Fish Passage from the Tidewater to the Sierras Workshop - Fish Passage at High Dams - Part 2

35th Annual Salmonid Restoration Conference held in Davis, CA from March 29 – April 1, 2017.

The Feasibility and Design Process for High Dam Fish Passage

From the engineer's and biologist's perspective…

Michael Garello, PE
HDR Engineering, Inc.

Overview

- Definitions of feasibility
- Summary of the feasibility and design process
- Biological linkages to engineering design
- Approaches to Implementation

Definitions of Feasibility

- Fish passage feasibility can be evaluated in the following terms:
  - Technical feasibility
  - Biological feasibility
  - Engineering feasibility
  - Economic feasibility

Definitions of Feasibility

- Technical feasibility - Does it satisfy fish passage and operational objectives of the project?
  - Compliance with technical design guidelines and criteria agreed to for the project.
  - Compliance with requirements from DSOD and others for the existing facility
  - Consistent with the intent of the existing operational requirements (i.e. water supply, flood control, or hydropower)

Definitions of Feasibility

- Biological feasibility - Does it satisfy biological objectives and performance criteria?
  - Consistent with recovery, reintroduction, and/or sustainable population goals.
  - Existing conditions capable of providing intended recovery response.
  - Biological data gaps and unknowns have been resolved to reasonable certainty.

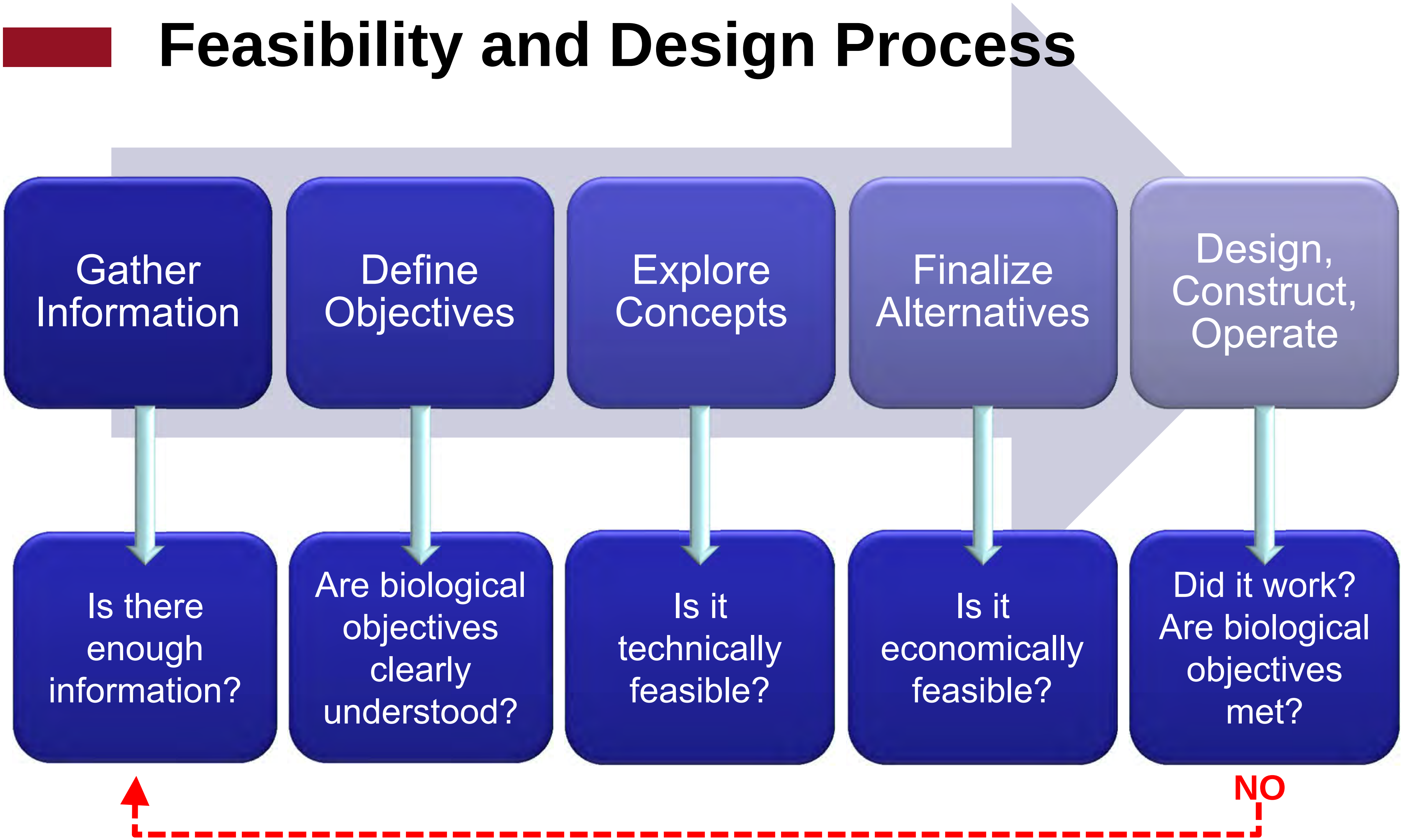
Definitions of Feasibility

- Engineering feasibility - Can it be built and operated?
  - Constructible
    - Geotechnical
    - Seismic
    - Structural
    - Hydraulic
  - Can be operated as intended
  - Adequate resources and access to operate (i.e. electrical power)

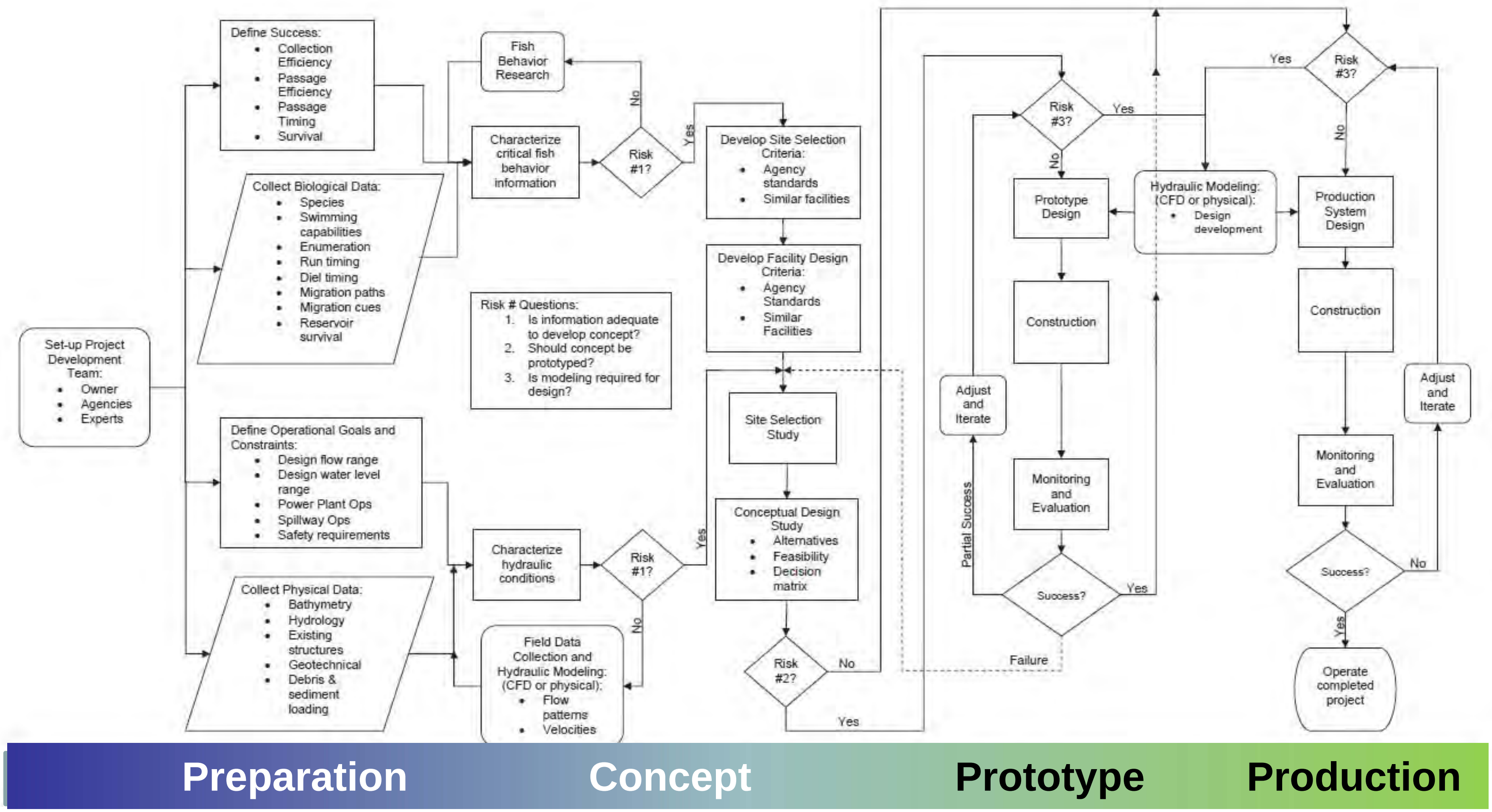
Definitions of Feasibility

- Economic feasibility – Can the proponent/owner implement such an action?
  - Financial resources are or could be available for implementation
  - Cost effectiveness

Feasibility and Design Process



Feasibility and Design Process



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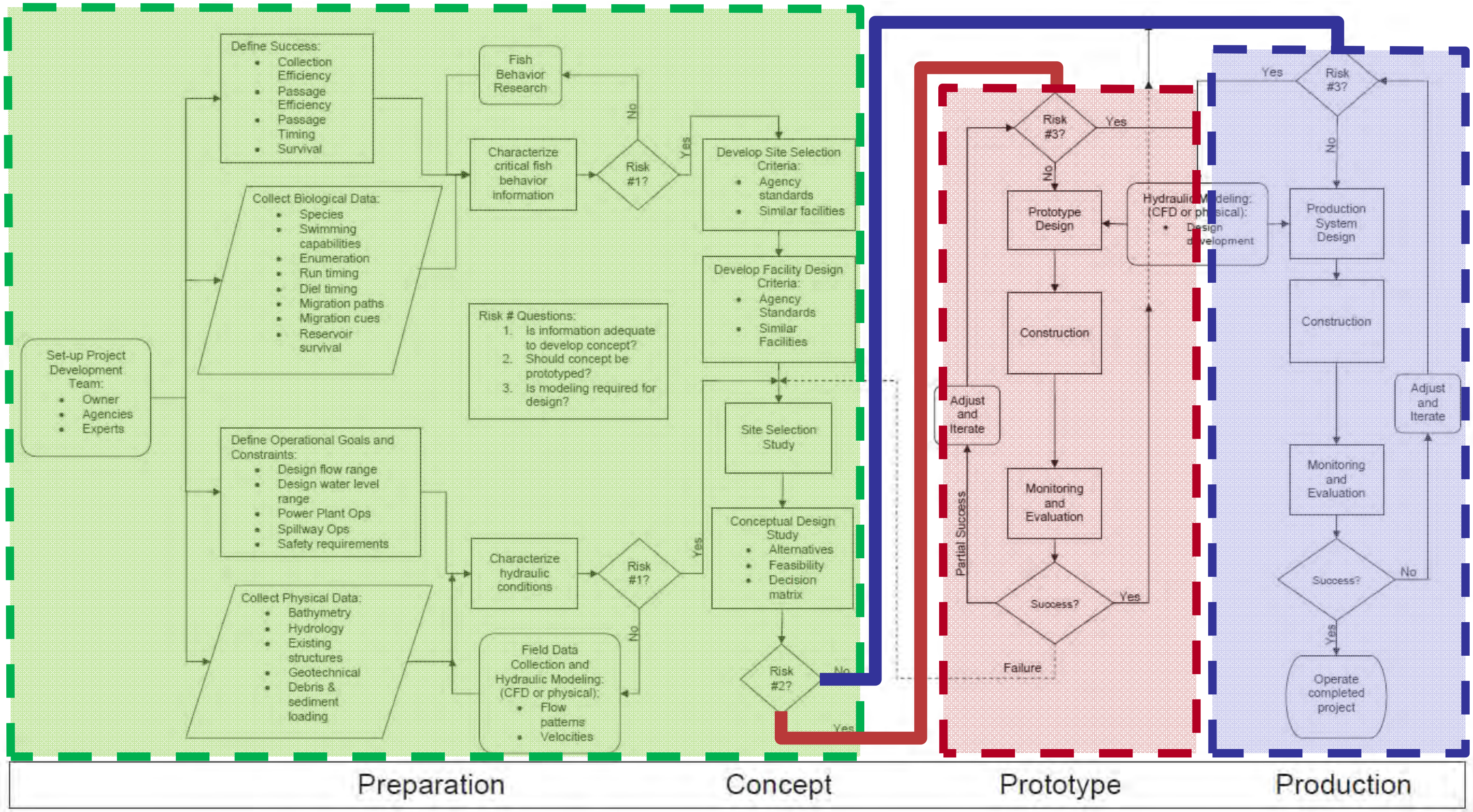
Feasibility and Design Process



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Feasibility and Design Process

Project Objectives
- Improve passage
- Reintroduction

Definition of Success
- Monitoring and evaluation
- Collection and passage efficiency
- Passage timing
- Survival

Operational Objectives
- Design flow range
- Design water level range
- Power plant operations
- Spillway operations
- Safety requirements

Biological Data
- Target species and life stages requiring passage
- Migration timing
- Population abundance and peak rate of migration
- Migration cues
- Reservoir transit and survival
- Colonization method (for reintroduction projects)

Physical Data
- Existing infrastructure
- Access / Ownership
- Geotechnical
- Debris loading conditions
- Bathymetry
- Hydrology

Feasibility and Design Process

- Every fish passage facility is influenced heavily by both site specific characteristics
- Physical and engineering aspects of most projects are often more readily available
- The linkage between physical, operational, and biological conditions <u>drive</u> the feasibility, design, operational success – Biomechanics

How often is there sufficient information regarding biomechanics and how does it influence feasibility?

