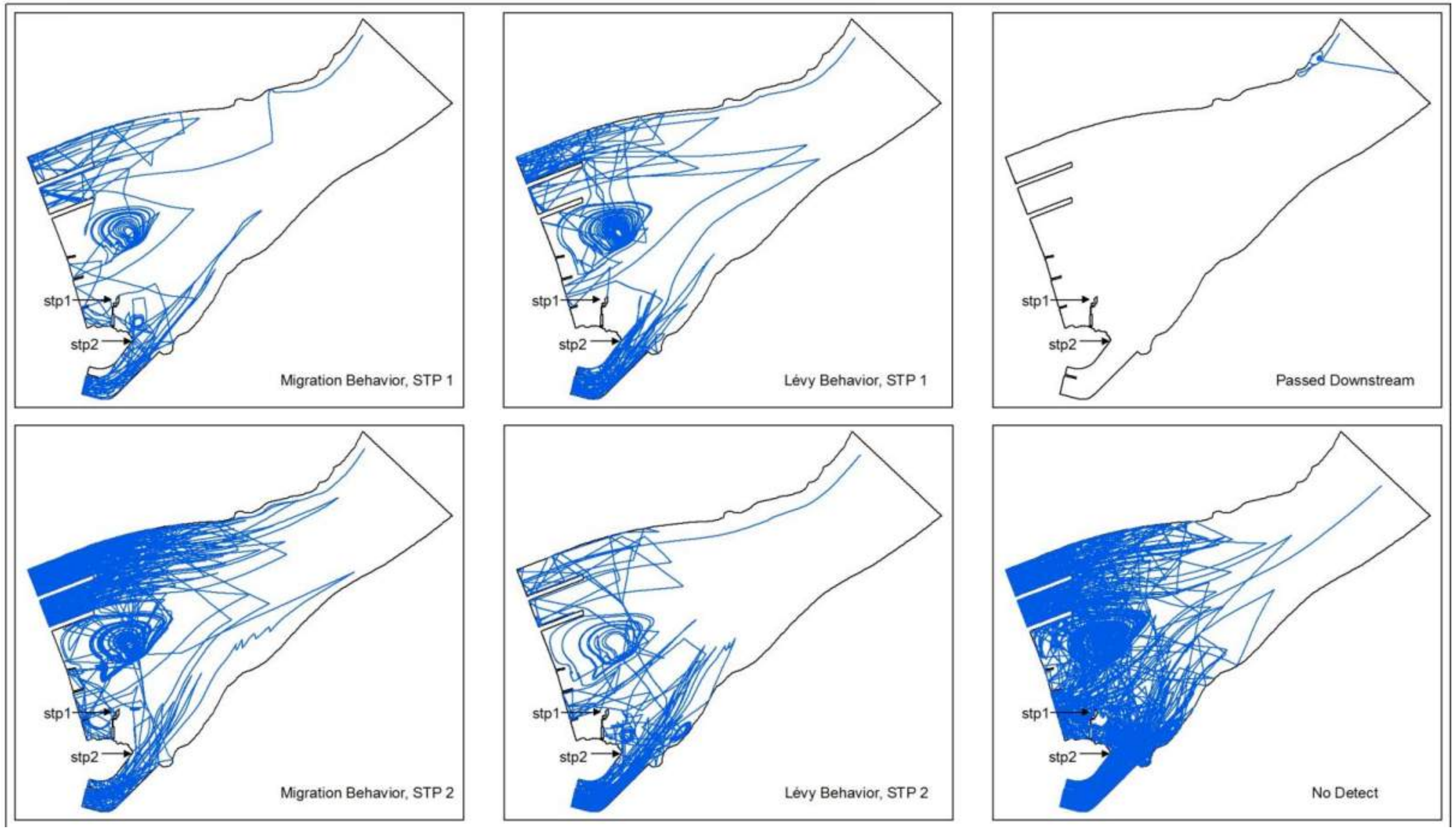


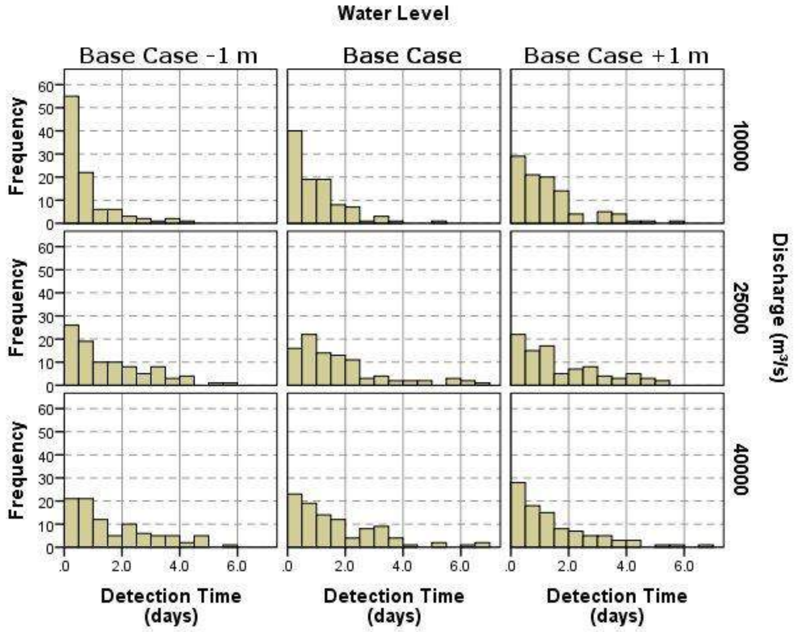




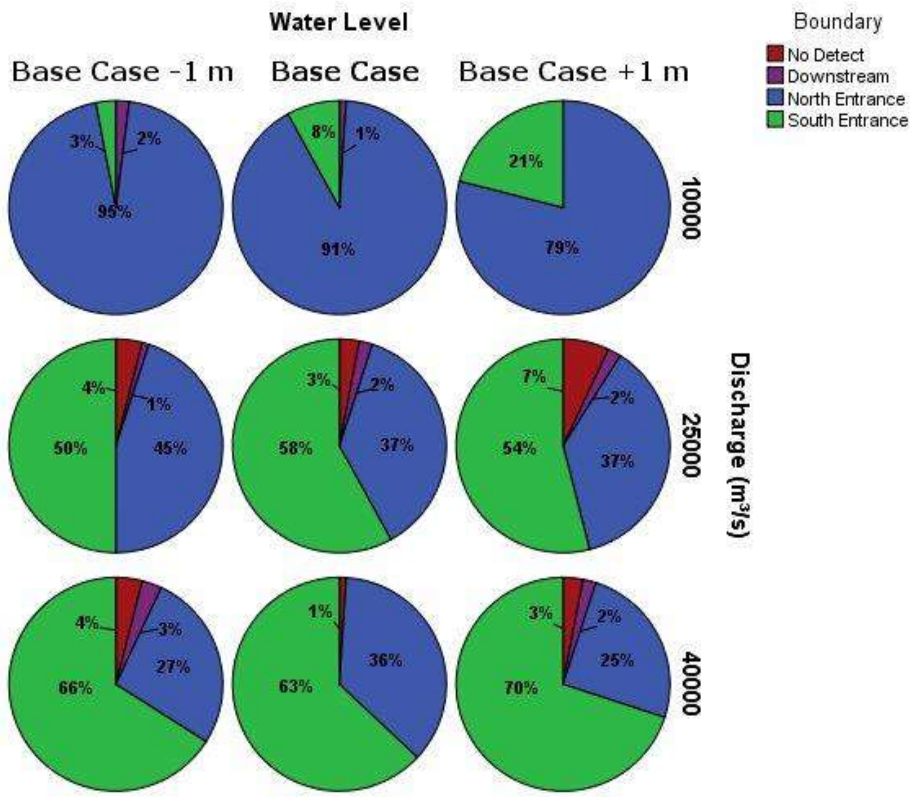


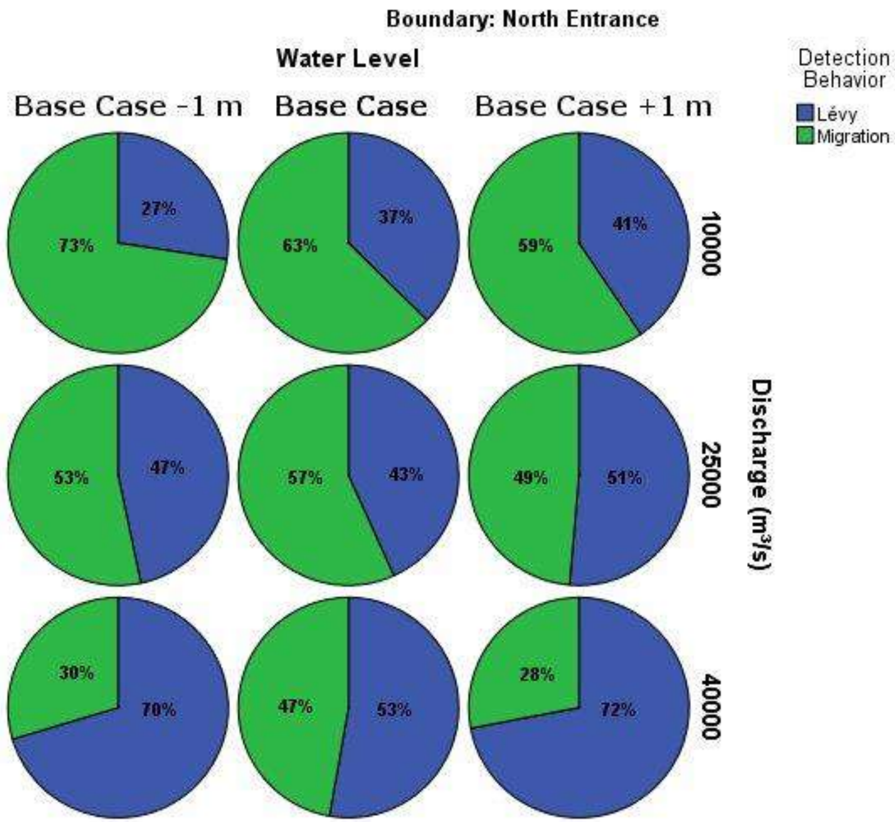
Agent-based Models





Agent-based Models
Proaility of Fishway detection and Non-passage



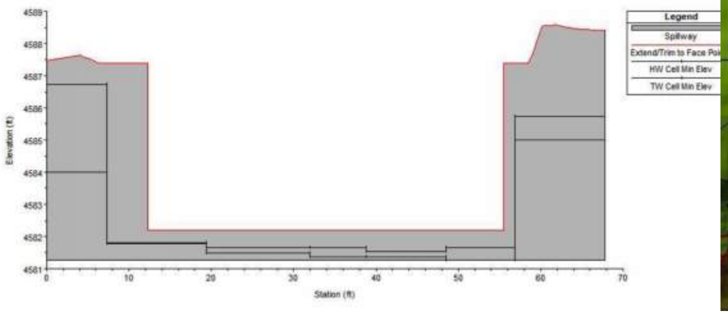


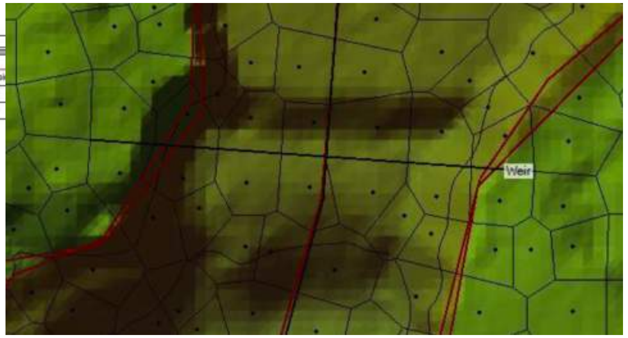
Hydraulic Analysis and Simulations Representing Reality

Reality:

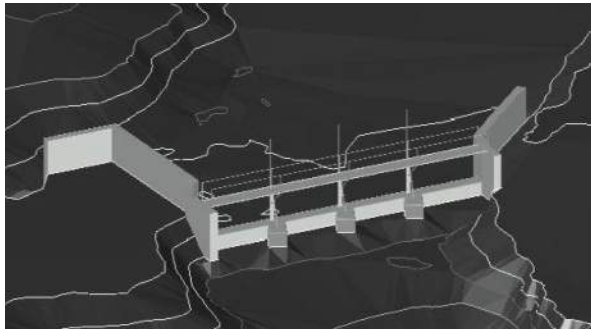
1D: $Q = CLH^{\frac{3}{2}}$

2D:

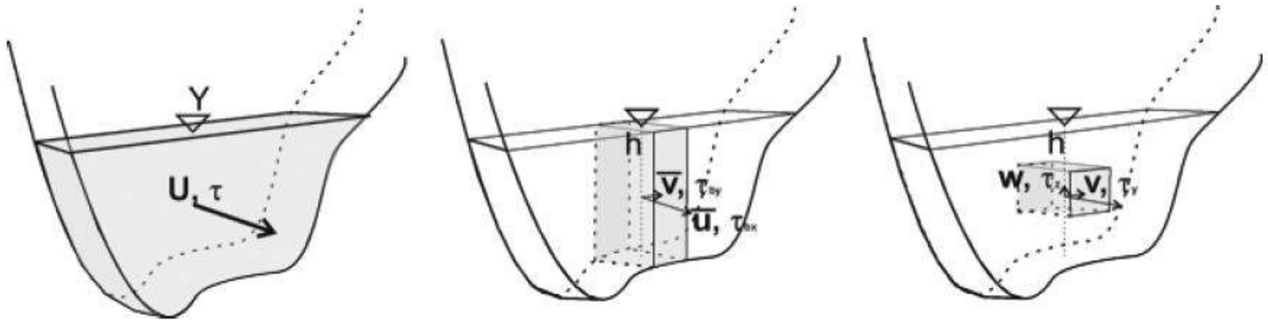


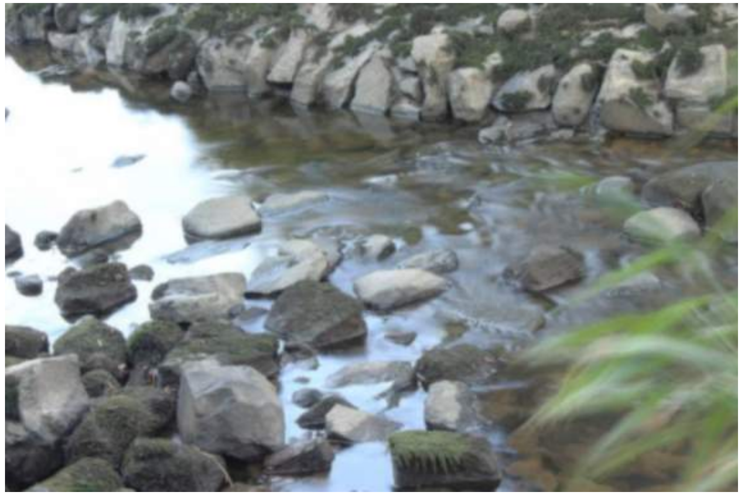


CFD:



Roughness in NLF – grain, form and drag





Roughness in NLF – grain, form and drag

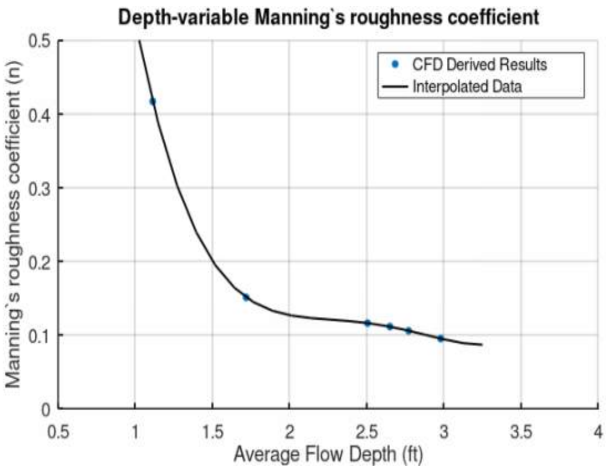
$$V = \frac{1.49}{n} R_h^{2/3} S_f^{1/2}$$

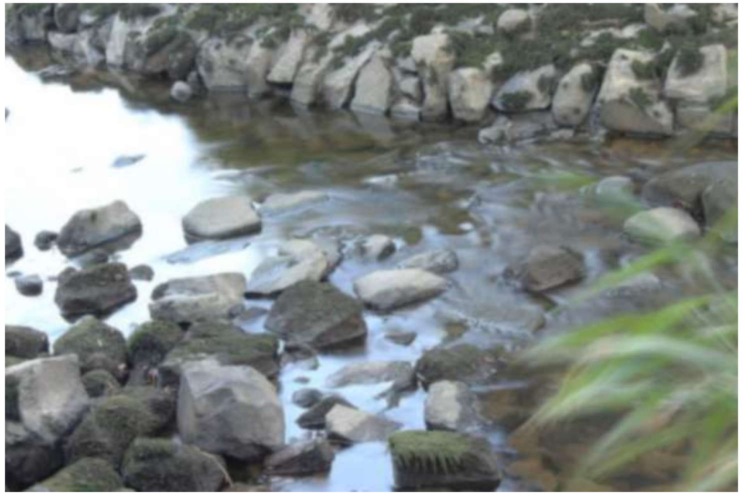
- V = average flow velocity, ft/s
- n = Manning's coefficient of roughness
- R_h, ft = channel hydraulic radius, (ratio of water area to wetted perimeter)
- S_f = slope of the energy grade line

$$n = \frac{0.0926 A R^{1/6}}{1.16 + 2\log_{10}(R/d_{84})}$$

$$n = (n_0 + n_1 + n_2 + n_3 + n_4) m_5$$

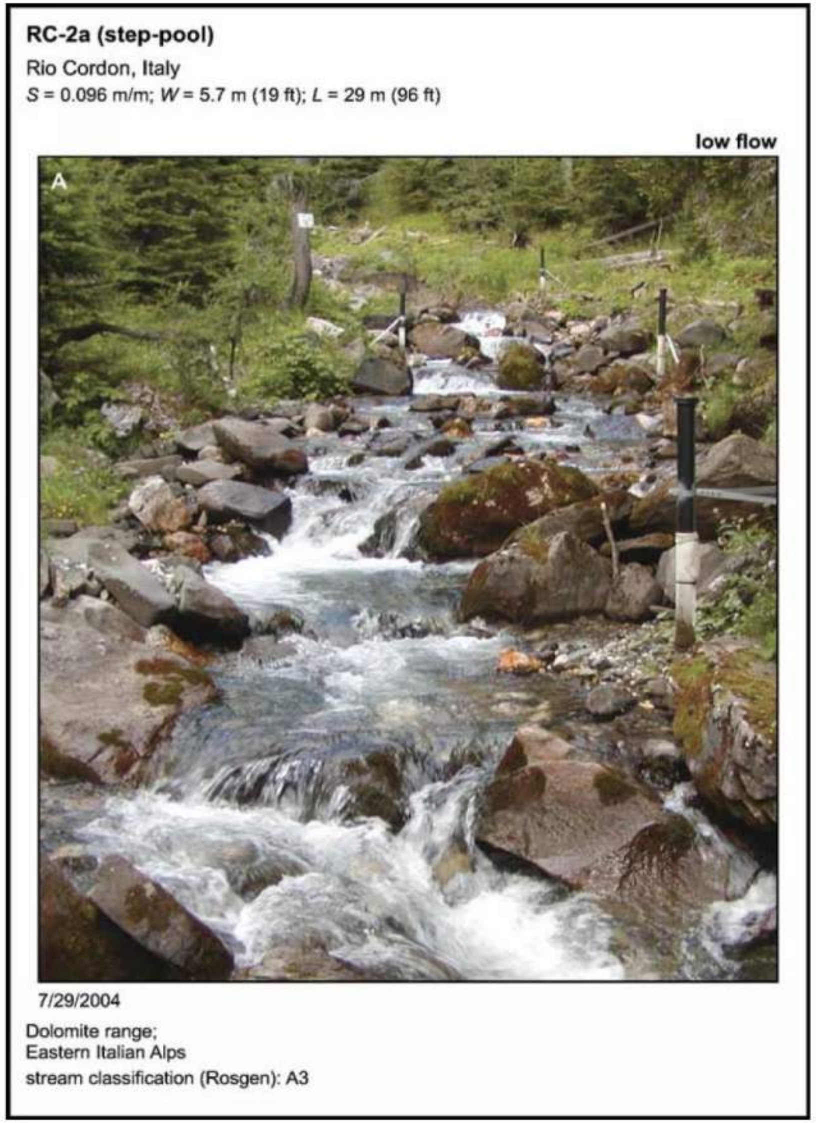
- n_0 is a function of bed material,
- n_1 is a function of channel cross-section irregularity,
- n_2 is a function of variation in channel cross-section,
- n_3 is a function of degree of large-scale obstructions,
- n_4 is a function of aquatic vegetation within the channel and,
- m_5 is a function of degree of channel meander.





