WATERPOWER
HYDRO BASICS

JULY 15-16, 2024

COLORADO CONVENTION CENTER
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WATERPOWER HYDRO BASICS
JULY 15-16, 2024
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Waterpower Hydro Basics

Natural Resource Stewardship: Instream Flows and Fish Passage

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Courtenay, British Columbia, Canada

Trinity Consultants

ECOFISH RESEARCH

Multiple Uses of Rivers

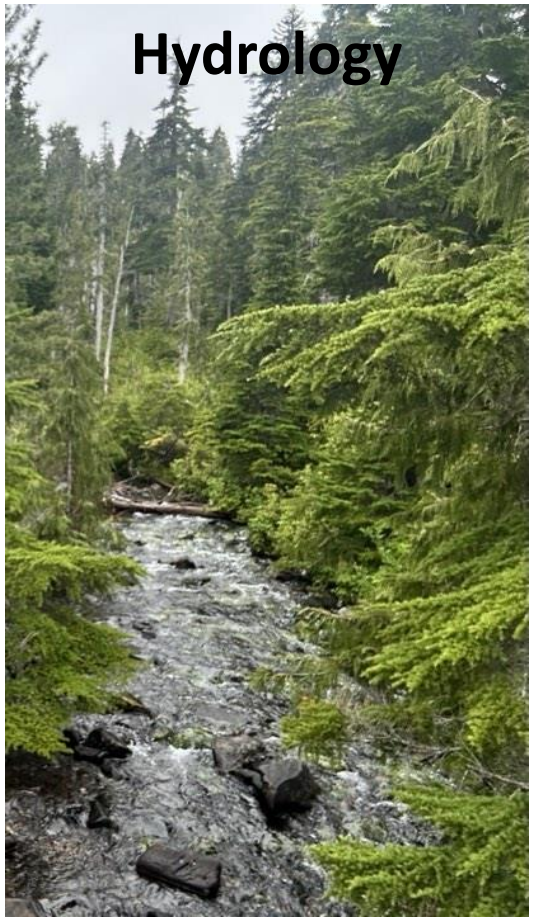
Outline

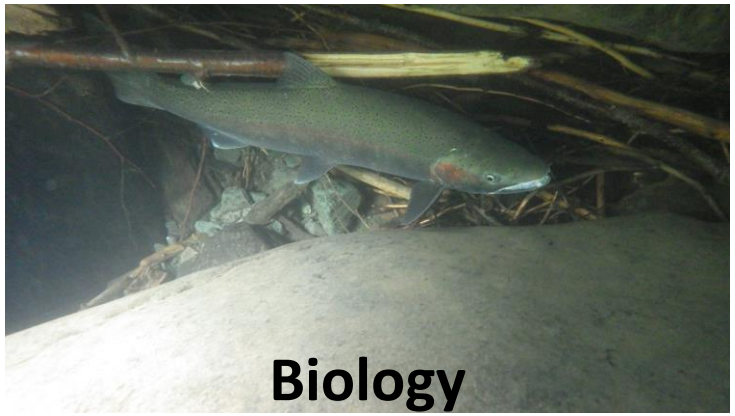
- Environmental considerations for instream flows
- Flow regimes at hydropower facilities
  - How facility type affects flow regime
  - Setting instream flows
- Fish passage
- Tools for assessment and mitigation

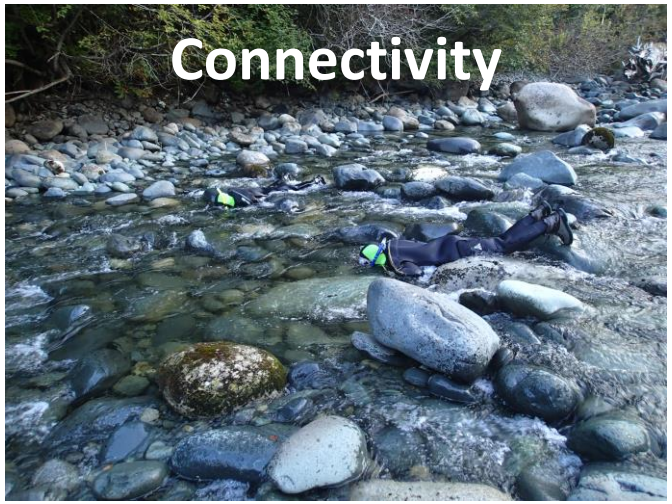
Instream Flows

- Definition: The amount of water flow maintained within a stream to meet various objectives, including environmental and social requirements
- May be prescribed as part of operating conditions
- No universal method for setting instream flows; requires consideration of trade-offs

Environmental Considerations for Instream Flows







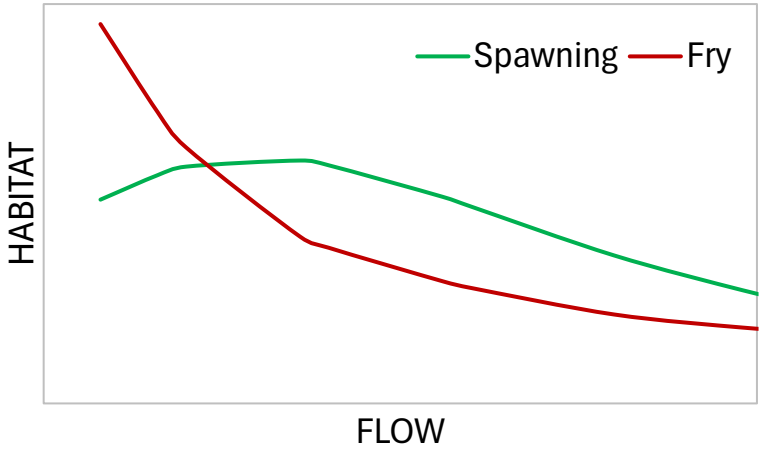
Instream Flow Council: https://www.instreamflowcouncil.org/

Hydrology

- Flow regime: magnitude, timing, duration, frequency, rate of change
- Minimum flows should be provided
- Occasional high flows are required for ecosystem functions
  - Flushing fine sediment, wetting of floodplain
- Timing of flows affects ecological cues
  - Fish spawning and migration; life cycle of aquatic insects
- Rapid flow changes can negatively affect fish
  - Fish stranding, changes to water temperature

Habitat

- Fish have preferred range of habitat conditions
  - Preferences depend on species and life stage
  - Habitat quantity varies with flow (depth, velocity)



- Changes to the flow regime can also affect habitat for birds, beavers, amphibians, insects
- Habitat often a key consideration for instream flow assessment (IFIM)

Geomorphology

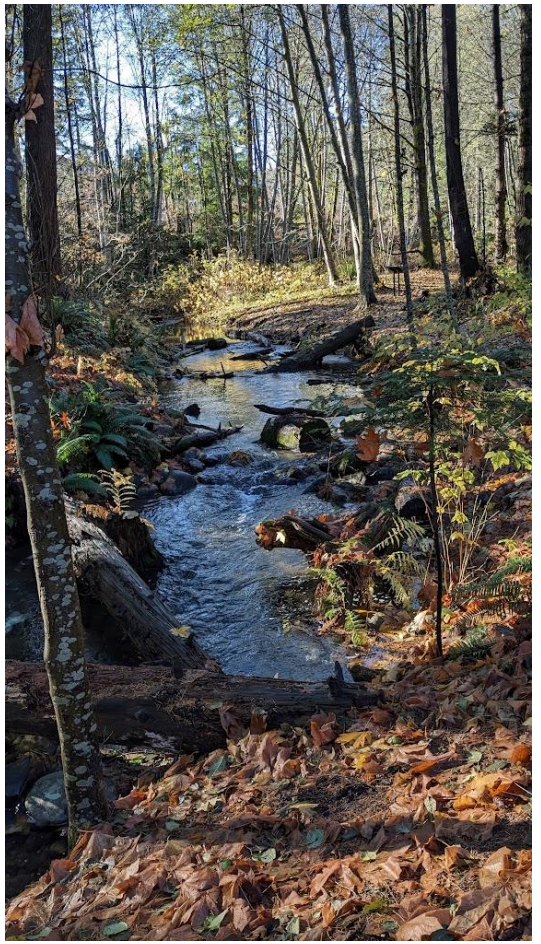
- Sediment
  - Erosion
  - Transport
  - Deposition
- Channel formation
- Habitat formation and alteration
  - Large woody debris transport
  - Scour pools
- Floodplain development

Water Quality

Parameter	Issue
Water Temperature	Extremes can result in lethal effects to fish Water temperatures affect growth, emergence, recruitment success; provide ecological cues
Dissolved Oxygen and Gas	Supersaturation of dissolved gas can be lethal to fish Low flows can deplete oxygen, affecting aquatic biota
Suspended Solids	Potentially lethal effects to fish Can smother incubating eggs and insect habitats
Nutrients	Water storage in dams can affect nutrient dynamics Flows contribute to dilution of pollutants Low flows can contribute to eutrophication

