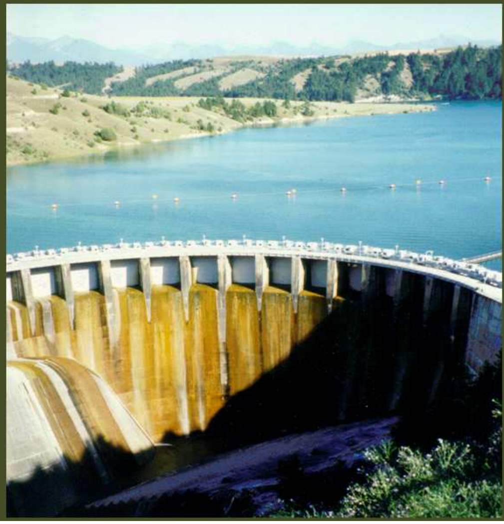
SELECTING APPROPRIATE TECHNIQUES FOR EVALUATING EFFECTS OF HYDROELECTRIC PROJECT DEVELOPMENT AND OPERATION ON AQUATIC RESOURCES

Presented by – Dudley Reiser, Stuart Beck and MaryLouise Keefe
R2 Resource Consultants
Redmond, Washington
Anchorage, Alaska



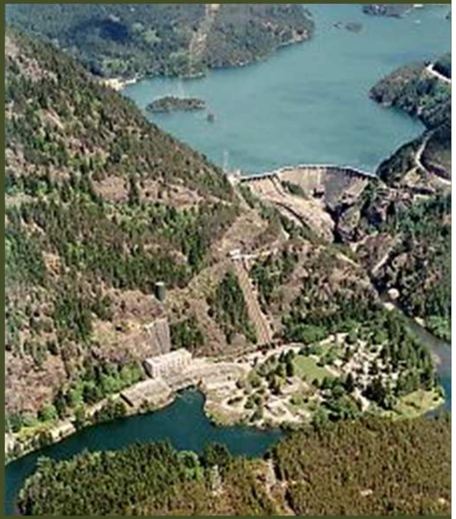
Alaska AWRA Meeting - April 4-6, 2011

PRIMARY "POTENTIAL" HYDRO-RELATED EFFECT ON FISH =

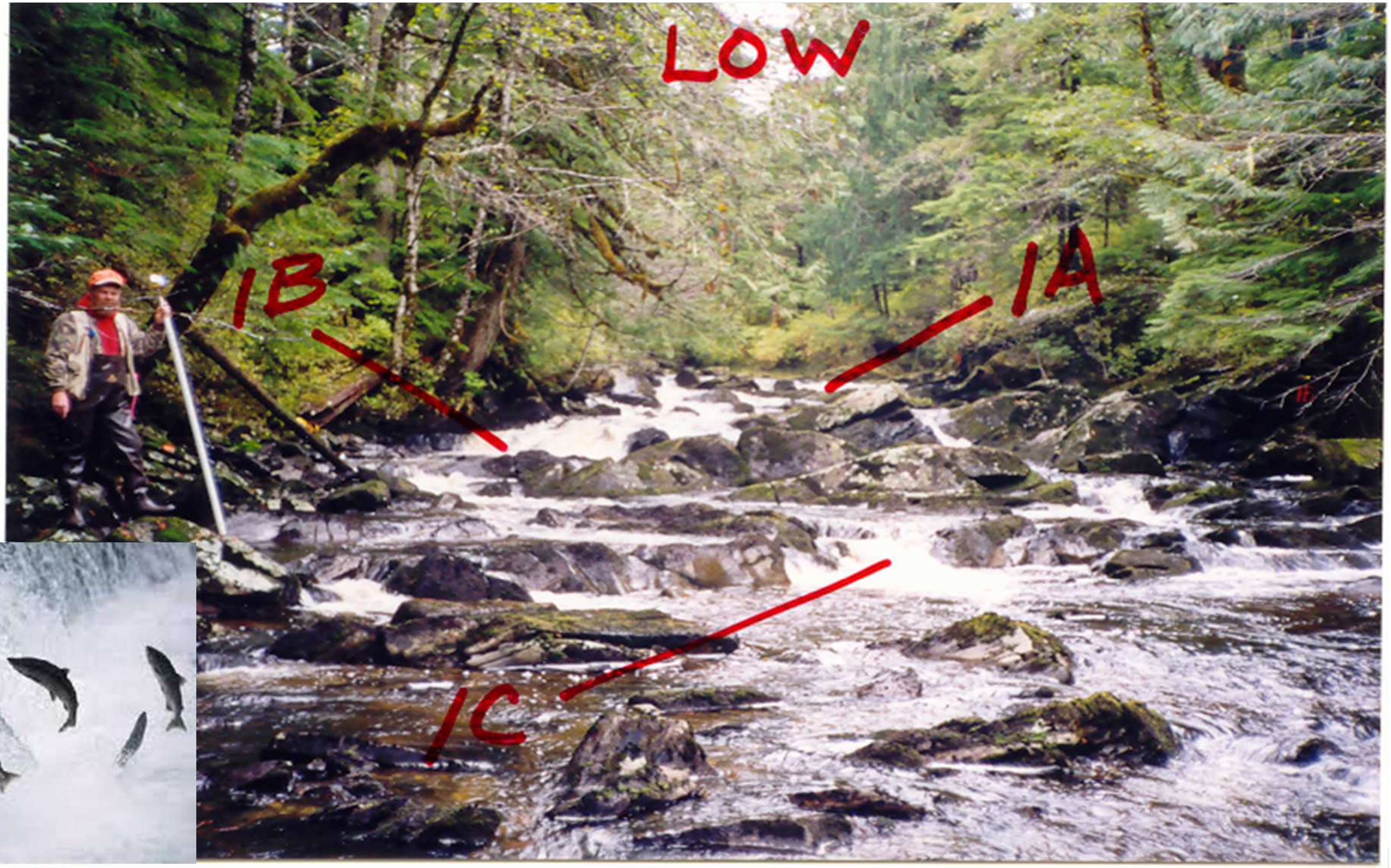
FLOW

Spawns questions of:

HOW CAN FLOW RELATED EFFECTS OF HYDRO PROJECTS INFLUENCE FISH POPULATIONS?



Which lifestage???????????????



UPSTREAM MIGRATION

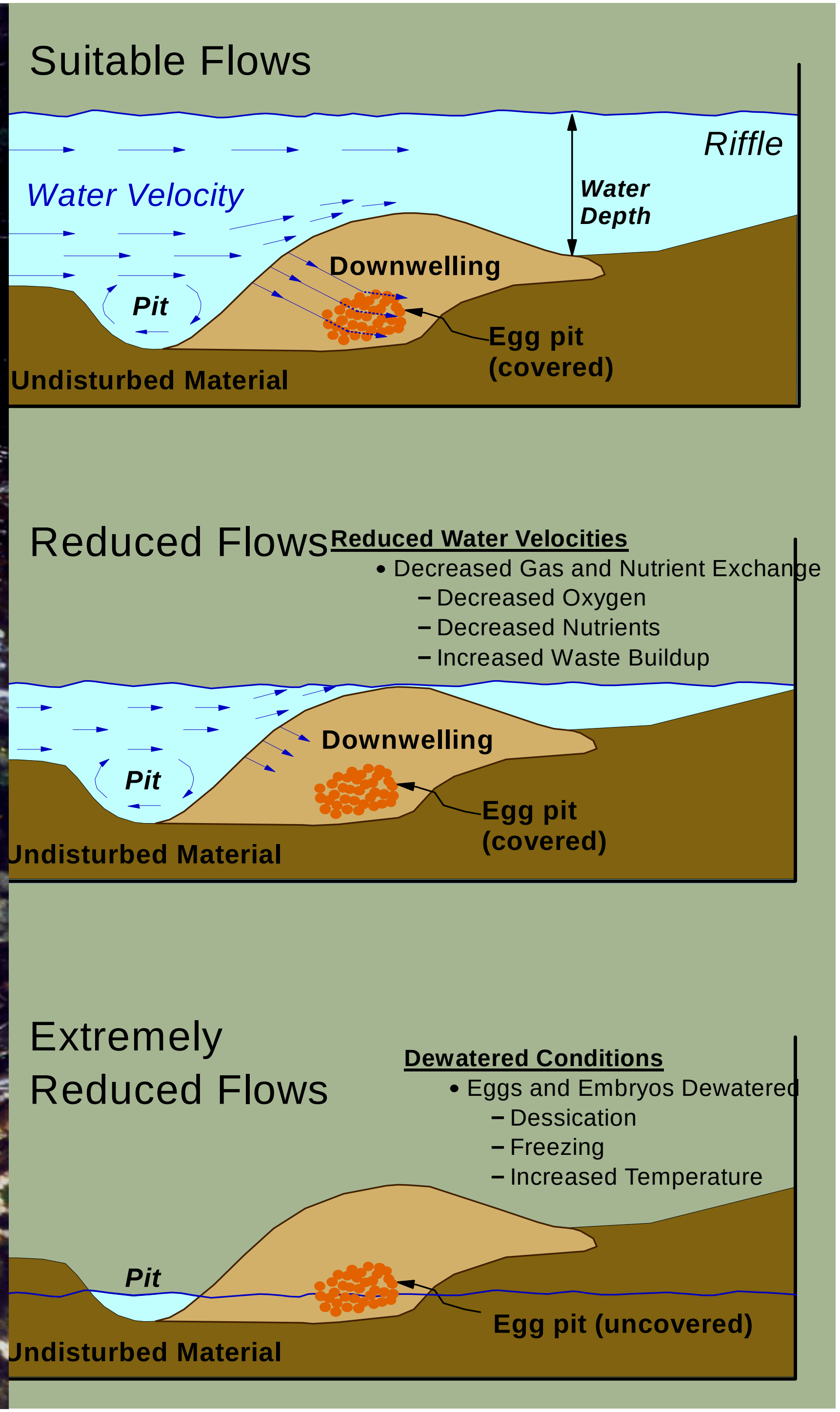
- **Streamflow influenced parameters: physical barriers, turbidity, water depth – minimum, water velocity - maximum, water temperature.**

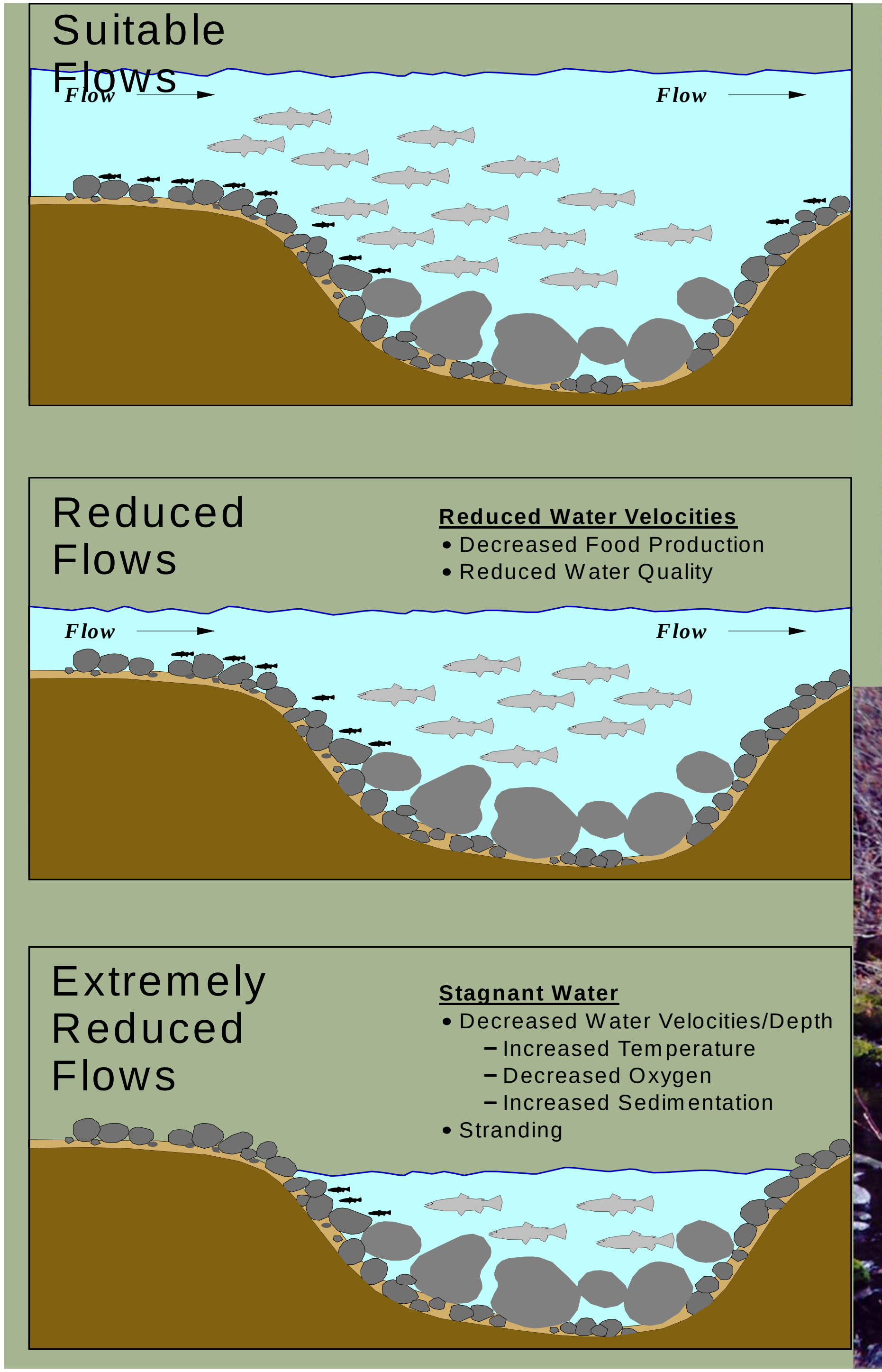
SPAWNING

- **Streamflow influenced parameters: water depth, water velocity, substrate, water temperature, dissolved oxygen, cover**