Flow Resistance in NLF – Natural Analogs

- Hicks, D.M. and P.D. Mason. 1991. Roughness Review of New Zealand Rivers: a handbook for assigning hydraulic roughness coefficients to river reaches by the "visual comparison" approach. National Institute of Water and Atmospheric Research Ltd., Christchurch, N.Z., 1991.
- Yochum, Steven E.; Comiti, Francesco; Wohl, Ellen; David, Gabrielle C. L.; Mao, Luca. 2014. Photographic Guidance for Selecting Flow Resistance Coefficients in High-Gradient Channels. Gen. Tech. Rep. RMRS-GTR-323. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 91 p.



Sizing NLF Channel Materials

- USBR (2007) recommends the use of two “well tested” methods for riprap sizing on rock ramps, i.e., the surface of the roughened channel-fishway:
  - ❑ Steep Slope Riprap Design presented in USACE (1991)
  - ❑ Abt and Johnson (1991)
- Tractive force and Shields equation are used to check factors of safety (FOS) resulting in design:

$$\tau^* = \frac{\tau_b}{\gamma R D} \qquad \tau_c^* = 0.05$$

NLF Channel Design
Structuring Channels for Ecohydraulics

- Roughened Channel:
  USBR (2007)
  Agency Design Guidance Documents

- Weirs / Structured Roughness:
  USBR (2016)
  Baki et al (2017)

- Step Pool:
  Zimmermann (2009)
  WSDOT (in prep.)

Questions and Discussion

Session 4 AGENDA

01	Design Intro & Biological Effectiveness by Tyler Kreider
02	Hydraulic Modeling by Barry Chilibeck
03	Roughness Design by Barry Chilibeck
04	Other Design Factors by Tyler Kreider Up Next!
05	Summary of NLF Monitoring Results by Bjorn Lake
06	Monitoring Methods by Barry Chilibeck and Tyler Kreider
07	Maintenance of NLFs by Marcin Whitman
08	Q&A (as time allows) led by Tyler Kreider

Nature-like Fishways:
Modern Perspectives and Techniques

Session 4:
Design, Monitoring, & Maintenance Considerations

Session 4.4 “Other” Design Factors

By: Tyler Kreider, P.E. Kleinschmidt Associates

3/27/24

AGENDA: “Other” Design Factors

01 Permitting

02 Public Safety

03 Infrastructure

“Other” Design Factors

- MANY factors can influence NLF design
- Designer’s Goals:
  - Identify critical constraints early in NLF Design
  - Address other constraint(s) while not compromising fish passage/primary project objectives
- Don’t be afraid to:
  - Start evaluating other factors early
  - Think creatively
  - Ask questions, especially “Why?”

Permitting

- No (legal) way around it for an NLF
- Treat regulators as part of the team
  - Consult them early
  - Build a relationship
  - Realize they may have regional experience that can improve the project
- Why?
  - Facilitates quicker reviews
  - Builds collaboration, not animosity

THANK YOU TO ALL OUR PARTNERS FOR A SUCCESSFUL PROJECT

Permitting

Federal Agencies/Organizations

- USACE (navigable waterways/wetlands)
  - Often lead federal agency
- SHPO (cultural/historic resources)
- FERC (hydropower)
- BLM (landowner)
- FEMA (flood control)
- USFWS
  - Rare, Threatened & Endangered (RTE) Species
- NOAA-NMFS (diadromous species)

State Agencies

- Dept. of Fish & Wildlife
- DEQ/DOC/DCNR/DEP/DNREC
  - Dam Safety
  - NPDES/stormwater
  - Section 401: Water Quality
  - State-listed RTE species

Local Agencies

- Code compliance
- Conservation Districts

Permitting

CA Fisheries Restoration Grant Program (ca.gov)

- May offer permit coverage/support (discuss with FRGP reg. coordinator)

SHPO

- Federal permit/nexus
- Historic architecture/structures & Cultural resources
- Phase 1A desktop screening/visit

Rare, Threatened & Endangered Species

- Reason to build the NLF?
- Reason not to build fish passage?
- Time of year restriction(s)

Permitting

FEMA/flooding

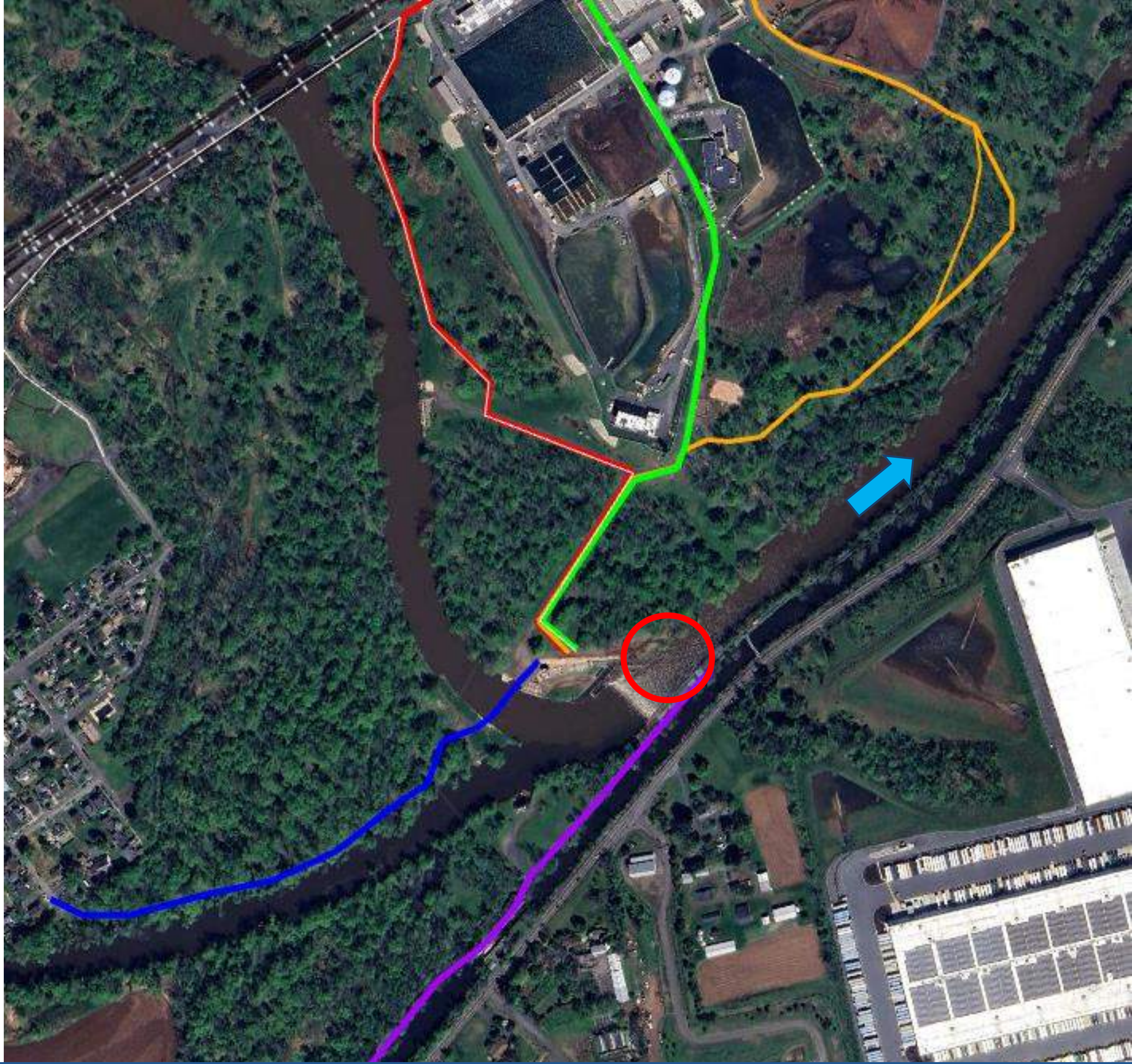
- Regulatory Floodway
- Seek “No-Rise” case typically
- Conditional Letter of Map Revision vs. Letter of Map Revision (LOMR)
- Limits fill in river/floodplain

USACE

- Nationwide Permit vs. Individual Permit
- Navigable waterways & wetlands
  - Jurisdiction starts/stops/overlaps?

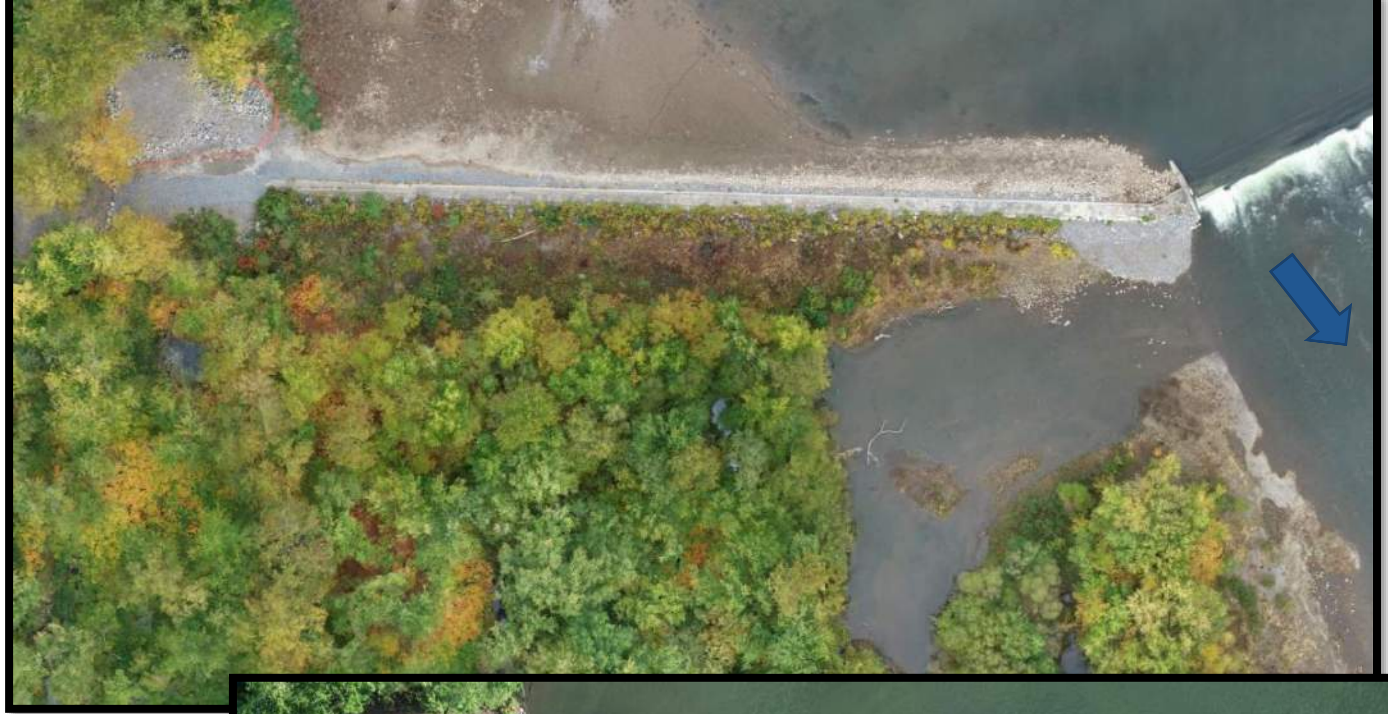
Permitting

- Permit area includes more than just the NLF area
  - Access route
  - Staging area
  - Material harvest area
- Allow reasonable buffer on permit & consultation areas
  - project dimensions may shift in final design = flexibility



Permitting

- Typically, NLFs are “good” projects that agencies get excited about
- Early identification of design constraints due to permitting =
  - Less changes
  - Agency buy-in
  - More accurate project timeline



Photos courtesy of KC Construction

Public Safety

- Is the site public?
  - Walk-in?
  - Boat-in?
  - Fishermen/women?
- Existing public safety measures?
- Future public use?
  - Desired or restricted?

Shikellamy NLF; Photo courtesy of KC Construction

Figure 79. Recreational kayaking at Midtown Rapids. Photo courtesy of Dave Friedl.

Public Safety

- Designed Public Engagement?
  - Signage/Education
  - Fishing?
  - Walking trails
  - Picnic areas
  - Boating/Whitewater boating?
  - Compromise fish passage to accommodate boaters OR allow fish passage in white-water project?
    - Midtown Rapids, Moorhead MN (Red River of the North; designed for fish passage)
    - Wingfield Park, Reno NV (Truckee River; not necessarily designed for fish passage)
- Risk/insurance considerations

Public Safety

- Put on your “teenage” hat
    - What would I want to try as a teen?
- Buoys/signage vs. floods
- Exercise due diligence warning(s) to reduce risk
- Risks may be similar to a natural stream system, but there may be very good reasons to exclude the public from entering a NLF

Other Infrastructure

- Identify design/maintenance constraints ASAP via:
  - Desktop Review
  - Dig Alert/811/Dig Safe/One Call
  - Field Visit
  - Discussing NLF concept with Landowner(s)
  - Talking to:
    - Locals (especially those that have lived in the area for decades)
    - Utility owners

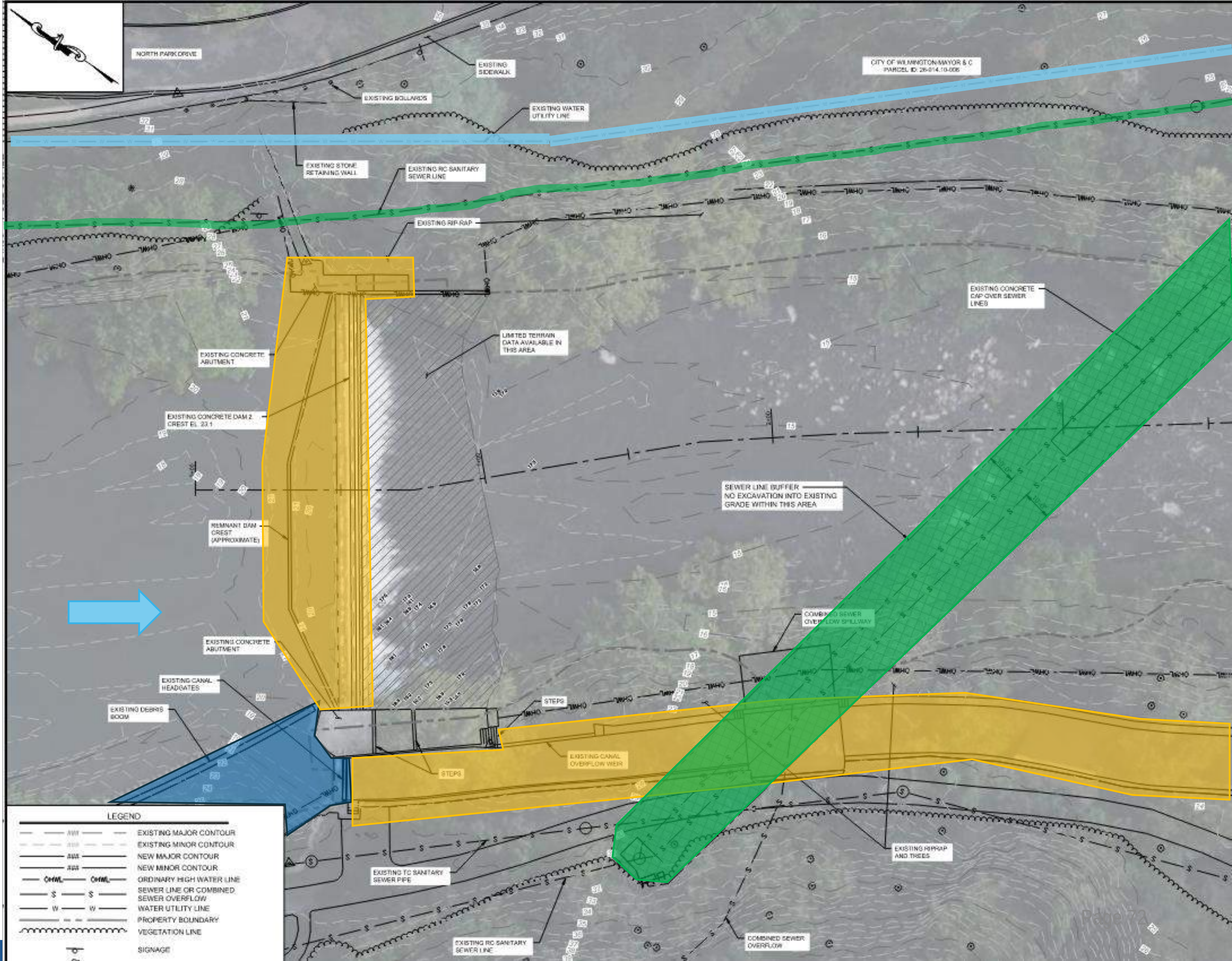
Other Infrastructure

Dam crest/Utility

- Variability
- Boulders downstream of crest
- Gate/stoplogs

Other Infrastructure

- Sewer/water/gas/ electric/ fiber optic lines
- Water intakes
- Historic/ cultural resources



Session 4 AGENDA

01	Design Intro & Biological Effectiveness by Tyler Kreider
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Nature-like Fishways:

NLF Monitoring Results

03/27/2024

AGENDA

01 Definitions & Terminology

02 Meta-Analyses

03 Case Studies

04 Summary

01

Mural by Esteban Camacho Steffensen.