How is that information obtained?

How much is enough?

Feasibility and Design Process

There are numerous references to guide fish passage practitioners through the selection of technical design guidelines and criteria. Here are just a few…

- Bell, M. 1991. Fisheries Handbook of Engineering Requirements and Biological Criteria. U.S. Army Corps of Engineers, North Pacific Division, Portland, Oregon.
- CDFW. 2009. California Salmonid Stream Habitat Restoration Manual Part XII Fish Passage Design and Implementation.
- NOAA. 2011. Anadromous Salmonid Passage Facility Design. NMFS, Northwest Region, Portland, Oregon.
- More to come…

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Engineering and biological linkages

Why are biological linkages important to the technical and economic feasibility?

Significant influence on the facility type, size, location, configuration, and operational requirements

Biological Basis of Design

- Ecological objectives
- Target species and life stages requiring passage
- Migration timing
- Population abundance and peak rate of migration
- Site biomechanics
- Habitat suitability/availability
- Colonization method (for reintroduction projects)

Operational Requirements

- Performance objectives
- Monitoring and evaluation

Engineering and Biological Linkages

- What are the target fish species?
- What life stages need to be accommodated? What about fry?
  - Parr and smolt released downstream
  - Fry returned to the reservoir at Swift to rear, but not at Baker (passed downstream)
- Do fish naturally congregate in one location or travel on one bank vs. the other?
- What is the reservoir transit time and success for out-migrating smolt?
- How many fish will be collected in a 24-hour time period?
- Do fish exist there now?
- Does wind and temperature influence currents and fish position in the reservoir?

Engineering and biological linkages

Examples: Influence Of Number of Species, Population Abundance, and Colonization Method On Fish Transport

Multiple species
Multiple release locations
Thousands of fish per day

Single species
Single release locations
Under 100 fish per year

Engineering and biological linkages

Examples: Influence Of Number of Species, Population Abundance, and Colonization Method On Fish Transport

NORTH FORK ADULT SORTING FACILITY
CLACKAMAS RIVER, WA

Multiple species
Thousands of fish per day

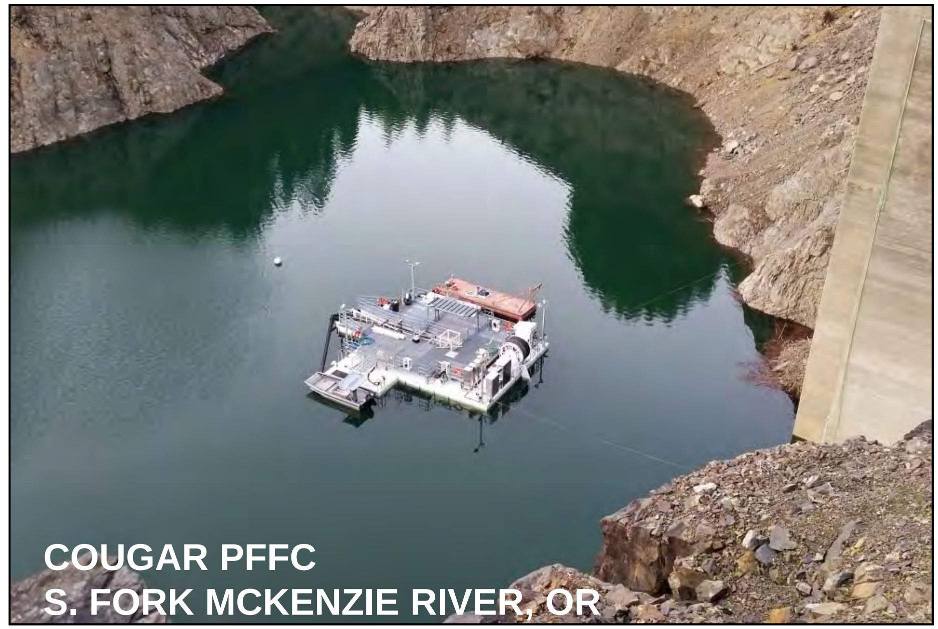
LOS PADRES DAM ADULT STEELHEAD TRAP
CARMEL RIVER, CA

Single species
Under 100 fish per year

Engineering and biological linkages

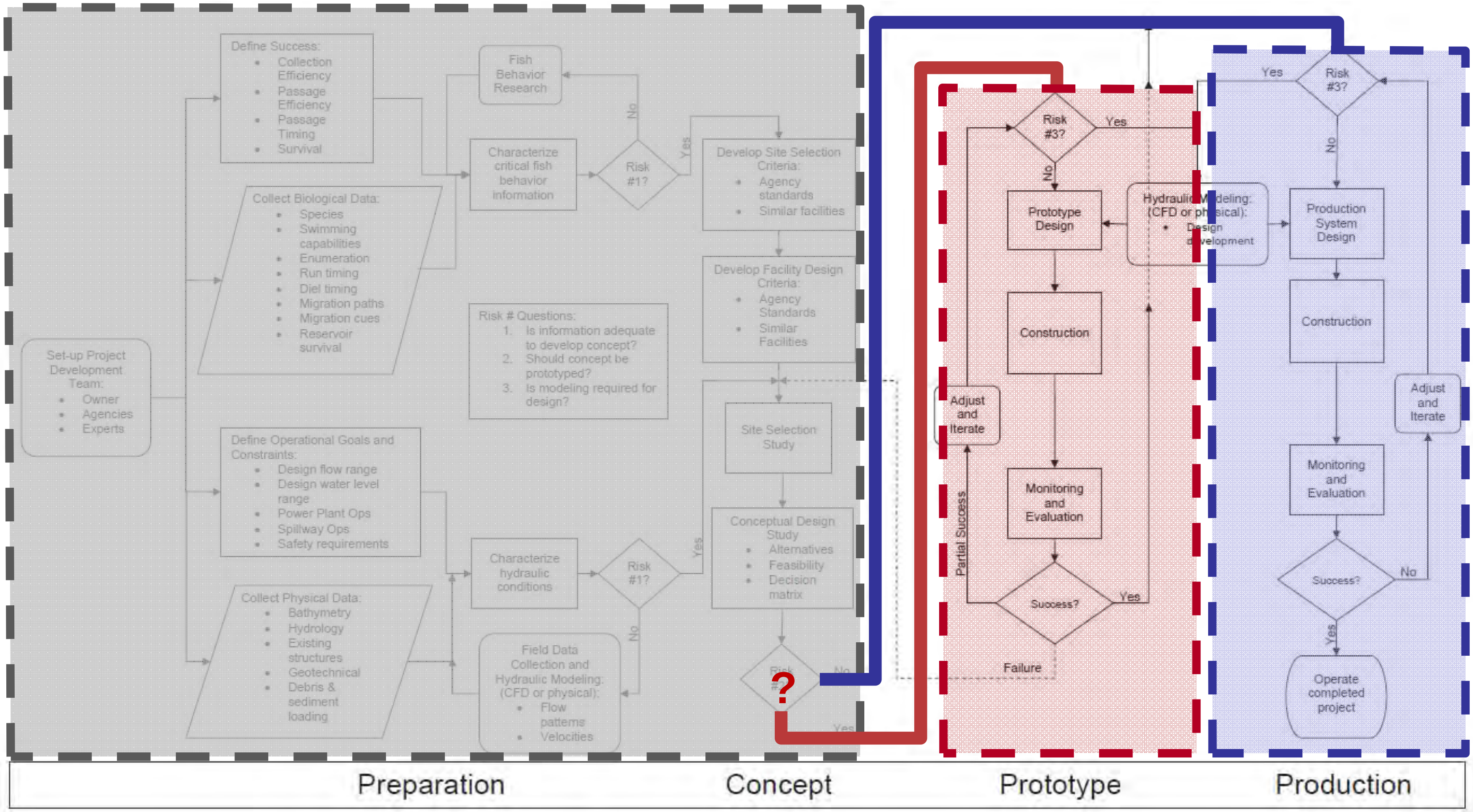
Examples: Influence Of Population Size And Performance Objectives

Holding capacity = 76,000 smolt
Pumping capacity = 1,000 cfs
Performance criteria = 75%
$60M – 70’ x 120’ barge



Holding capacity = 200 smolt
Pumping capacity = 100 cfs
Performance criteria = R&D
$10M – 40’ x 60’ barge

Implementation



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Approaches to Implementation

Often we are left with a lot of questions at the end of the feasibility and conceptual design process…

Sufficient Information?

Unknown Operating Environment?

More Studies?

Proven track record for chosen technology?

Has this been done before?

Are we confident in the outcome?

Research Approach or Full-Scale Implementation?

Approaches to Implementation

Example 1: Successful after decades of study, trial and error, and cost…


(photo by PSE)

Upper Baker FSC and Gulper
Upper Baker Dam, Baker River, WA

- The initial prototype “gulper” facilities operated at Upper and Lower Baker Reservoirs since the 1960’s.
- Initial attraction flows were on the order of 130 to 140 cfs.
- Guidance nets were installed for the first time in 1987-1988.
- The full-scale Upper Baker FSC system was installed in 2008 for $60M (just 9 years ago).
- After several years of modifications, collection efficiencies are now at 85 to 93%.

Approaches to Implementation

Example 2: Not initially deemed a success but establishes important lessons learned and is very early in the study process.

- USACE, Portland District desired to study conditions at 4 reservoirs prior to implementation of a full-scale system.
- The PFFC was implemented for in 2014 as a means of testing collection inlet orientation, attraction, and reservoir transit.
- USGS recently released a second monitoring report indicating marginal results due to a number of key operational and environmental factors.


(photo by USACE)

Cougar Portable Floating Fish Collector
Cougar Dam, McKenzie River, OR

Approaches to Implementation

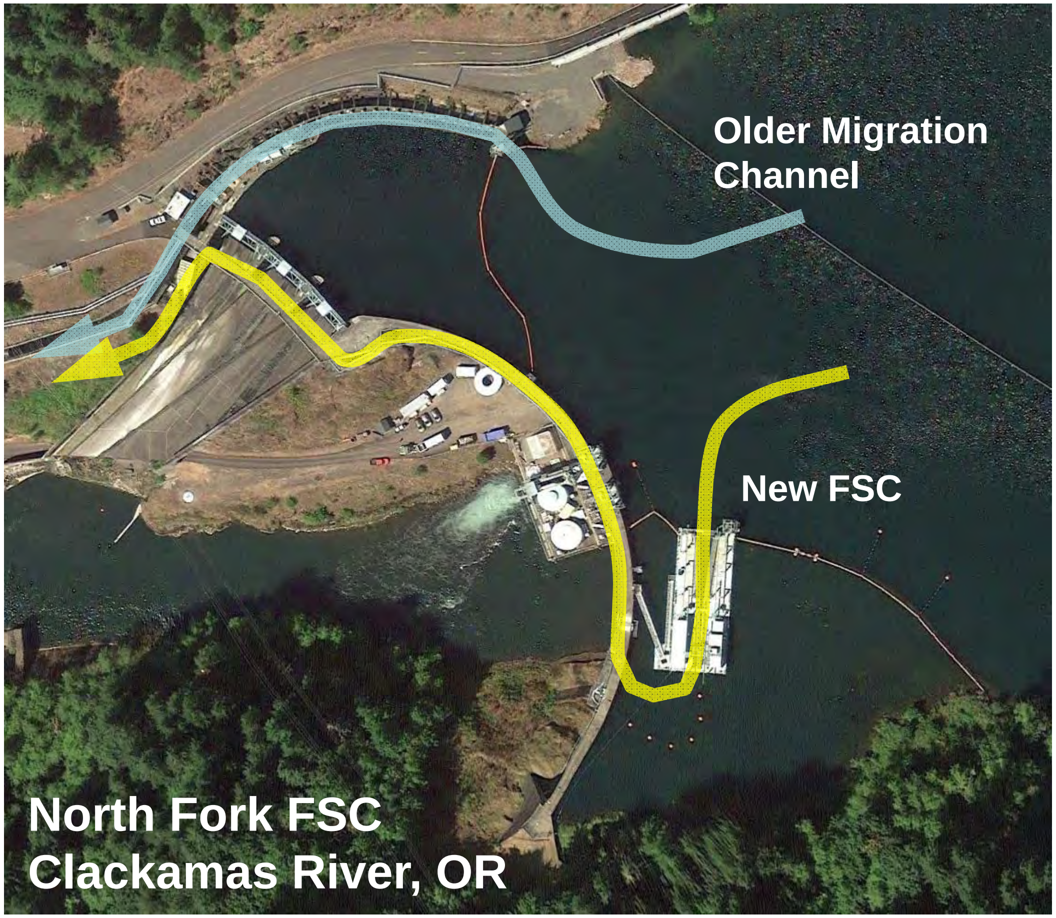
Example 3: Full-scale implementation with no fish and very little information. There could be successes sometime in the future…maybe…possibly…

Cushman Dam No. 2 Adult Collection Facility
Skokomish River, WA

- Tacoma Power's reintroduction and fish passage efforts included a 150-ft tall fish elevator.
- It was operable in 2013 with a construction cost of $28M.
- Less than 10 adult fish were collected during the first years of operation.
- The facility is well ahead of any population response to ongoing reintroduction efforts.

Approaches to Implementation

Example 4: Slam dunk. Zero unknowns. Perfect operating environment. Decades of data collection.