INCUBATION


9 21 '98


Suitable Flows
Riffle
Water Velocity
Water Depth
Downwelling
Pit
Egg pit (covered)
Undisturbed Material
Reduced Flows
Reduced Water Velocities
• Decreased Gas and Nutrient Exchange
– Decreased Oxygen
– Decreased Nutrients
– Increased Waste Buildup
Downwelling
Pit
Egg pit (covered)
Undisturbed Material
Extremely Reduced Flows
Dewatered Conditions
• Eggs and Embryos Dewatered
– Dessication
– Freezing
– Increased Temperature
Pit
Egg pit (uncovered)
Undisturbed Material


Suitable Flows
Flow
Flow
Reduced Flows
Reduced Water Velocities
• Decreased Food Production
• Reduced Water Quality
Flow
Flow
Extremely Reduced Flows
Stagnant Water
• Decreased Water Velocities/Depth
– Increased Temperature
– Decreased Oxygen
– Increased Sedimentation
• Stranding


REARING
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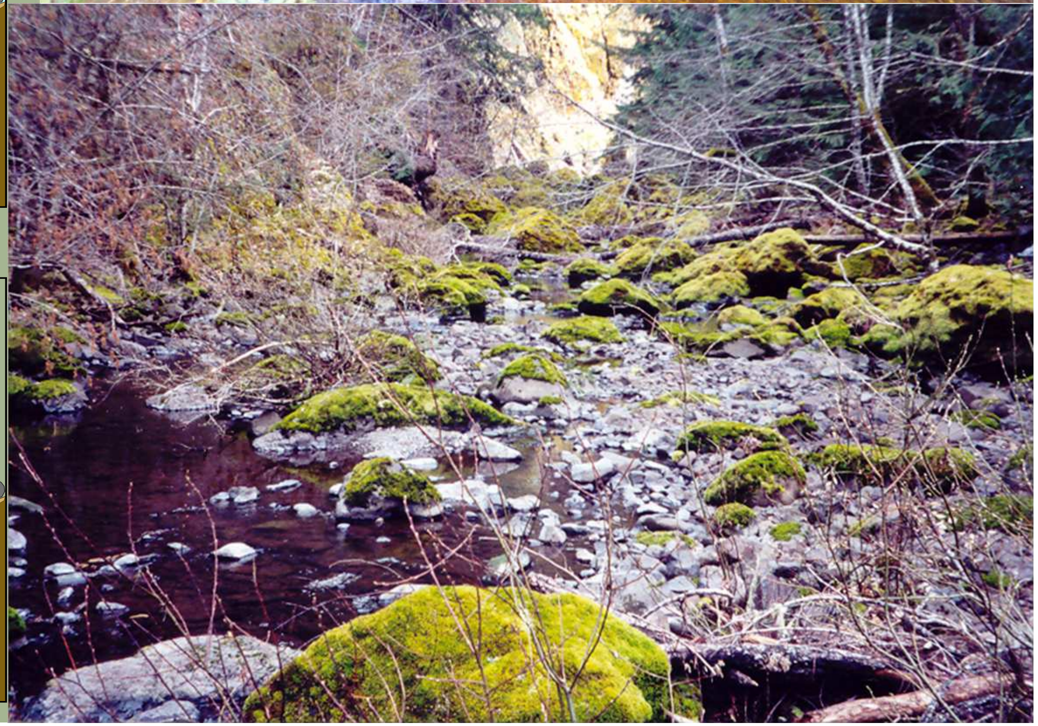


DOWNSTREAM PASSAGE

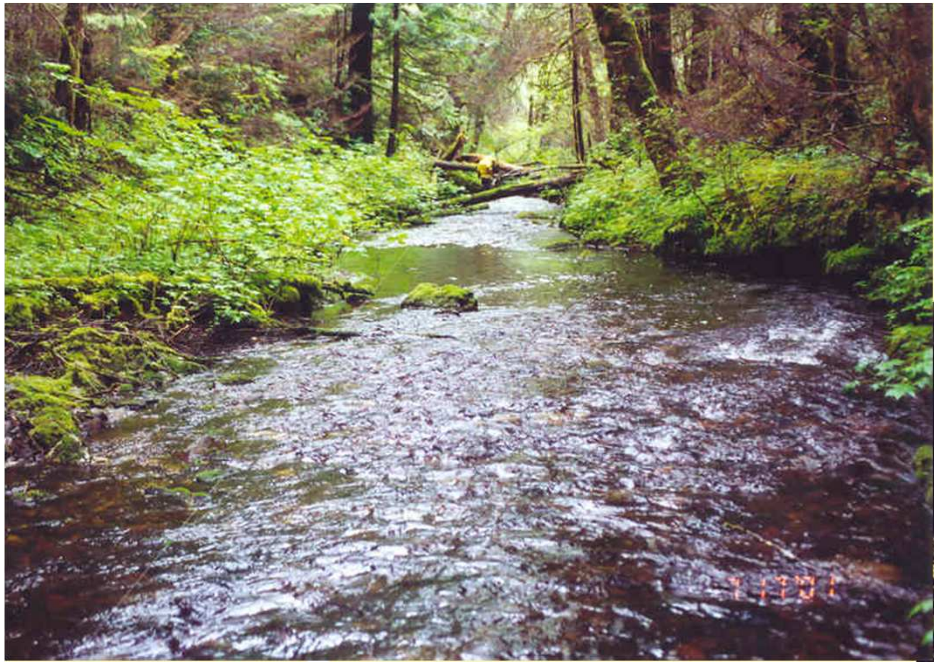
- **Movement typically synchronous with runoff; turbidity, freshets, water temperature**

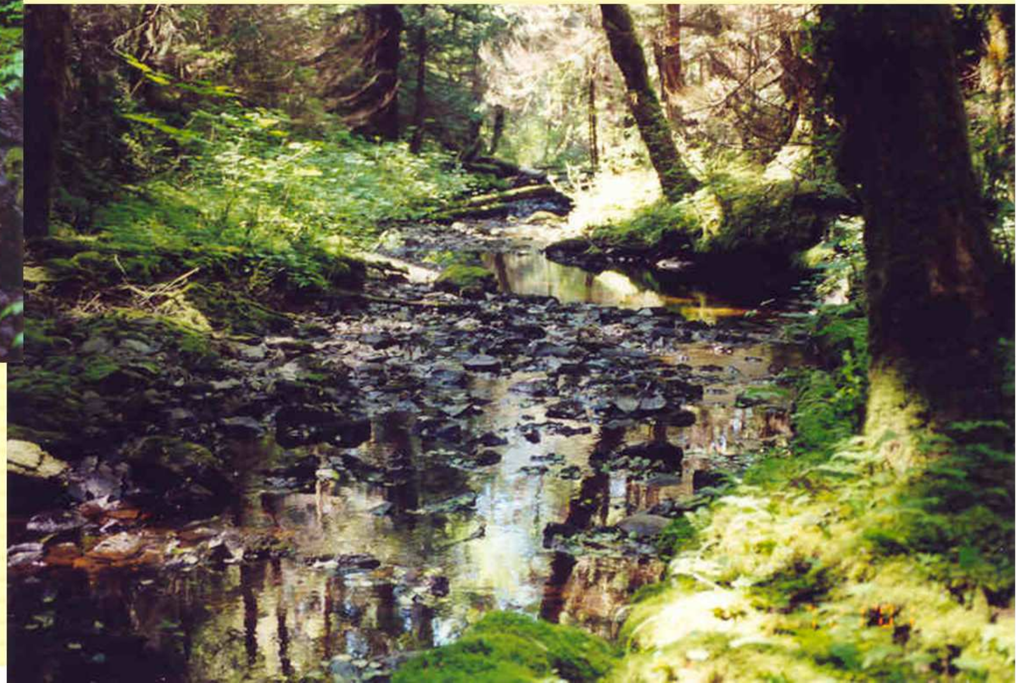
HABITAT FORMATION AND FUNCTION

- **Sediment transport – pools/riffles, riparian habitat, substrate quality, aquifer recharge ,hyporheic zone.**

ICE FORMATION AND FUNCTION

- Channel formation, sediment transport, side channel and off-channel connectivity, overwintering habitat conditions.