Definitions & Terminology

Performance

- Biological
- Physical
- Ancillary Benefits

Definitions & Terminology

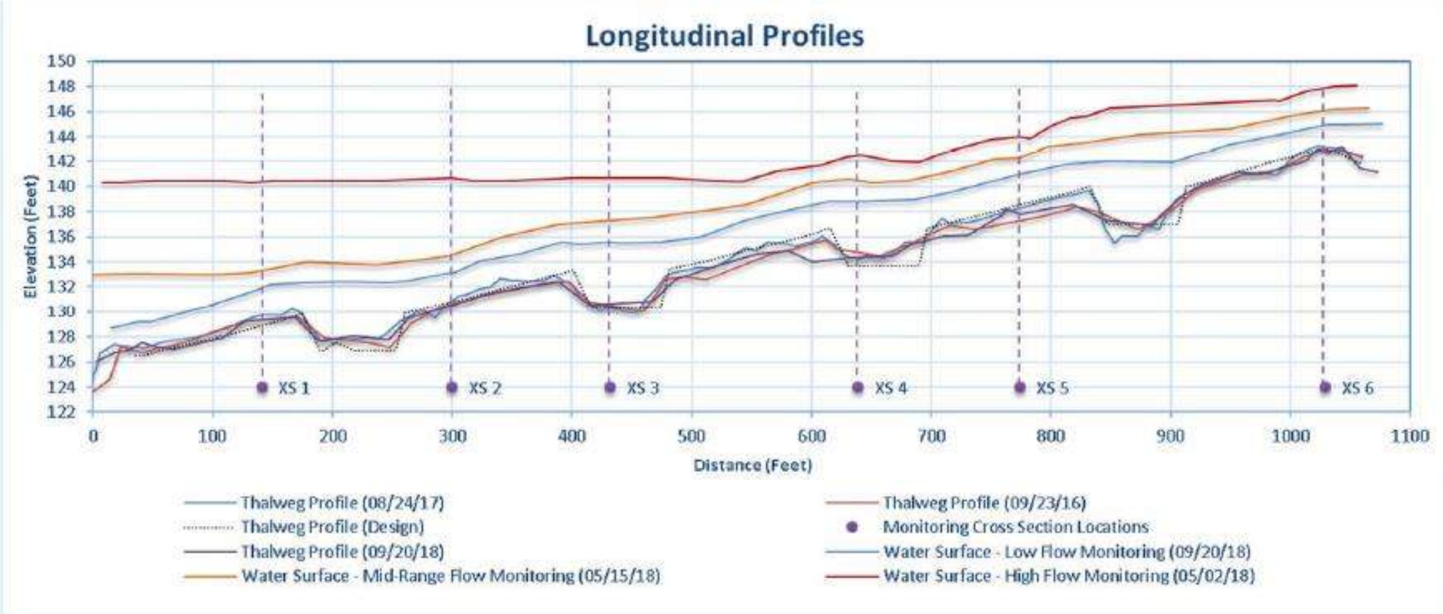
Biological Performance

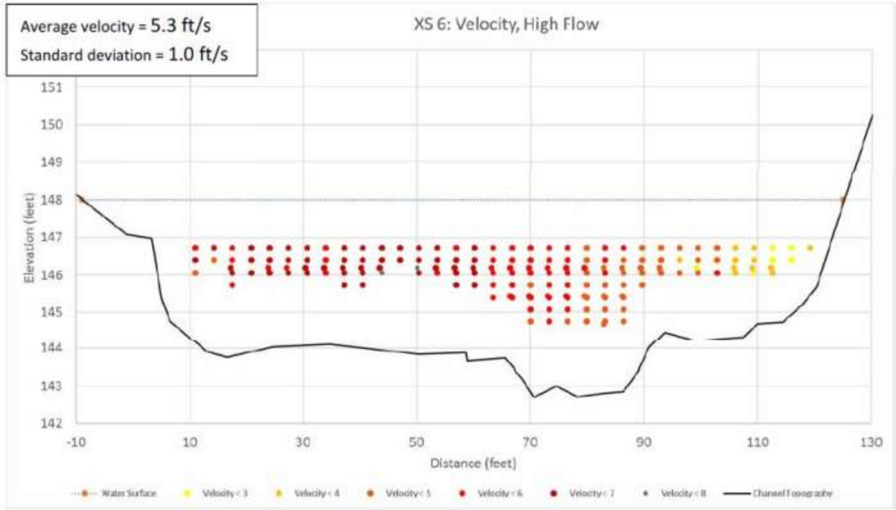
1. Safe – fish that use the fishway are not injured
2. Timely – fish that use the fishway are not delayed
3. Effective – fish that desire to pass the fishway are successful
    - Attraction efficiency – probability of a fish to find the fishway
    - Passage efficiency – probability of a fish to pass the fishway

Definitions & Terminology

Physical Performance

1. Does the fishway meet hydraulic design criteria?
2. Does the fishway meet bed mobility criteria?
3. Does the fishway withstand stochastic events?





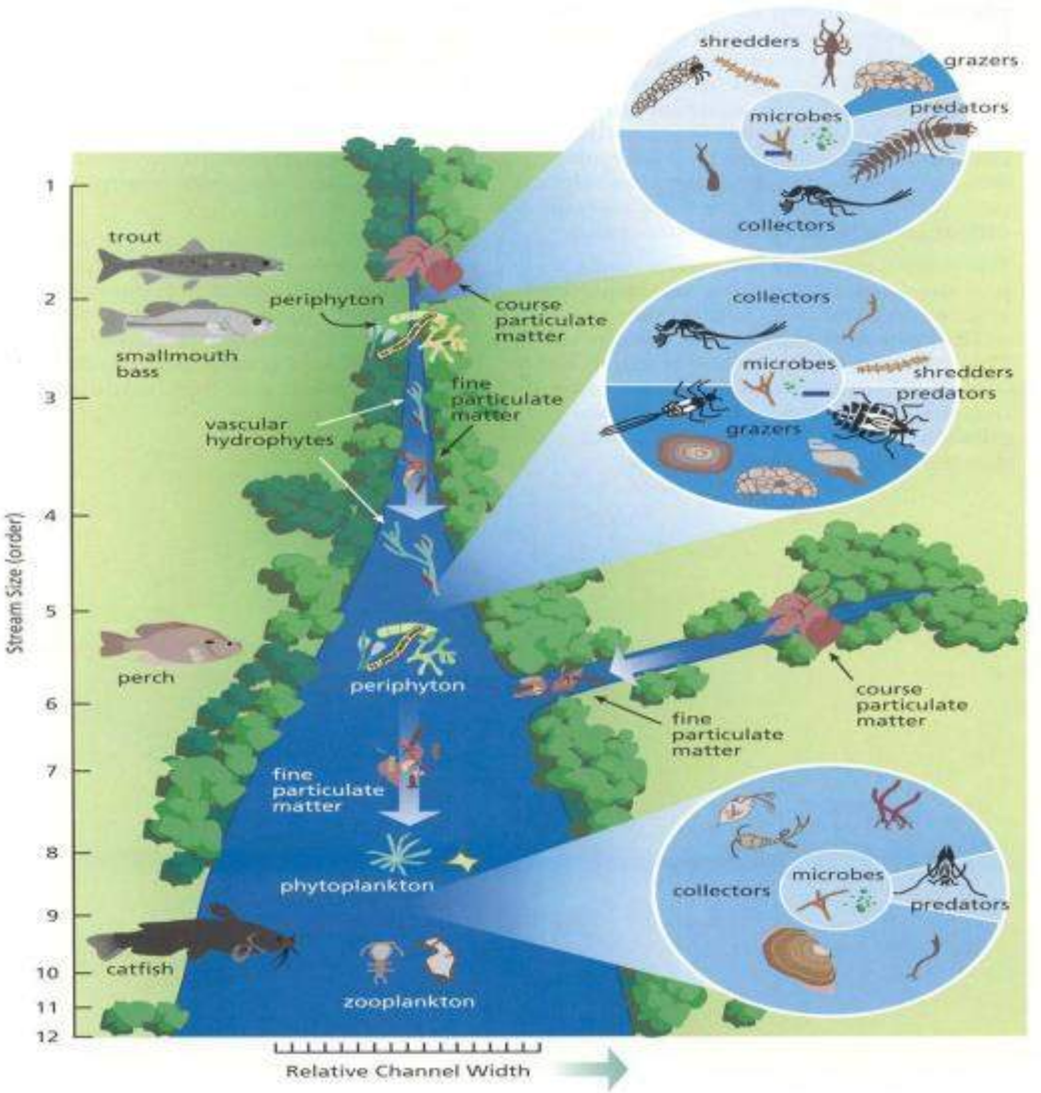
Definitions & Terminology

Ancillary Benefits

1. Does the fishway provide habitat value?

2. Does the fishway minimize operation and maintenance?

3. Does the community accept the fishway?



Adapted from Vannote 1980 by NRCS

02

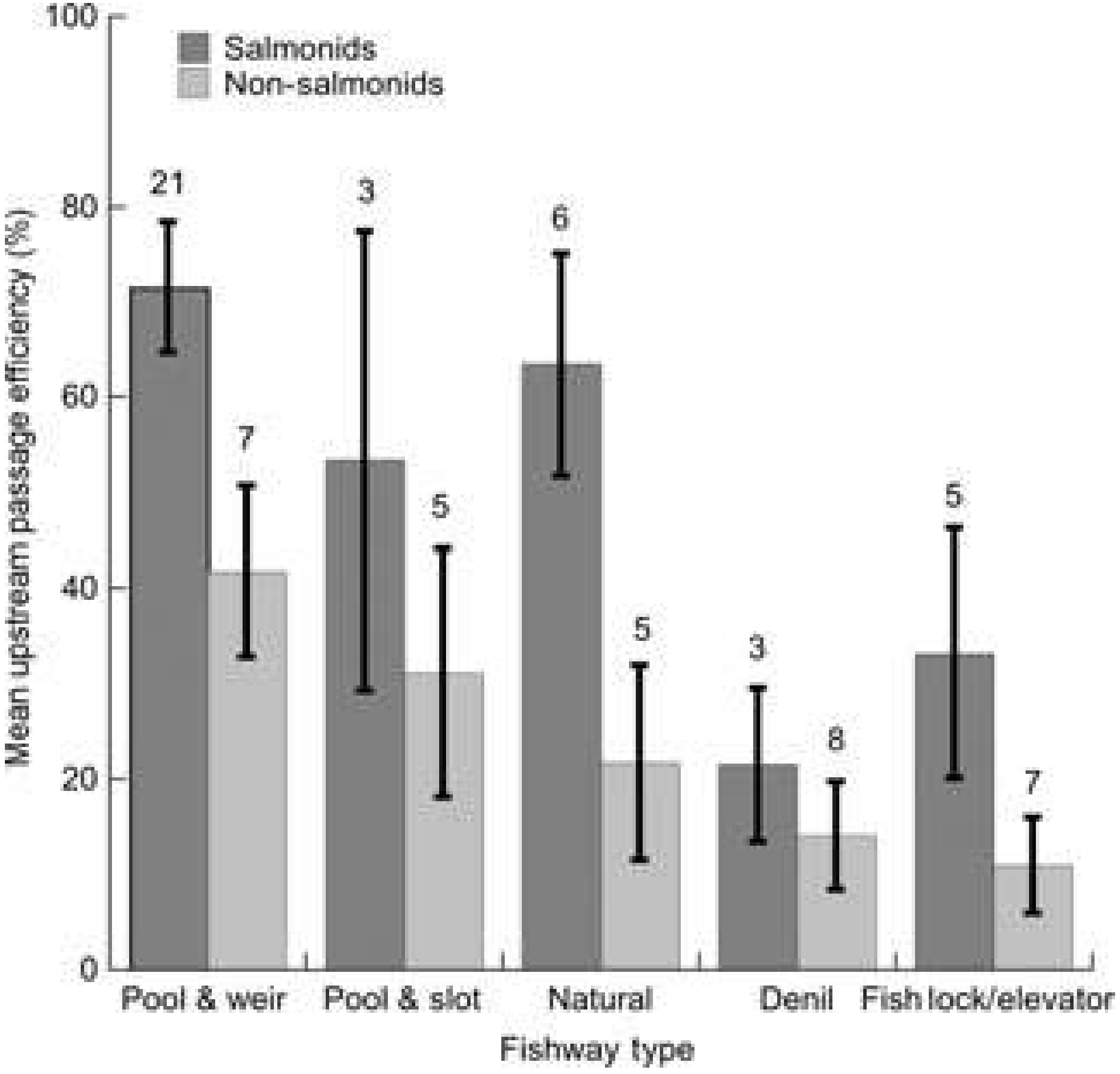
*Cartoon from Catherine Graham in Jager et al 2013

Meta-Analysis Summary

Published Literature

- Noonan, M. J., J. W. A. Grant, and C. D. Jackson. 2012. A quantitative assessment of fish passage efficiency. Fish and Fisheries 13:450-464.
- Bunt, C. M., T. Castro-Santos, and A. Haro. 2012. Performance of Fish Passage Structures at Upstream Barriers to Migration. River Research and Applications 28:457-478.
- Hershey, H. 2021. Updating the consensus on fishway efficiency: A meta-analysis. Fish and Fisheries 22:735-748.

Noonan et al 2012



(a)

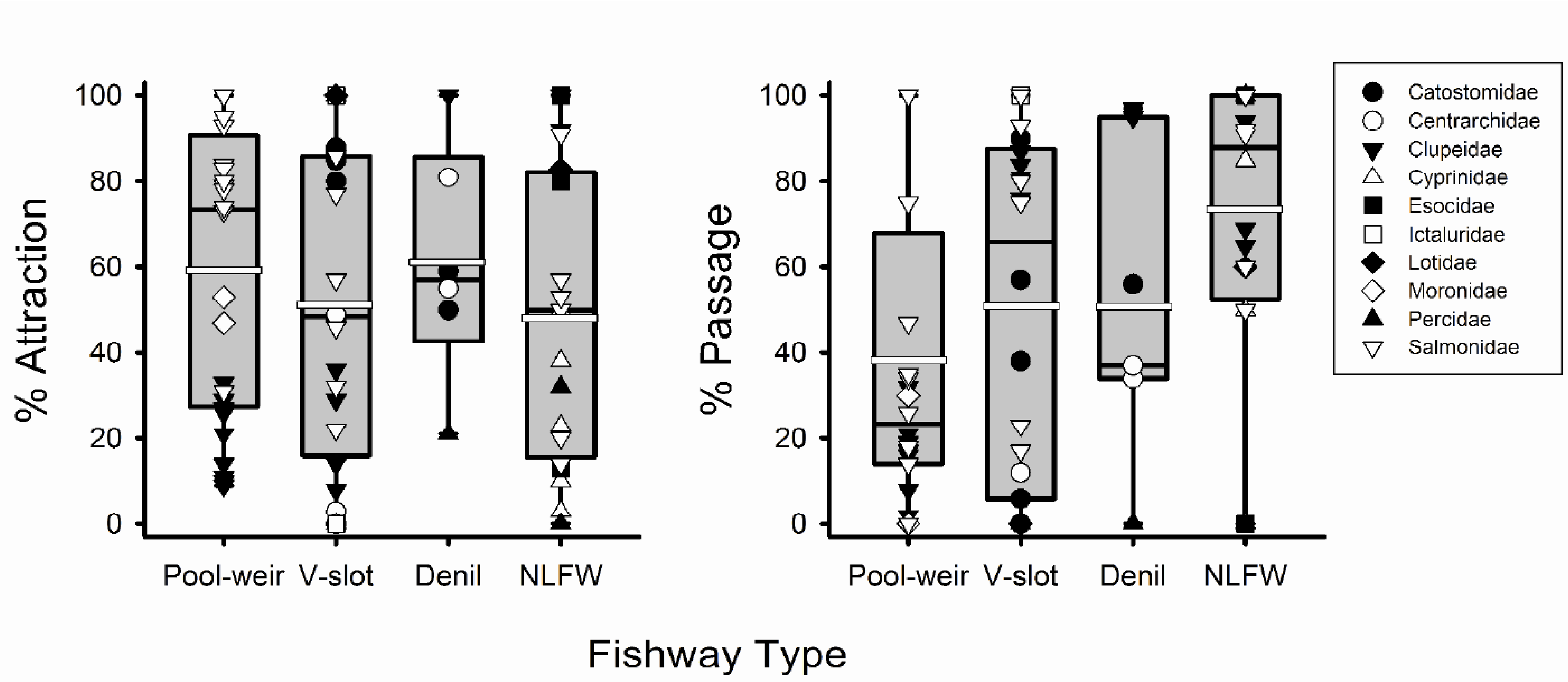
Type of fishway	Length (m)	SE	*n*	Slope (%)	SE	*n*	Velocity ($m\ s^{-1}$)	SE	*n*
Pool and weir	190.3	±71.4	7	8.1	±0.75	11	1.78	±0.18	9
Pool and slot	175.6	±101.8	5	6.3	±2.42	3	2.07	±0.33	3
Natural	202.9	±41.4	10	4.2	±1.11	9	1.80	±0.50	2
Denil	14.2	±5.3	8	14.5	±1.47	10	0.89	±0.21	7

(b)

	Length (m)	Velocity ($m\ s^{-1}$)
Slope (%)	−0.703** (23)	−0.474 (13)
Velocity ($m\ s^{-1}$)	0.594* (13)	

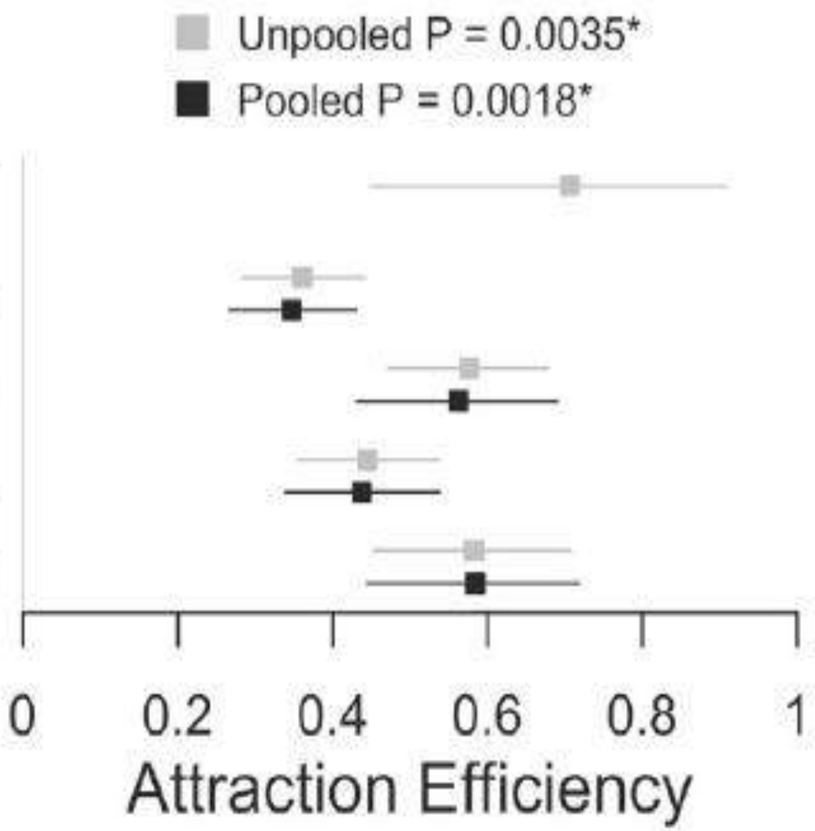
*$P < 0.05$; **$P < 0.01$.