Connectivity

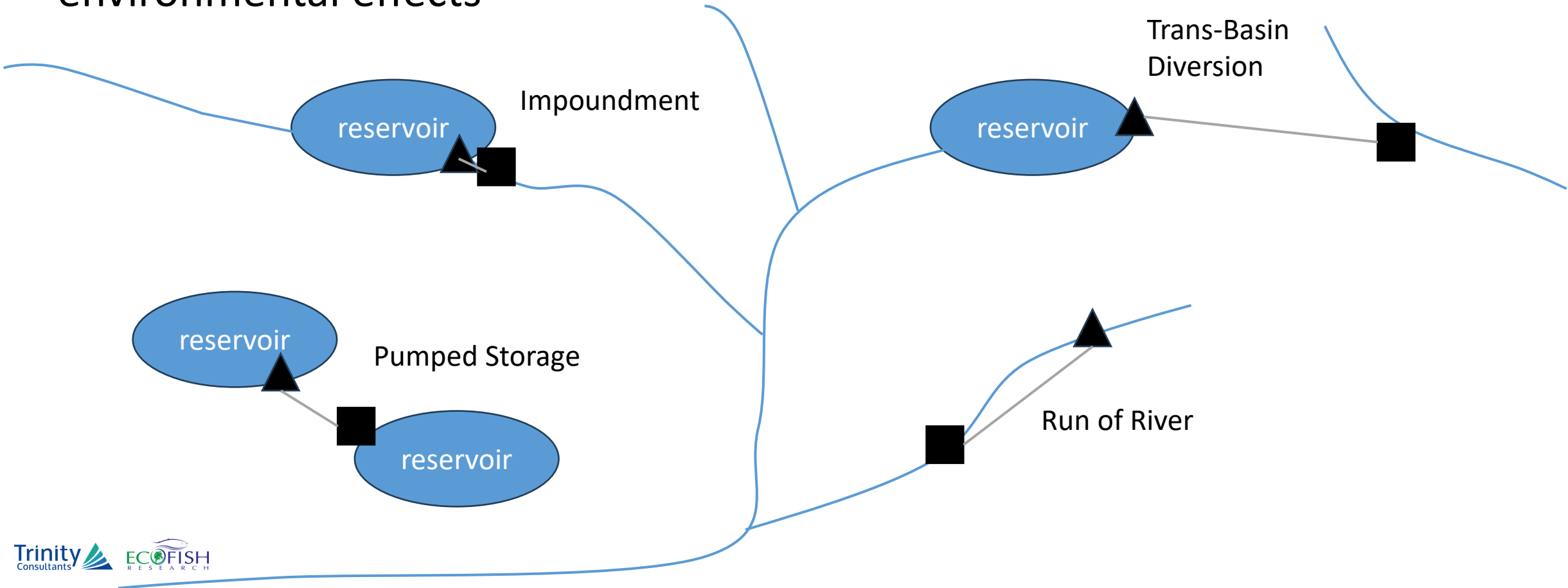
- Fish passage at natural features
  - Flow-dependent migration barriers (e.g., falls, riffles or infrastructure)
  - Shallow stream sections
  - Side channels
- Passage of insects for fish food downstream



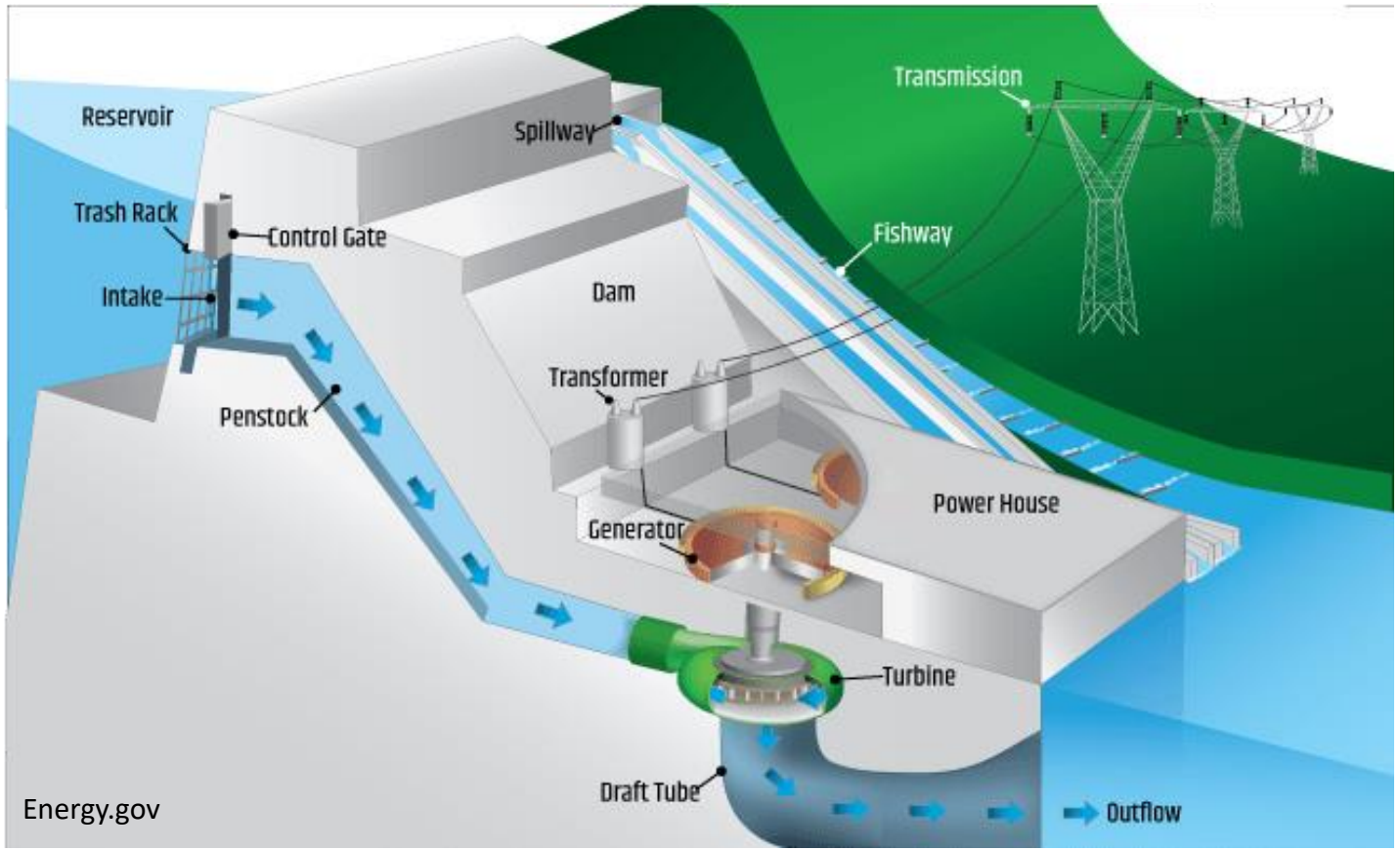
Flow Regimes at Hydropower Facilities

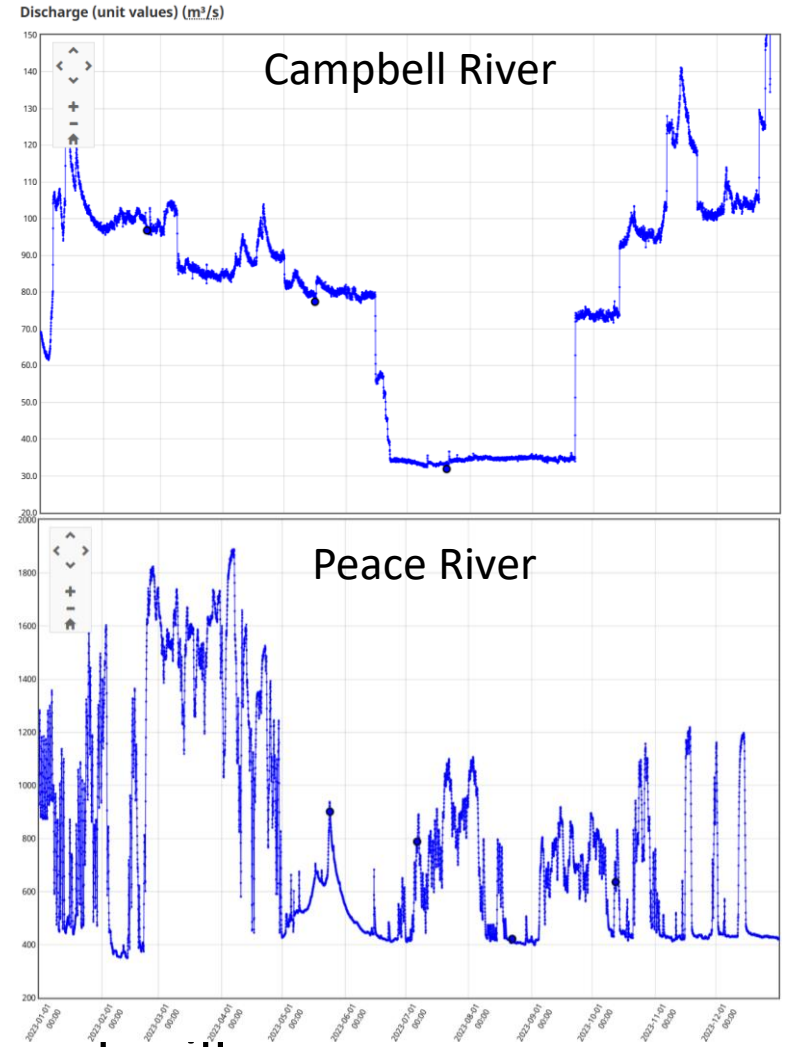
Flow Regimes at Hydropower Projects

- Project configuration affects the instream flow regime, and associated environmental effects