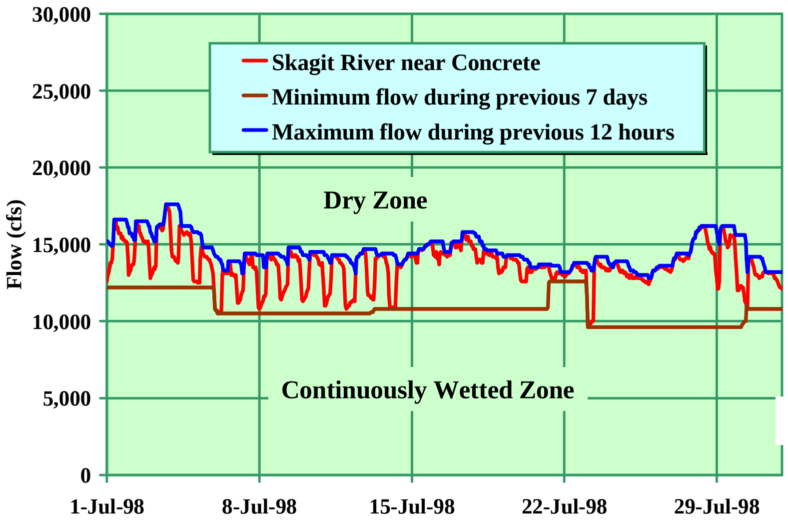


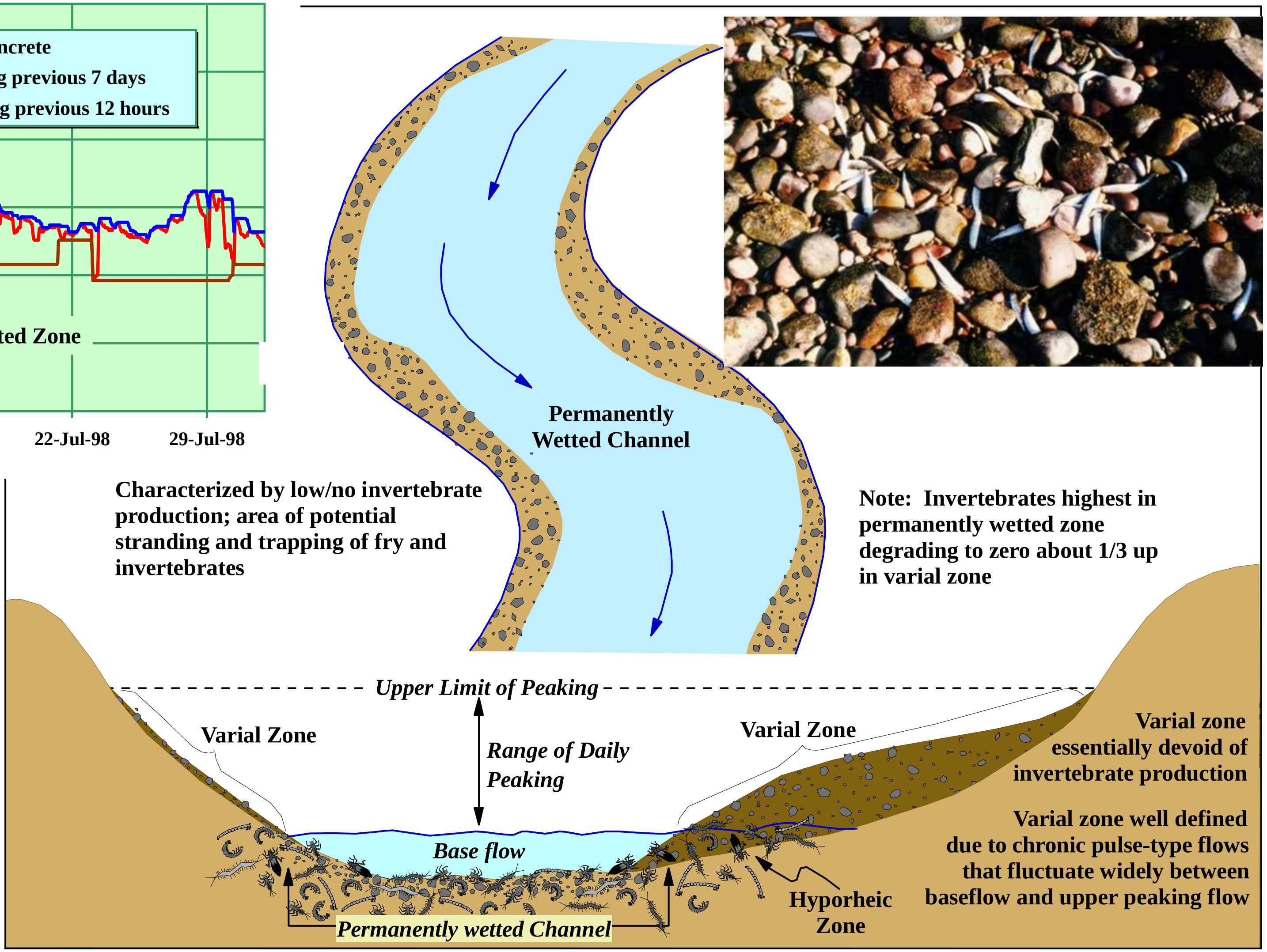


Side Channel Connectivity

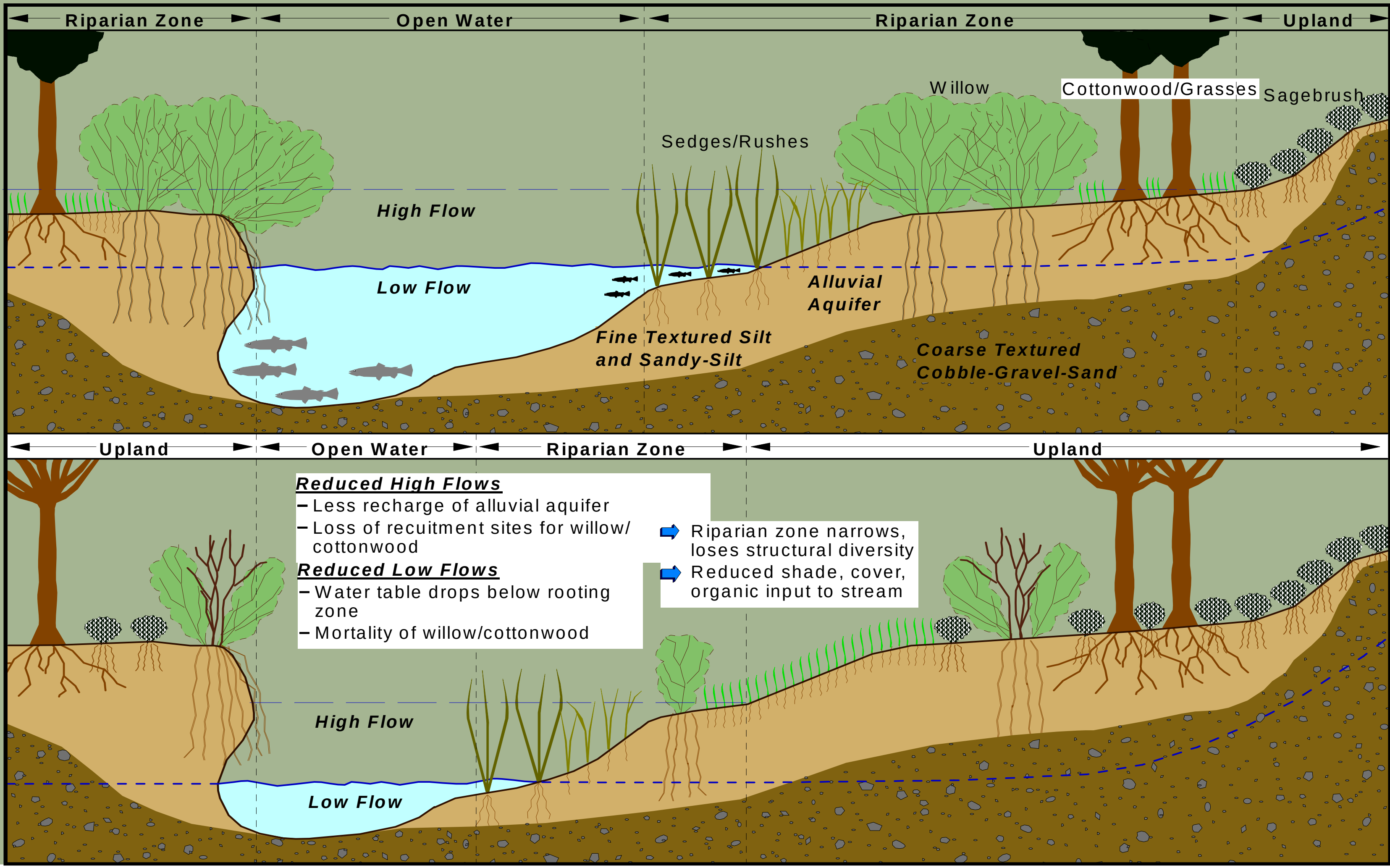
- **Fry nursery habitat, juvenile rearing habitat, velocity and thermal refuge habitats, spawning habitat, gravel and wood recruitment.**

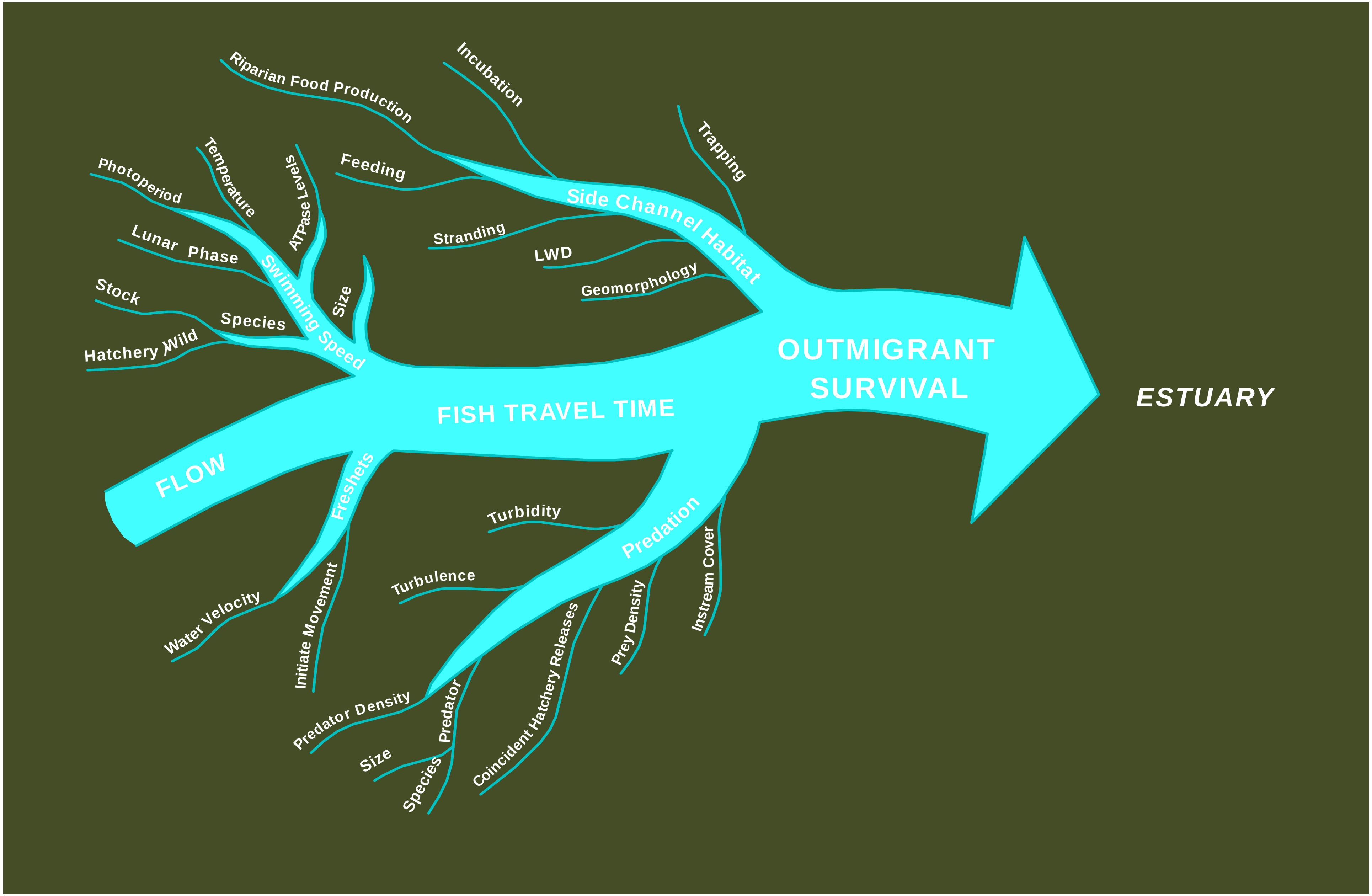
Pulse Type Flows – Ramping Rates Stranding Potential





Channel – Riparian-Q Interactions





Freshwater – Estuarine Dependencies

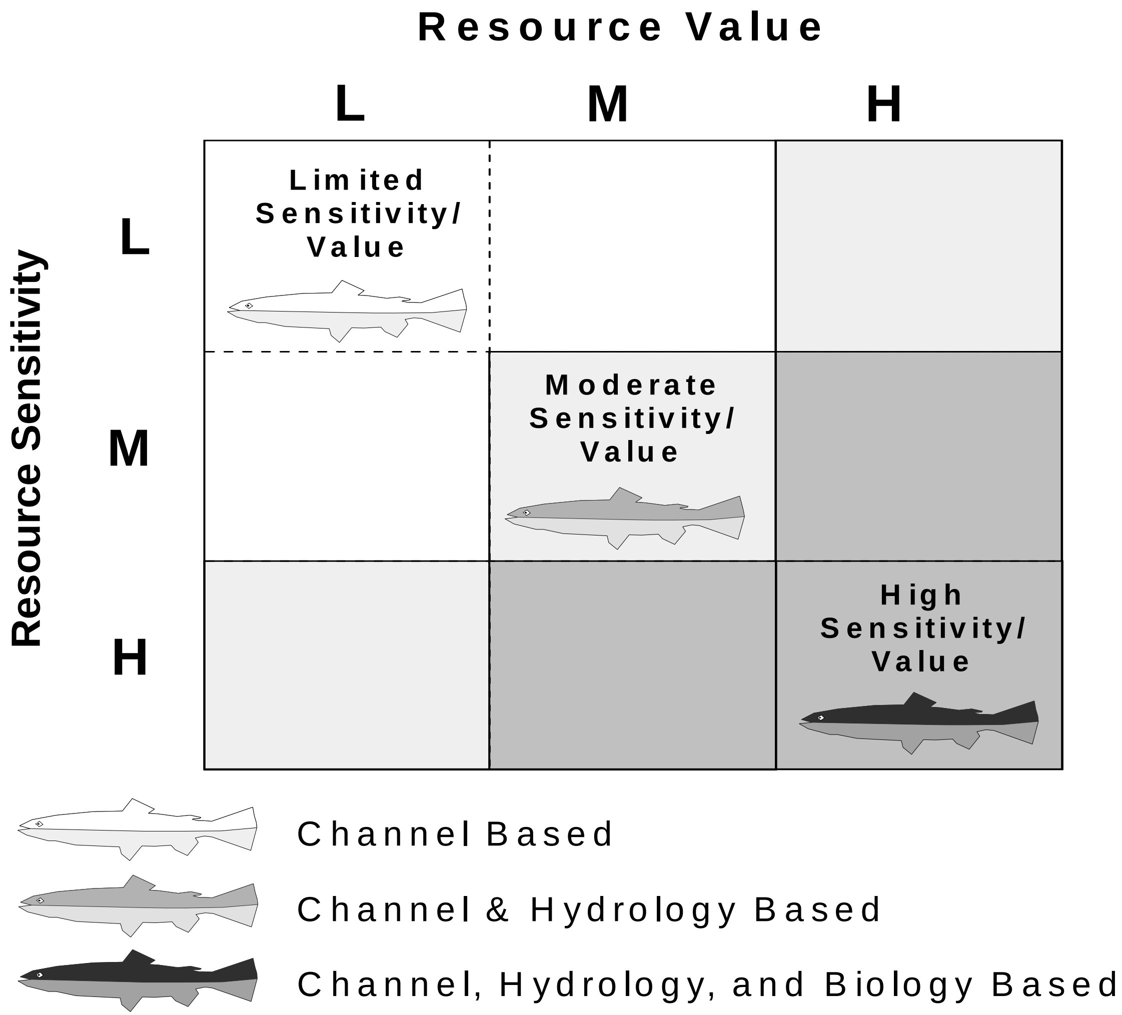
Common Hydro-Flow Related Issues

- Fish (and other aquatic biota) habitat based flows
- Peaking/Load following impacts – stranding
- Flushing flows – sediment transport
- Channel forming flows – sediment and bed movement
- Riparian/Process flows - floodplain function
- Side channel connectivity
- Pulse flows – adult attraction/smolt outmigration
- Temperature regulation – thermal impacts?
- Water quality – DO, TDG, etc….
- Upstream passage
- Downstream passage ……

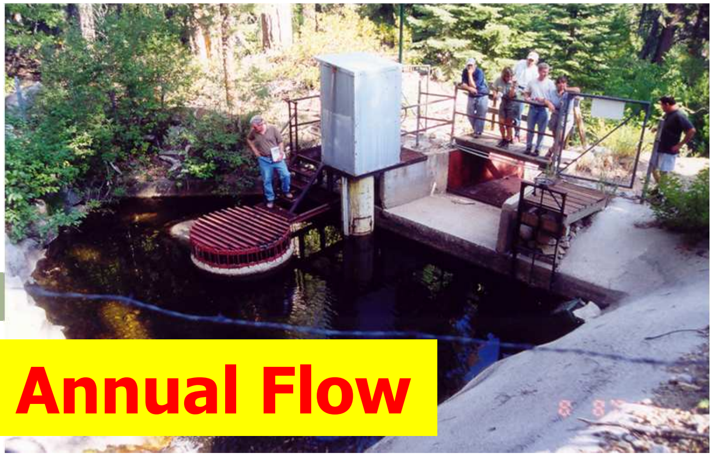
General Methods to Assess Effects

- Spatial Habitat Requirements and Impacts
  - Many different methods
  - IFIM PHABSIM1D- and 2D- modeling - most common
  - See IFC 2004 for more methods
  - Consider hierarchical approach

Conceptual Hierarchical Approach to Assessing Instream Flow Needs



Tennant Method



Hydrology based - % of Average Annual Flow

Table 1. Instream flow regimes for fish habitat (Tennant, 1976).