Bunt et al 2012, 2016



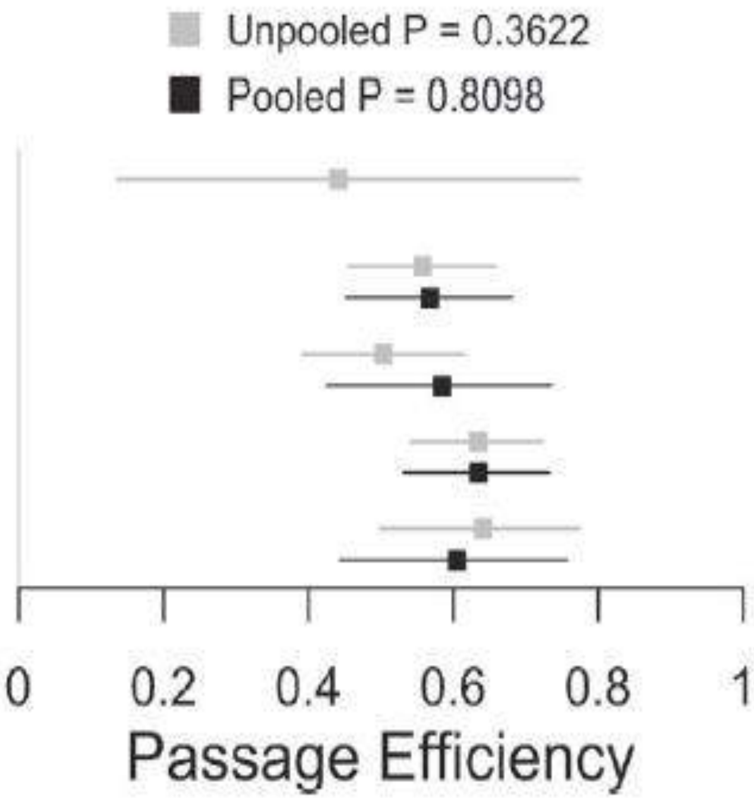
Hershey 2021

Fishway Type	N	Estimate	tau^2
Denil	7	0.7061	0.1150
Nature-Like	66 (59)	0.3608 (0.3469)	0.0861 (0.0869)
Pool and Weir	53 (26)	0.5764 (0.5629)	0.1411 (0.1104)
Vertical Slot	76 (61)	0.4456 (0.4374)	0.1126 (0.0999)
Locks and Lifts	8 (7)	0.5827 (0.5843)	0.0257 (0.0272)



Hershey 2021

Fishway Type	N	Estimate	tau^2
Denil	8	0.4417	0.2148
Nature-Like	76 (63)	0.5574 (0.5676)	0.1163 (0.1217)
Pool and Weir	63 (33)	0.5036 (0.5843)	0.1821 (0.1996)
Vertical Slot	78 (62)	0.6339 (0.6341)	0.1131 (0.1076)
Locks and Lifts	27 (16)	0.6413 (0.6050)	0.0955 (0.0866)

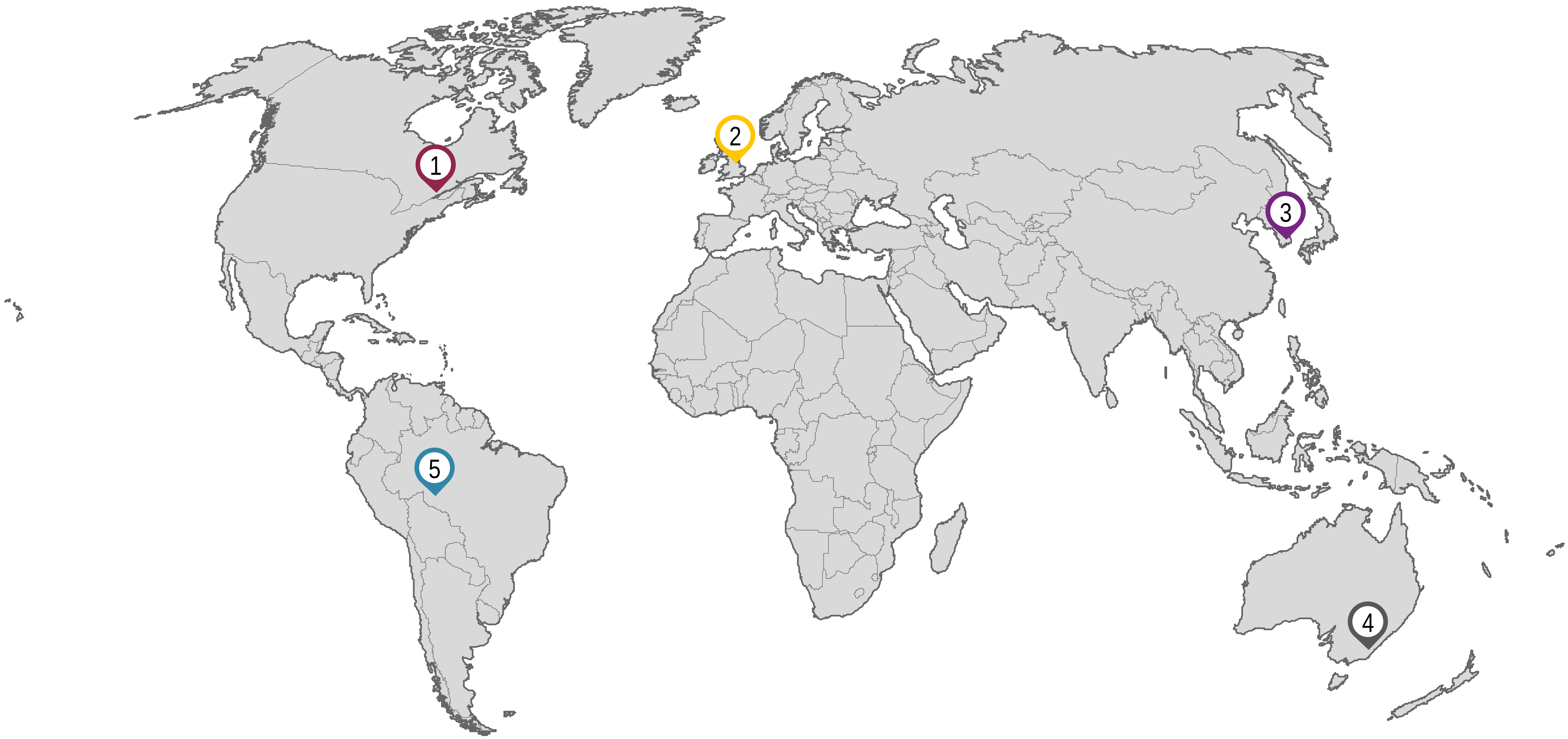


03

Case Studies

- International
- United States

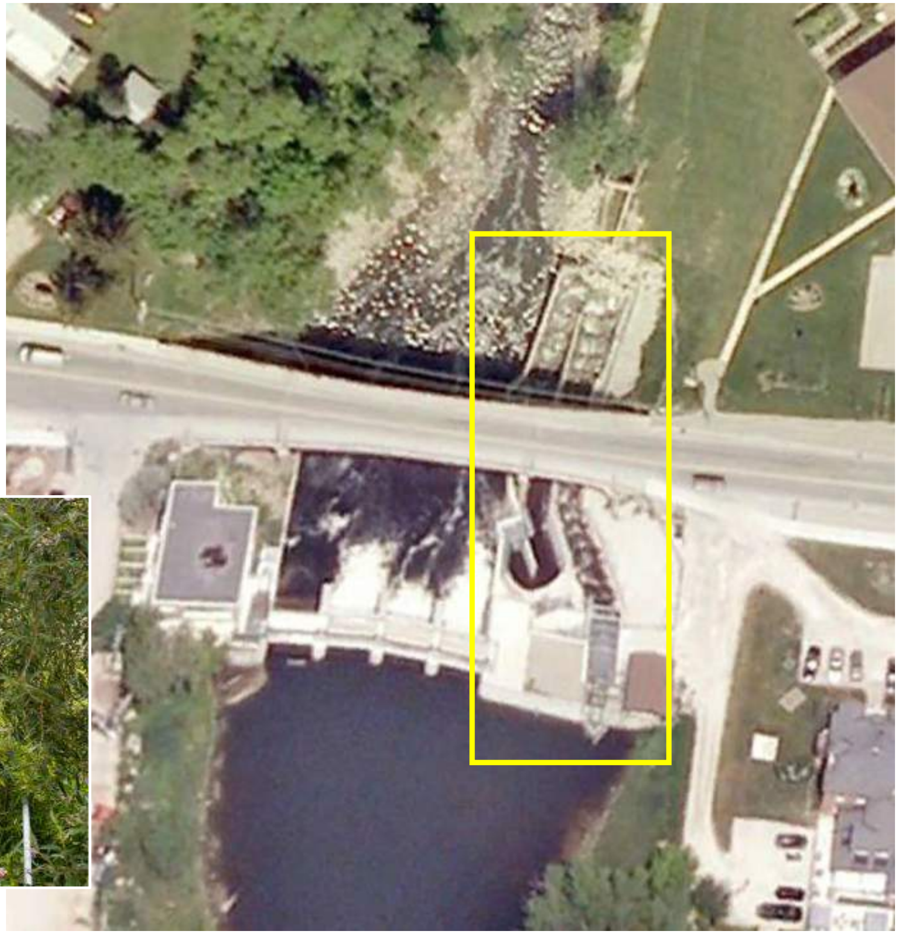
International Case Studies



Thornbury Fishway, Beaver River, Ontario, Canada

Bunt & Jacobson 2019 NAJFM 39:460-467

- Target Species
  - Chinook Salmon
  - Rainbow Trout
- Fishway Specs
  - 126 m Step Pool
  - 29 2X3 m pools
  - 0.3 m drop per pool
- Effectiveness
  - Attraction = 53%
  - Passage Efficiency = 100%
  - Delay = 152 ± 122 min



Rodley Fishway, River Aire, Yorkshire, United Kingdom

Dodd et al 2017 JEM 204:318-326

- Target Species
  - Brown Trout
- Fishway Specs
  - 150 m Step Pool
  - 12 notched grade controls
  - 0.1 – 0.15 m drop per pool
- Effectiveness
  - Attraction = 45%*
  - Passage Efficiency = 76%*
  - Delay = <1 to 286 hrs

Sangju Fishway, Nakdong River, Gyeongsang, Korea

Kim et al 2016 Water 8:1-18

- Fishway Specs
  - 700 m Step Pool
  - 1% slope
  - 6-18 m width, 0.5 m + depth
- Effectiveness
  - Trap Checks – 1,474 individuals, 19 species
  - Attraction Efficiency = 20.7%
  - Passage Efficiency = 14.5%
  - Delay = 1.2-1,559 hrs
  - Size selection

Vanitys Fishway, Cotter River, ACT, Australia

Broadhurst et al 2013 Mar Freshwater Res 64:900-908

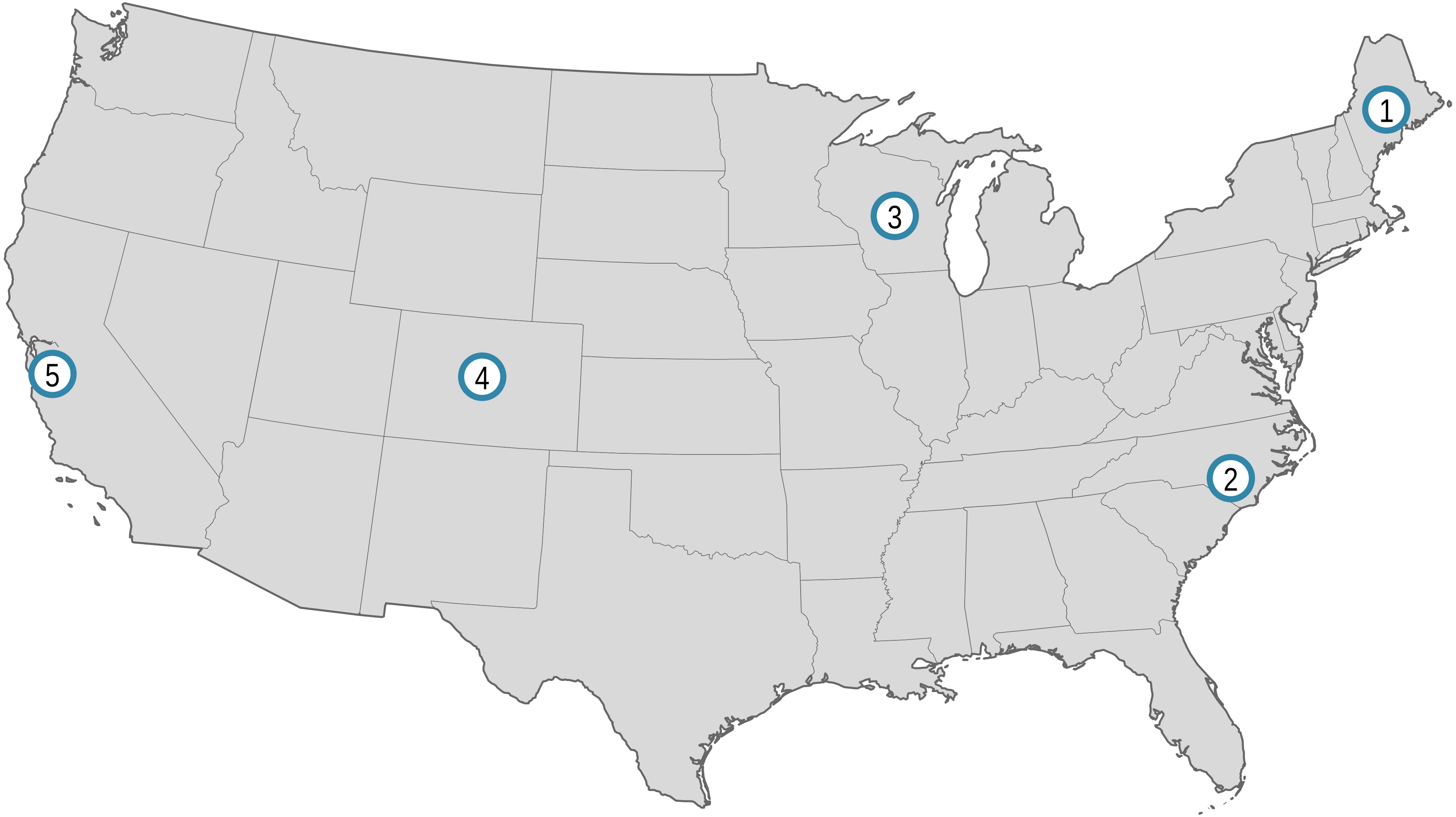
- Target Species
  - Macquarie Perch
- Fishway Specs
  - 40 m Roughened Channel
  - 1:30 slope
- Effectiveness
  - 2 US/DS sampling periods (post, +5 yr)
  - Abundance and distribution increased
  - Size distribution suggested multiple cohorts

Santo Antonio Fishway, Madeira River, Rondonia, Brazil

Hahn et al 2022 Hydrobiologia 849:323-338

- Target Species
  - 3 Species of Goliath Catfish
- Fishway Specs
  - 1,400 m
  - 2.5% slope
  - 4-10 m^3/s
- Effectiveness
  - Attraction Efficiency ≤ 4%
  - Passage Efficiency = 0%
  - Release in Fishway = 0-12.2%

Case Studies from the U.S.



Howland Bypass, Piscataquis River, Maine

Molina-Moctezuma et al 2021; Peterson 2022

- Target Species – Atlantic salmon, sea lamprey, and alosines
- Fishway Specs
  - 1,000 ft Roughened Hybrid
  - 2.4% max slope
- Effectiveness
  - Downstream smolts approached natural survival and migration rate
  - Passage Efficiency = 78% sea lamprey, 57% Atlantic salmon
  - Delay = 3 hr median up to 120 days
  - High fall back rates for Atlantic salmon

Lock and Dam 1, Cape Fear River, North Carolina

Raabe et al 2019

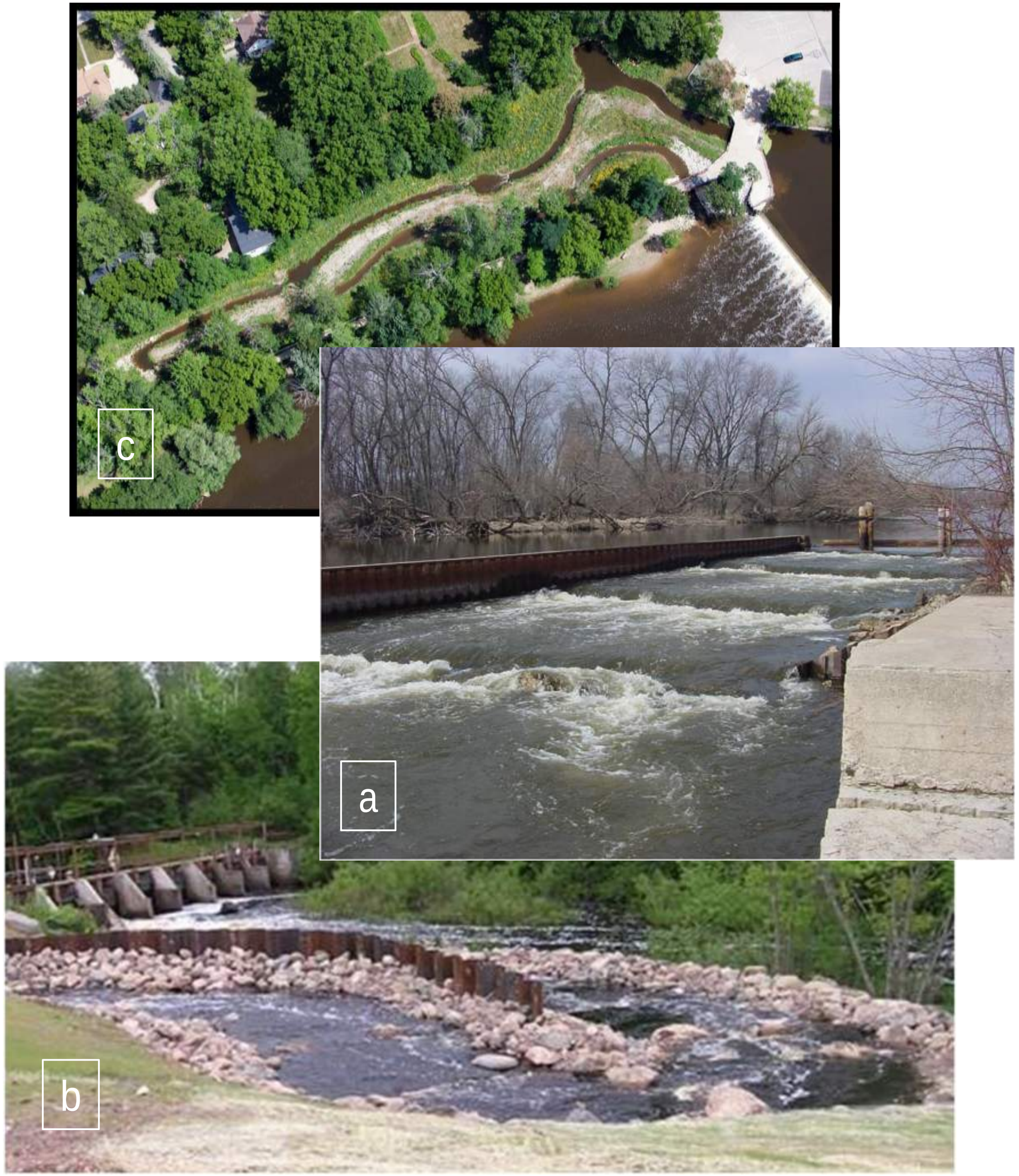
- Target Species – Atlantic sturgeon, American shad, Blueback Herring, Striped Bass and Flathead Catfish
- Fishway Specs
  - 300 ft X 280 ft Roughened Hybrid
  - 3.5 to 5 % slope
- Effectiveness
  - Passage Efficiency = 55-65% AS, 19-25% SB, 13-80% FC
  - Delay means = 14.7 days AS, 11.6 days SB, 17.4 days FC
  - Confirmed Atlantic sturgeon passage