- Decades of information obtained from using migration channel and studying forebay.
- $42M full-scale FSC operable in 2015.
- Initial collection efficiencies on the order to 87 to 95%

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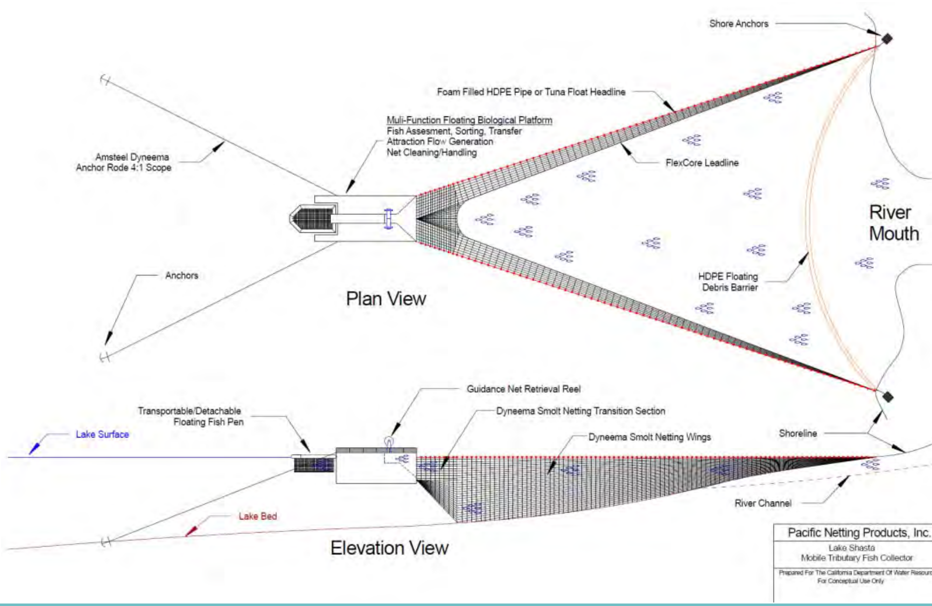
Approaches to Implementation

- We will discuss implementation of some more experimental technologies and approaches in the next presentation…



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Approaches to Implementation

Research Approach	Full-scale Implementation
Large data gaps	Limited data gaps
High level cost risk	Low level cost risk
High performance risk	Low performance risk
Operating environment unknown	Operating environment known
New Technology	Technology w/ long track record

Which path do we choose….?

Fish Passage Technologies for High Dams

How do others do it? Is there hope for emerging technologies?

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Overview

- Overview of technologies for upstream fish passage
- Overview of technologies for downstream fish passage
- Summary of small-scale and experimental technologies

Examples of Upstream Fish Passage

- Technical Fish Ladders
- Lifts and Elevators
- Hydraulic Locks
- Trap and Transport Facilities

Not included:

- Nature-Like Fishways
- Pescalators and Fish Pumps
- Locks

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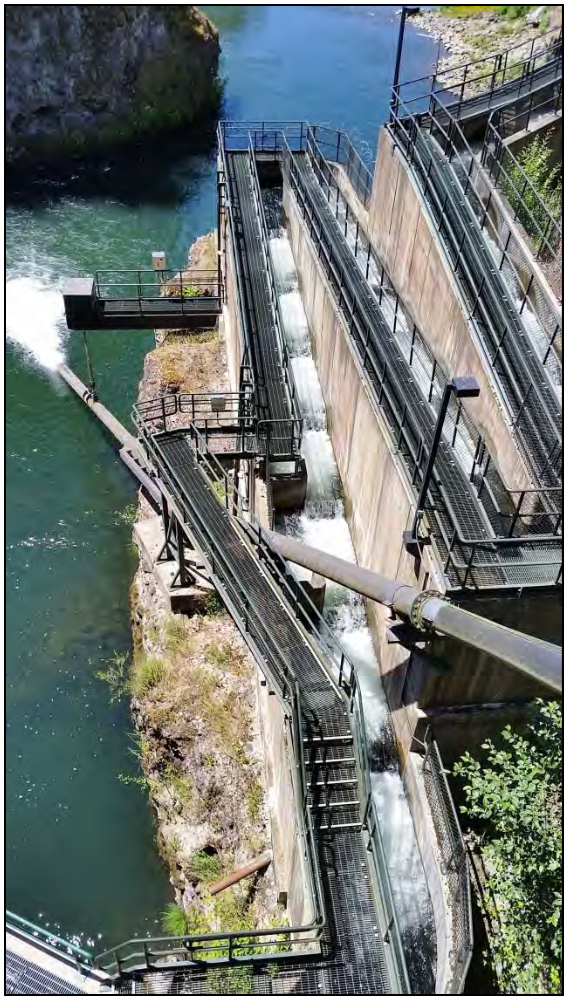
Technical Fish Ladders



River Mill Hydroelectric Project
Clackamas River, OR

Faraday Diversion Dam and North Fork Fish Ladder
Clackamas River, OR

Technical Fish Ladders

- Fish ladders on the mainstem of the Columbia River range in height from 70 to 105 and have proven effective for migrating salmonids.

  - Larger fish ladders with 120 to 150 cfs capacity each.
  - Up to 2 and 3 ladders per dam
  - Large AWS systems with multiple entrances

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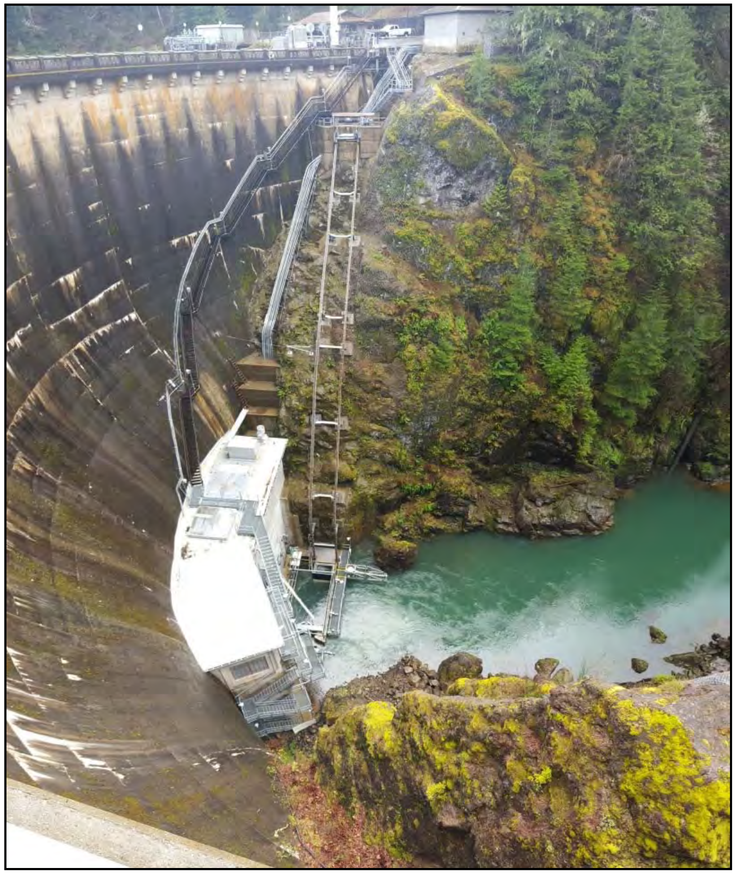
Technical Fish Ladders

- More on technical fish ladders
  - Pelton Dam. 2.84 mile long fish ladder at Pelton re-regulation Dam. Deschutes River, OR. Abandoned in 1968.
  - Itaipu Dam. 6.2 mile long fish ladder on Parana River. Brazil/Paraguay.
  - Other fish ladders exist in other parts of the world using technology from the Pacific Northwest with varied success.

Fish Lifts and Elevators



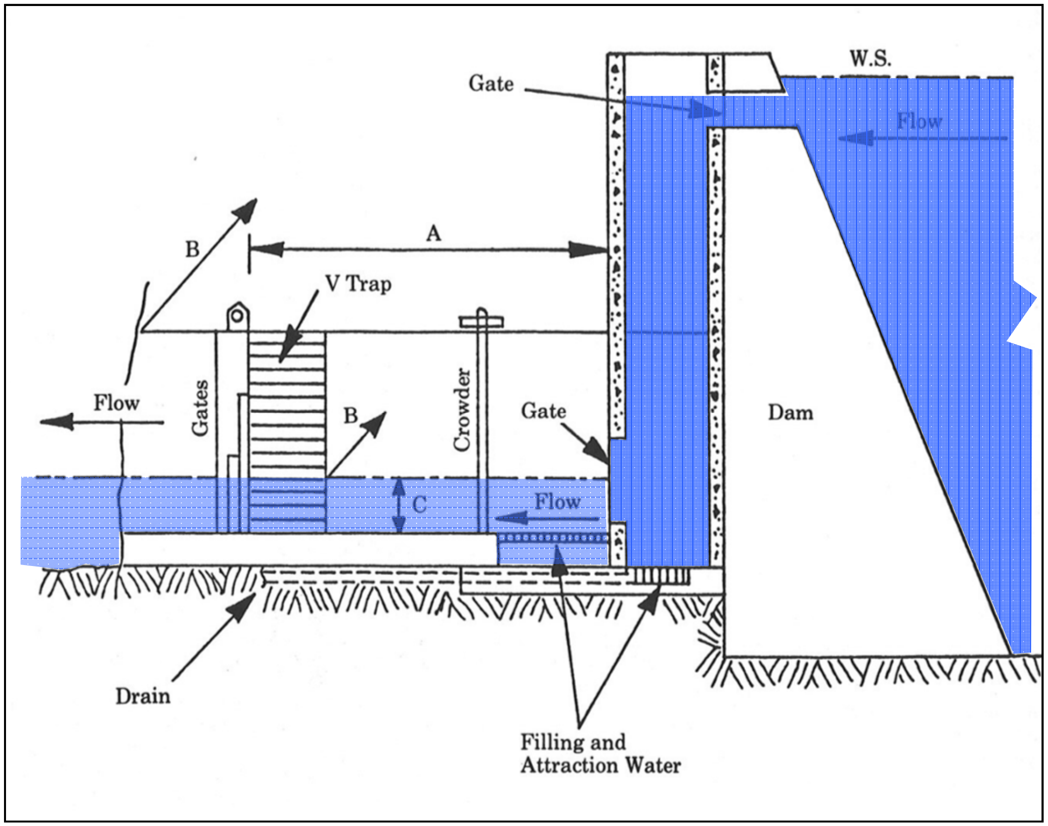
Cushman Dam No. 2
Skokomish River, WA

Paradise Dam
Burnett River, Australia

Fish Lifts and Elevators

- Other fish lifts and elevators around the globe:
  - Touvedo Dam. Lima River, Portugal. 140-ft tall.
  - Tallowa Dam, Shoalhaven River, Australia. 141-ft tall.
  - Funil Dam. Grande River, Brazil. 164-ft tall.

Fish Locks



Concept Fish Lock
(Fisheries Handbook. Bell, 1991)

Lower Baker Adult Collection Facility
Baker River, WA

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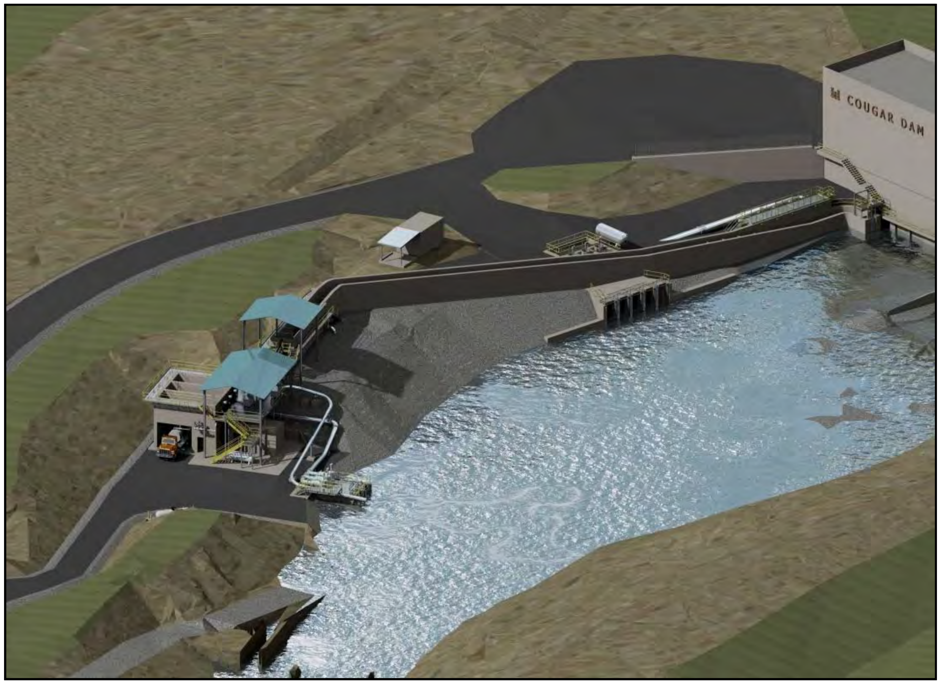
Trap and Transport



Cougar Dam Adult Fish Collection Facility
S. Fork McKenzie River, OR
(rendering by USACE)