Narrative Descriptions of Flows	Recommended Base Flow Regimes (QAA)	
	Oct. – Mar.	Apr.-Sept.
Flushing Flow	200%	200%
Optimal Range	60 – 100%	60 – 100%
Outstanding	40%	60%
Excellent	30%	50%
Good	20%	40%
Fair	10%	30%
Poor or Minimum	10%	10%
Severe Degradation	10%	10%

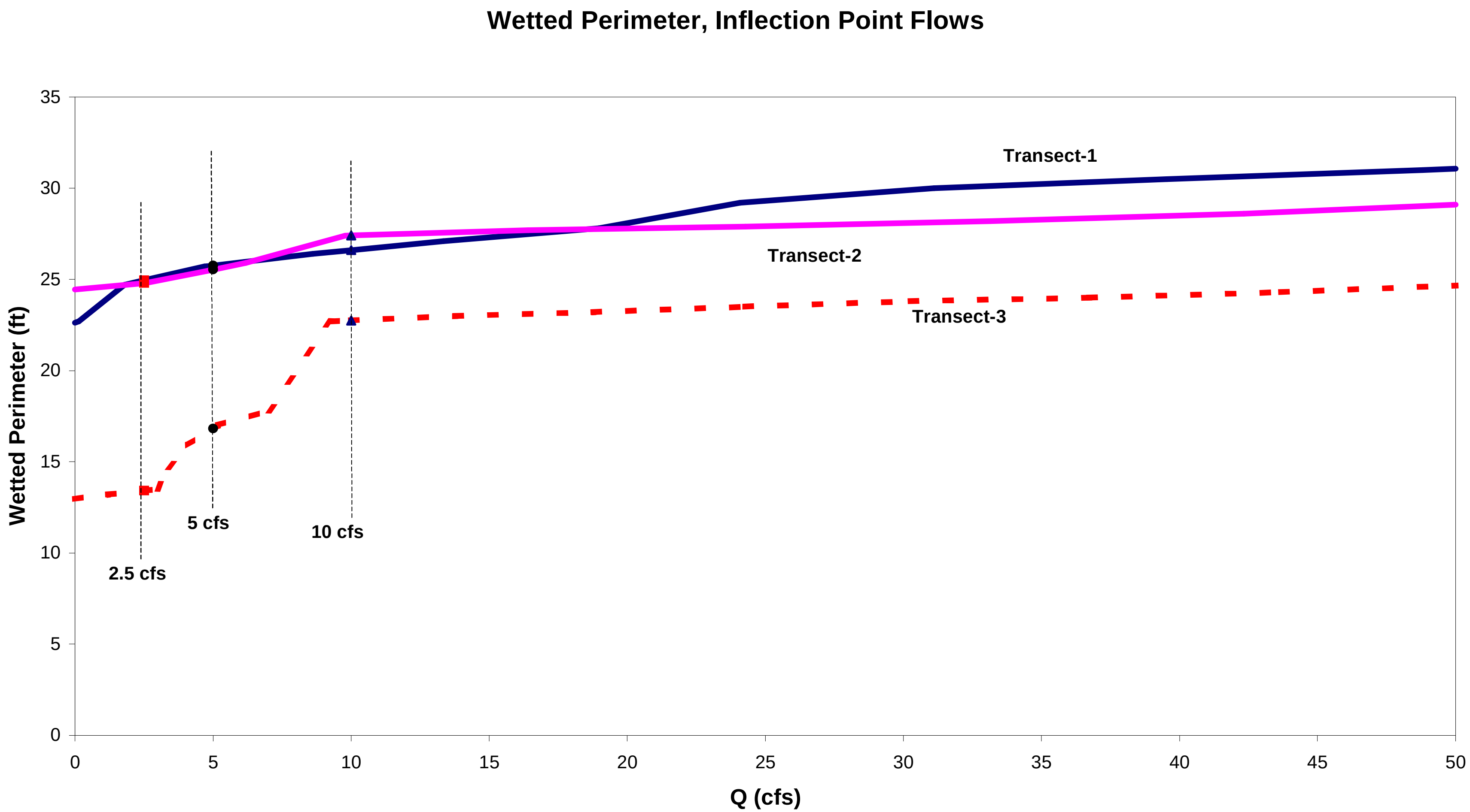
Indicators of Hydrologic Alteration (Richter et al. 1996)

Hydrological Based

Comparison of 32 hydrological parameters relative to unaltered vs. altered conditions