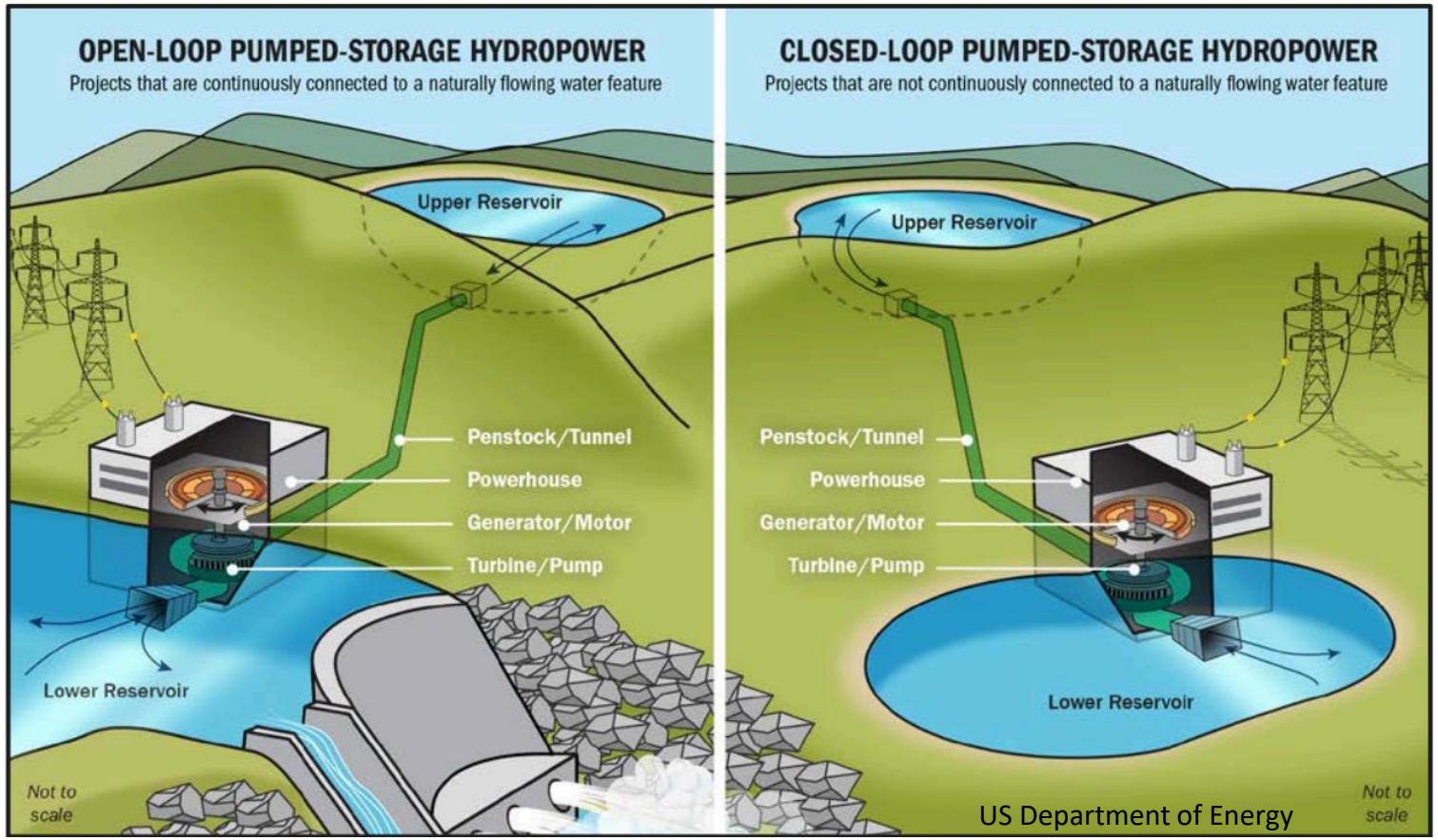
Impoundment Facility





Downstream flow regime dependent on turbine outflow and spill

Pumped Storage Facility



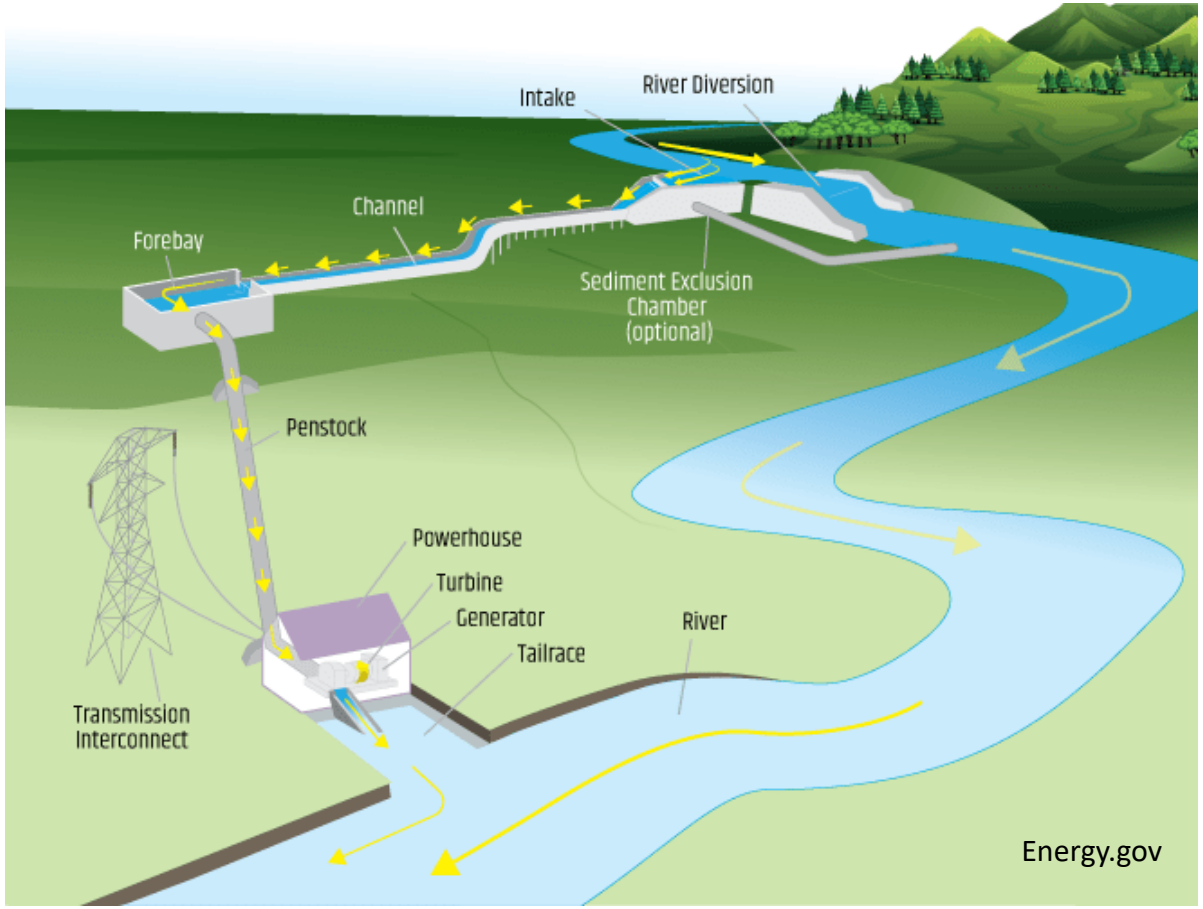
US Department of Energy

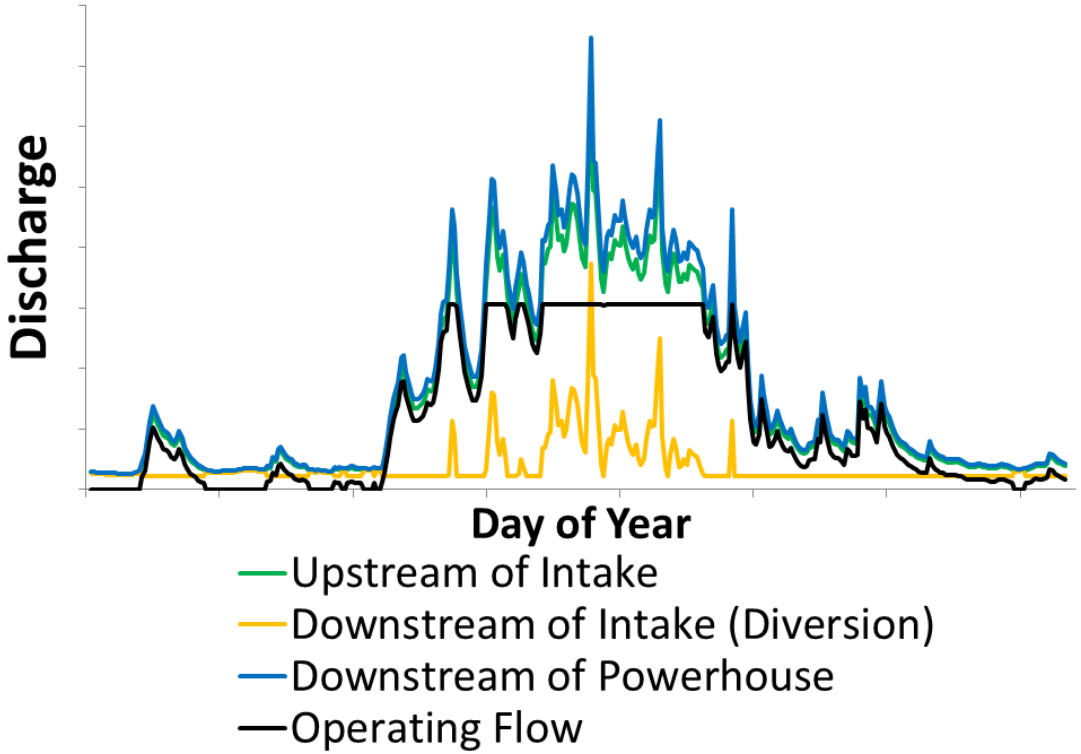
Water is transferred between reservoirs

- Used for power generation during high demand
- Pumped upstream during low demand