*Photo Courtesy Margaret Fields TNC

Various Sites in Wisconsin

Bruch and Haxton 2023

- Target Species – Lake Sturgeon
- Fishway Specs
  - a) Eureka, Fox River – partial, step pool, 3% slope
  - b) Winter, Chippewa River – bypass, step pool, 2.7% slope
  - c) Mequon-Thiensville – Milwaukee River, bypass, pool-riffle, 1.1% slope
- Effectiveness
  - a) 250 LS annually pass, in-fishway spawning
  - b) 48 LS annually pass
  - c) No passage yet, restoration still in-progress



Fossil Creek Reservoir Inlet Diversion, Poudre River, Colorado

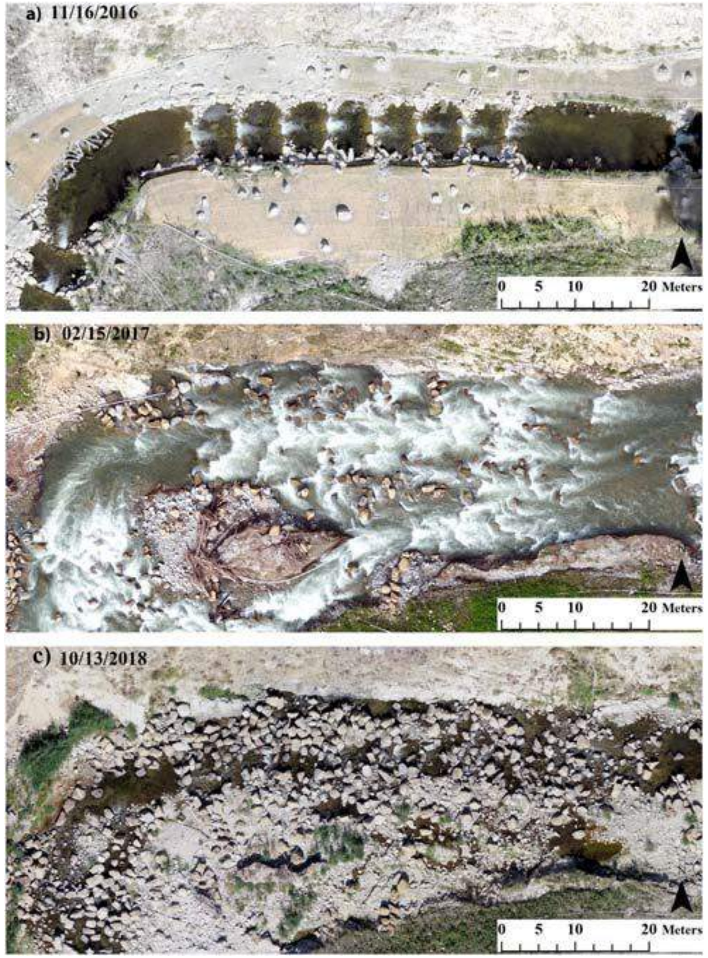
Richer et al 2020

- Target Species – Brassy Minnow, Brown Trout, Longnose Dace, Longnose Sucker
- Fishway Specs
  - 30 ft Trapezoidal Roughened Channel
  - 5 % slope
- Effectiveness
  - Extended study – 5 to 51% range, 19% overall
  - Enclosed study – 24 to 98% range, 81% overall
  - Confirmed passage for all target species

San Clemente Dam Removal, Carmel River, California

Harrison et al 2018, Smith et al 2020, Boughton et al 2020, Smith et al 2021, East et al 2023, and Ohms et al 2023

- Target Species – Steelhead
- Fishway Specs
  - 3,750 ft long reroute channel with 53 step-pools
  - 1 ft drop per pool
- Effectiveness
  - Steelhead and Pacific lamprey pass
  - Increased size distribution
  - Steelhead 2D fish densities are on par if not greater than other reaches



04

Summary

- Biological
  - Mixed bag with entrance efficiency likely being the limiting issue
  - Positive results for multi-species passage
- Physical – Mixed bag from stable to "auto-naturalized"
- Ancillary Benefits – People really like them! Stream health indices improve

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Nature-like Fishways:
Modern Perspectives and Techniques

Session 4:
Design, Monitoring, & Maintenance Considerations

Session 4.6 Monitoring Methods

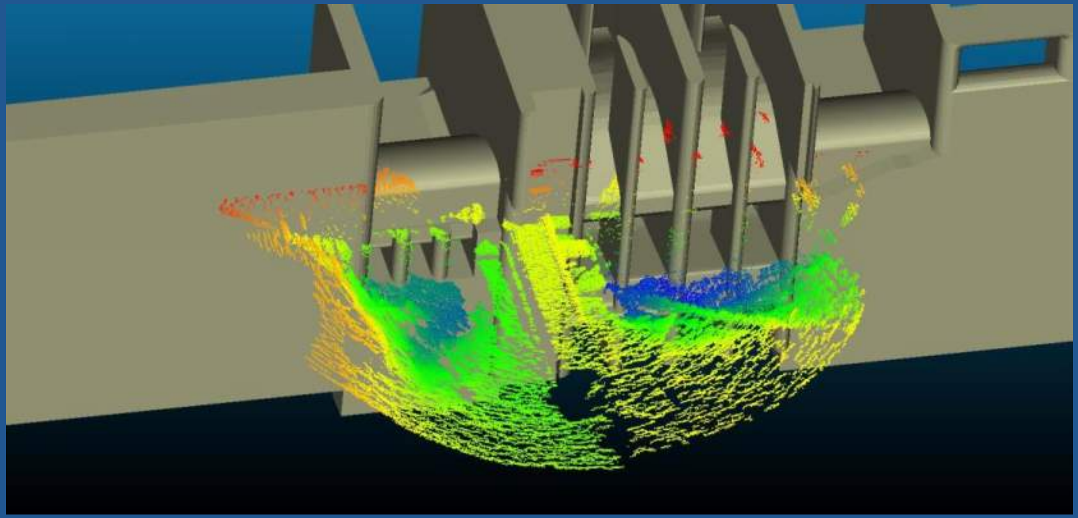
By: Barry Chilibeck & Tyler Kreider

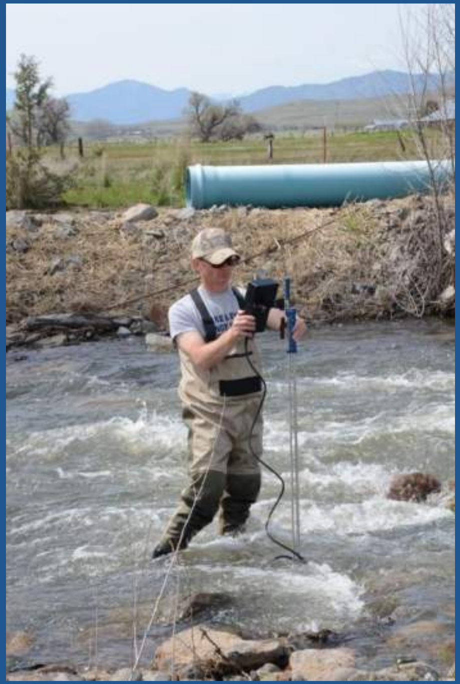
3/27/24

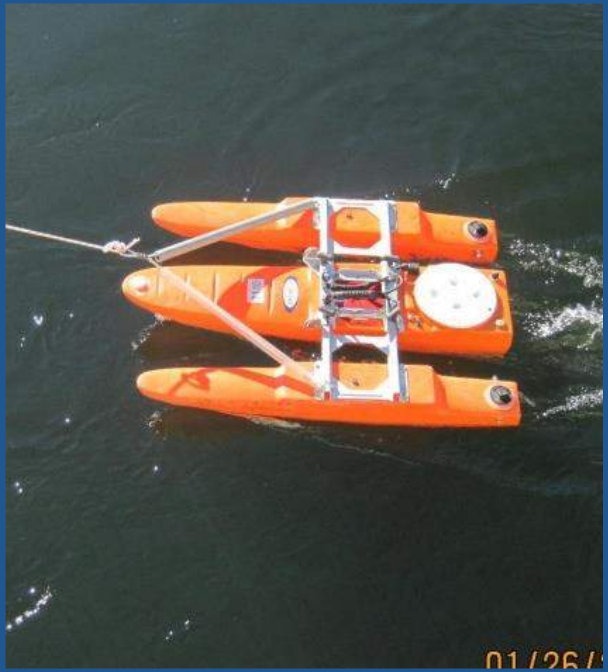
AGENDA: Monitoring Methods

01 Physical Monitoring

02 Biological Monitoring







Discussion Topics

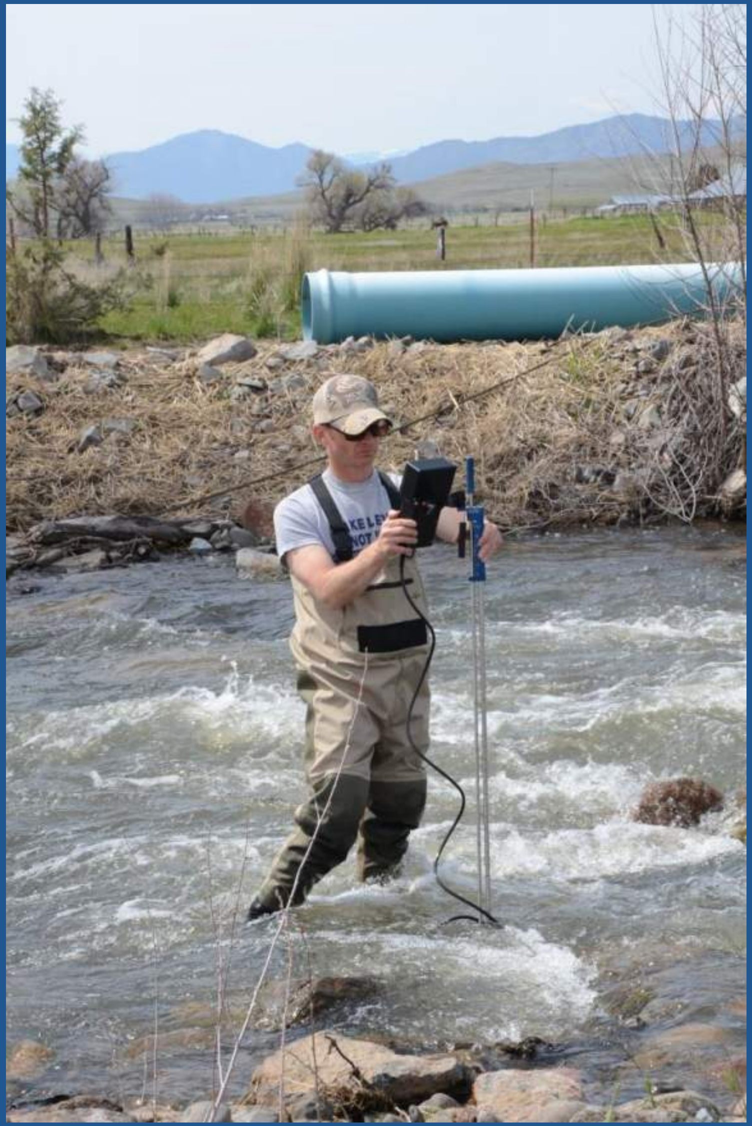
- Objectives
- Flow Measurement
- Physical Surveys
- Data for Validation in Design and Construction
- Systems and Scenarios

Physical Monitoring Objectives and Methods

- Physical surveys are part of the data collection phase of design and assessment programs
- Data:
  - Stage Data
  - Flow or Discharge Data
  - Physical Surveys
  - Sediment Surveys
  - Hydroclimate and Sensing data

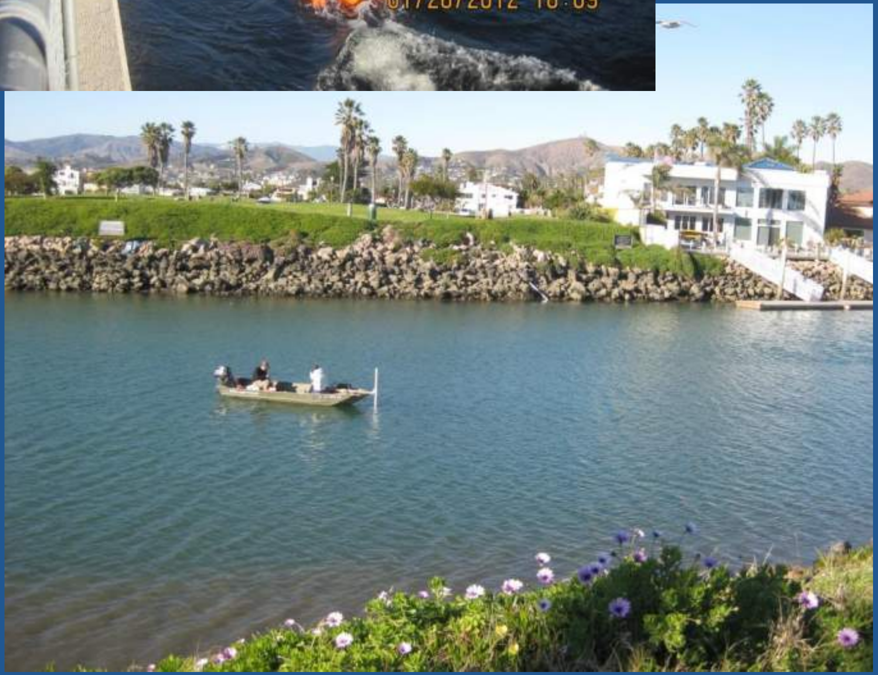
ADV Flow Tracker

- Next Generation Cup and Propeller
- Measures Velocity at a Point
- USGS Methods for Measuring Discharge
- replacing the propellor but not the pygmy meter
- Next gen instruments are smaller and lighter



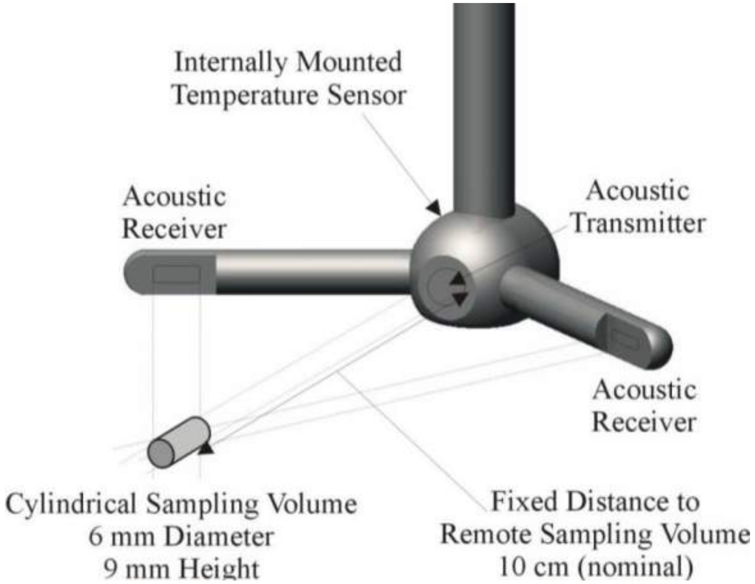
ADCP

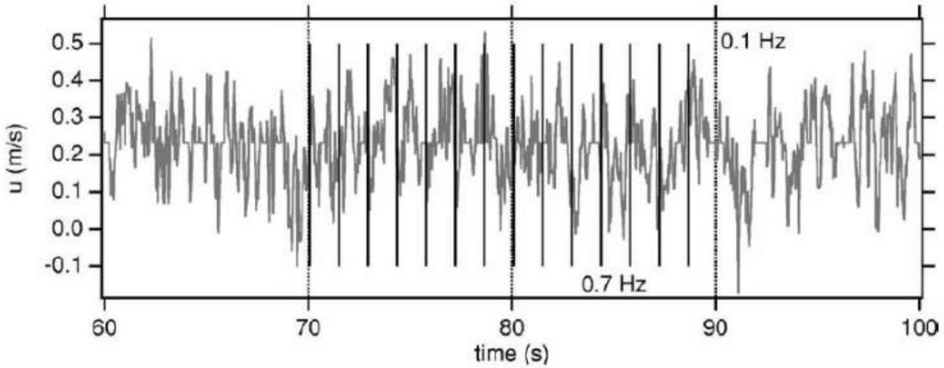
- Acoustic Doppler Current Profiler
- Measures instantaneous at discrete bins
- USGS Methods for Discharge (trusted)
- Non-Intrusive
- Manned or Unmanned Boat
- 5-beam depth sounder



Direct Sensing Turbulence - ADV Flow Tracker

- 1 second sample rate
- 40 second measurement period
- processing includes error and variation