Lower Granite Dam Adult Collection Facility
Snake River, WA

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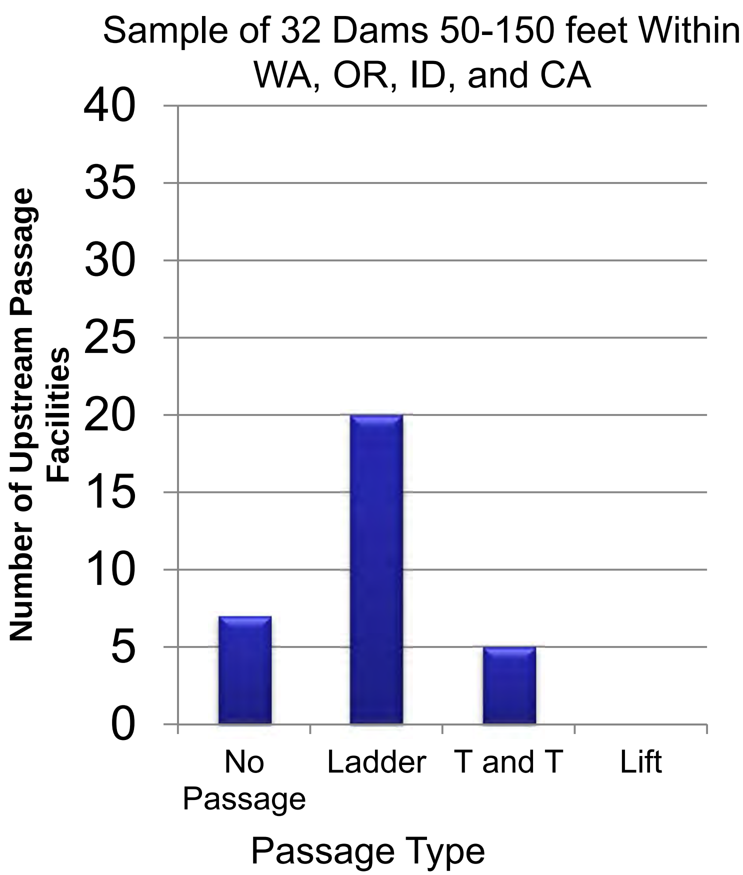
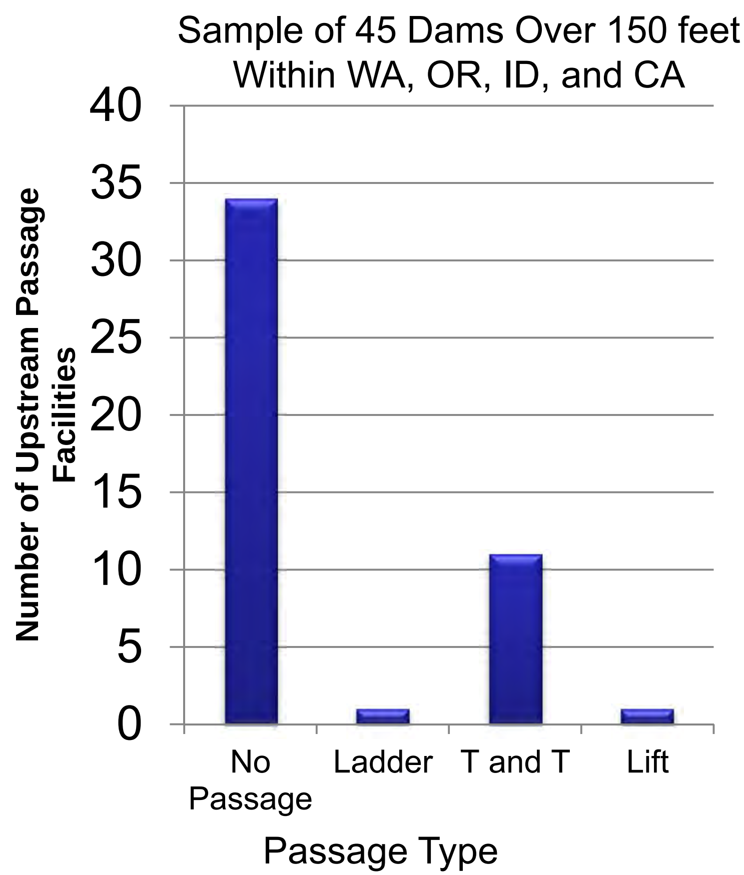
Clackamas River Adult Sorting Facility, OR

Applicability of Upstream Fish Passage Technologies to High Head Structures





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Construction Costs of Select Upstream Collection Facilities

Name	Type	Construction Cost
Merwin Dam	Trap and Haul	$40M
Foster	Trap and Haul	$20M
Cougar Dam	Trap and Haul	$10M
North Fork Sorting Facility	Trap and Haul	$8M
Minto Collection Facility	Trap and Haul	$30M
Lower Baker	Trap and Haul	$22M
Cushman Dam No. 2	Fish Lift, Trap and Haul	$28M

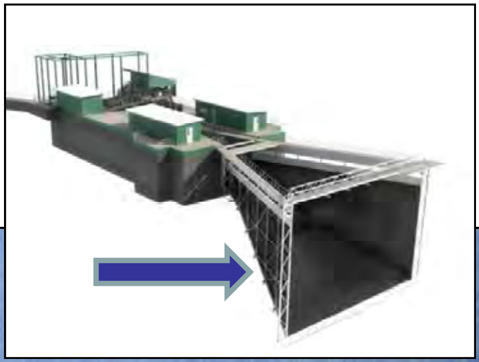
Downstream Fish Passage

- Floating Surface Collectors
- Fixed Collectors
- Surface Spill Facilities
- Bypasses

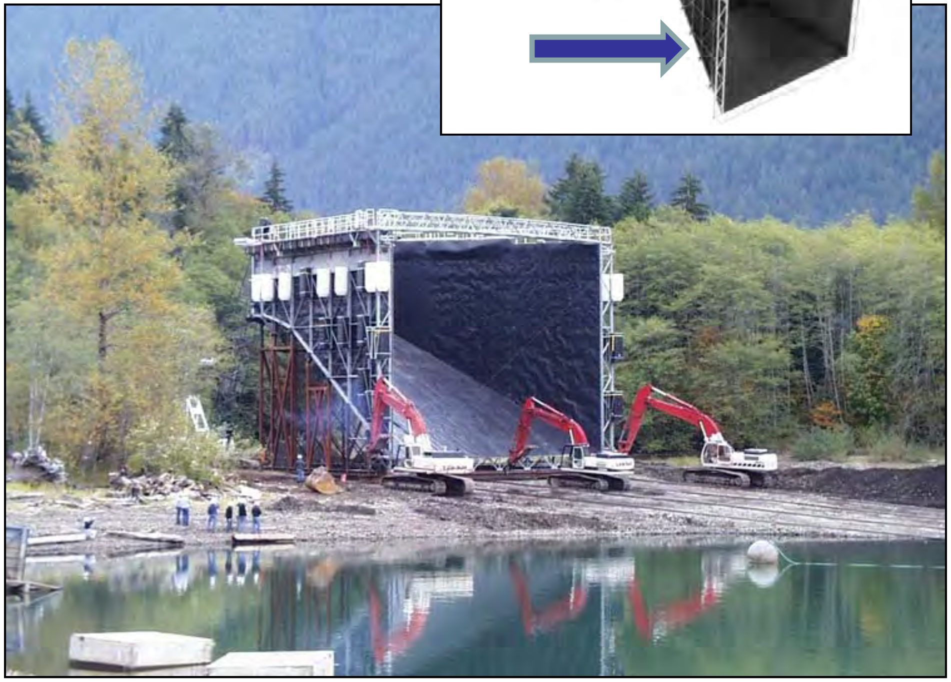
Not included:

- Turbine Passage
- Raised Weir Spillways

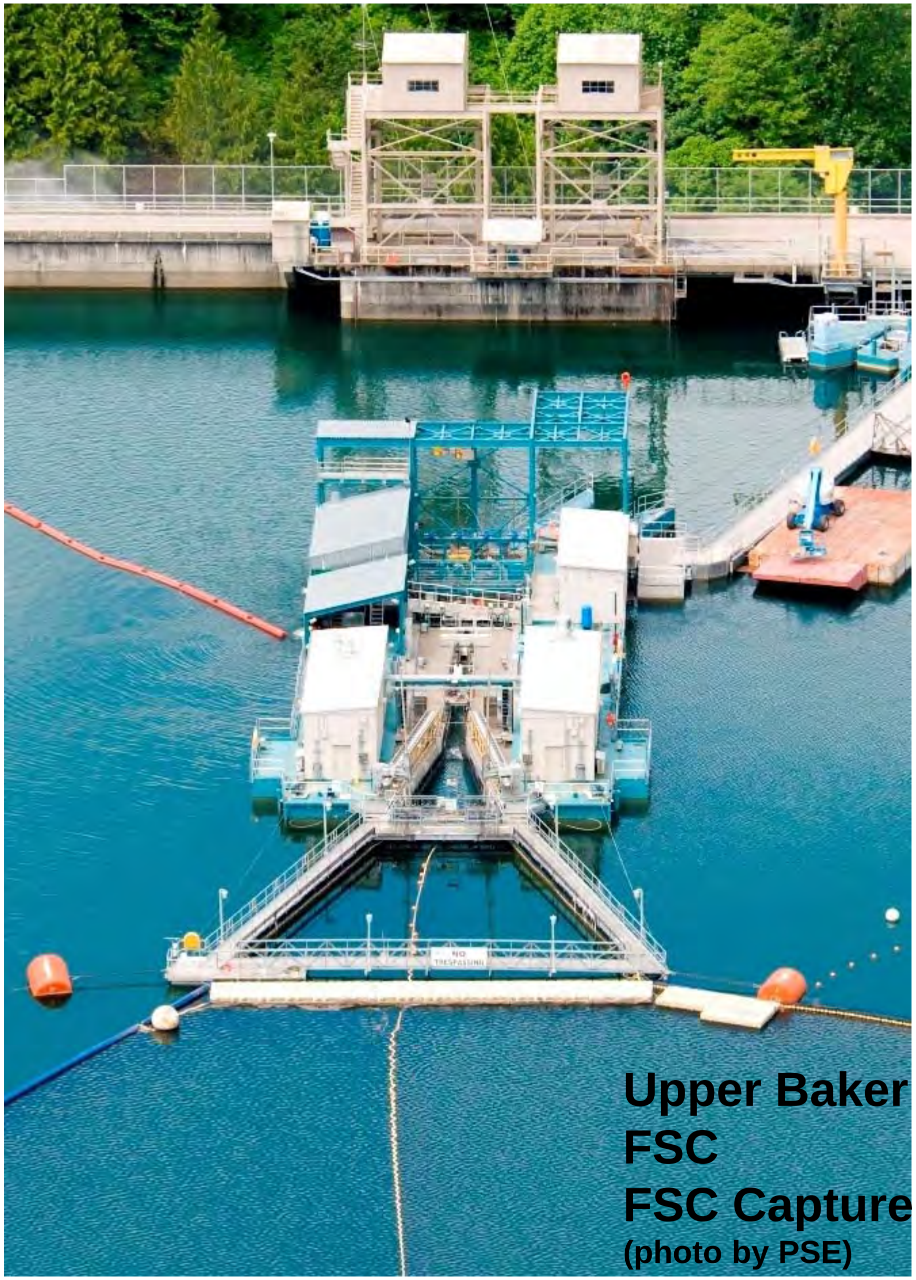
Floating Surface Collectors



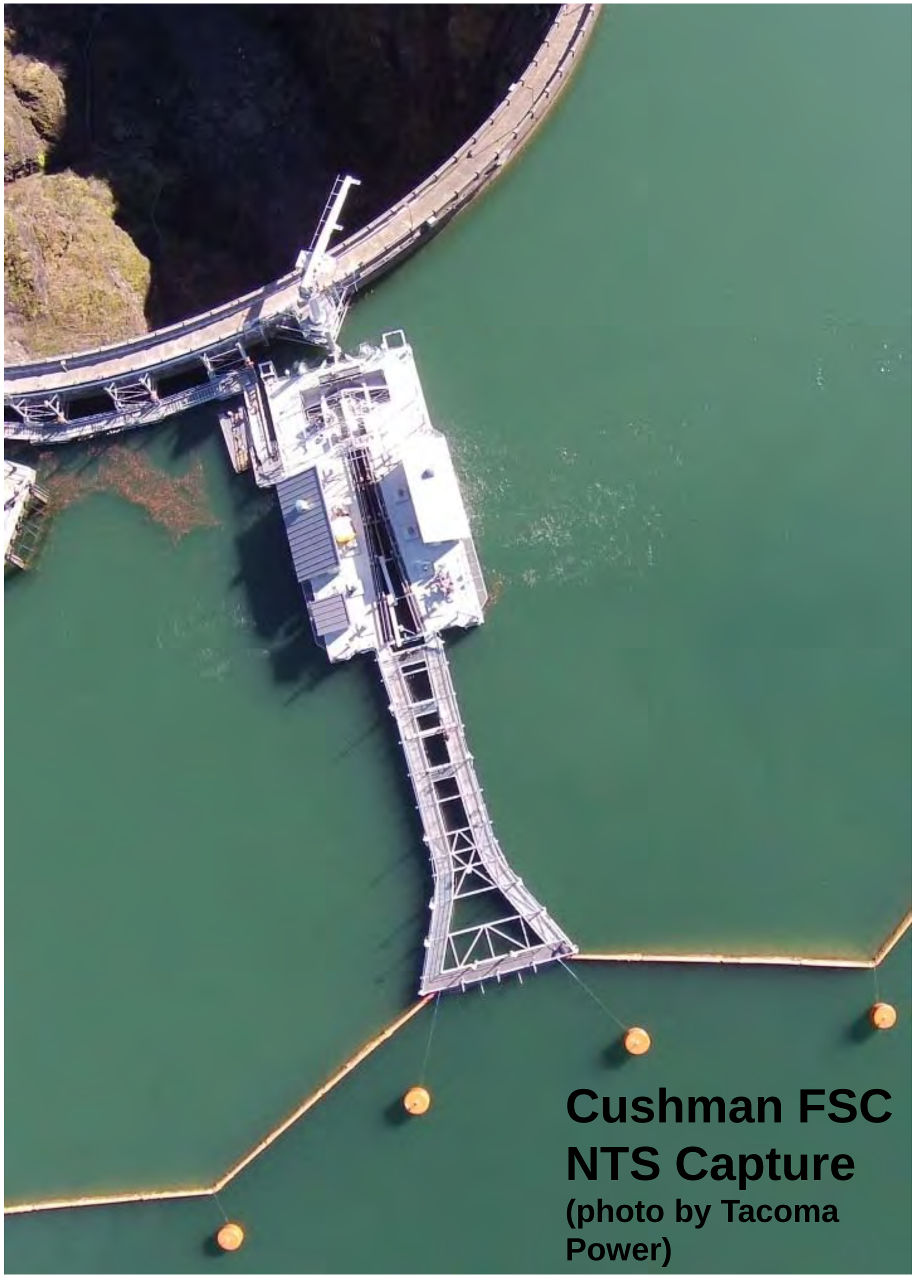
Floating Surface Collector
Upper Baker Dam, WA
(photo by PSE)