Potential environmental effects will differ for open vs closed loop systems

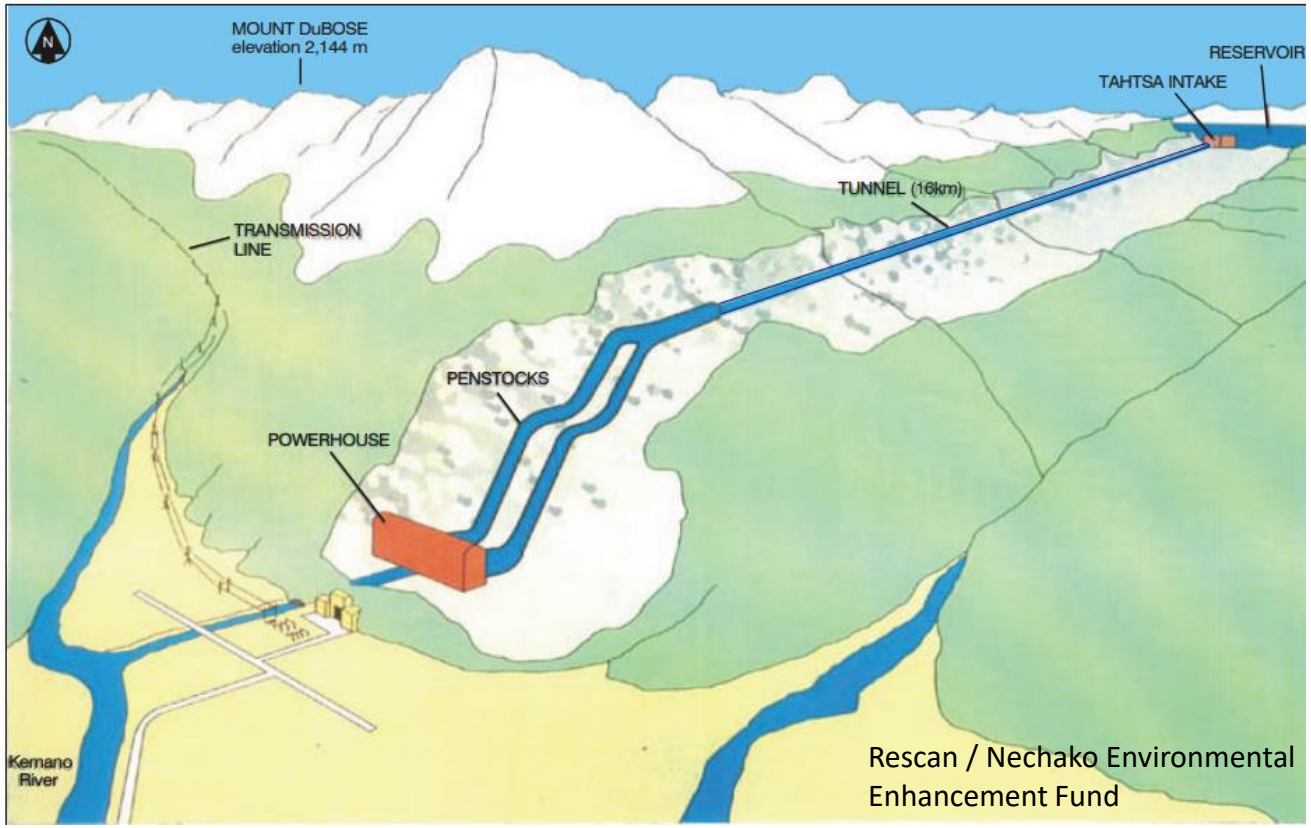
Run of River Diversion Facility

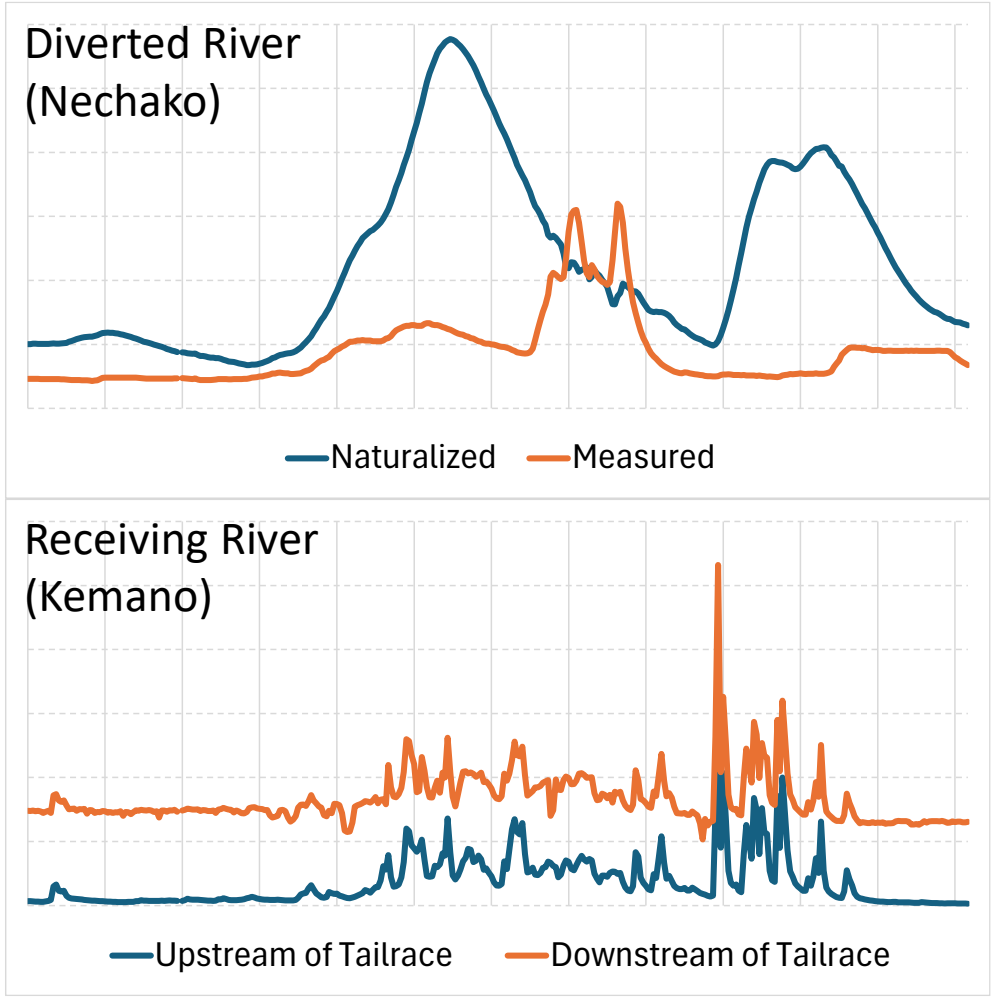




Reduced flow in diversion reach, flows upstream and downstream unchanged (on a daily timescale)

Trans-Basin Diversion Facility





Reduced flow in diverted stream, increased flow in receiving stream

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Setting Instream Flows

- Instream flows developed to mitigate the flow-related effects
- No universal method for determining instream flows
  - Different regions have different methodologies
  - Effort typically depends on context - risk and complexity
- Methods
  - Biological opinion
  - Standard setting
  - Building block
  - Trade-offs analysis

Biological Opinion

- Instream flows set based on judgement of experienced instream flow biologists

2.9 m^3/s

4.5 m^3/s

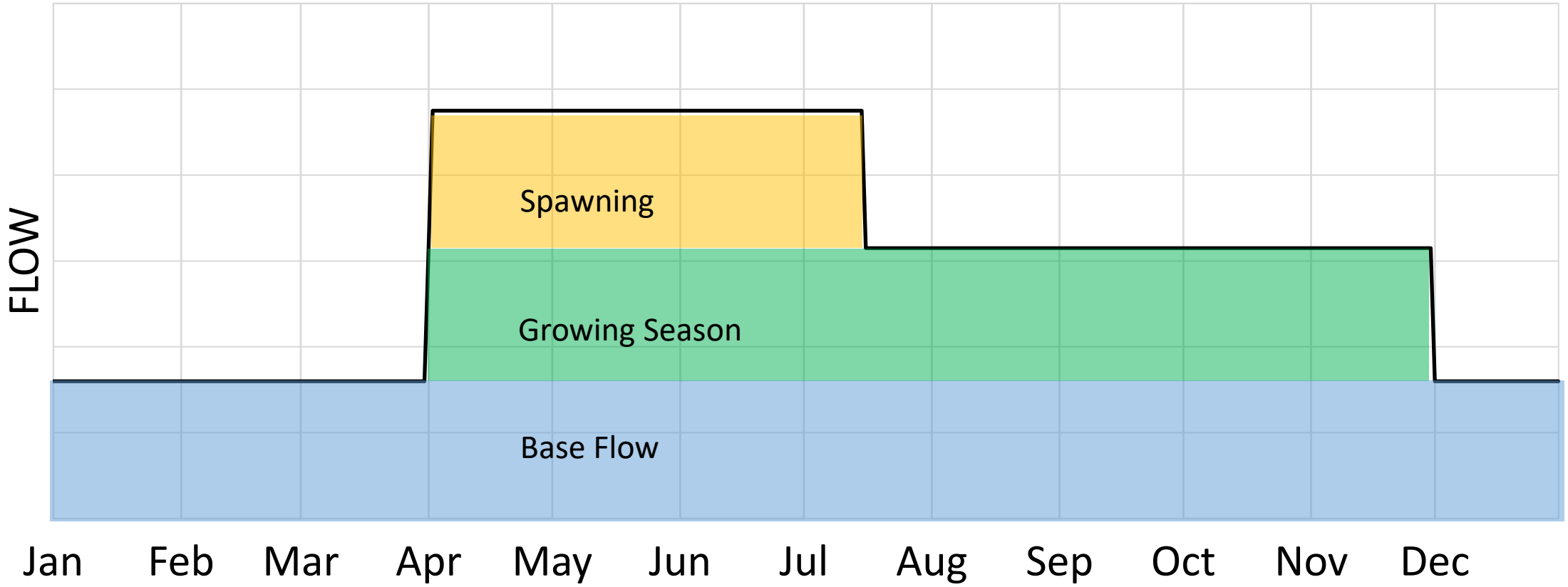
7.9 m^3/s

10.4 m^3/s

Standard Setting

- Instream flows prescribed based on hydrology
- Examples:
  - Tennant (1976)
    - e.g., 20% of mean annual discharge = good conditions
  - Modified Tennant methods, may consider
    - Natural variation in flow
    - Fish life stages present and seasonal flow needs
  - Presumptive Standards (e.g., Richter *et al*. 2012)
    - Classify risk to fish based on the amount of flow change, (e.g., < 10% departure = low risk)