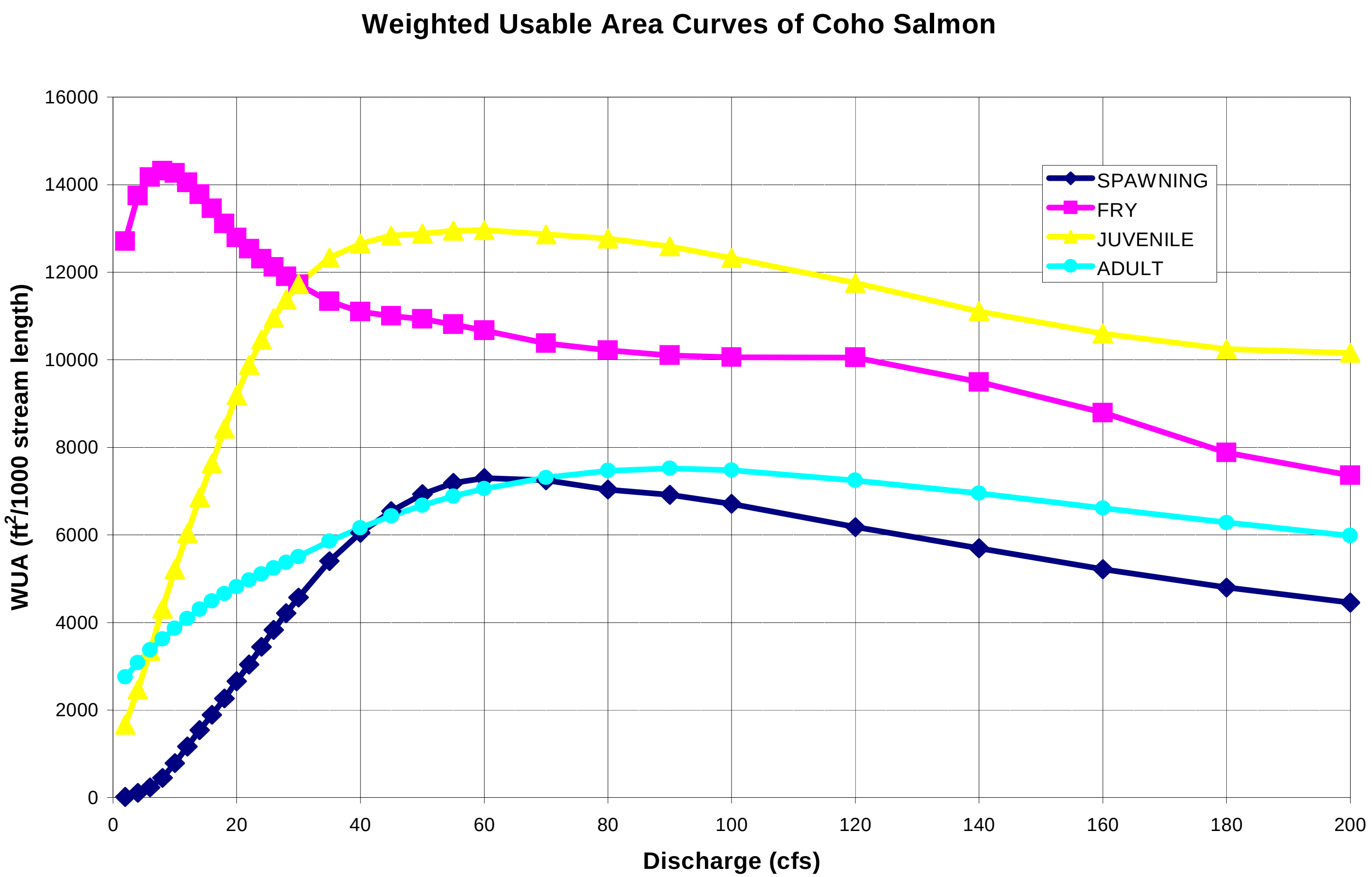
Wetted Perimeter

WP – "inflection points" = minimum flow

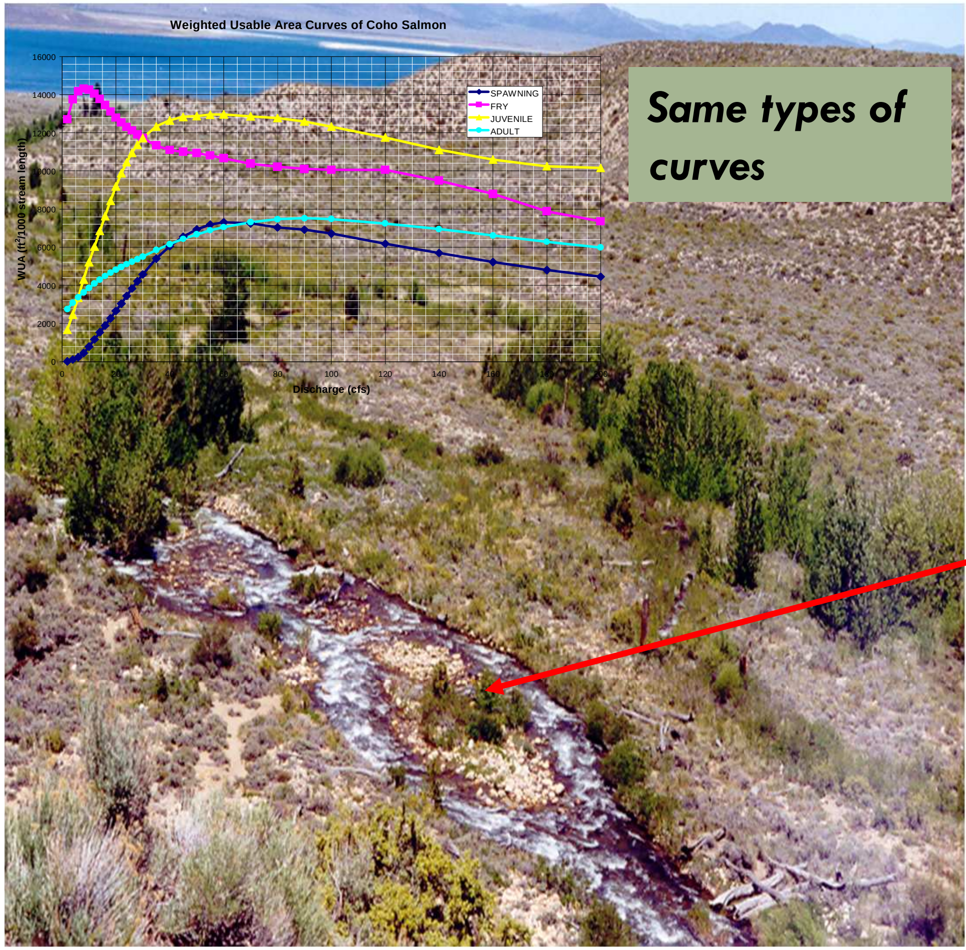


PHABSIM – 1-dimensional modeling Habitat:Q

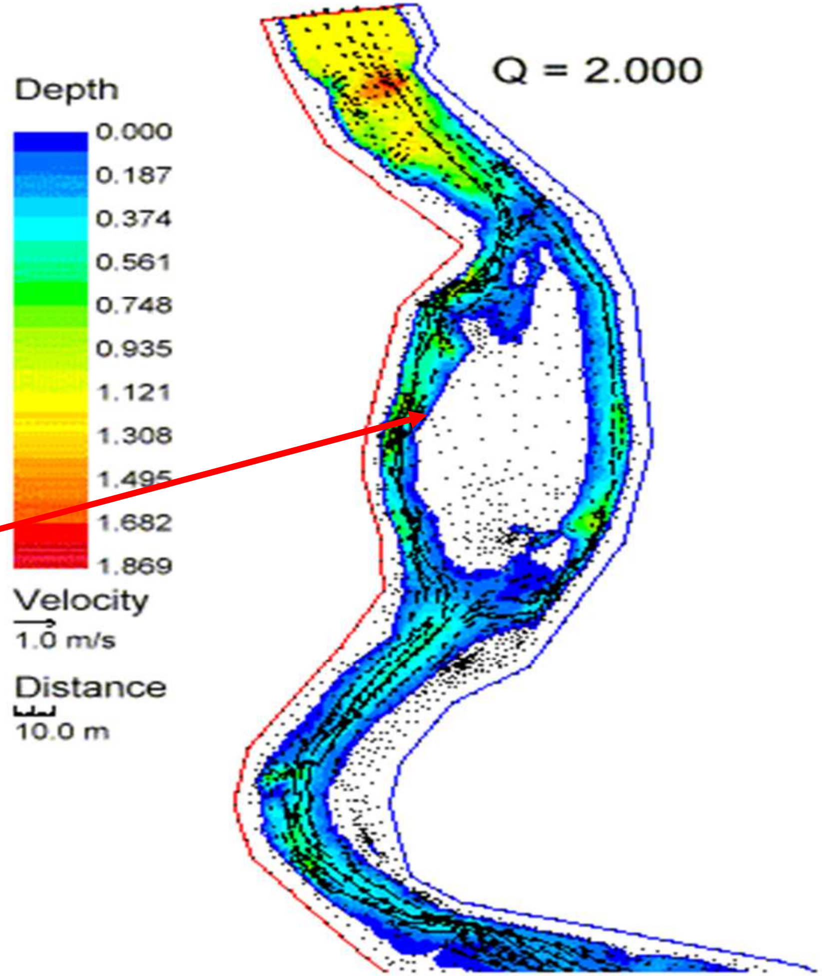
Weighted usable area (WUA) v Q – <u>starting point</u>
Incremental method – evaluate tradeoffs



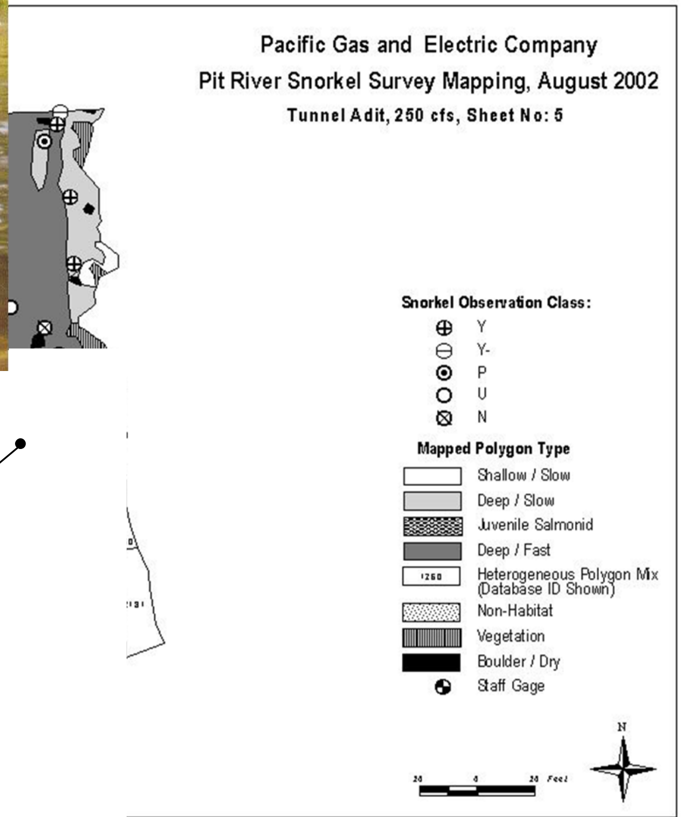
PHABSIM -2-dimensional modeling

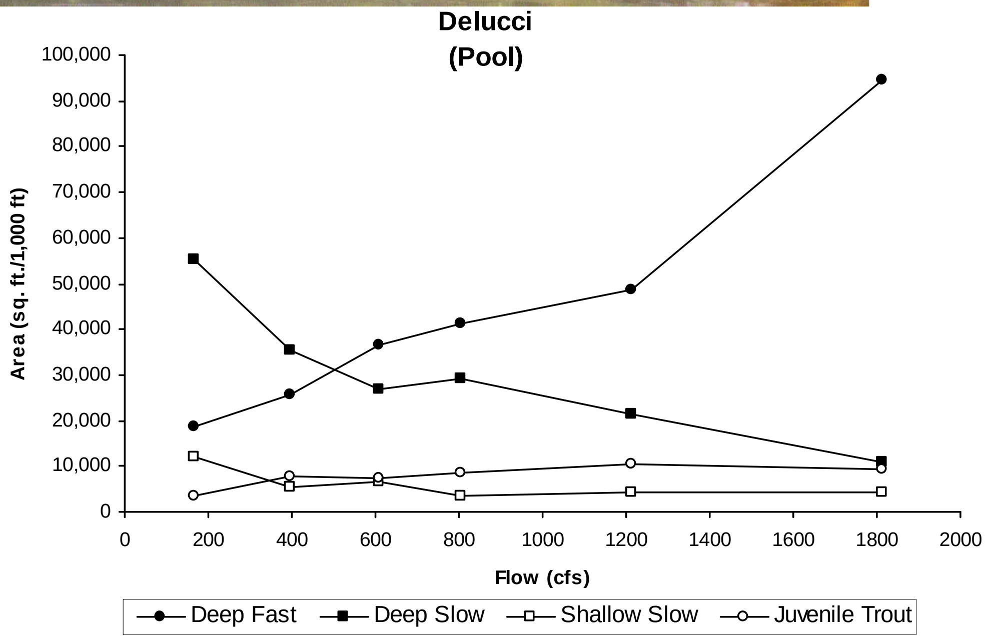


Same types of curves



HABITAT MAPPING AT MULTIPLE FLOWS





General Methods to Assess Effects

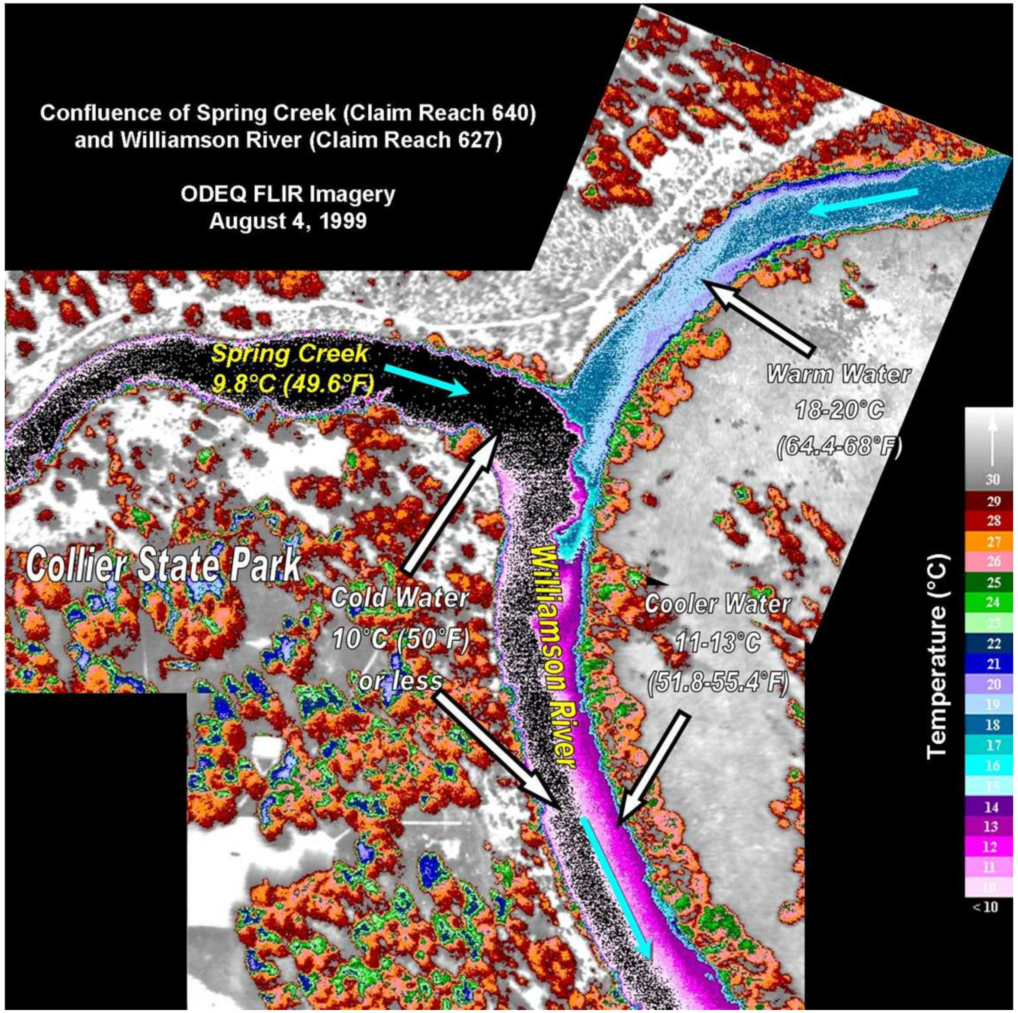
- Side Channel/off-channel Connectivity
  - Side channel – main channel stage/discharge relationships: define functionality of channel
  - Aerial Photography/Habitat mapping
  - GIS mapping
- Upstream Fish Passage Issues
  - Powers and Orsborn (1984) – physical obstacles (falls, cascades and chutes)
  - Thompson (1974) - flow related (minimum depth and maximum velocity)
  - Hydraulic Modeling

General Methods to Assess Effects

- Downstream Passage
  - Hydrologic modeling - define project operational effects
  - Species periodicities
- Fluvial Geomorphology Issues
  - Sediment transport modeling
  - Substrate characterization
  - RTK/GPS Topographic surveys

General Methods to Assess Effects

- Temperature Effects
  - Temperature monitoring and modeling
    - SNTEMP – surface flow method
    - River1D – under ice method
    - FLIR/TIR imaging



A FEW CASE STUDIES

- Whitman/Connell – Ketchikan
- Sultan River – Washington
- Baker River – Washington
- Pit River - California
- Clackamas River – Oregon


CONNELL and
WHITMAN DAMS
Ketchikan Public Utilities

Flow Related Issues

- Instream flows below Connell Dam and Whitman Dam to meet fish spatial needs
- Side channel watering
- Flows below Connell to allow passage through falls – cascades
- Reservoir operation effects on tributary connectivity