Upper Baker Net Transition Structure (NTS)
(photo by PSE)



Upper Baker FSC
FSC Capture
(photo by PSE)



Cushman FSC
NTS Capture
(photo by Tacoma Power)

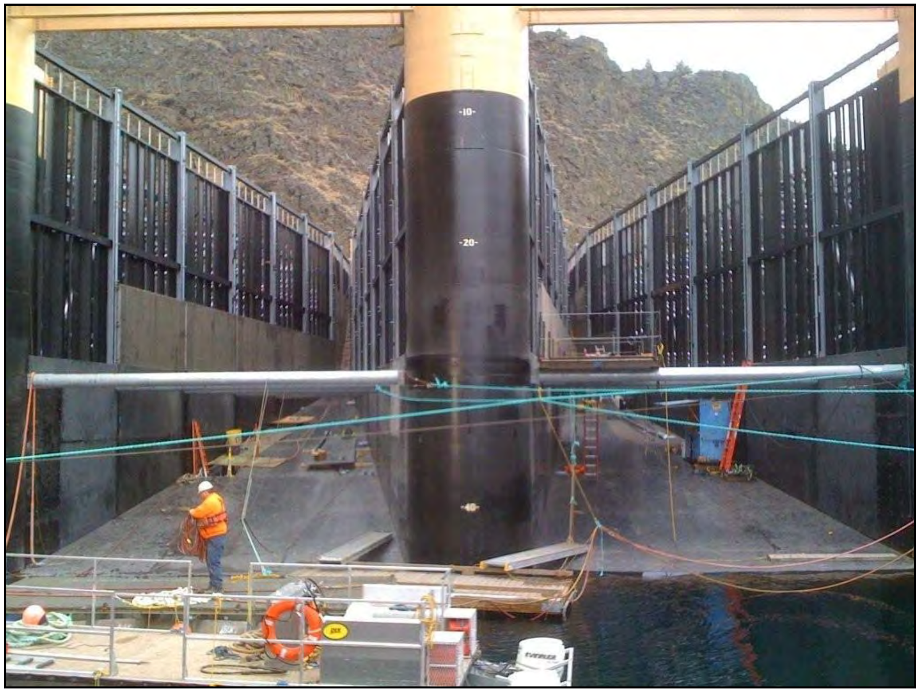
Swift FSC prior to deployment
(photos by PacificCorp)

Example Full-Scale FSCs

Name	Owner-Location	Reservoir Fluctuation (ft)	Design Attraction Flow (cfs)	Capture Type	Fish Transport	Year Constr.
Upper Baker	PSE-Baker River, WA	30	500/1000	FSC	Trap and transport	2008
Lower Baker	PSE-Baker River, WA	30	500/1000	FSC	Trap and transport	2013
Swift	PacifiCorps-Lewis River, WA	100	600/800	FSC	Trap and transport	2012
North Fork	PGE-Clackamas River, WA	10	600/1000	FSC	Bypass conduit	2015
Cushman	Tacoma Power, Skokomish River, WA	20	250	NTS	Trap and transport	2015

Fixed Surface Collectors

Pelton Round Butte Fixed Surface Collector
Deschutes River, OR
(photo by PGE)



Entrance to Pelton Round Butte Fixed Surface Collector under construction
(photo by PGE)

Example Fixed Collectors

Name	Owner-Location	Reservoir Fluctuation (ft)	Design Attraction Flow (cfs)	Fish Transport	Year In Operation
River Mill	PGE – Clackamas River, OR	2 to 6	500/700	Bypass conduit	2012
Pelton Round Butte	PGE – Deschutes River, OR	1 to 9	6000	Trap and Transport	2009
Soda Springs	North Umpqua River, OR	16	1850	Bypass conduit	2012
Cle Elum	USBR – Yakima River, WA	80 (Multiple inlets)	400	Helical bypass conduit (experimental)	Under Construction

Surface Spill Facilities

Juvenile Surface Spill Facility
Wanapum Dam, WA

Downstream Bypass Facilities

7.2 Mile Long 3-Reservoir Bypass
Clackamas River, OR

4,600 ft Juvenile Fish Bypass
Rocky Reach, Columbia River, WA

Implementation Costs of Select Downstream Collection Facilities

Name	Type	Cost (US$)
Upper Baker	FSC	$50M
Lower Baker	FSC	$50M
Swift	FSC	$60M
North Fork	FSC	$42M
Cushman	FSC	$24M
River Mill	Fixed Collector	$12M
Pelton Round Butte	Fixed Collector	$108M
Soda Springs Bypass	Dam Bypass Collector	$65M[1]
Cle Elum Dam	Multi-Port w/Helix	est $135M[2]

[1]Combined with other major fish passage and power unit improvements.
[2]Estimated cost only. Not yet constructed.

Experimental Technologies

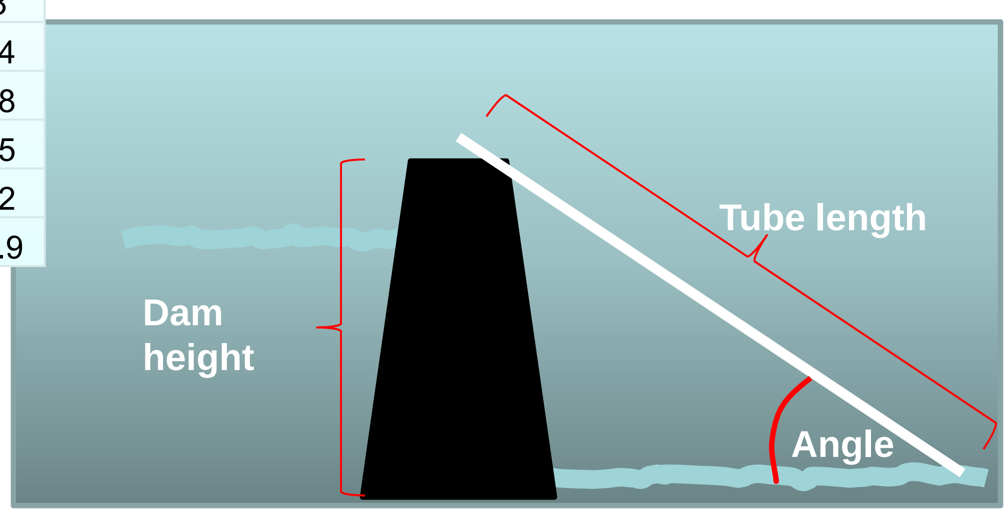
- WHOOSHH
- The Helix (passive multi-inlet fixed collector with helical bypass)
- Pilot Studies and Small Scale Prototype Collectors
- Head of Reservoir Collection

WHOOSHH

- Fish transport tube system
- Coming to a dam near you…

Barrier Elevation

	Angle				
Tube length (ft)	**0**	**10**	**20**	**30**	**40**
100	0.0	17.4	34.2	50.0	64.3
500	0.0	86.8	171.0	250.0	321.4
1000	0.0	173.6	342.0	500.0	642.8
1250	0.0	217.1	427.5	625.0	803.5
1500	0.0	260.5	513.0	750.0	964.2
1750	0.0	303.9	598.5	875.0	1124.9



WHOOSHH INNOVATIONS

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WHOOSHH Example Projects

- Buckley Weir, White River WA, Prosser Hatchery WA

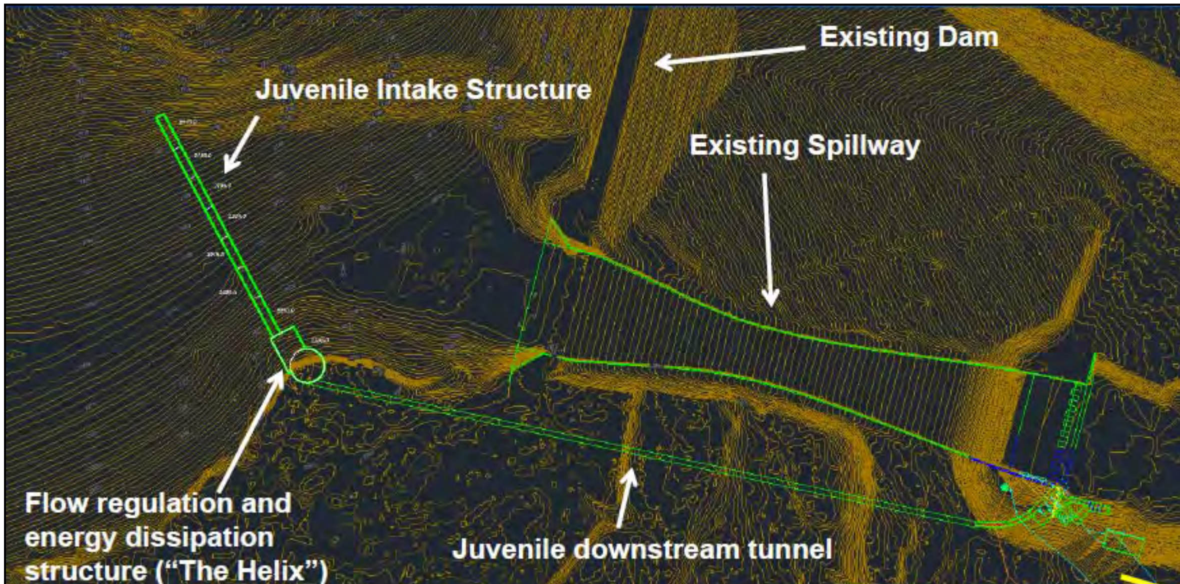
  2015, 2016. Volitional entry and size selection. Pink, Coho, Chinook
- Priest Rapids Hatchery, WA (DoE/PNNL)

  2014, 2015 Epithelial, gamete and stress assessment. Fall Chinook
- Roza Dam/Cle Elum Hatchery, WA (BOR, Yakama Nations)
  - 2014, 2015 Epithelial, survival, reproductive success. Spring chinook
  - 2016 Combined with 1100' feasibility.
- Priest Rapids Dam, WA

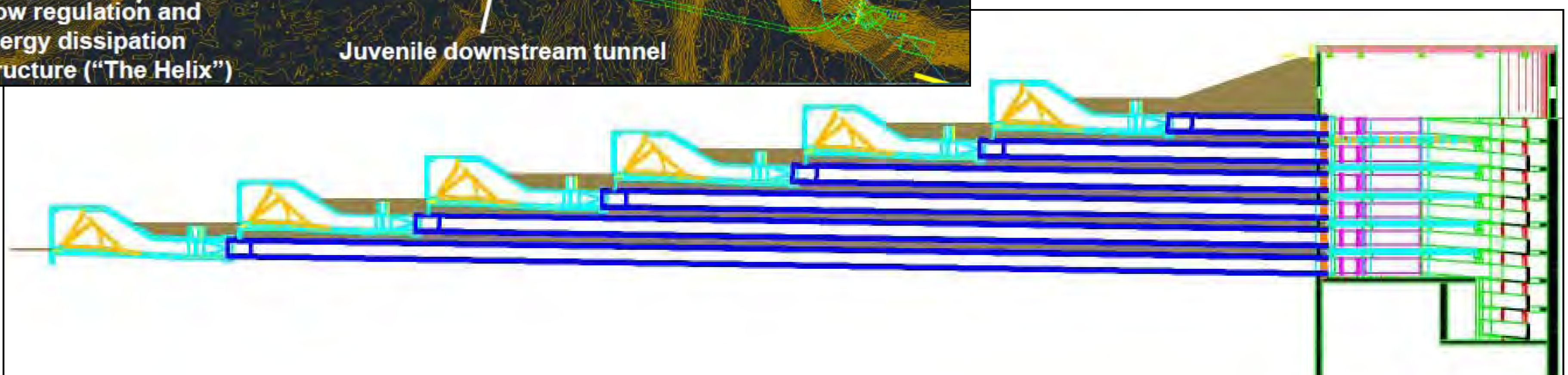
  2016 Migration study on Columbia mainstem. Sockeye salmon
- Cle-Elum Dam, WA

  Summer 2017. Volitional 1700' (160' vertical) with spawning assessment. Sockeye salmon (radio tag and or pit tag)

The Helix (passive multi-inlet fixed collector with helical bypass)



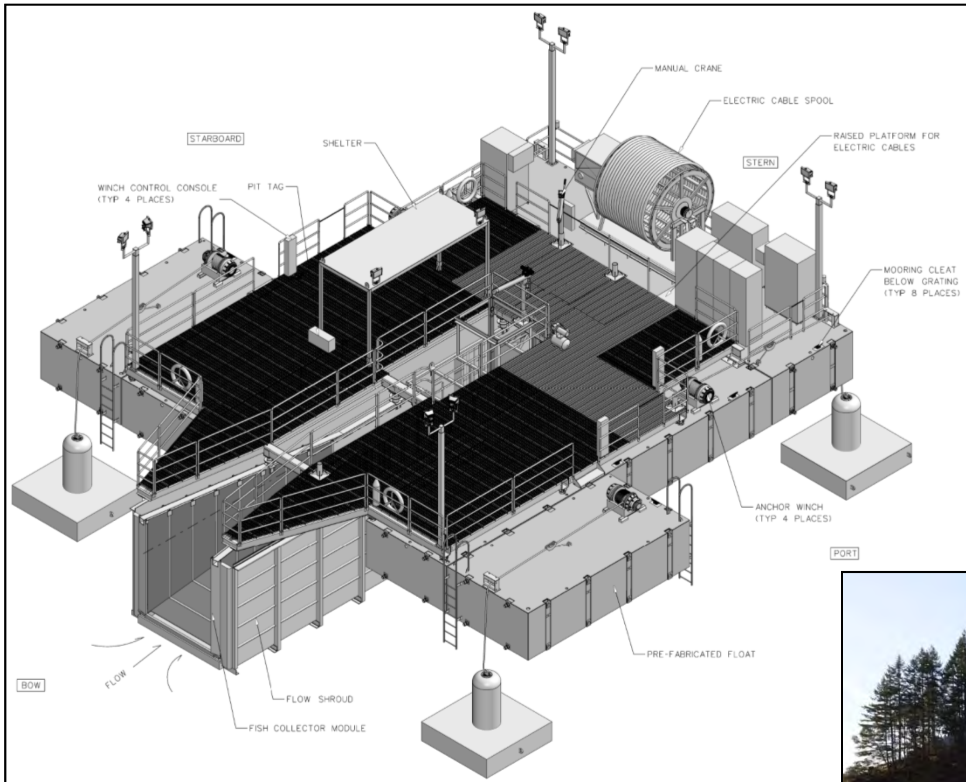
- Passive downstream fish passage
- Lower O&M costs
- High capital costs
- Construction started at Cle Elum Dam, WA in fall of 2015.