Building Block



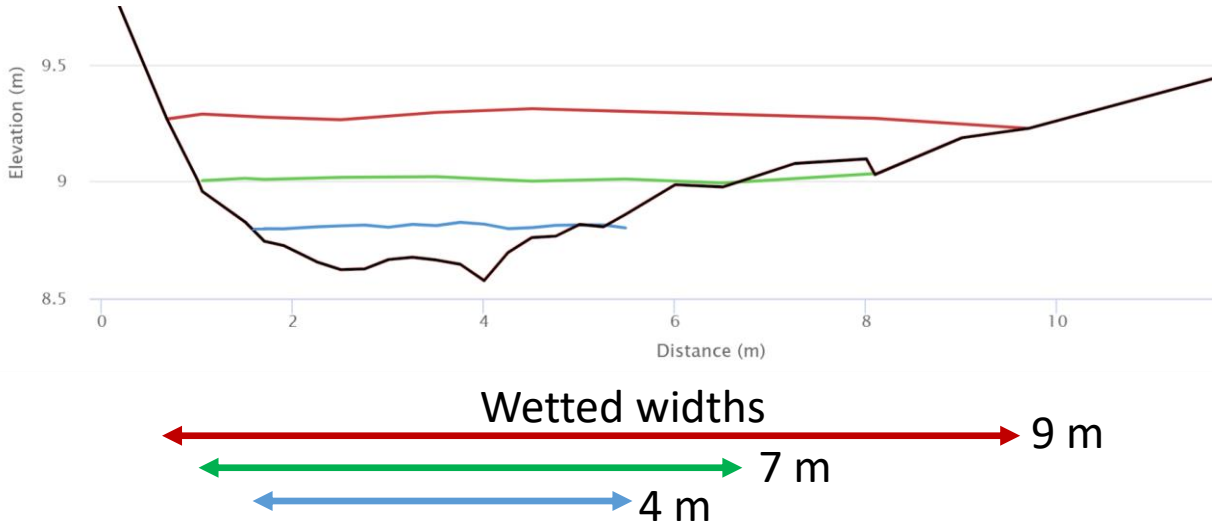
Trade-Offs Analysis

- Example – Structured Decision Making

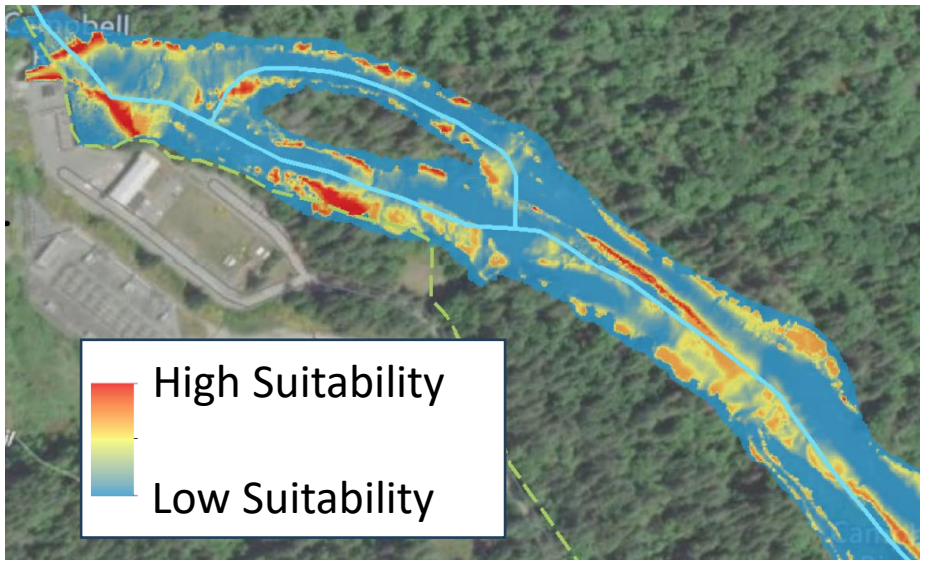
Quantitative Methods

- Hydrological (e.g., Indicators of Hydrological Alteration)
- Hydraulic (wetted width, wetted perimeter)
- Habitat simulation (PHABSIM, SEFA, River2D, Telemac)

Channel Cross-Section at 3 flow conditions



Hydraulic Habitat Suitability (2D Model)



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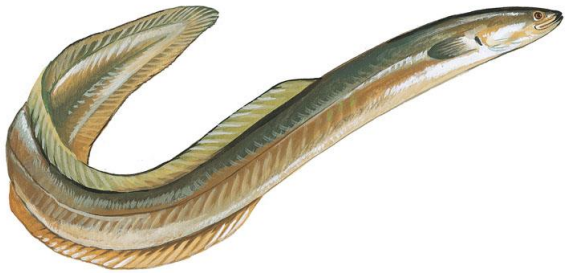
Trade-Offs Between Alternative Instream Flows

Issue	Performance Measure	Preferred Direction	Alt 1	Alt 2	Alt 3
Fish Side Channel Access	Average Flow (m^3/s)	Higher	93	**114**	100
Chinook Habitat	Weighted Usable Area (1000 m^2)	Higher	358	309	**366**
Caribou Calving	Days without Island Connections	Higher	8	**30**	19
Osprey Nesting	Years Flooded	Lower	**12**	18	14
Archaeological Sites	Days Above Flood Threshold	Lower	**2**	13	7
River Open-Water Flooding	Days Above Flood Threshold	Lower	2	19	**1**
Power Exports	Power Generation (MW)	Higher	**136.3**	31	54.5

Fish Passage

Fish Life History Strategies

- Diadromous Fish – parts of life cycle in freshwater, part in salt water
  - Anadromous - Spawn and rear in freshwater, mature in marine environment
  - Catadromous - Spawn in marine environment, rear and mature in freshwater



- Potamodromous – entire life cycle in freshwater, migrate within freshwater systems

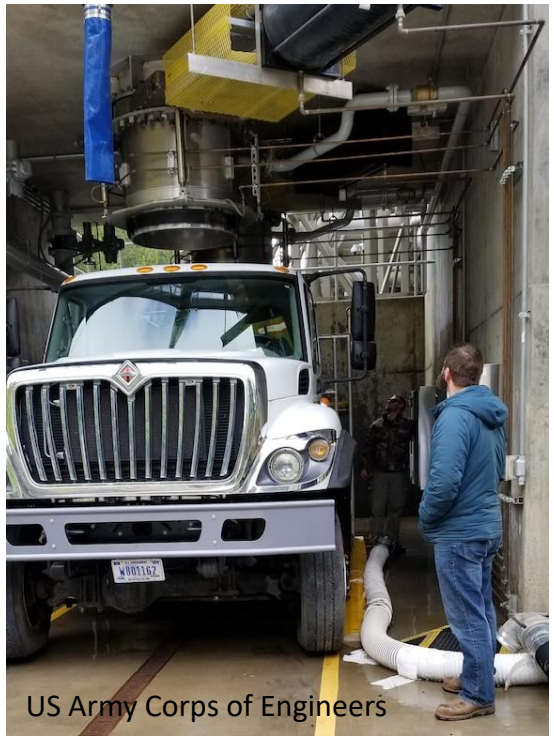
Illustrations: USFWS, Duane Raver, NOAA

Upstream Fish Passage – Fishways

- Fish ladders
  - Pool and weir
  - Vertical slot
  - Denil
- Nature-like fishways
  - Rock ramp and weir
  - Bypass channels
- Eel Ladders

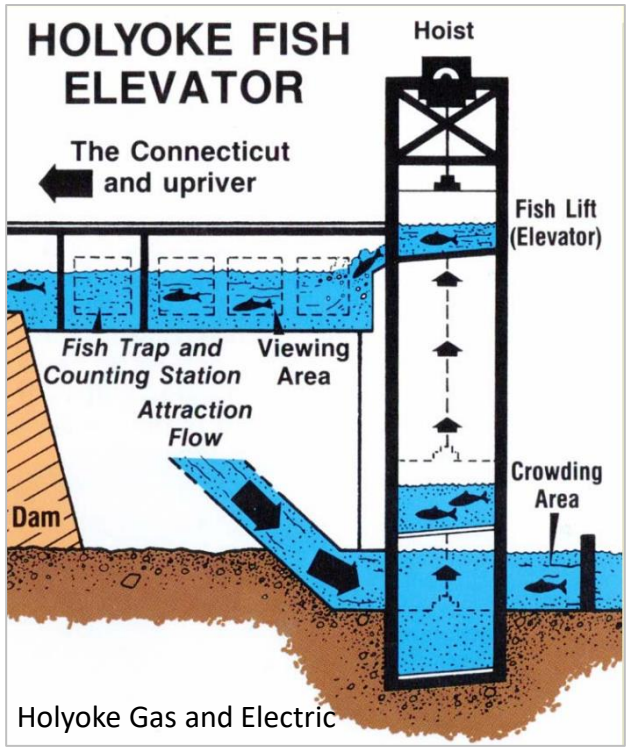
Upstream Fish Passage – Mechanical Solutions