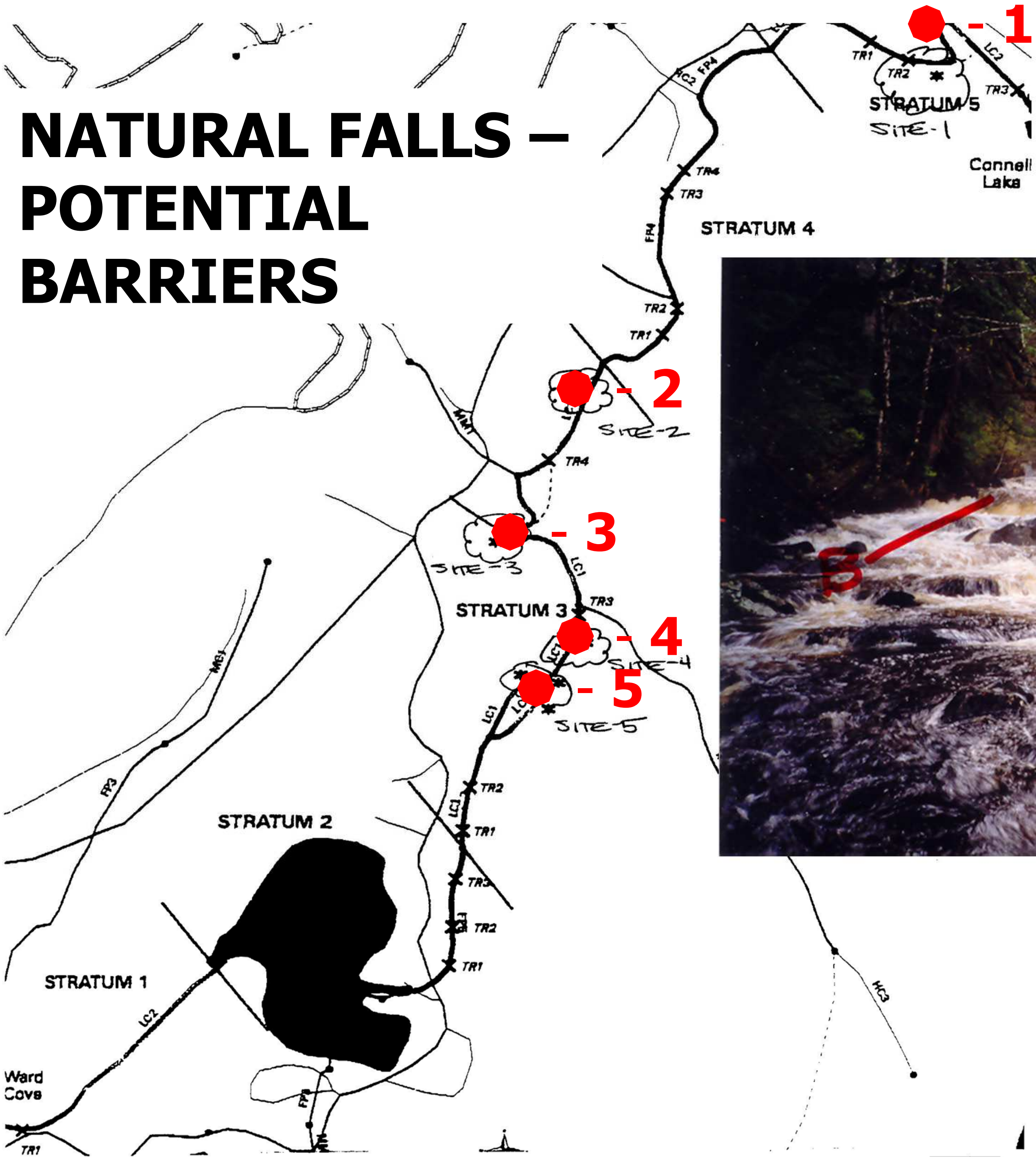
Instream Flow Methods

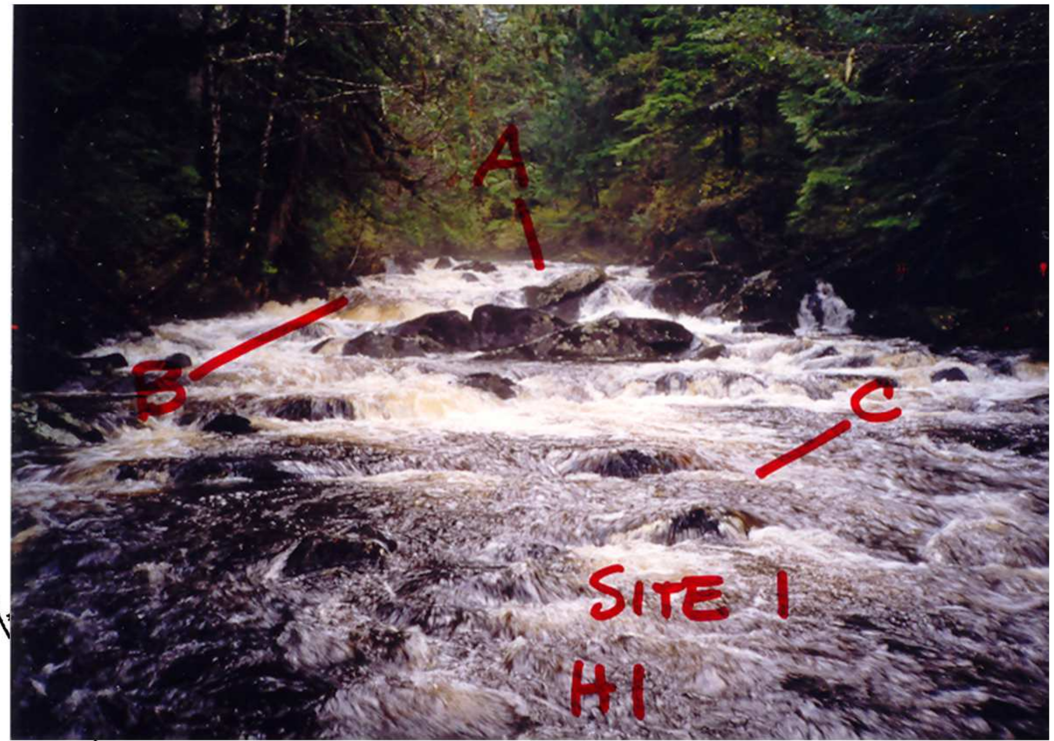
- **PHABSIM – 1-D modeling: Ward Creek**
- **Wetted Perimeter – Whitman Creek**

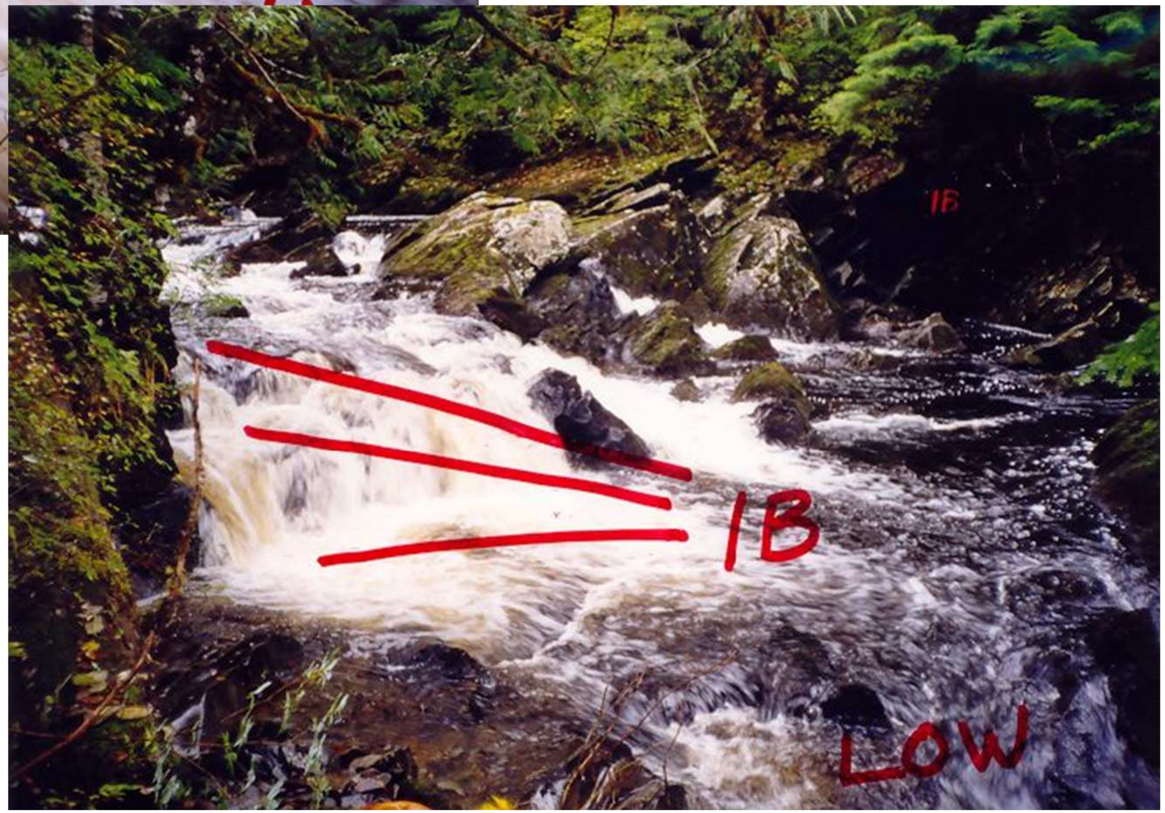
Fish-Flow Barrier Analysis

- **Potential passage barriers in Ward Creek – locations and types?**
- **What are physical and hydraulic conditions at sites**
- **Does Q influence passage potential?**
- **“Flow Windows” for passage**

NATURAL FALLS – POTENTIAL BARRIERS







3 Field Surveys

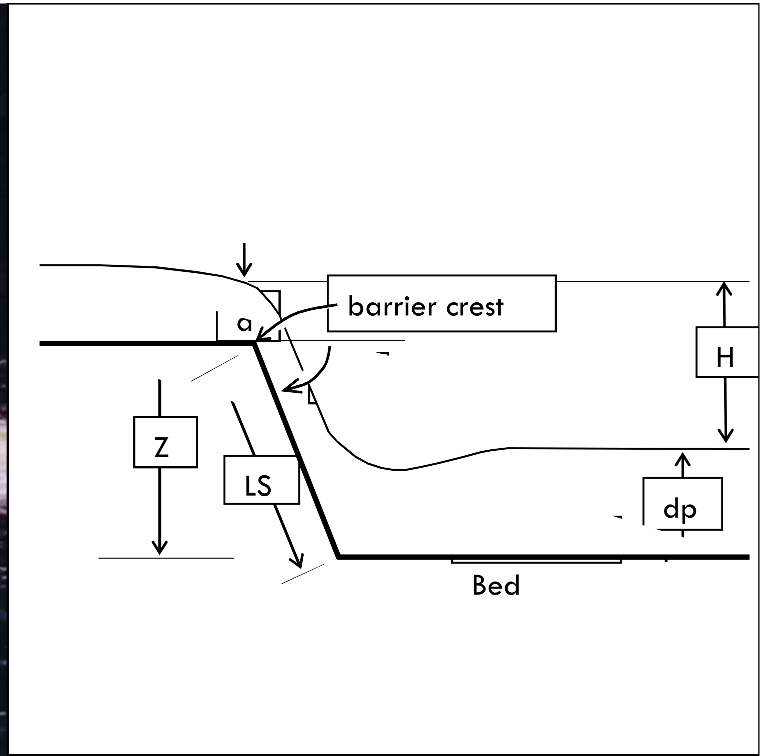
Low Flow - 20 cfs

Mid-Flow - 40 cfs

High Flow - 100 cfs

Surveys/Barrier Geometry

- **Longitudinal bed slope upstream of the barrier (Se),**
- **Chute length (LS),**
- **Elevation difference between barrier crest and streambed of the plunge pool (Z),**
- **Chute angle (Sp).**



FALLS BARRIER ANALYSIS

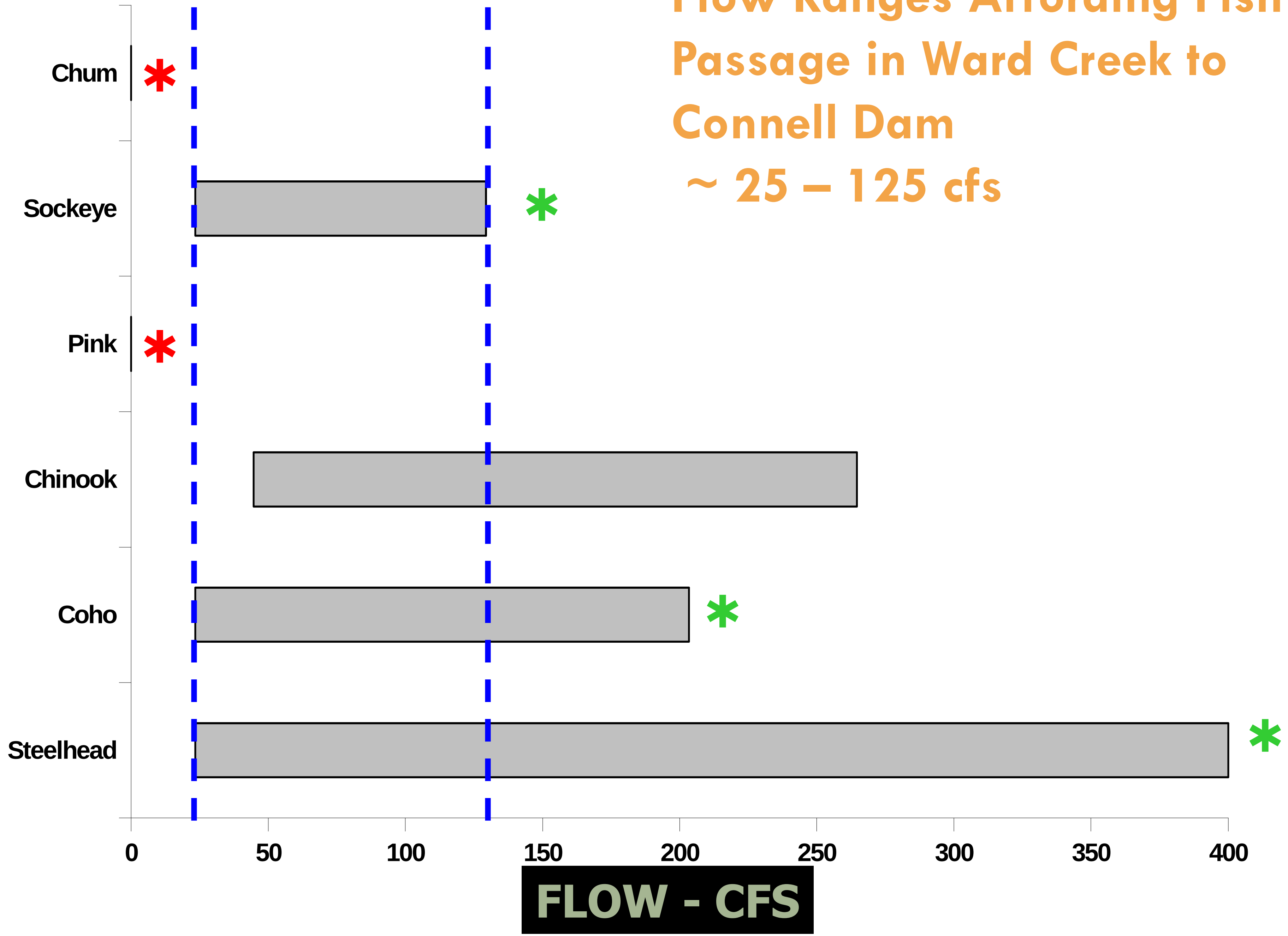
- Vertical and Horizontal Distances
- Plunge Pool Depth
- Crest Velocity
- Crest Water Depth