(from USBR)

Cougar Portable Floating Fish Collector

S. Fork McKenzie River, OR

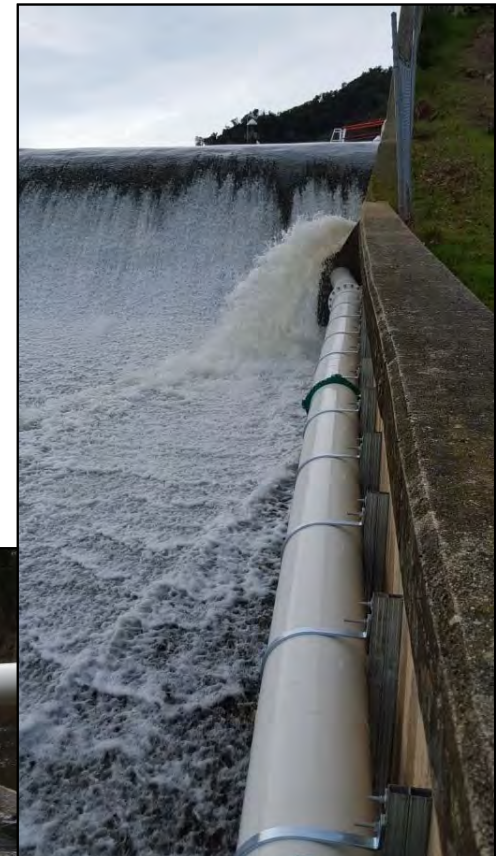


- Small scale – lower cost option to inform future actions
- Portable – location within reservoir can be modified
- Transportable – can be disassembled into 12 separate pieces and hauled on mountain roads
- Deployable – to be used at Detroit and Looking Glass Reservoirs within 10 to 15 year study

Objectives:

- Capture native outmigrating smolt for tag and recapture reservoir transit studies
- Research collection performance using lower (100 cfs) attraction flow and position optimization

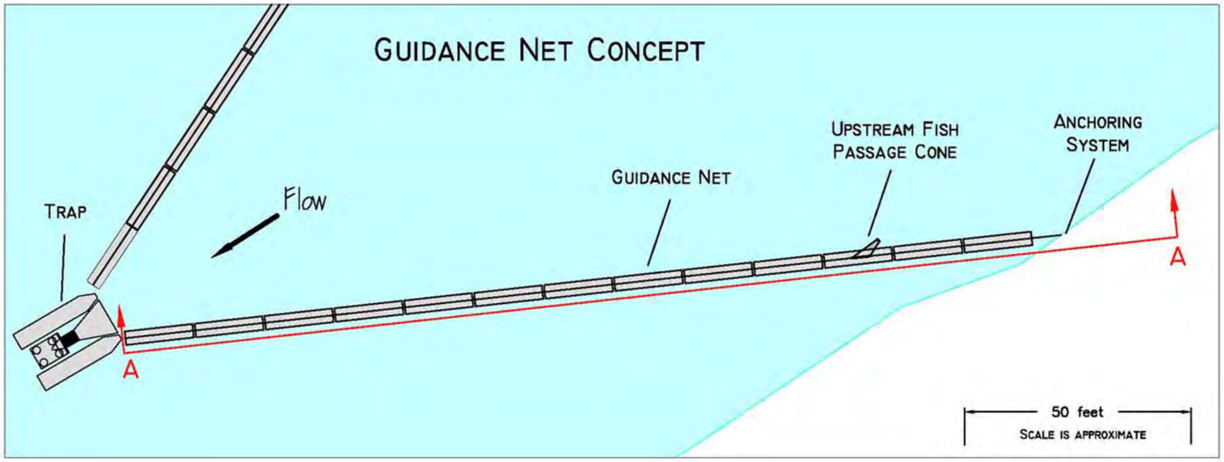
Los Padres Dam Downstream FWC and Bypass

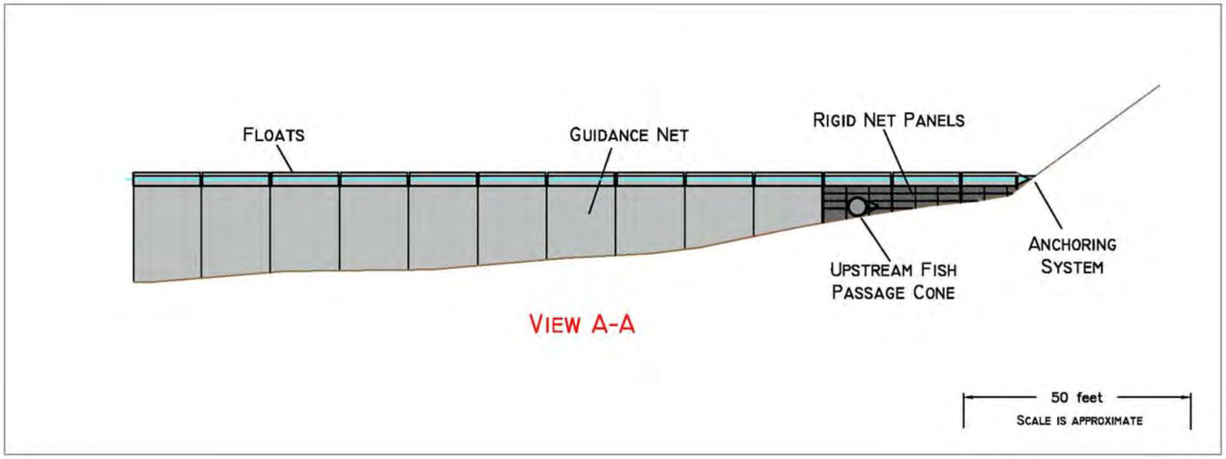


- Gravity flow only
- 5 to 15 cfs design range
- Accommodates 8 ft of reservoir fluctuation
- Rigid pipe bridge through ogee
- Solid panel BGS
- 1,100 ft bypass
- Discharges to stilling basin pool

Carmel River, CA

Head of Reservoir Collection





(Slide modified from DWR)

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Key Factors that Influence Selection and Design of Fish Passage Facilities

What is important and why is it important to know….

Michael Garello, PE
HDR Engineering, Inc.

Key Fish Passage Parameters

- What components do fish passage facilities need to consider?

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Key Fish Passage Parameters

- Block fish
- Guide fish
- Attract fish
- Collect fish
- Crowd fish
- Sort fish
- Lift fish
- Convey fish
- Measure fish
- Tag fish
- Transport fish
- Release fish

A complete system of design elements that work together to accomplish a biological/ecological driven objective given unique operational environment…

Key Fish Passage Parameters

- Historical record of performance
- Operating environment

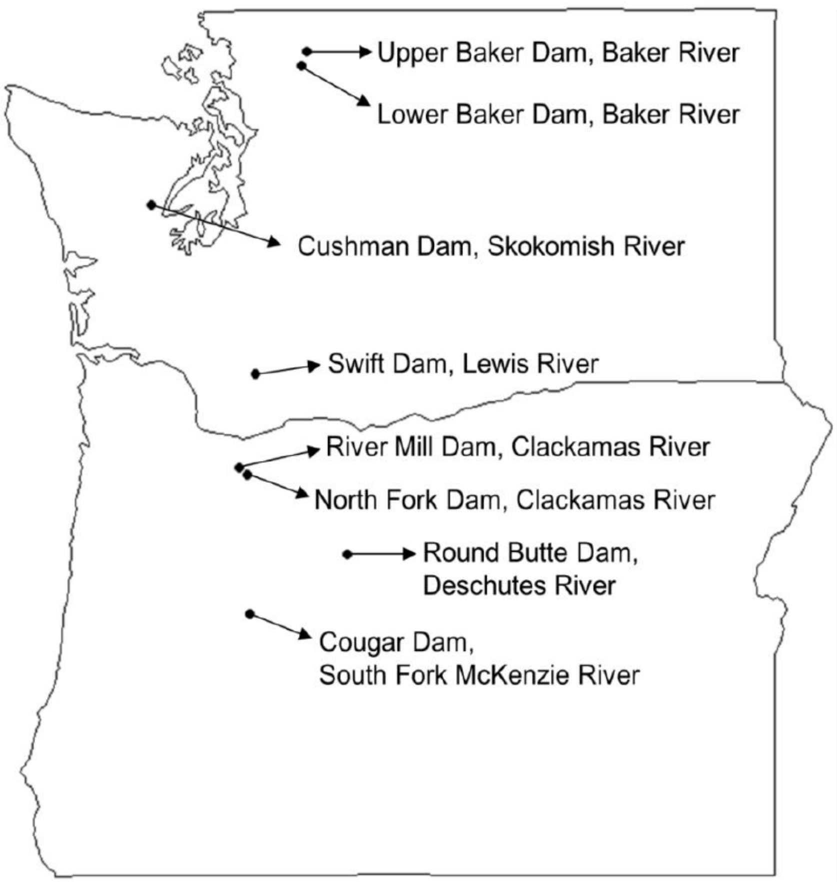
Historical Record of Performance

- Examples of select benefits resulting from years in service:
  - Operational data
  - Flexibility and reliability
  - Trials and errors made by others
  - Lessons learned from similar installations
  - Cost of construction and operation
  - Influence on fish and fish populations
  - Performance

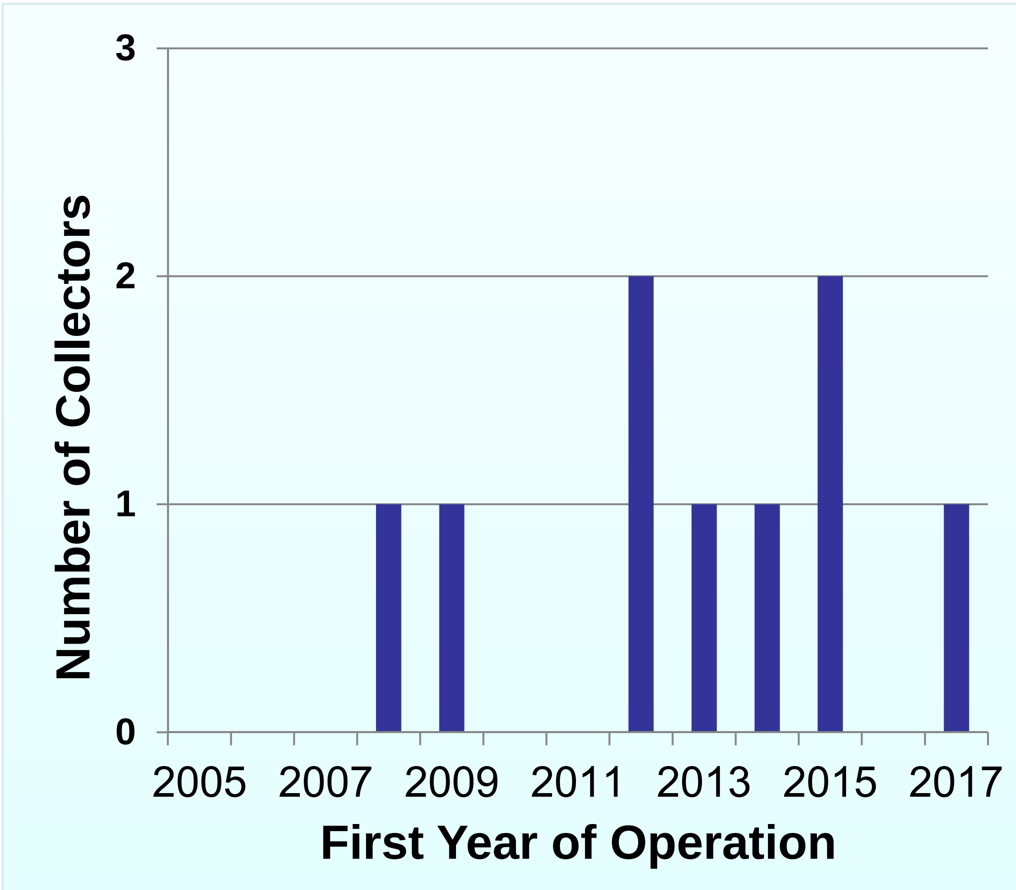
Historical Record of Performance

- Upstream passage has a century long history of trial and error with a long track record of successes and failures.
- Downstream passage at high dams is relatively new and continues to evolve.
- Recent sensitivity to cost, demand on resources, and expansion into difficult operating environments have opened new doors to experimental technologies and small scale facilities.

Historical Record of Performance



(Adapted from USGS, 2017)



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Historical Record of Performance

Measure of performance through the 2015 operational season.

Project	Years in Service	Collection Efficiency*
Upper Baker	8	86.3 to 92.5%
Lower Baker	3	87.3 to 92.1%
Cushman	1	32.9%
Swift	4	11.8 to 18.6%
North Fork	1	87.3% to 94.5%
River Mill	4	96.9% to 98.9%
Round Butte	7	39% to 62%
Cougar	2	<1%

*Average collection efficiency with range by various species.