Trap and Haul



US Army Corps of Engineers

Fish Lift

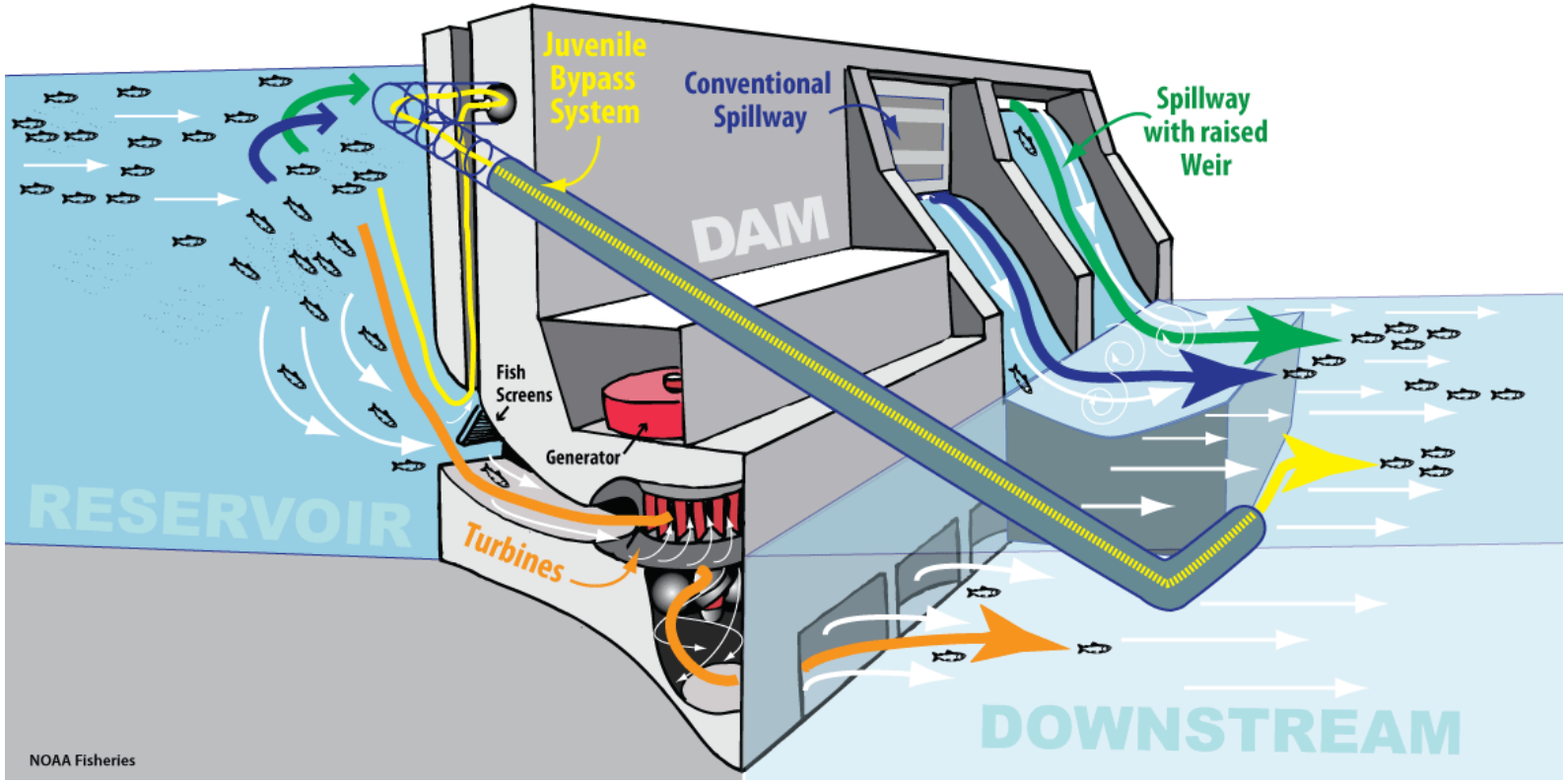


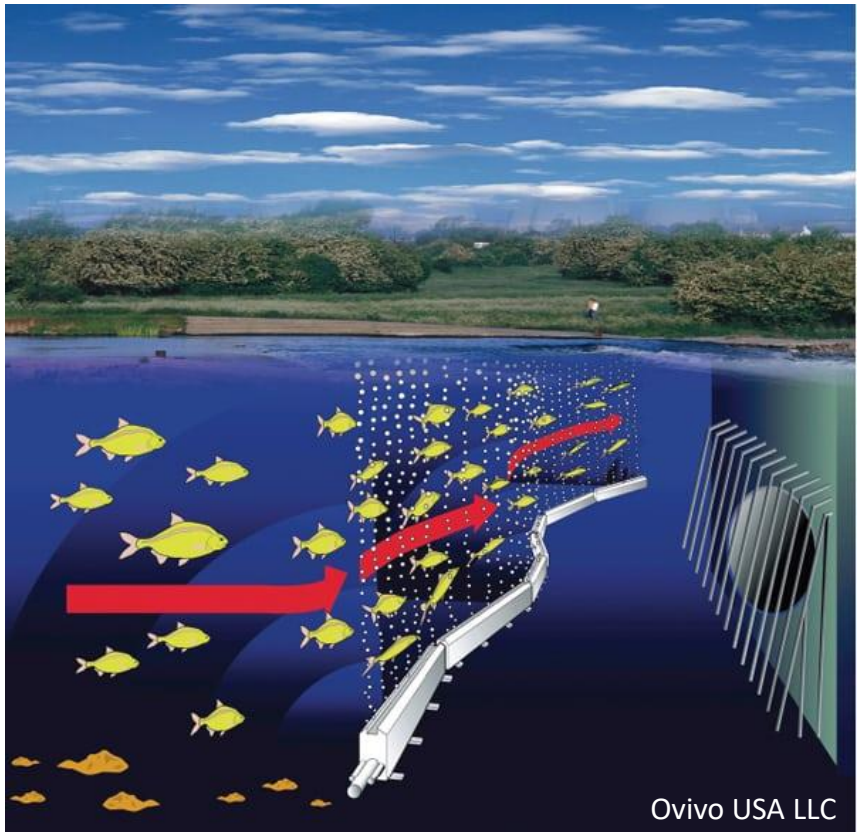
Holyoke Gas and Electric

Whooshh – "Salmon Cannon"

Associated Press

Downstream Passage – Guidance and Deterrence

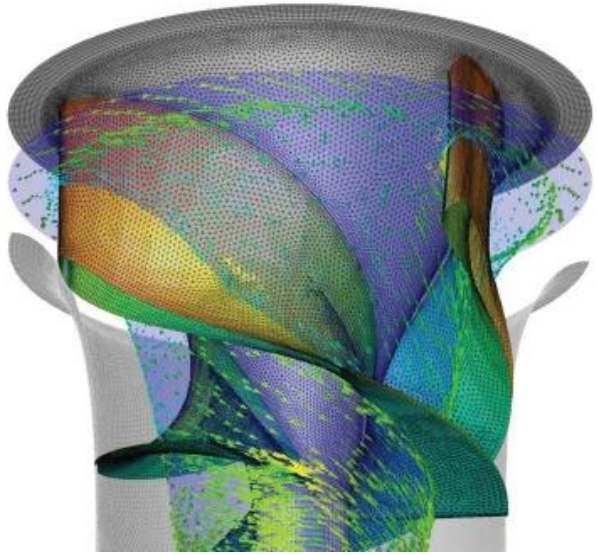




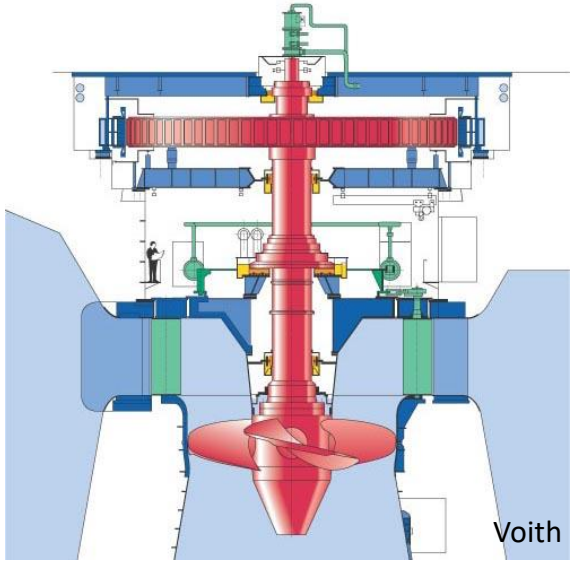
Downstream Passage – Turbines

- Fish may be harmed via turbine strikes, pressure and shear forces
- Fish friendly turbines can have high survival rates (95-100%)

Alden Turbine



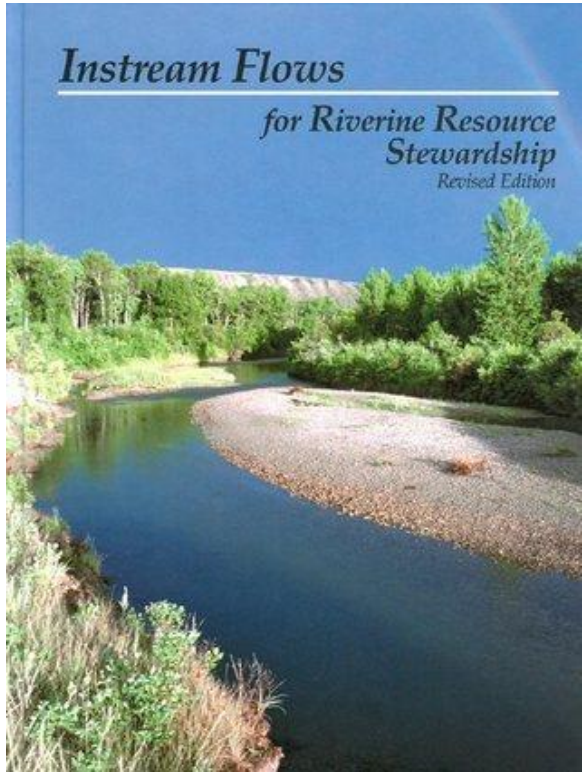
Kaplan Turbine

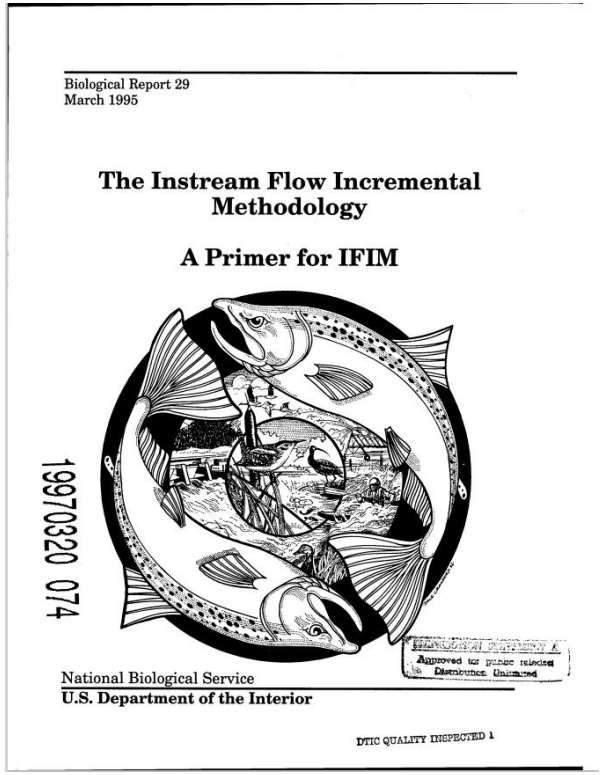


Archimedes Screw

Tools for Assessment and Mitigation

Literature Review




Biological Report 29
March 1995

The Instream Flow Incremental Methodology

A Primer for IFIM

19970320 074

National Biological Service
U.S. Department of the Interior

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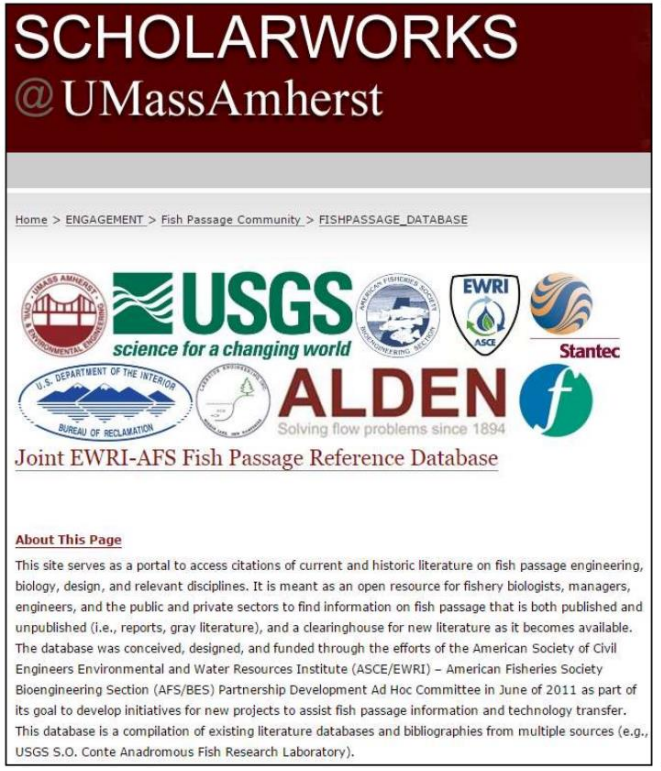
SCHOLARWORKS @UMassAmherst