Swimming Performance

PARAMETER		StH	CO	CK	Pink	Sock	Chum
Sustained Velocity	(ft/s)	**4.6**	**3.4**	**3.4**	**2.6**	**3.2**	**2.6**
Prolonged Velocity	(ft/s)	**13.7**	**10.6**	**10.8**	**7.7**	**10.2**	**7.7**
Burst Velocity	(ft/s)	**26.5**	**21.5**	**22.4**	**15**	**20.6**	**15**
Minimum Swimming Depth	(ft)	**0.55**	**0.55**	**0.55**	**0.55**	**0.55**	**0.55**

Flow Ranges Affording Fish Passage in Ward Creek to Connell Dam

~ 25 – 125 cfs

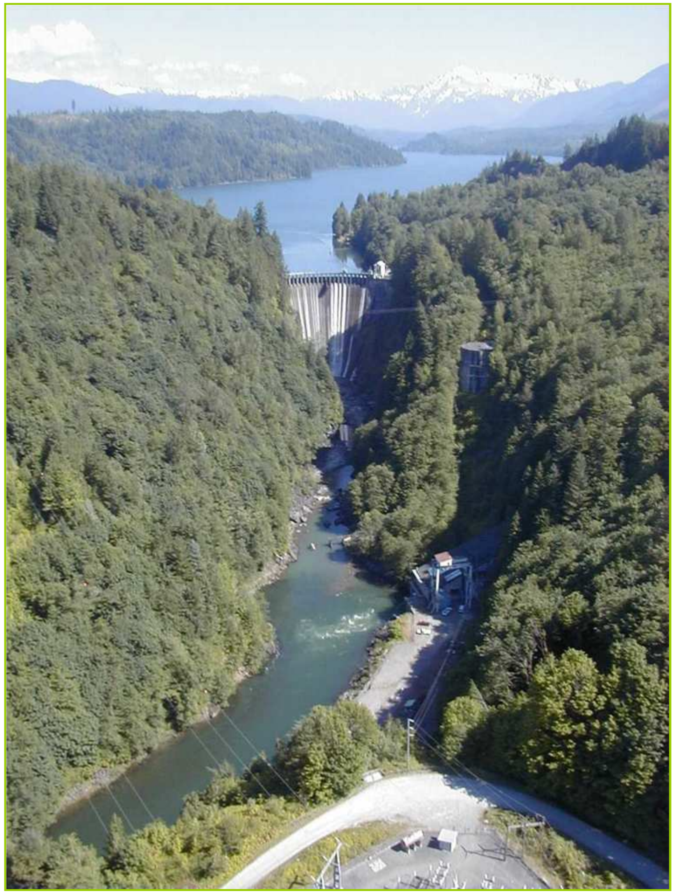


BAKER DAM PROJECT
Puget Sound Energy

- FLOW RELATED ISSUES
  - Instream Flows for Fish
  - Side Channel Habitats
  - LWD Distribution and Utility
  - Ramping Rates and Varial Zone Formation
    - Redd dewatering
    - BMI dewatering