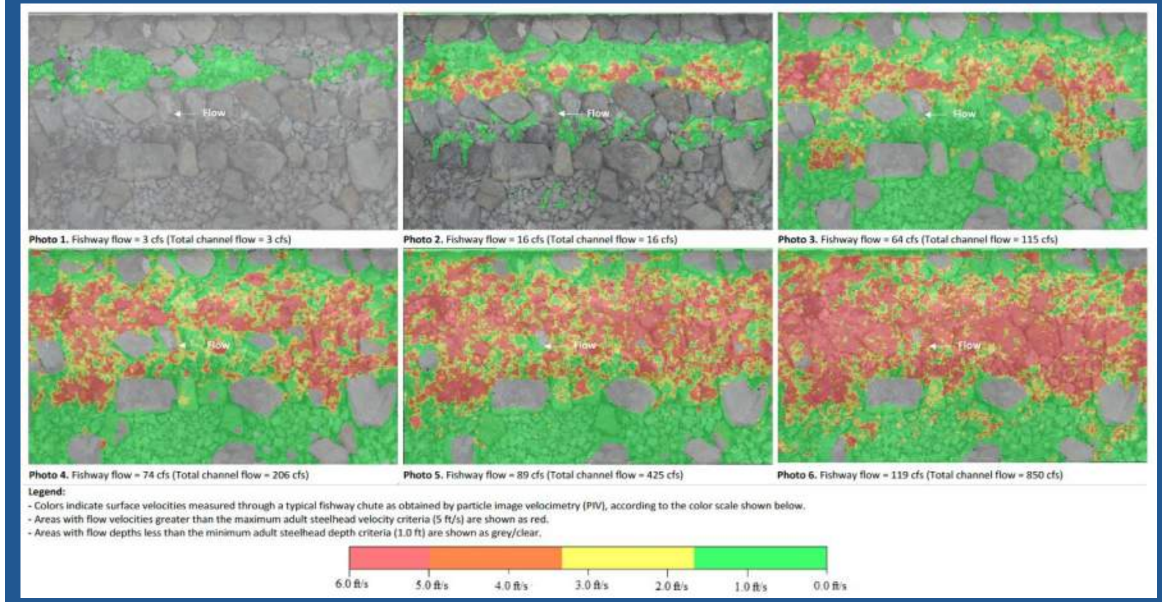


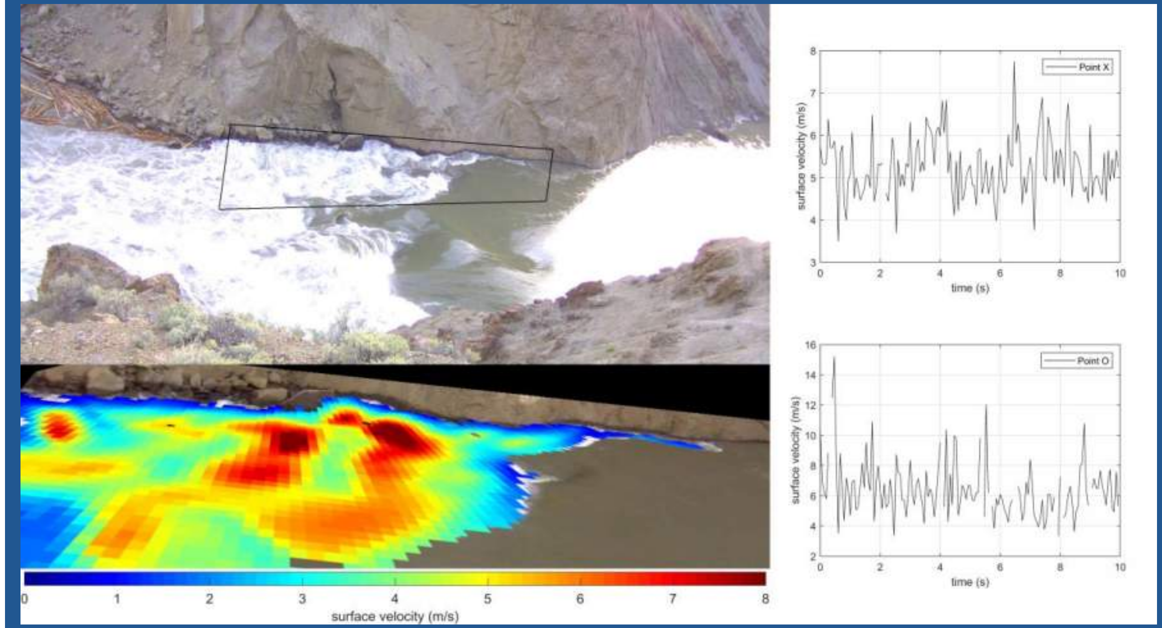


K.B. Strom and A.N. Papanicolaou (2007). ADV measurements around a cluster microform in a shallow mountain stream. J. Hydraulics. Doi:10.1061/(ASCE)0733-9429

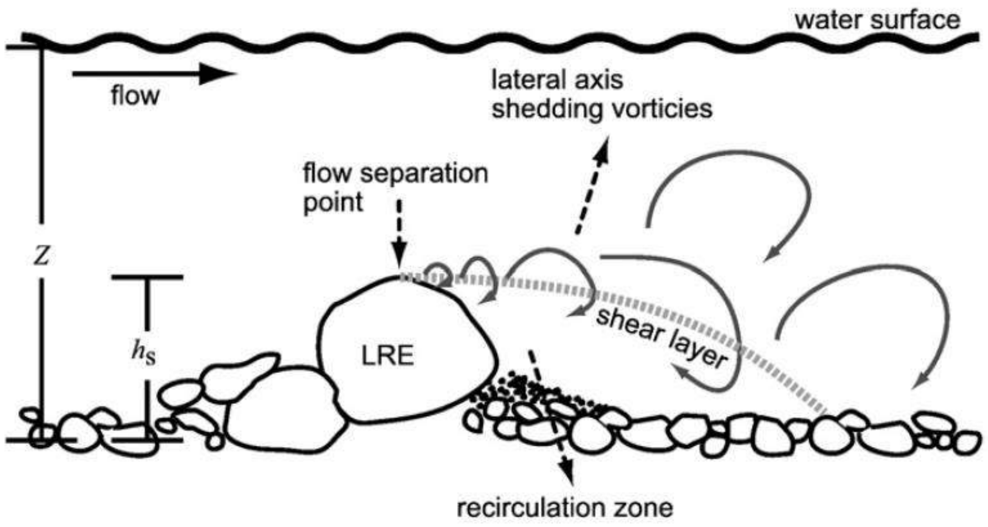
Remote Sensing: LSPIV

- **L**arge **S**cale **P**article **I**mage **V**elocimetry
- Image based, non-intrusive approach
- PIV methods + Image Transformation
- Provides 2-D surface velocity measurements on a spatial grid
- Proof of application: Creutin et al. (2003), Muste et al. (2004), Kim et al. (2008), Papanicolaou et al. (2010), NHC (2011)



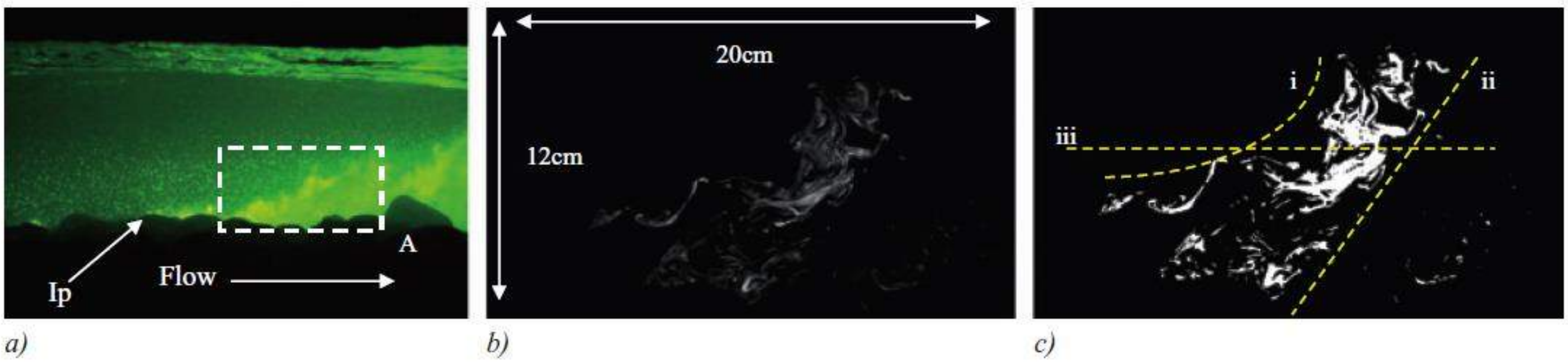


Micro-hydraulics



Lacey R.W.J., and A.G. Roy (2008) The spatial characterization of turbulence around large roughness elements in a gravel-bed river, Geomorphology, 102, 542-553.

R.J. Hardy; J.L. Best; D.R. Parsons; G.M. Keevil (2011) On determining the Processes and Landforms (February 2011), 36 (2), pg. 279-284geometric and kinematic characteristics of coherent flow structures over a gravel bed: a new approach using combined PLIF-PIV. Earth Surface



Field Data Collection

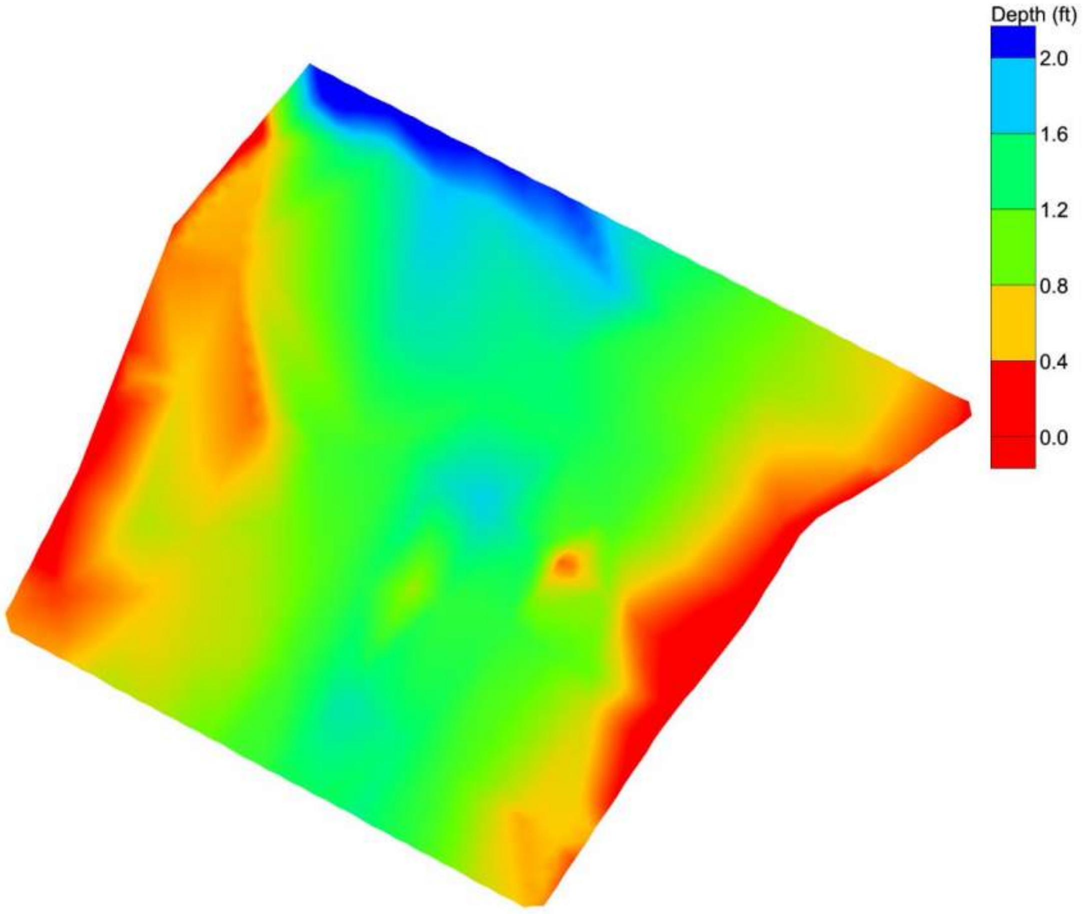
Survey:

280 topo points

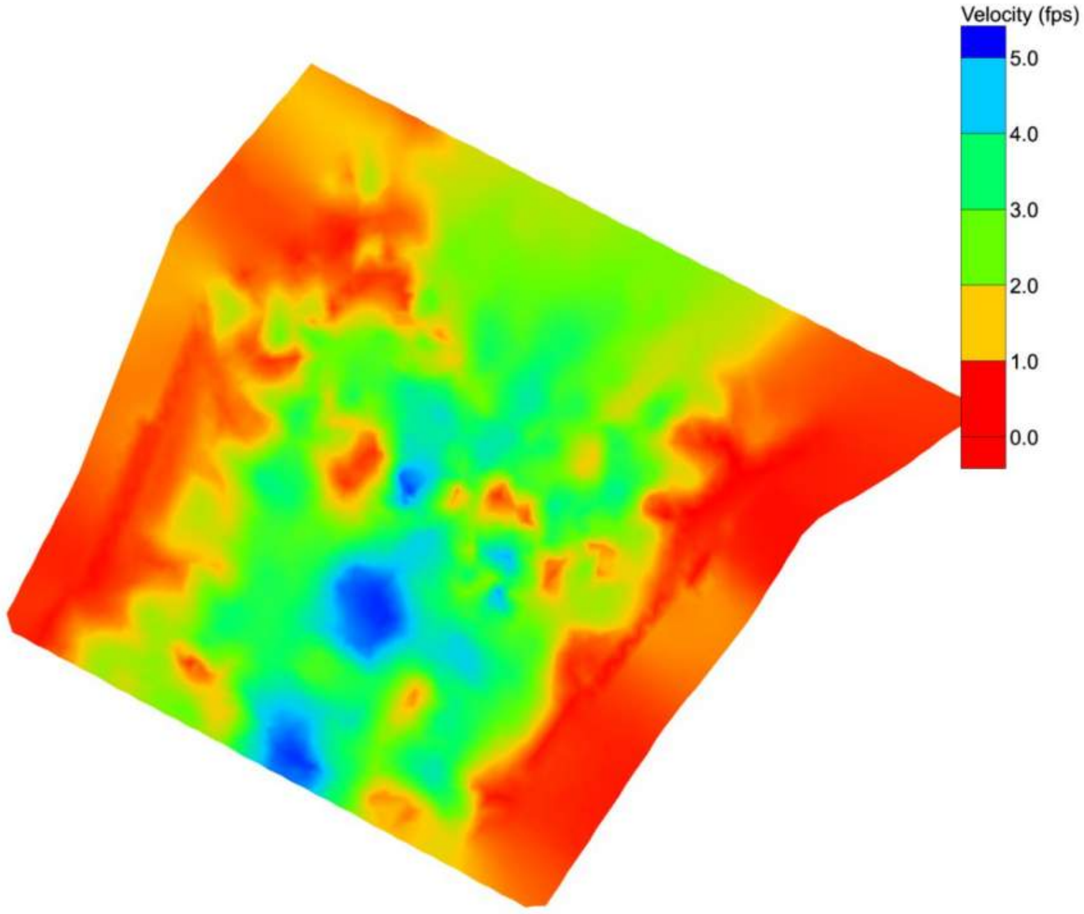
50 boulders

- Field Survey – TS / RTK
- ADV (Flow Tracker)
- LSPIV / UAV

Ecohydraulics

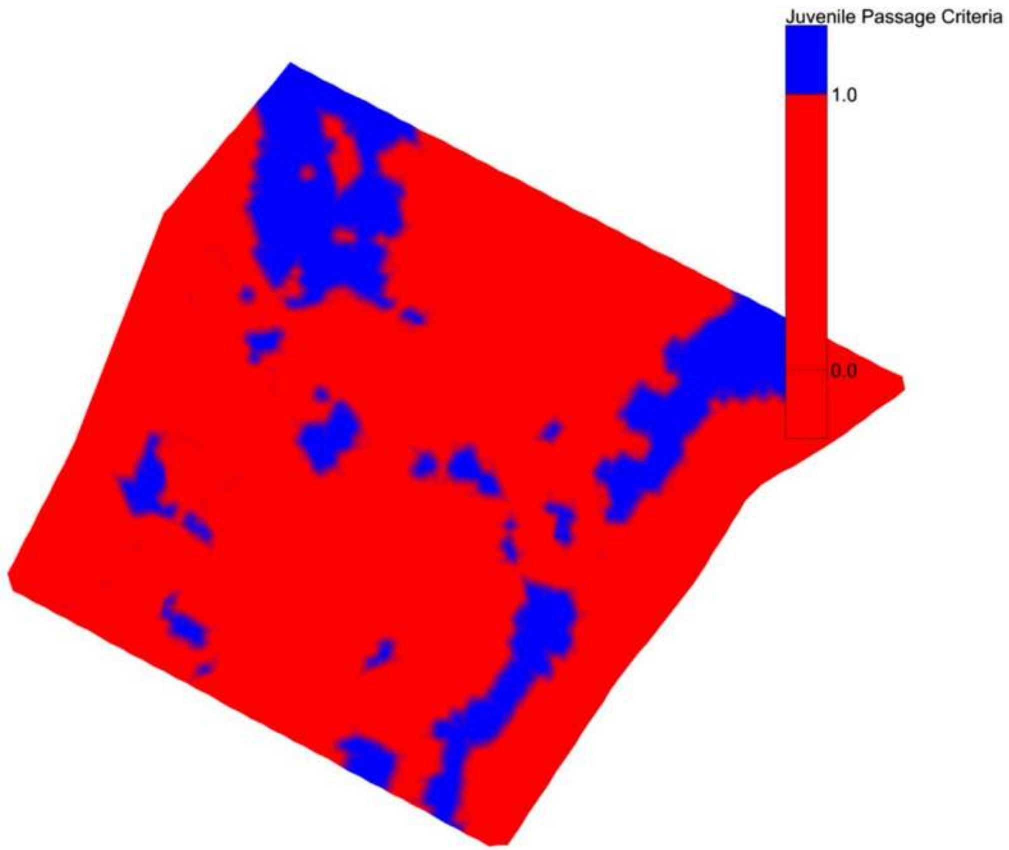


Depths



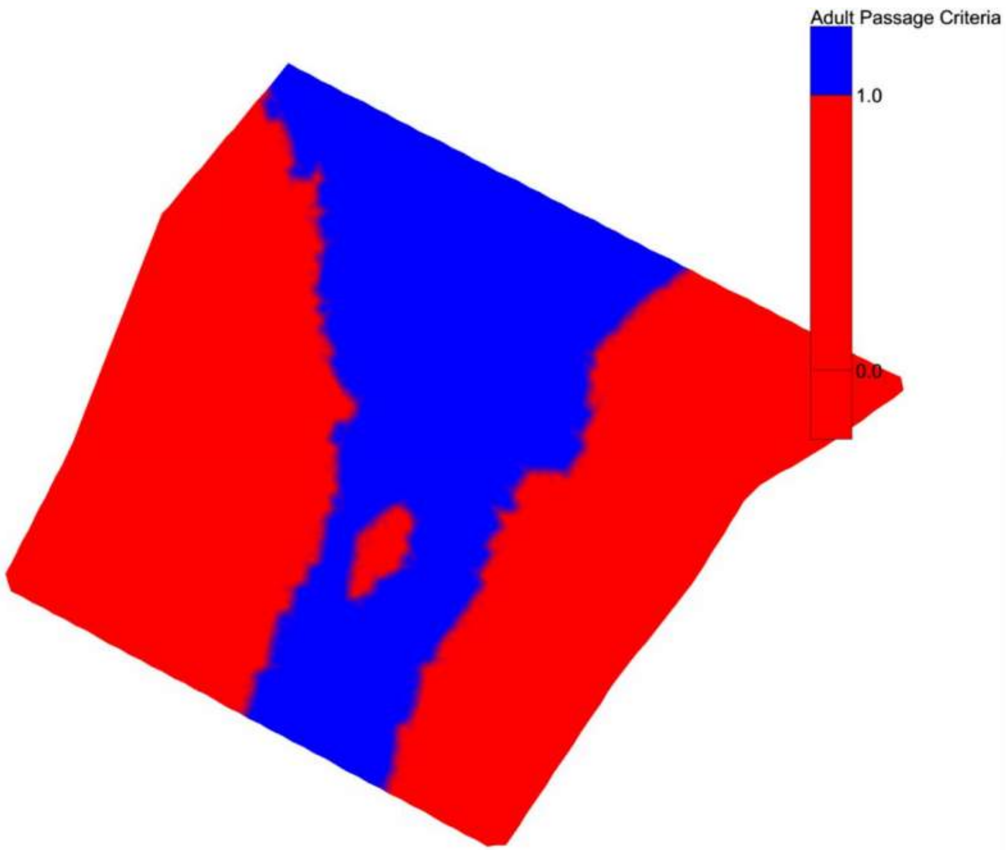
Velocities

Fish Passage Assessment



Juvenile Salmonid Passage Criteria:

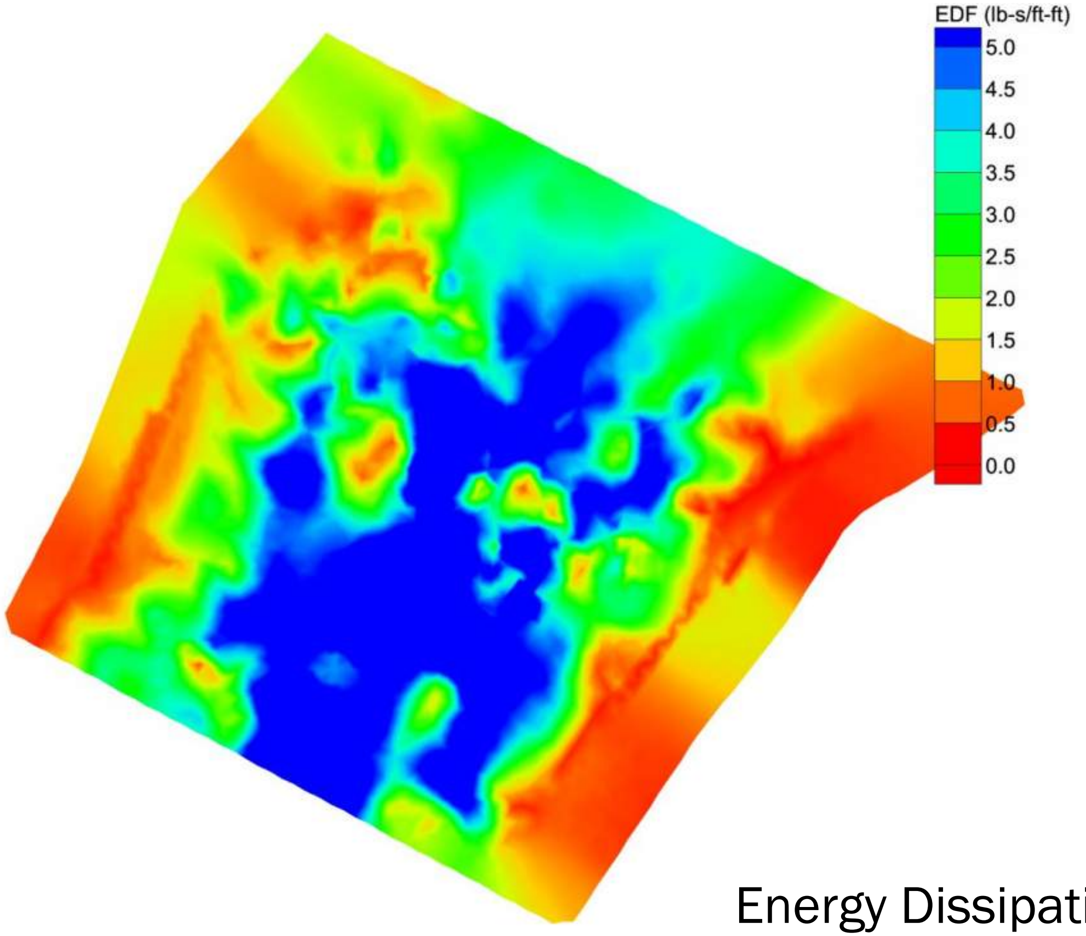
- Velocity < 1 ft
- Depth > 0.5 ft



Adult Salmonid Passage Criteria:

- Velocity < 6 fps for culvers < 60 ft
- Velocity < 5 fps for culvers 60 to 100 ft
- Depth > 1 ft

Energy Dissipation Factor

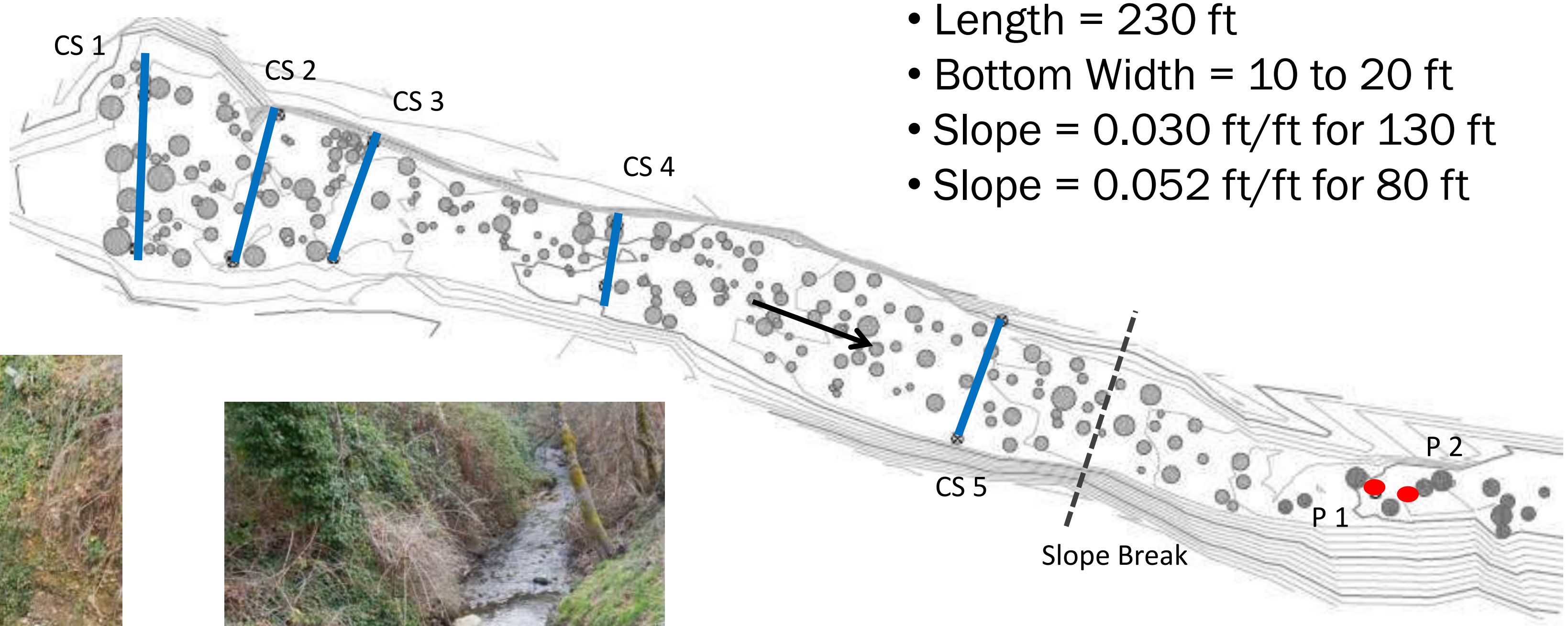


Energy Dissipation Factor: EDF = ***Y***VS
Roughened Channel: EDF < 7 lb-ft/s/ft^3 (Bates 2003)

Monitoring NLF Sites

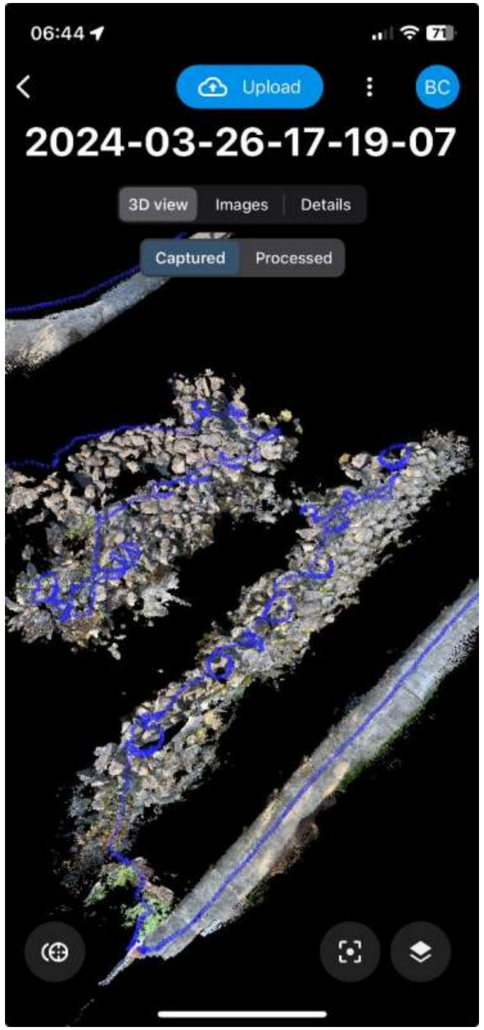
Characteristics:

- Length = 230 ft
- Bottom Width = 10 to 20 ft
- Slope = 0.030 ft/ft for 130 ft
- Slope = 0.052 ft/ft for 80 ft



Monitoring NLF Sites – UAV Data Collection

- UAV and portable LIDAR has revolutionized field spatial data collection
- Combined still and video capture allows both physical and hydraulic data collection
- Realize the value of a Geomatic Engineer



Biological Monitoring

- Purpose of biological monitoring?
  - Curiosity
  - Confirm performance of the NLF
  - Identify and correct problems
  - Gain information for improvement
  - Prove NLF effectiveness/efficiency/success:
    - > 75% of target species fish that reach the NLF (effective)
    - > 90% of fish that enter fishway pass upstream (efficient)
    - < 5-day delay for diadromous species passage (timely)

Biological Monitoring

- Define monitoring criteria (set pre-design!):
  - Target species
    - Resident vs. diadromous species
    - Single species → all fish species in river
  - Upstream vs. downstream passage?
  - Goal/objective being evaluated & baseline
  - Study reach/extent
  - Duration of study
  - Statistical approach/method
  - Off-ramp for success and failure
- Evaluate biological monitoring alternatives based on criteria and desired investment $
- Regulatory buy-in (if applicable)

Biological Monitoring

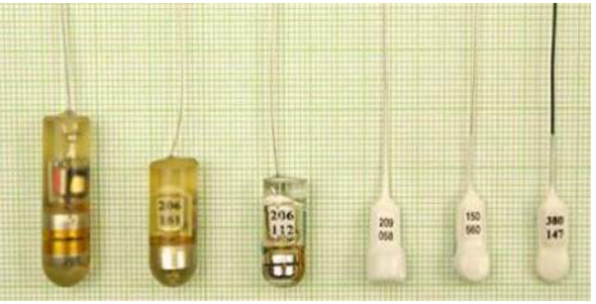
One-time/short duration

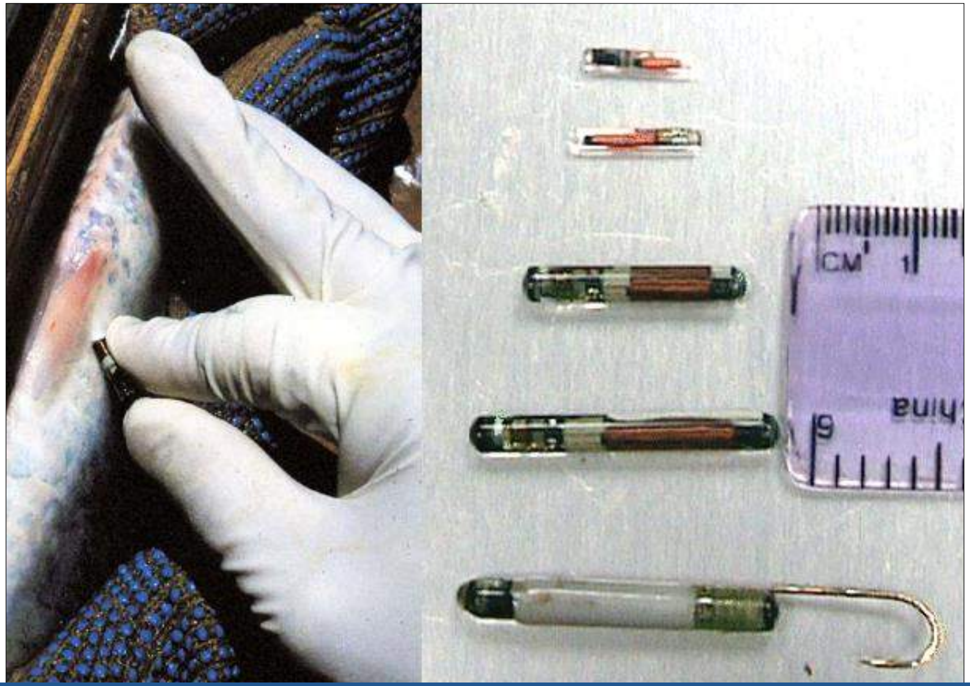
- Visual observation
- Hook & line sampling (if legal for species)
- Electrofishing
- Seining
- eDNA
- Multibeam sonar

https://www.wellsreserve.org/blog/finding-fish-with-edna

https://nrtraininggroup.com/wp-content/uploads/Electrofishing-Certification1-700x400.jpg

Shad seining on the Brandywine, Courtesy of Jim Shanahan, Brandywine River Restoration Trust.





Biological Monitoring

Extended/Longer-term

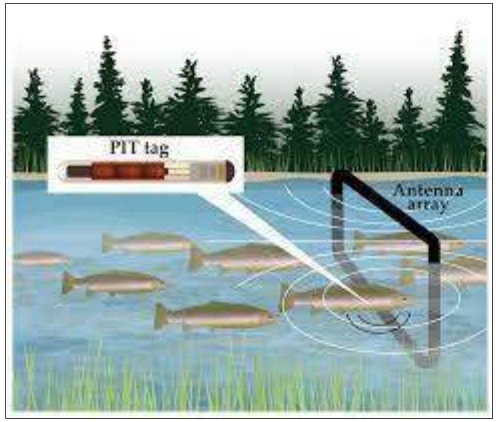
- Video/multi-beam sonar
- eDNA
- Mark-Recapture (visual tags)
- Radio Telemetry
- Passive Integrated Transponder (PIT tag)
- 3-D Acoustic Telemetry

Radio Telemetry

- Set up network of radio receivers
- Implant appropriately sized radio tags (gastric or surgical) into specimens
- Assess 1D movement (i.e. movement between locations A and B)
- Pros:
  - Can be used in turbid water with entrained air
- Cons:
  - Prone to false positive readings
  - Depth limited – water absorbs radio waves

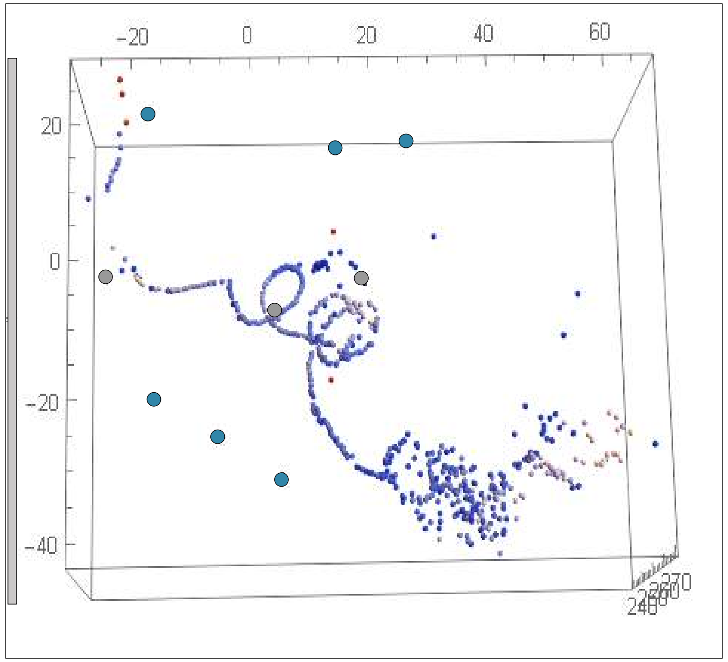
PIT Telemetry

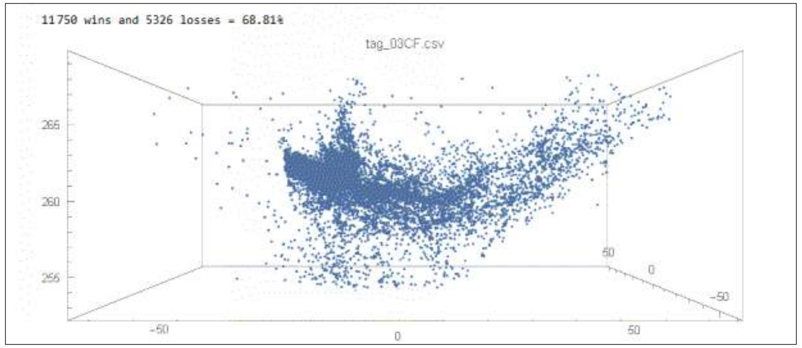
- Passive integrated transponders – the same microchips we put in our pets
- Internal microchip activated by electro-magnetic induction as it passes through a special antenna
- Pros:
  - Cost effective way to measure simple 1D movement.
- Cons:
  - Difficult to set up whole-channel antennas