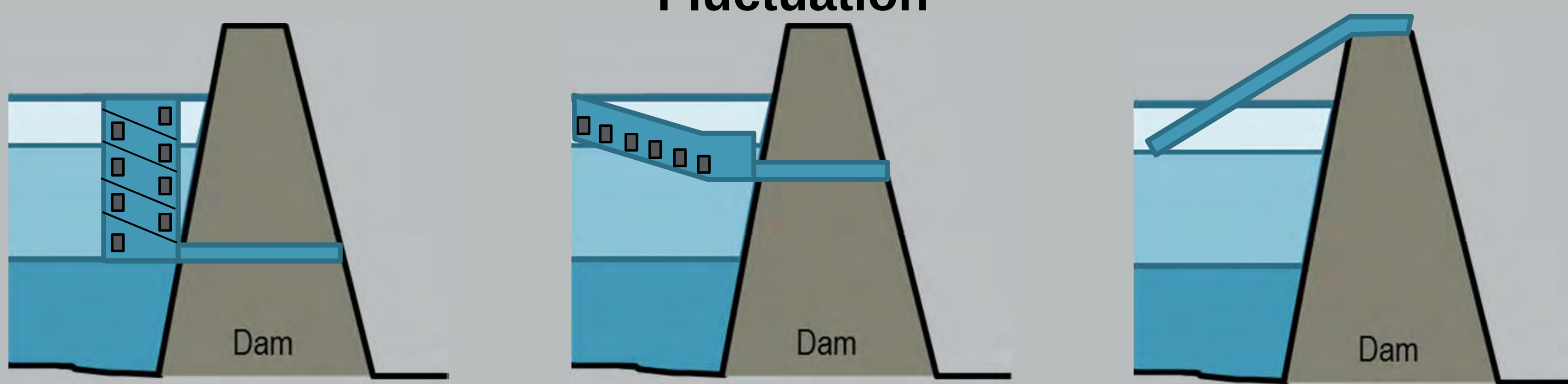
*Note that not all collection efficiencies are measured the same from facility to facility.

(Adapted from USGS, 2017)

Operating Environment

- Seasonal changes in pool volume and pool elevations influence fish ladder feasibility
- Soda Springs accommodates roughly 16 feet of fluctuation
- North Fork was able to accommodate up to 20 feet of fluctuation prior to reservoir operational changes
- All fish ladder exit concepts at high dams are relatively experimental with little to no record of performance

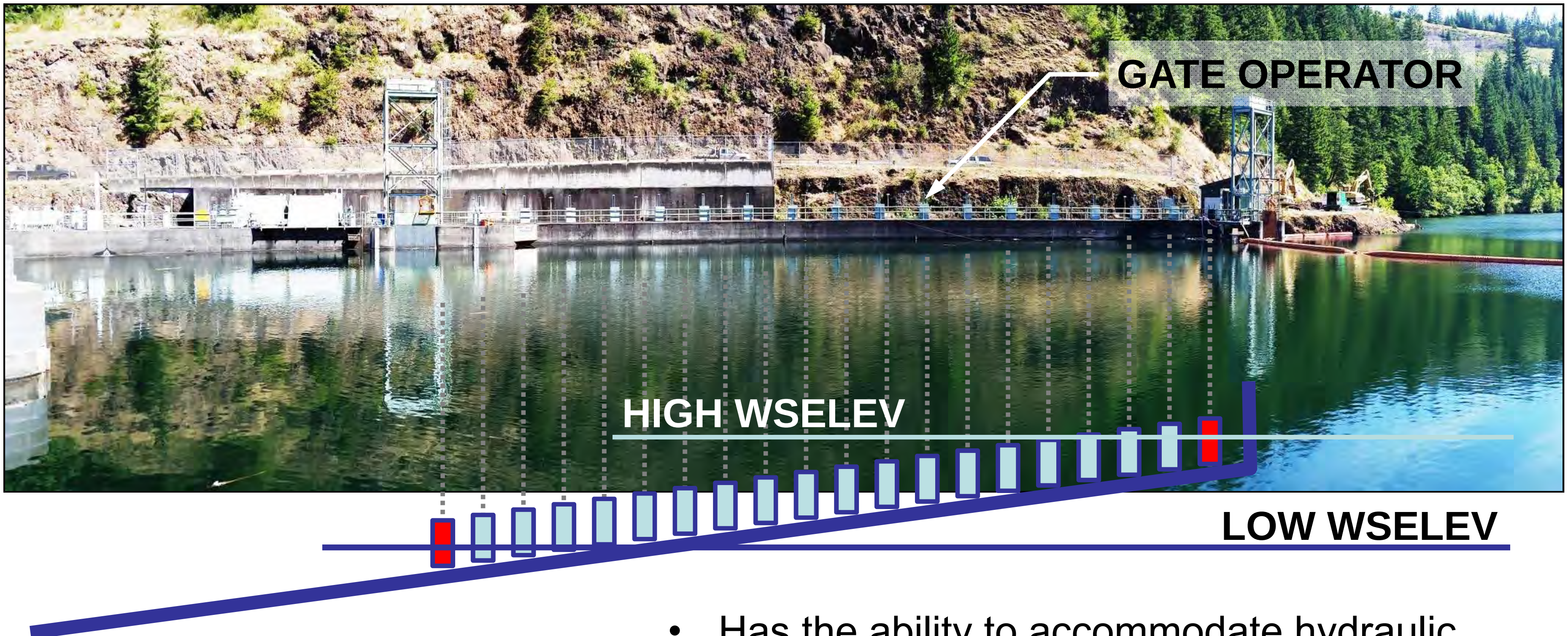
Fish Ladder Exit Concepts to Accommodate Large Reservoir Fluctuation



Helical Multi-Port Exit | Linear Multi-Port Exit | Return Flume

Operating Environment

- Reservoir Fluctuation

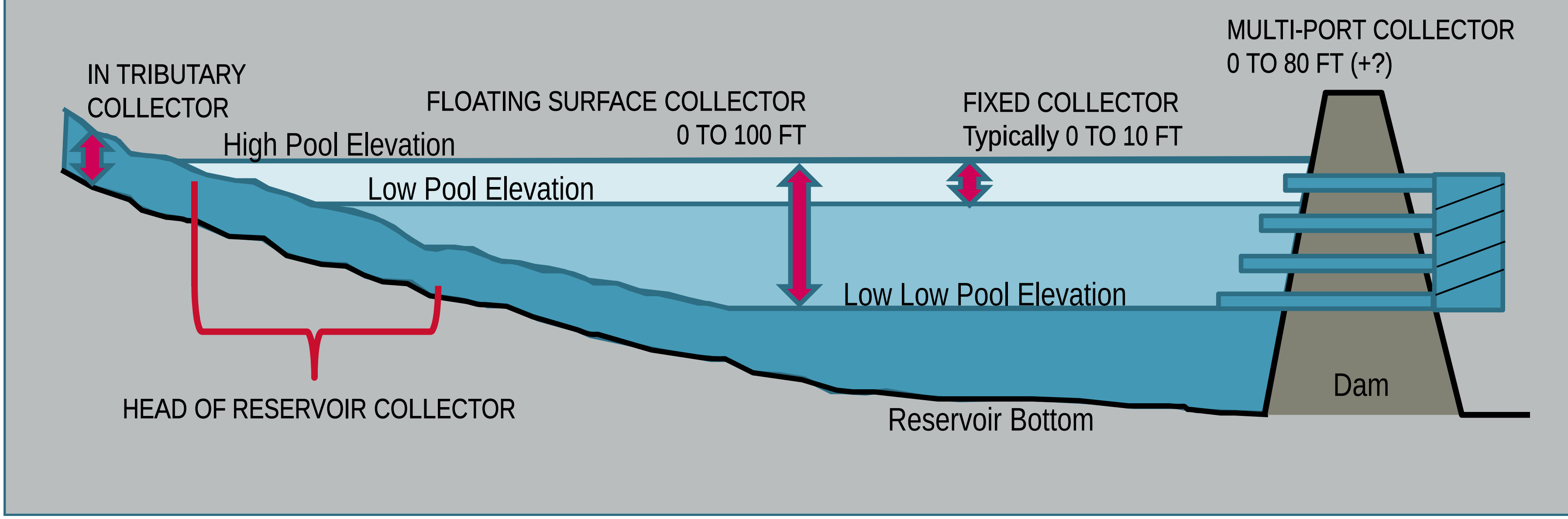


North Fork Fish Ladder Exit
Clackamas River, WA

- Has the ability to accommodate hydraulic connection throughout reservoir fluctuation using linear multi-gated exit.

Operating Environment

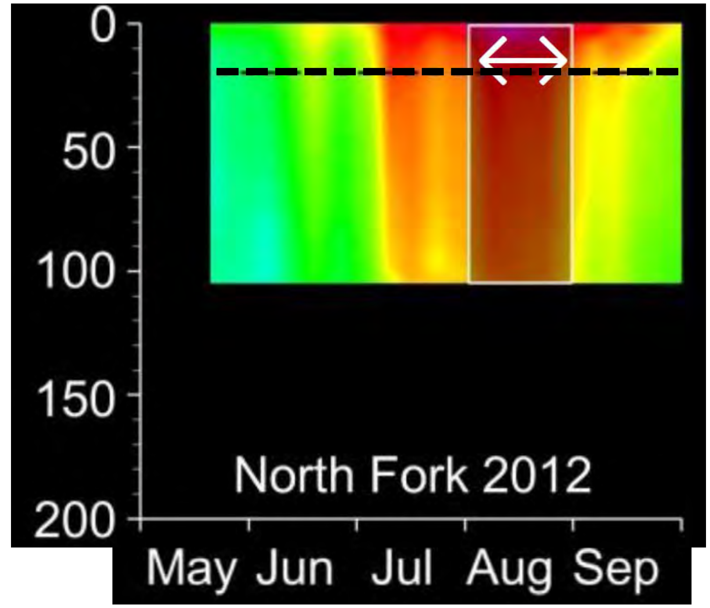
- Seasonal changes in pool volume and pool elevations influence collector selection
  - Swift FSC - 100 ft of seasonal water level change
  - Cougar PFFC – 160 ft of elevation change (up to +57 ft or -22 ft per day during flood control operations)
  - River Mill Fixed Collector – Normally regulated with 2 ft of variation, can be up to 6 ft
  - Pelton Round Butte – Normally regulated with 1to 2 ft of variation



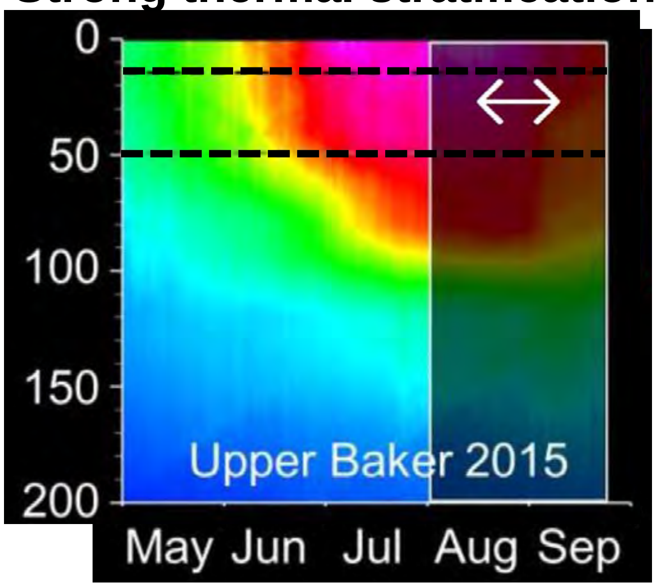
Operating Environment

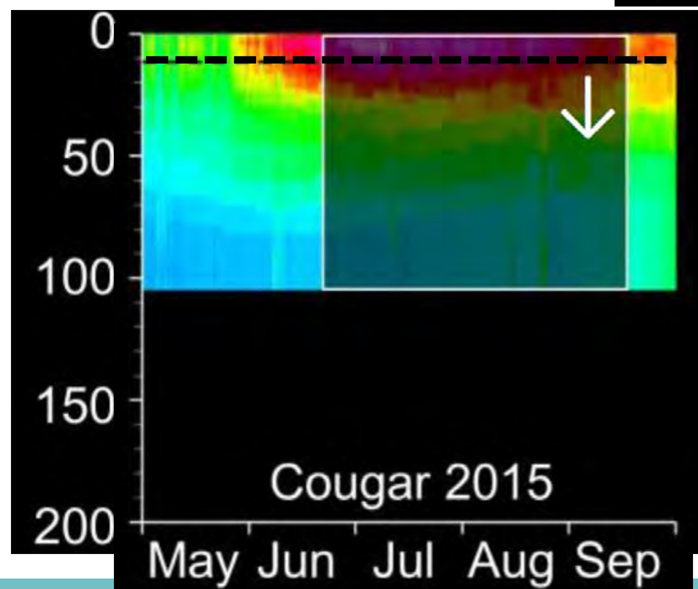
- Temperature complexity influences both upstream and downstream fish passage

Weak thermal stratification



Strong thermal stratification





(Adapted from USGS, 2017)