Home > ENGAGEMENT > Fish Passage Community > FISHPASSAGE_DATABASE

Joint EWRI-AFS Fish Passage Reference Database

About This Page

This site serves as a portal to access citations of current and historic literature on fish passage engineering, biology, design, and relevant disciplines. It is meant as an open resource for fishery biologists, managers, engineers, and the public and private sectors to find information on fish passage that is both published and unpublished (i.e., reports, gray literature), and a clearinghouse for new literature as it becomes available. The database was conceived, designed, and funded through the efforts of the American Society of Civil Engineers Environmental and Water Resources Institute (ASCE/EWRI) – American Fisheries Society Bioengineering Section (AFS/BES) Partnership Development Ad Hoc Committee in June of 2011 as part of its goal to develop initiatives for new projects to assist fish passage information and technology transfer. This database is a compilation of existing literature databases and bibliographies from multiple sources (e.g., USGS S.O. Conte Anadromous Fish Research Laboratory).


Recent Developments in the Evaluation and Application of Behavioral Deterrents for Reducing Fish Entrainment at Cooling Water Intakes

3002018734

Final Report, December 2020

EPRI ELECTRIC POWER RESEARCH INSTITUTE

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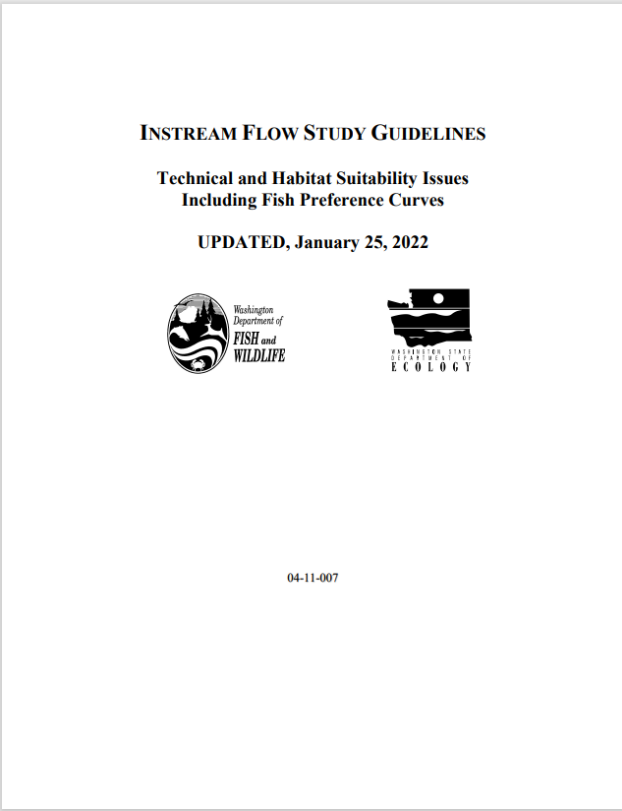
Guidelines and Design Criteria

- Issued by different regions / agencies, but underlying science is often transferrable


INSTREAM FLOW STUDY GUIDELINES

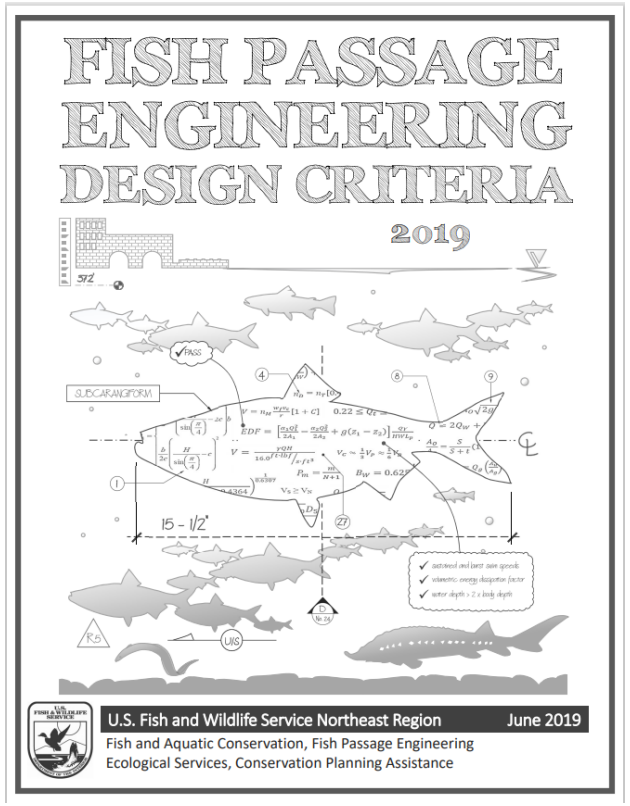
Technical and Habitat Suitability Issues
Including Fish Preference Curves

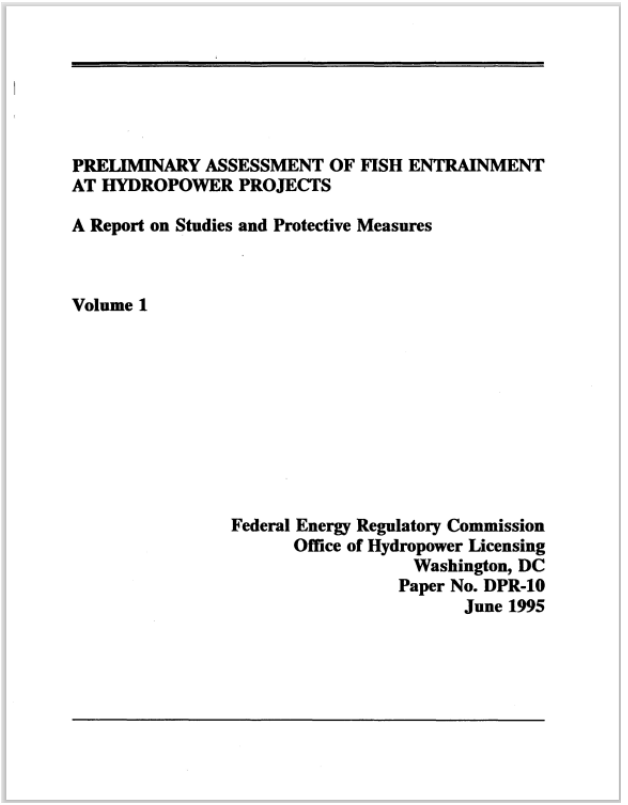
UPDATED, January 25, 2022

Washington Department of FISH and WILDLIFE

ECOLOGY

04-11-007




PRELIMINARY ASSESSMENT OF FISH ENTRAINMENT AT HYDROPOWER PROJECTS

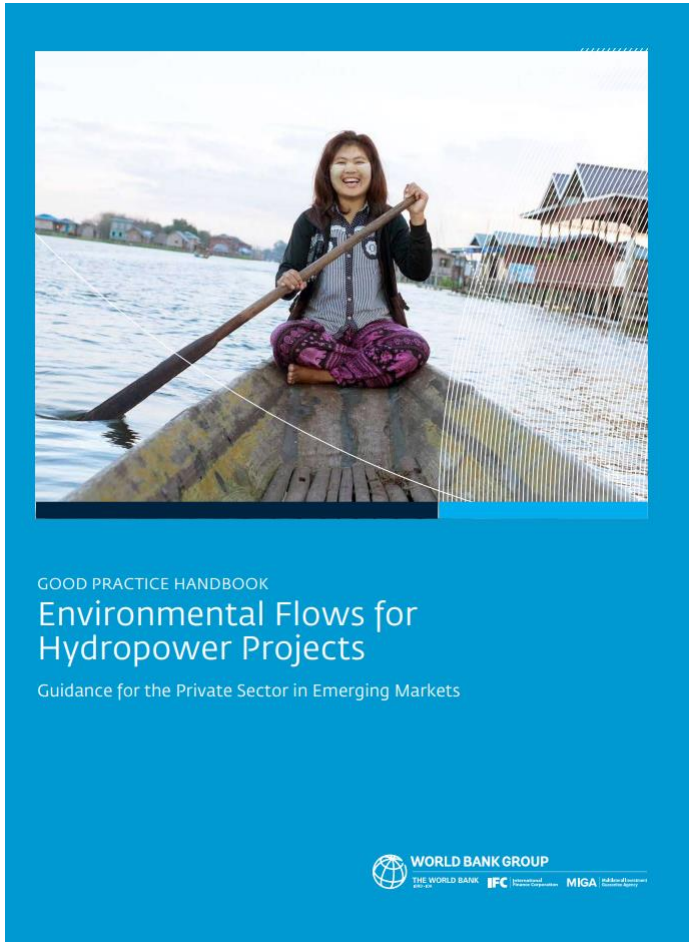
A Report on Studies and Protective Measures