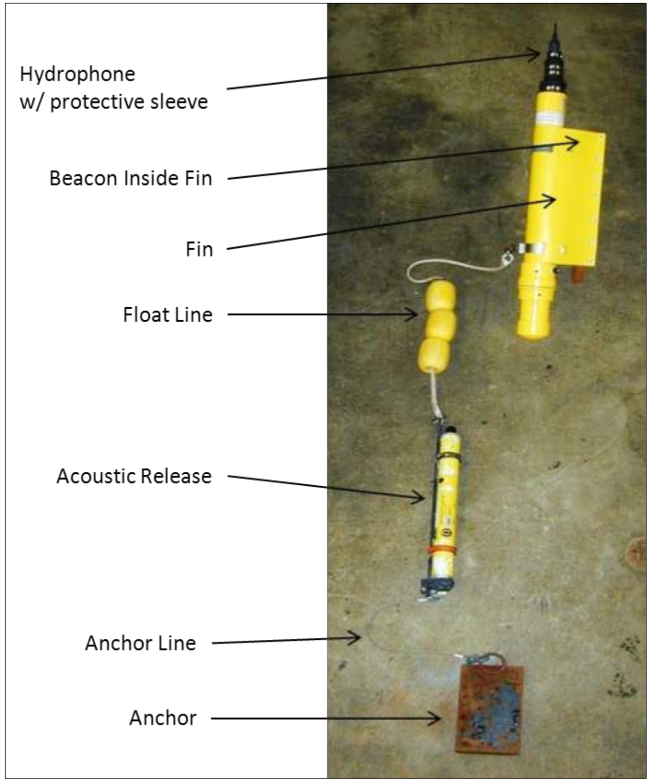


Acoustic Telemetry

- Use sound to locate fish in 1, 2, and 3 dimensions
- Sound moves > 1 km/s in 18^{o} C water
- Pros:
  - Not depth limited – good for deep forebays
  - Able to quantify precise behavior in regions of interest
- Cons:
  - 2 and 3D positioning studies difficult to setup and process because of clock synchronization and multipath error
  - Limited range in turbulent water







Session 4 AGENDA

01	Design Intro & Biological Effectiveness by Tyler Kreider
02	Hydraulic Modeling by Barry Chilibeck
03	Roughness Design by Barry Chilibeck
04	Other Design Factors by Tyler Kreider
05	Summary of NLF Monitoring Results by Bjorn Lake
06	Monitoring Methods by Barry Chilibeck and Tyler Kreider
07	Maintenance of NLFs by Marcin Whitman Up Next!
08	Q&A (as time allows) led by Tyler Kreider

Nature-like Fishways:
Modern Perspectives and Techniques

Session 4:
Design, Monitoring, & Maintenance Considerations

Session 4.7: Maintenance of NLFs

AMERICAN FISHERIES SOCIETY
BIOENGINEERING SECTION

March 27, 2024

Maintenance of NLFs: Agenda

Challenges, design, and post construction inspection

01	Begin with the end in mind
02	What constitutes success and resilience?
03	Post construction inspection and monitoring
04	Pre- and Post-bed mobilizing surveys

“ Begin with the end in mind” – Steve Covey

Design considerations

- NLF - allure of low operation needs
  - Especially attractive with current temporary funding surge

o Design challenges

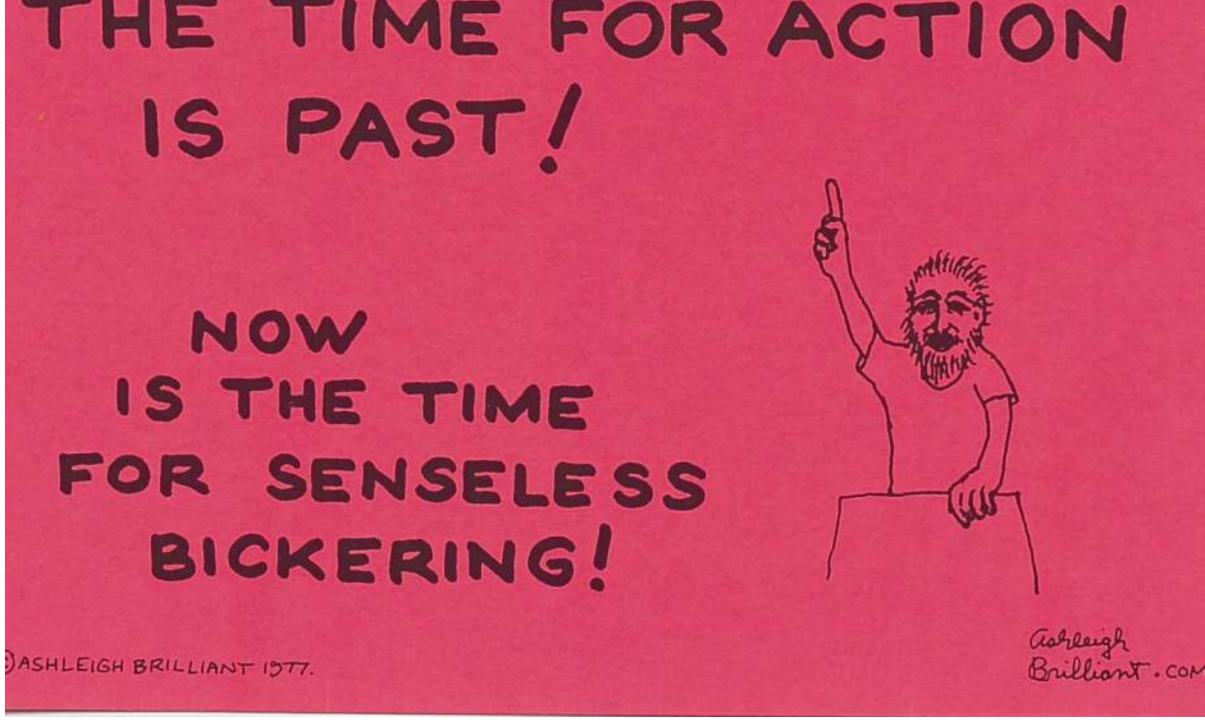
- Access for operation (any gates/flash boards, valves, traps, etc.)
- Access for inspection
- Access for remedy/repair

- Good news: most intensive monitoring and access needed in first three years - typically easier due to less vegetation

What constitutes success and resilience?

Design Considerations:

- Designing in backstops and redundancy, naturalizing
- Designing out critical elements where failure of one element causes barrier or unzips treatment (eg headcut)
- Designing out unneeded or unobtainable discontinuities
- Consider long profile context,
    - slope and.streampower
    - sediment transport and erosion
- Anchor point for debris removal



Post construction inspection and monitoring

Purpose

- Ensure achieving connectivity goals – biological and physical
- Early indications and remedy of physical degradation

Biological monitoring covered earlier in session

Post Construction

Two guiding questions

- Are physical changes causing degradation in performance?
- Is NLF channel spanning or bypass channel ?
  - Different considerations for
    - Sediment transport
    - Debris movement
    - Flood forces

Post construction inspection and monitoring - Physical

Record keeping and independent verification

- Most common error: Underfunded
- Goal not achieved
- Repeated poor design elements
- Delay compounding cost of remedy

Post construction inspection and monitoring - Physical

Physical

- Is water, debris, sediment passing site as intended?
- Is treatment structurally "stable" or evolving in an acceptable though unanticipated manner?
    - Examples:
        - Braiding
        - Channel evulsion/meander
    - use of baseline Pre and post construction (as built) surveys and photo monitoring:
- QA/QC spreadsheet and tolerances
- Benchmarks
- Photo/video monitoring points

Post construction inspection and monitoring - Physical

- Use of previous modeling and biological monitoring
- Is debris, trash, or sediment repeatedly accumulating in an adverse manner?
- Are changes in channel characteristics supporting goals?
- Most deficiencies will surface in first five years
  - Role of vegetation in most projects
    - Project gets stronger, but harder to access
  - Role of bed mobilizing flows
    - Foundational elements remain in place
    - Mobile elements are replaced by natural sediment

Physical Monitoring Phases: Pre-bed-mobilization surveys

•Initial settling is typical - concrete/rock interfaces

•monitoring for winnowing, tunneling

•document low flow and moderate flow conditions:

- water surfaces/ flow rate
- Velocities
- Turbulence (e.g.particle studies with drones)
- Flow anomalies

Physical Monitoring Phases: During bed-mobilizing flows

- If possible, use telemetry
- or afterwards look for: Flow anomalies - reversals, ponding

Physical Monitoring Phases: Post-bed-mobilizing flows

- Has configuration, and thus flow patterns and passage, changed in:
  - An unanticipated manner?
  - Unacceptable manner?
- photo points and resurveys

Remedies

- Trash removal (rare)
- Debris removal
- Sediment removal (rare)
- Resealing of weirs/bands
- Partial reconstruction or reseeding (rare)
- Funding
  - Performance bond
    - usually with adverse land owner in litigation context
    - under-used mechanism

Questions?

Small Dams – Wilder Dam

Another rock weir loses invert rock due to impoundment/ debris dam upstream

Small Dams – Wilder Dam

Bank cutting

Session 4 AGENDA

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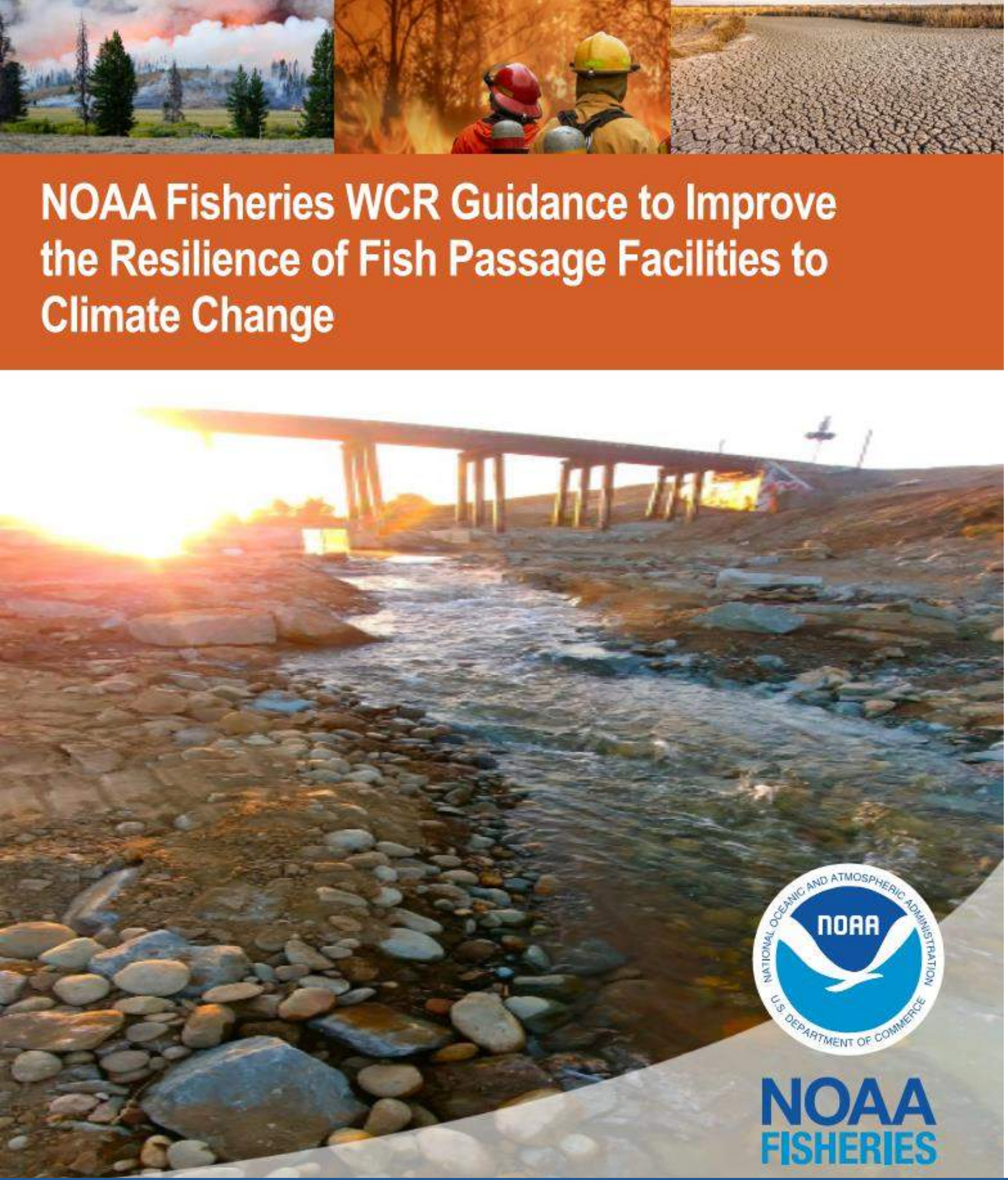
Session 4.8: Q&A/Open Discussion

March 27, 2024

Design Session Q&A

1. Threshold Design - how conservative is the threshold for:
   a. passage?
   b. success?
   c. stability?
2. Good enough passage?
   a. 50%?
   b. 85%?
   c. 100%?



Design Session Q&A

3. Variability & Adaptability
    1. Resident species
    2. Climate change?

Design Session Q&A

4. Invasive Species
   a. Selective barrier design?
   b. Desirable feeding habitat in NLFs?

Dracula of the Deep, Part I: Meet the Flathead Catfish, The Pacific Northwest's "Freshwater Freight Train"

By Dan Magneson/USFWS Fishery Biologist

https://usfwspacific.tumblr.com/post/166081598330/dracula-of-the-deep-part-i-meet-the-flathead

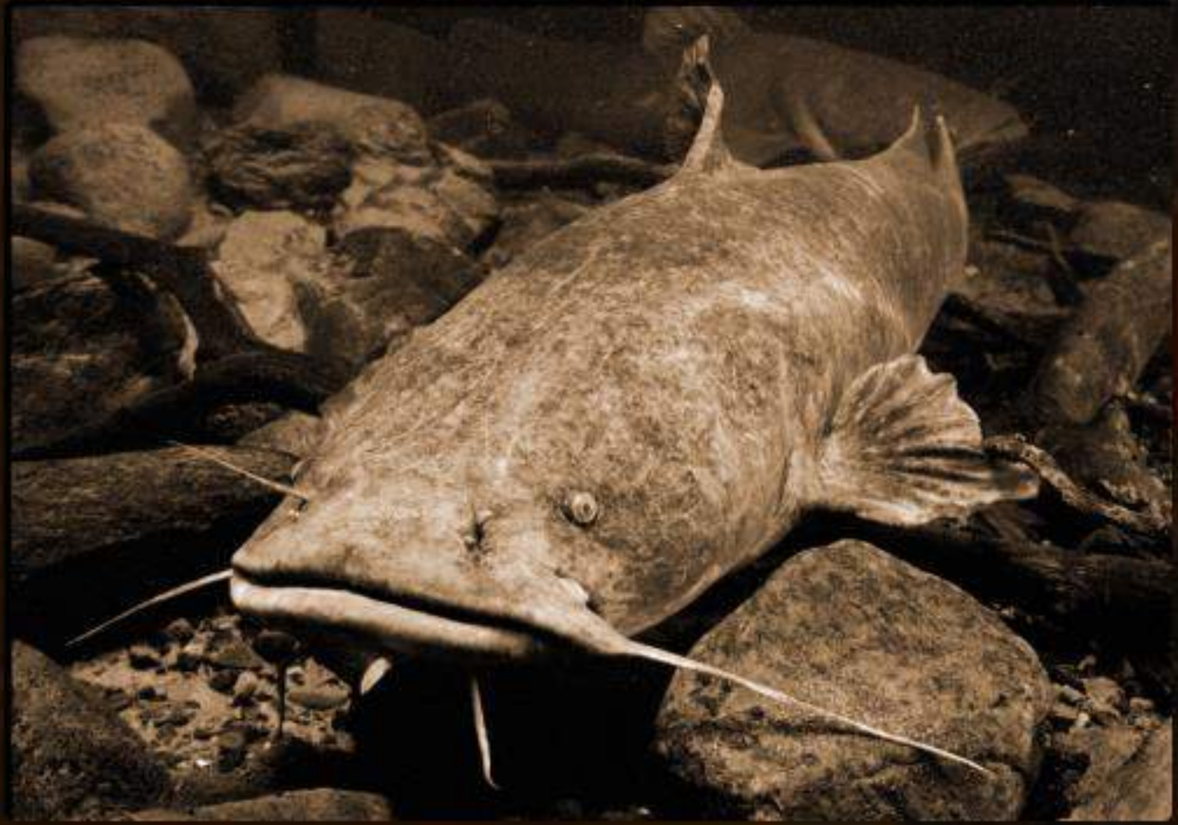
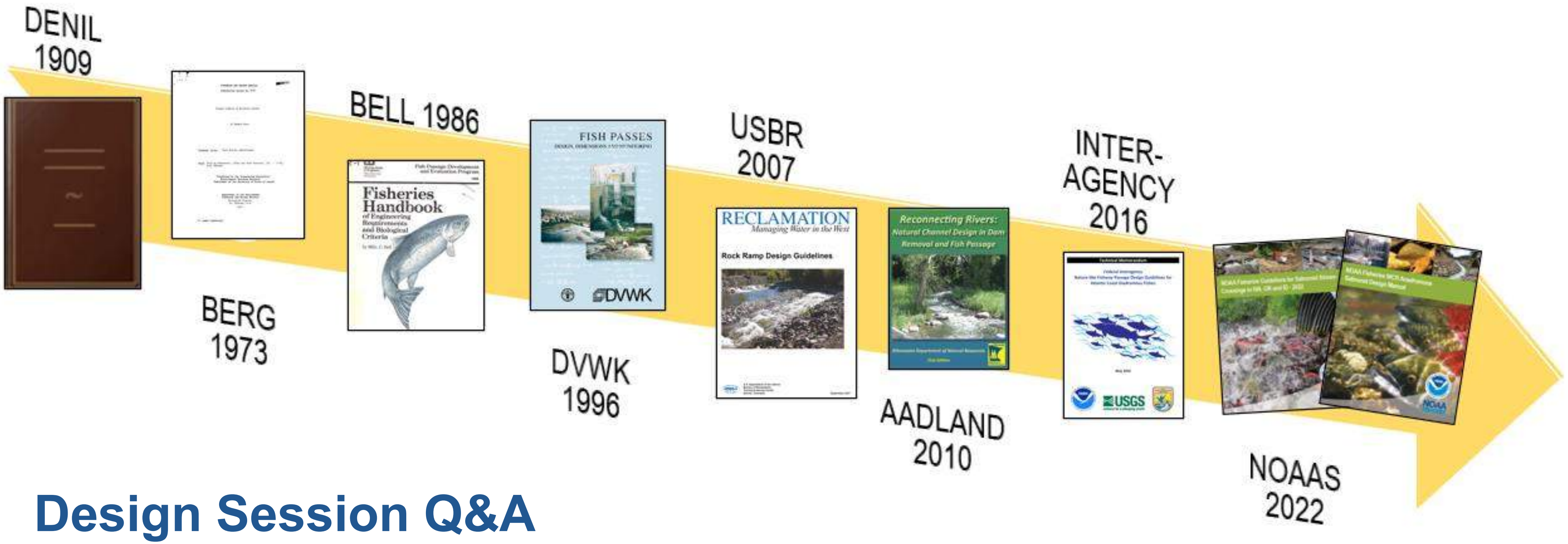


Photo: Their legendary size and strength make them the stuff of lore, much Dracula but the fantastical flathead catfish is very real. Photo credit: in-fisherman.com



Design Session Q&A

5. Feedback on current Guidelines?