Operating Environment

- Reservoir Transit

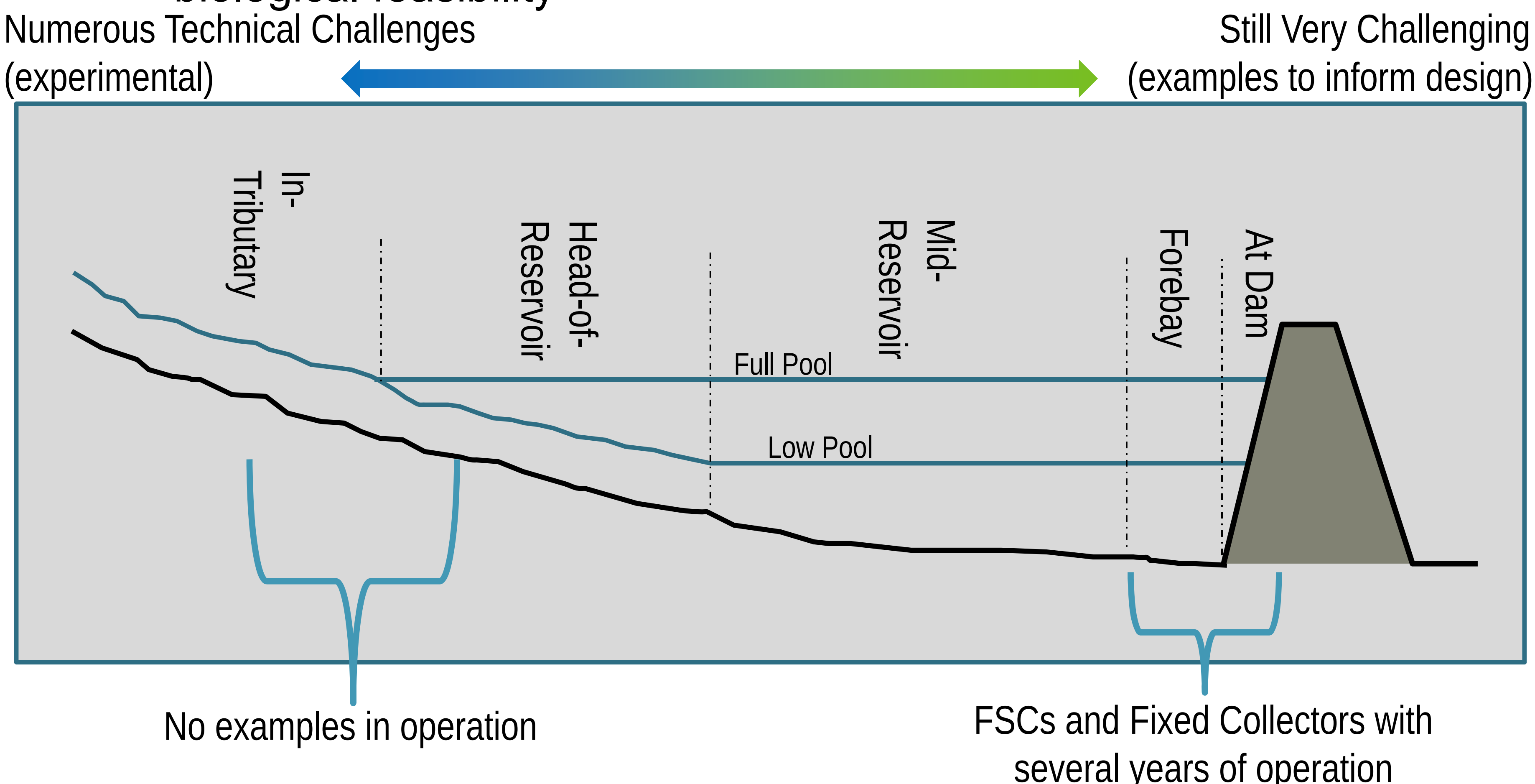
Low Uncertainty ↔ High Uncertainty

- Well mixed water column
- Cooler water temperatures
- Low predation
- Narrow, simple navigational pathway

- Thermally stratified
- Higher water temperatures
- High predation
- Complex navigational pathways
- Multiple tributaries

Operating Environment

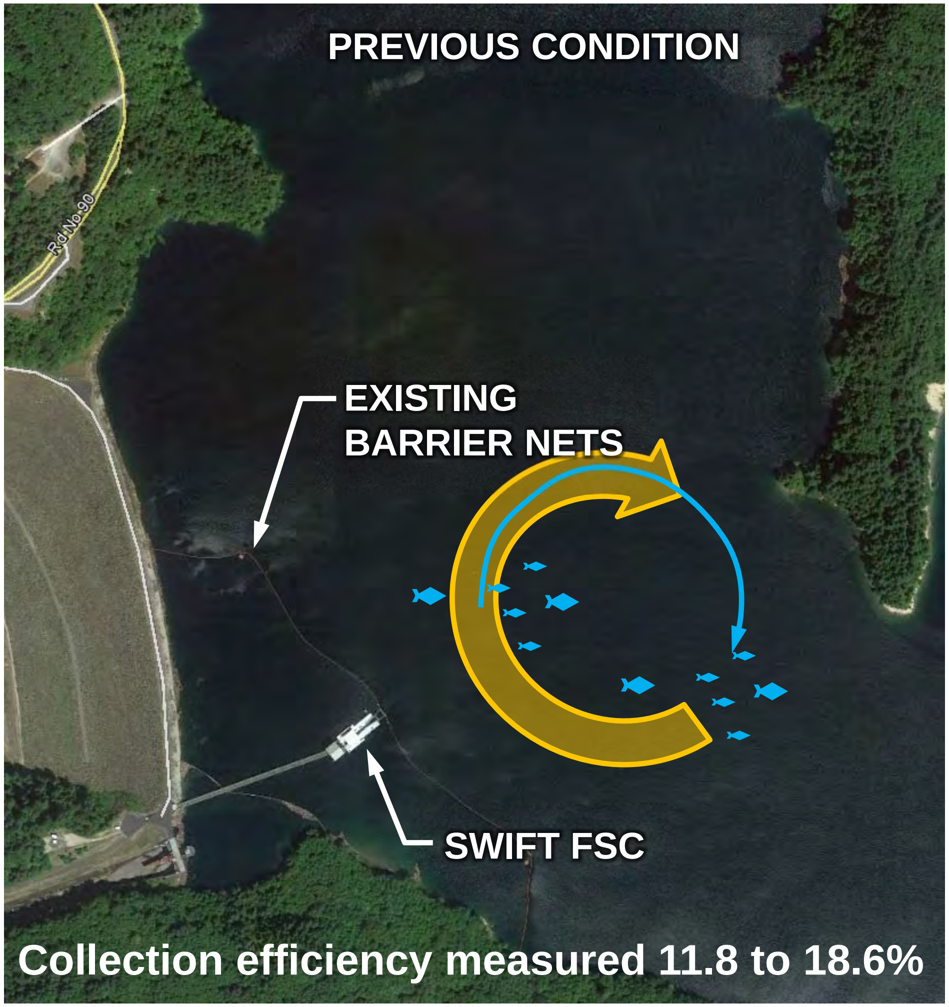
- Reservoir transit and the tradeoff between technical and biological feasibility

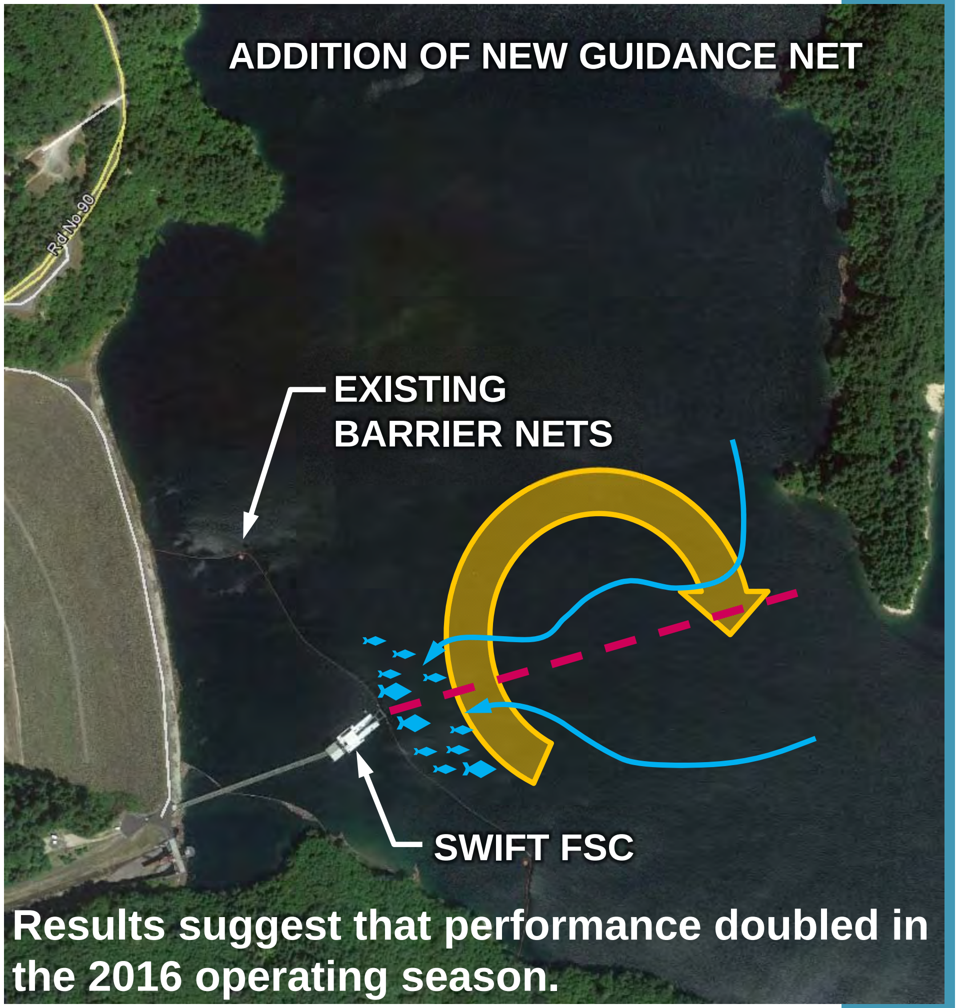


RECLAMATION
Managing Water in the West

Operating Environment

- Research Approach - Using monitoring data to improve knowledge and performance…





Key Fish Passage Parameters

- **What should the attraction flow targets consist of?**
  - Influence of existing operations
  - Zone of influence
  - Influence on migration ques of target species
- **Reservoir transit and survival**
  - Temperature, predation, loss of or false migration cues
  - Reservoir shape and complexity
  - Seasonal circulation patterns
- **Debris management**
- **Naval architecture of floating systems**

Key Fish Passage Parameters

- **Where are the fish going to be?**
  - Depth and orientation to existing infrastructure
  - Migration patterns leading them to the point of collection
  - Contribution of multiple tributaries

- **When are fish going to be there?**
  - General variation in species life history
  - Migration cues in upper watershed
  - Reservoir conditions

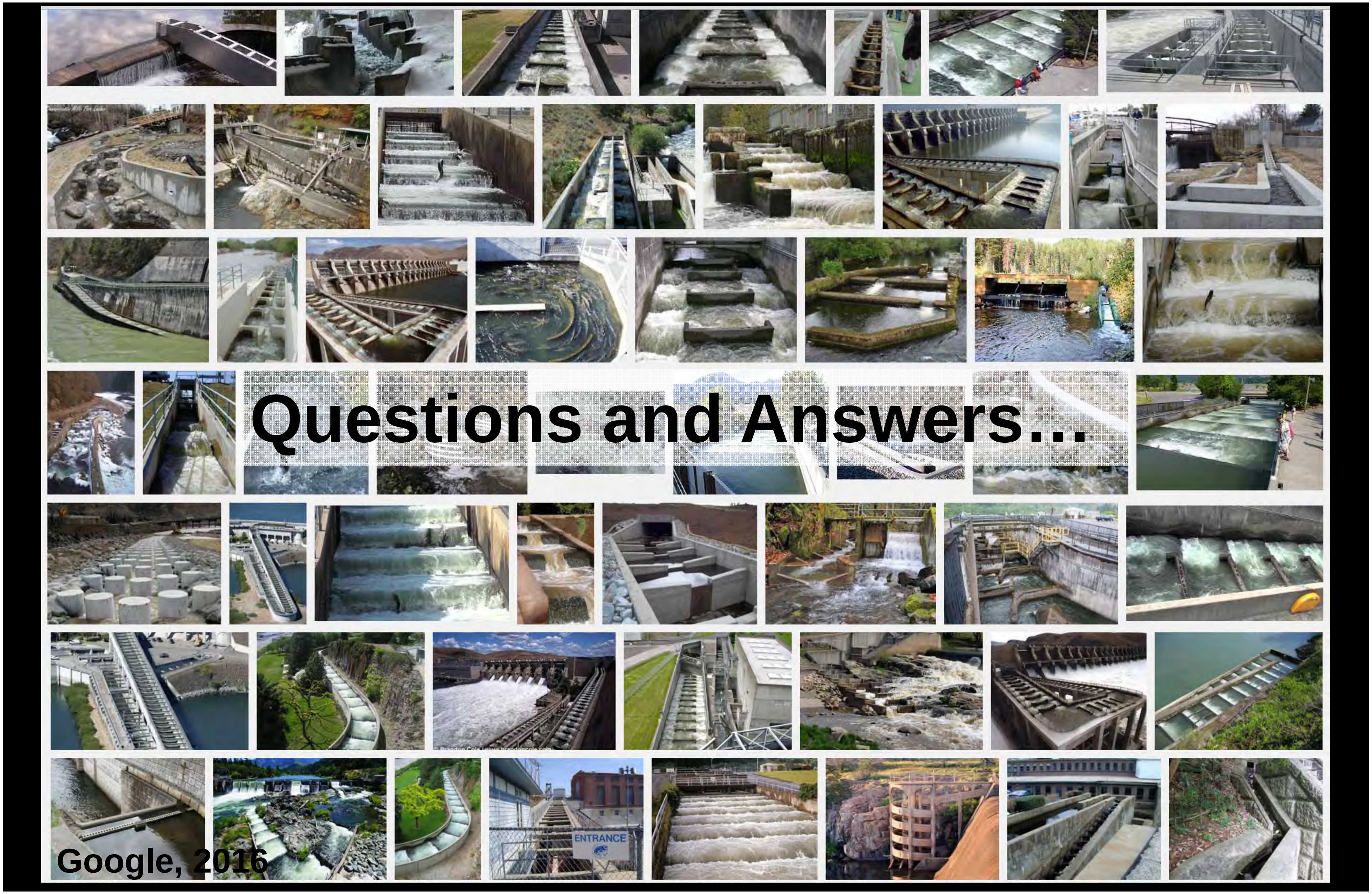
(photo by PGE)

Cougar PFFC (photo by HDR)

Key Design Parameters

An investment in knowledge pays the best interest.... (Benjamin Franklin)

Santa Paula Fish Ladder
Santa Paula Creek, CA



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Case Study I: Santa Felicia Dam

(not available online)

Upstream Fish Passage Feasibility Assessment

Jonathan Mann
California Department of Fish and Wildlife