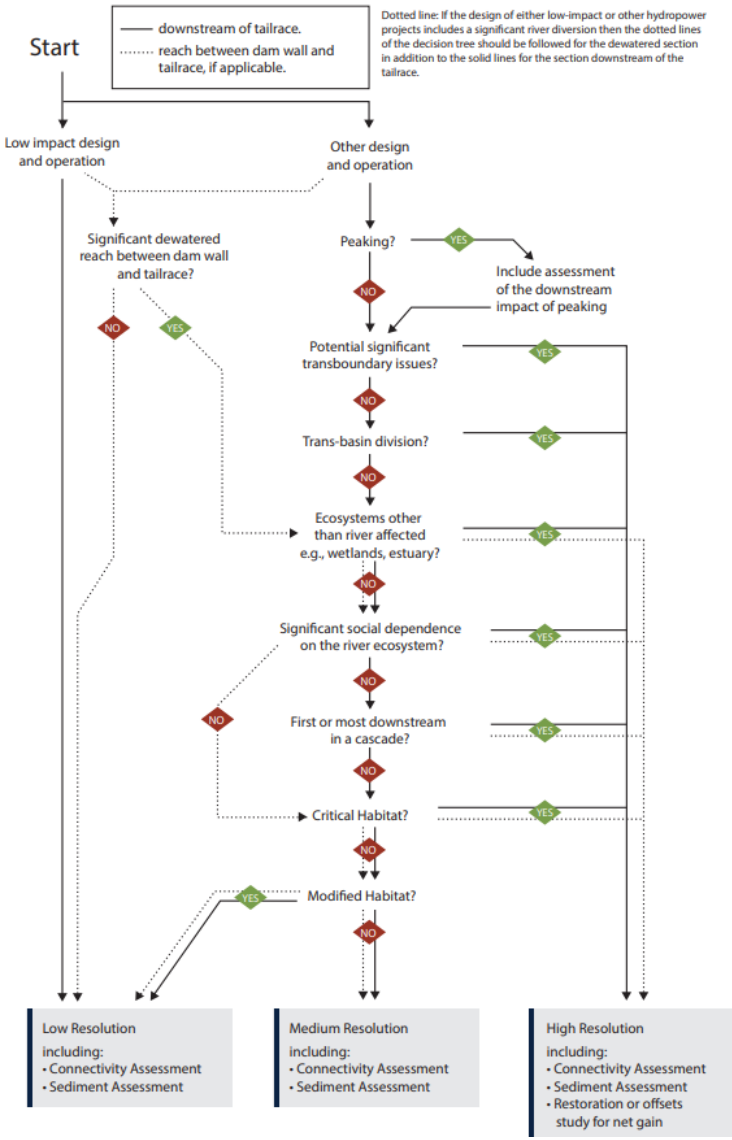
Volume 1

Federal Energy Regulatory Commission
Office of Hydropower Licensing
Washington, DC
Paper No. DPR-10
June 1995

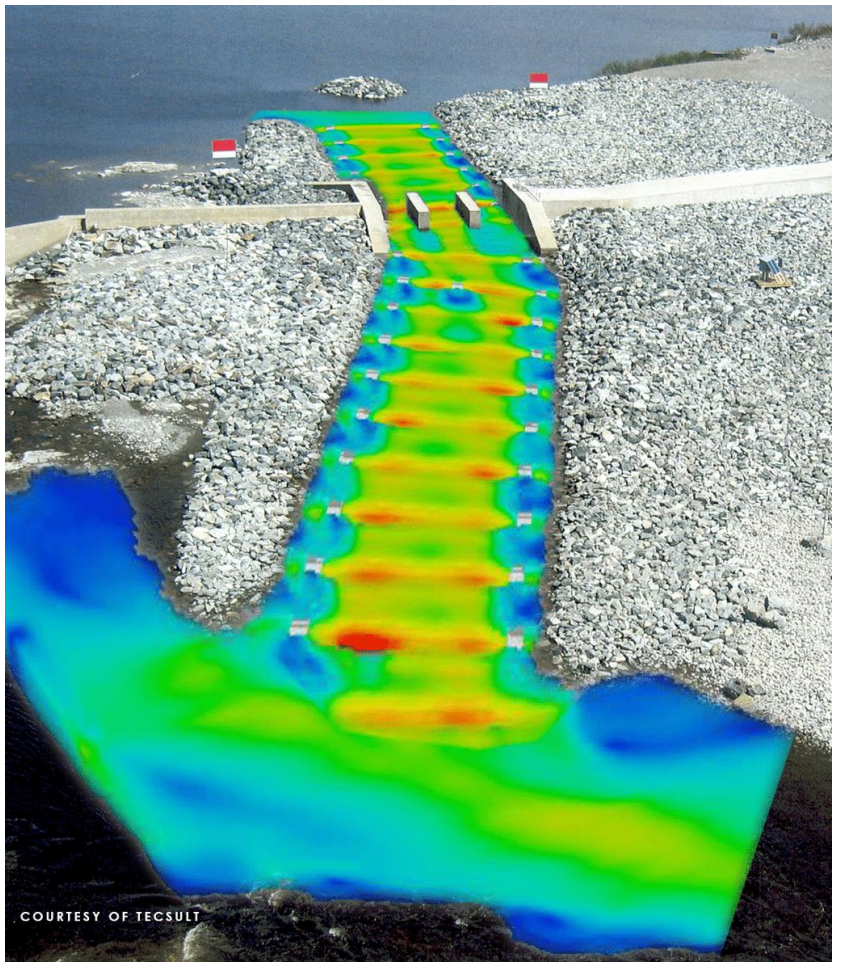
Screening Assessments

- These assessments provide a coarse screening of risk, to determine requirements for assessment and mitigation
  - Can use to inform design
- Details of screening framework will vary by region

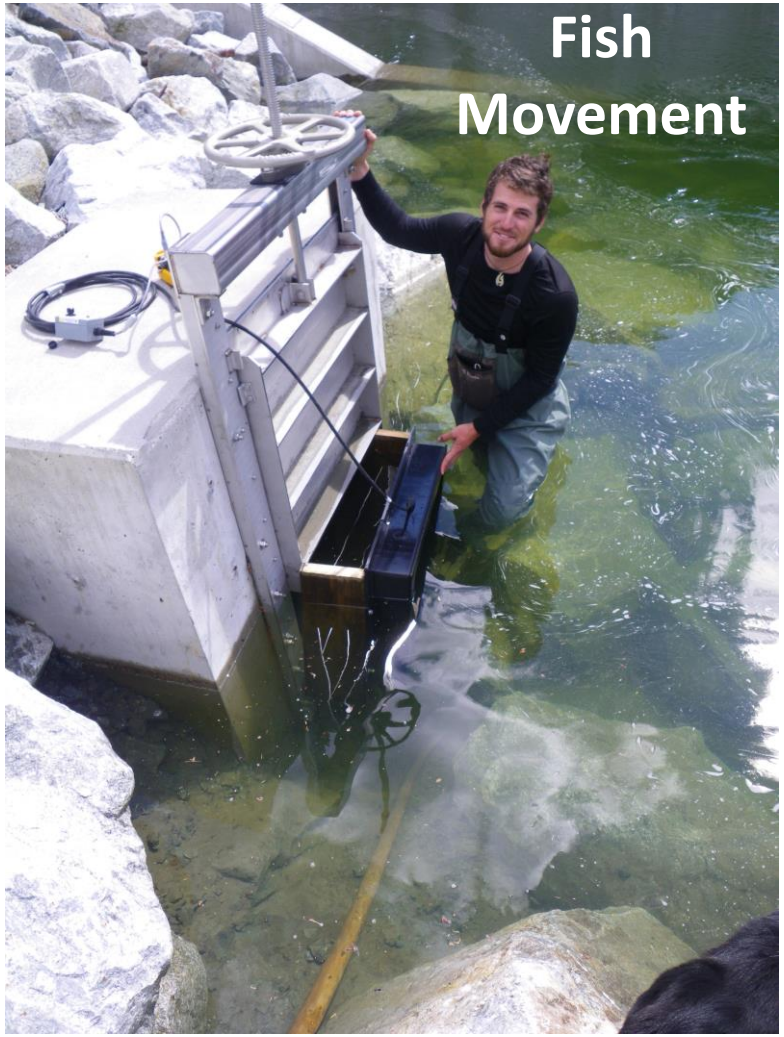




Physical and Numerical Hydraulic Modelling



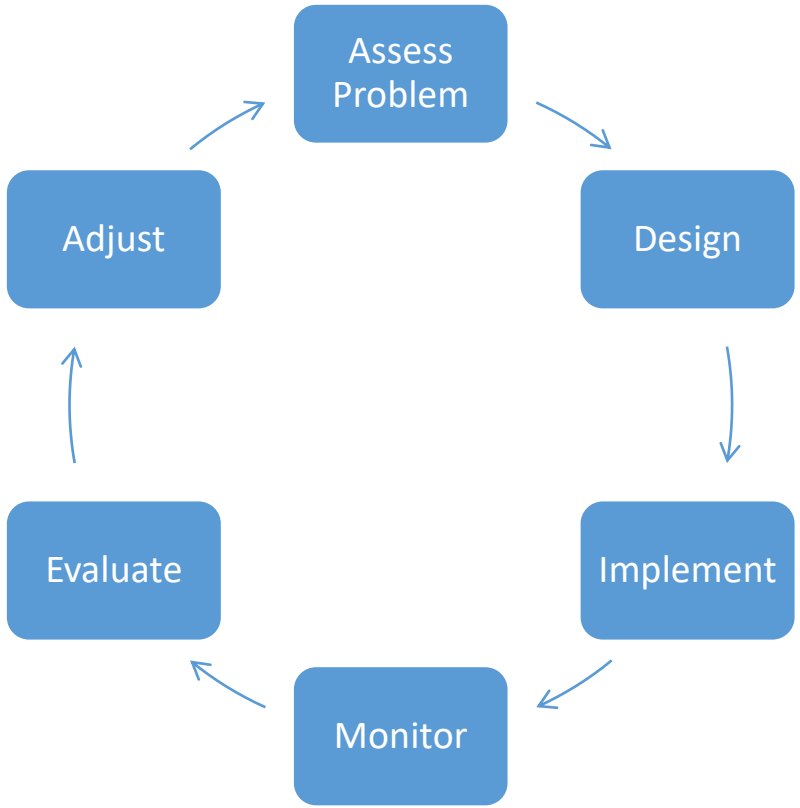
Field Studies



Monitoring and Adaptive Management

- Types of Monitoring
  - Compliance
  - Effectiveness
  - Environmental Response
- Monitoring parameters
  - Water quantity
  - Water quality
  - Water temperature
  - Stream channel morphology
  - Fish community
  - Fish habitat
  - Invertebrates

Adaptive Management



DFO. 2012. Long-term monitoring protocols for new and upgraded hydropower projects in British Columbia and Yukon Territory.

Balancing Multiple Uses of Rivers







Photos: Comox Valley Record

Contact

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