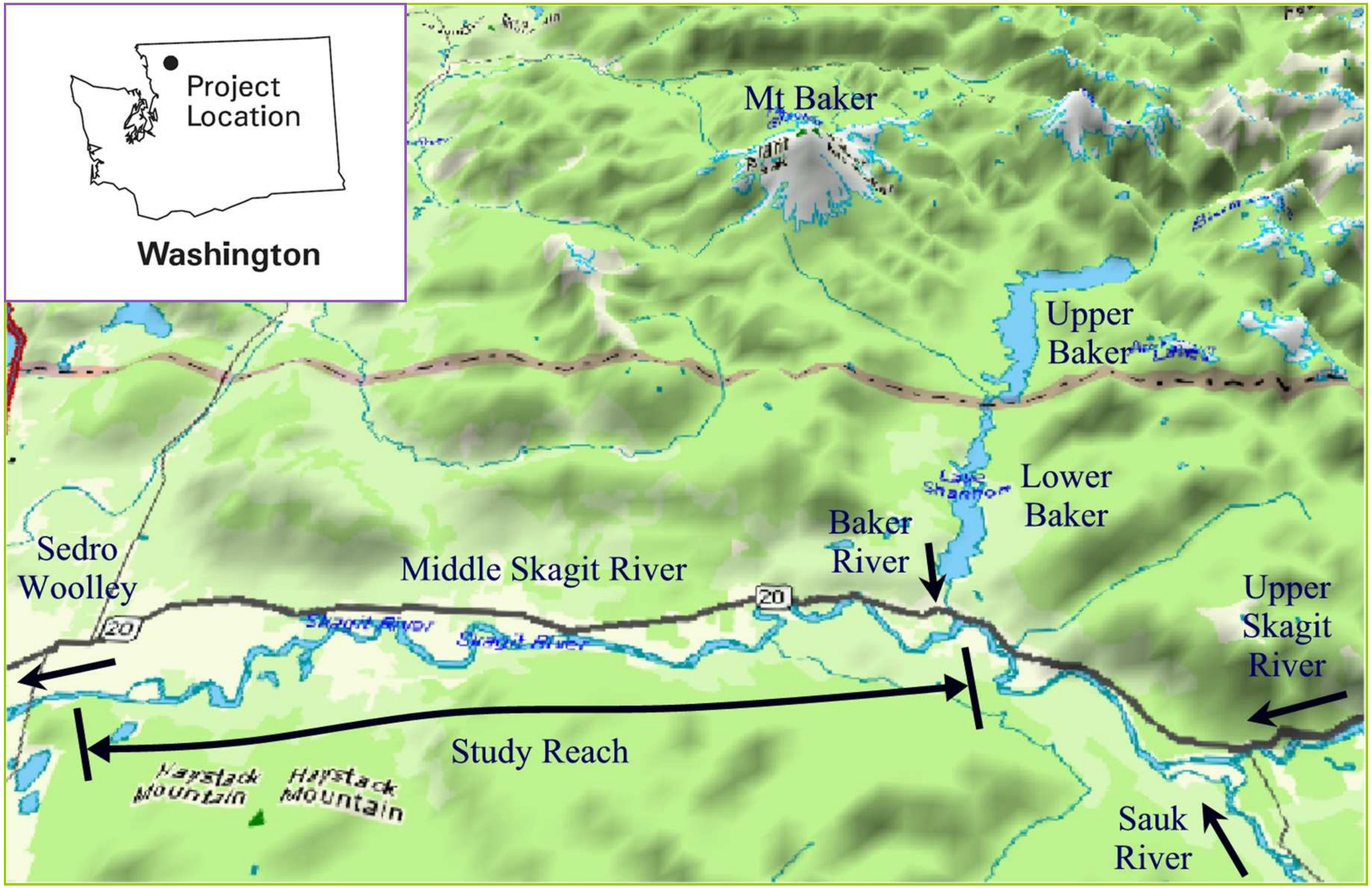
Upper and Lower Baker Developments

Lower Baker Development

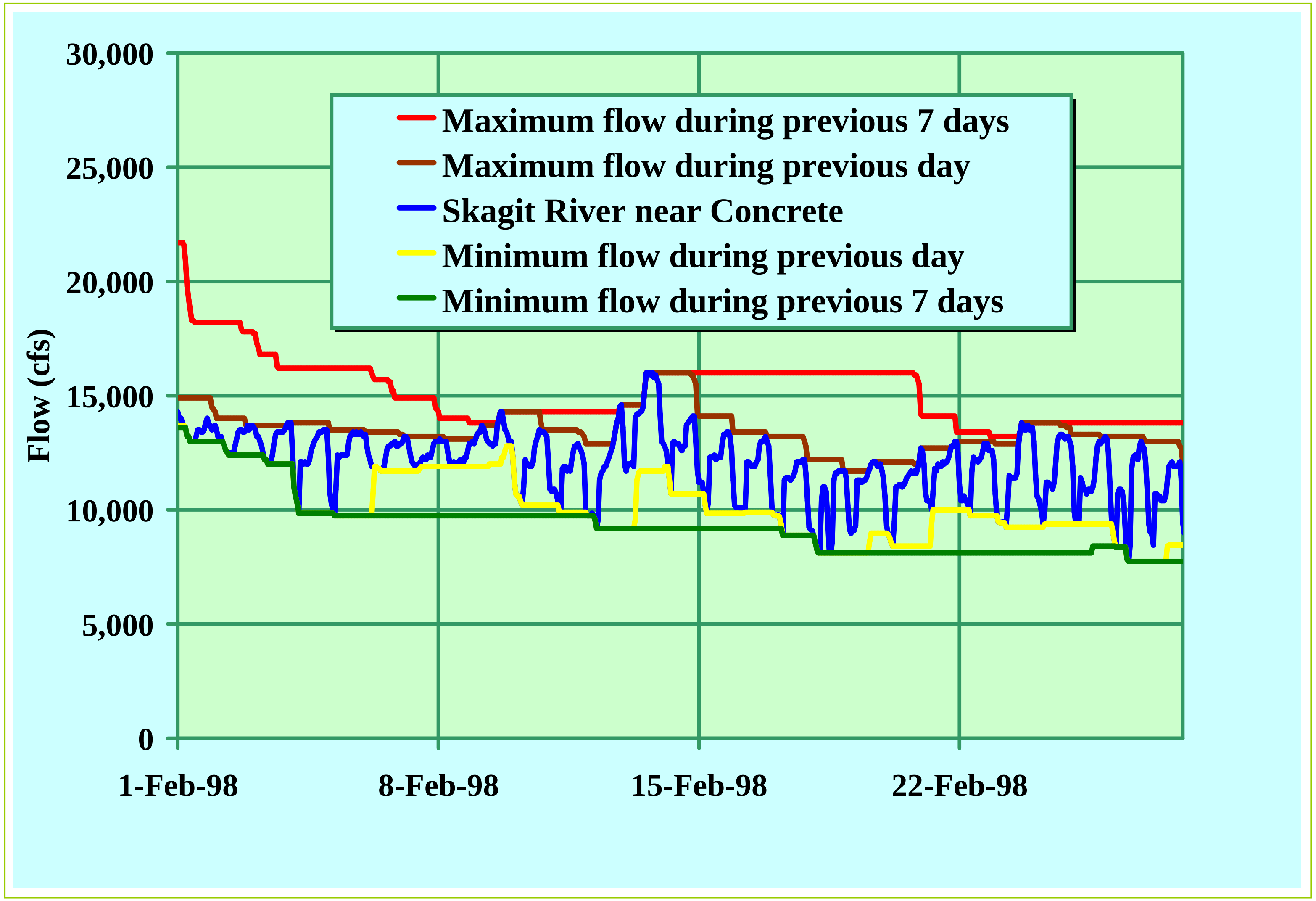


Upper Baker Development

Baker Project Instream Flow Study Area

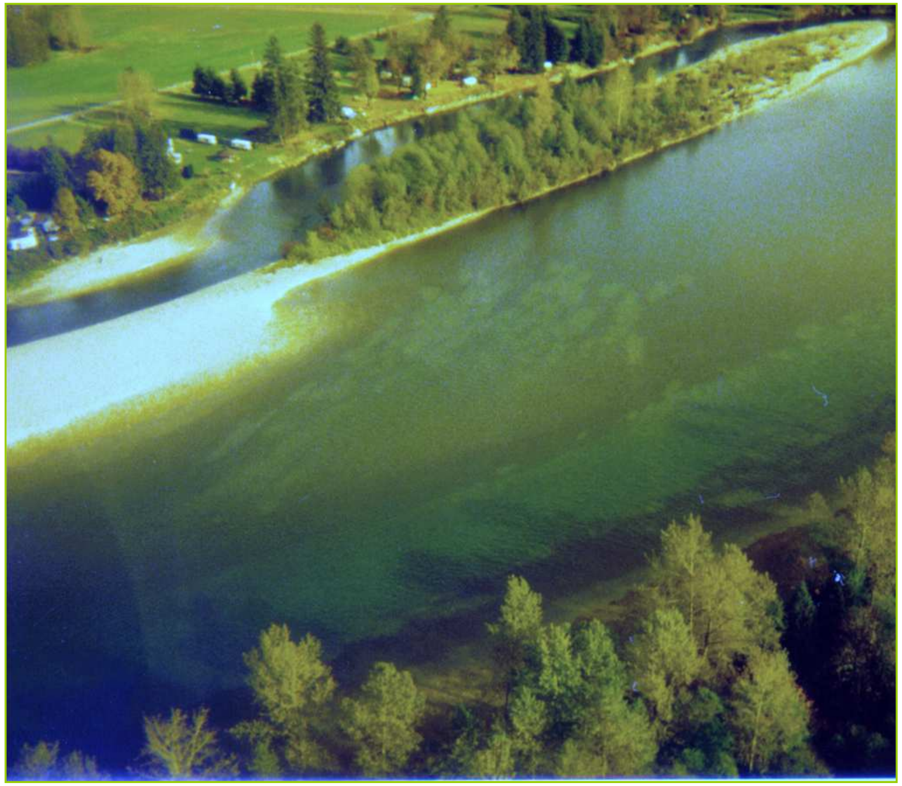


Daily and Weekly Flow Range



Varial Zone

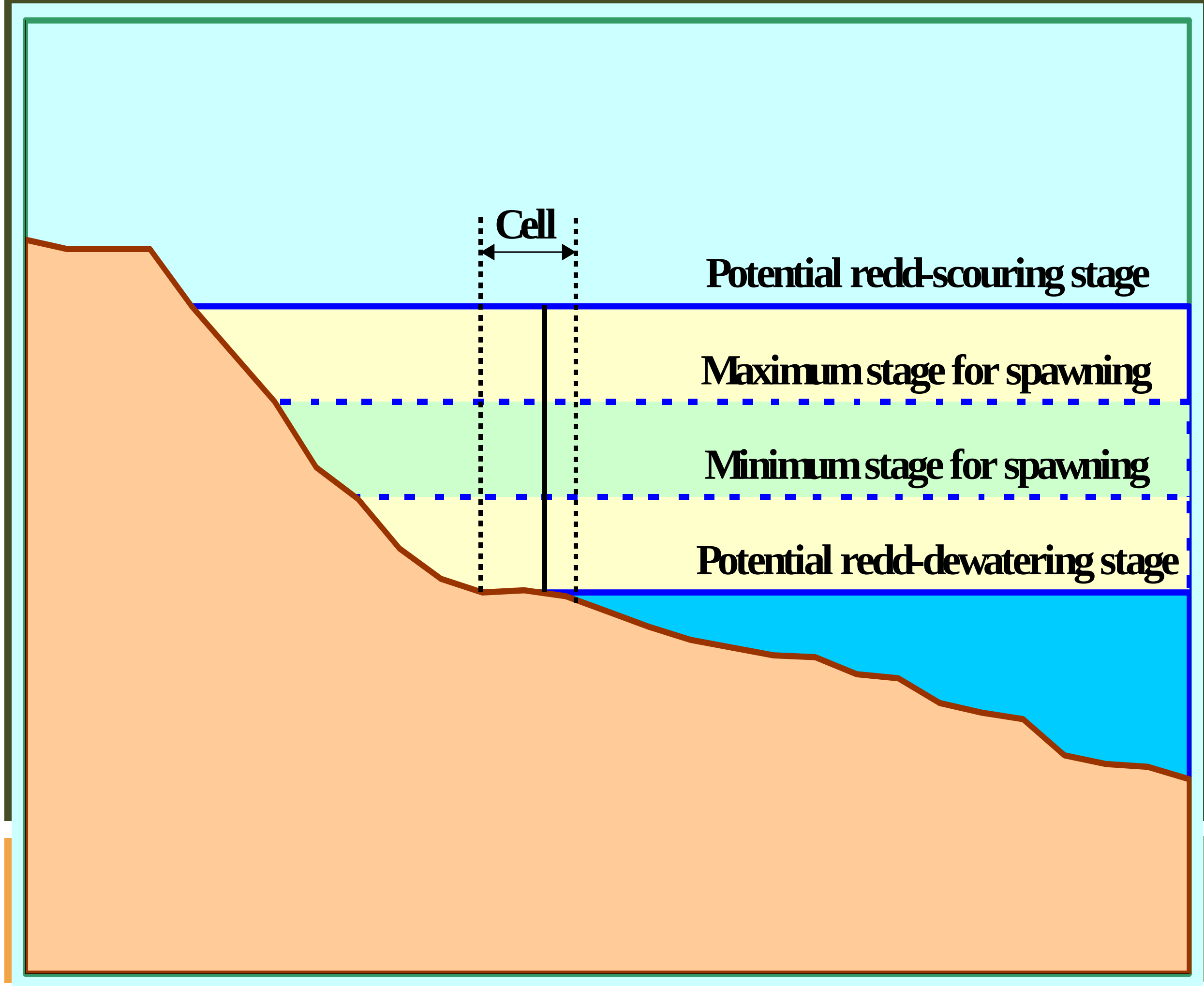
Potential Redd Dewatering



METHODS

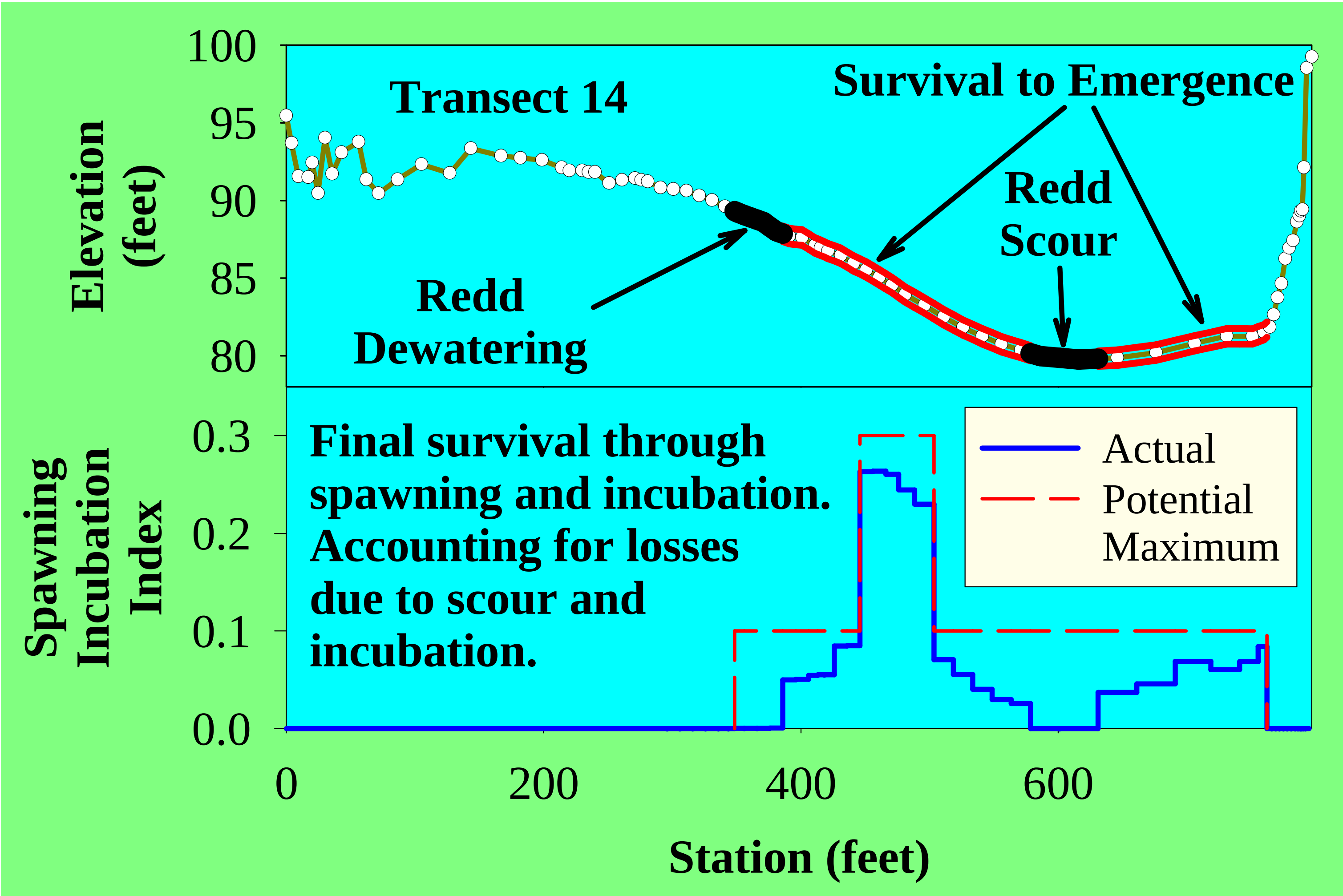
- <u>**HYDROPS Ops Model**</u>
- <u>**UNSTEADY Flow Attenuation Model**</u>
- **PHABSIM – 1-D; 2-D considered but not used**
- **IHA – used to evaluate effects of different project operations on suite of 40 flow metrics**
  - **Normative Flow regime generally favored**
  - **Exceptions – if Fish Flows suggest higher flows**
- **Side Channel Mapping**
- <u>**Effective Habitat Model**</u>
- **Varial Zone Analysis**

EFFECTIVE SPAWNING /INCUBATION HABITAT



- Based on hourly hydrograph
- Accounts for cumulative spawning activity
- Accounts for risk of redd scour/dewatering during incubation
- Chinook salmon spawning at Transect 14 of Middle Skagit River selected to illustrate model

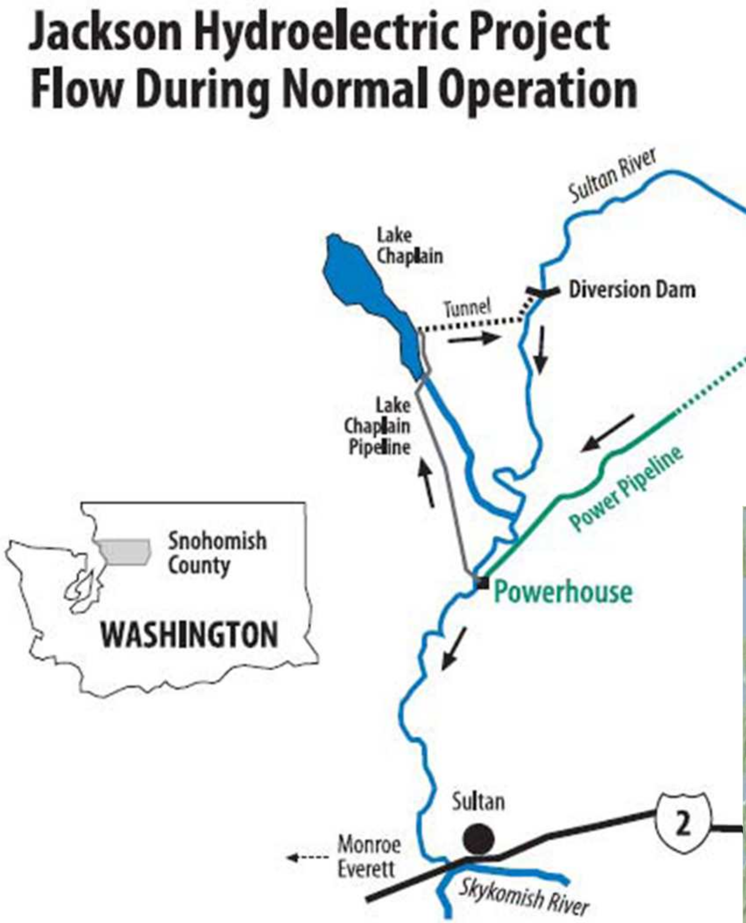
Conditions on March 15 – Spawning Habitat

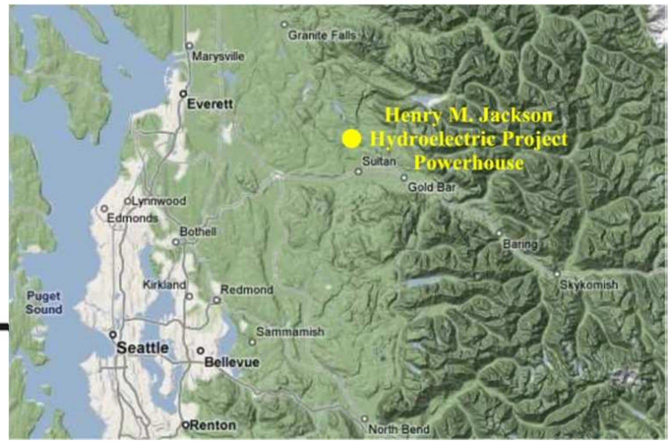


Value

- Integrated Operations Model and Spawning/Incubation Model used to evaluate tradeoffs between power generation – egg survival.
- **One of many models used to evaluate and negotiate operating conditions for license**

Henry M. Jackson Hydroelectric Project (FERC 2157) Public Utilities District No. 1 of Snohomish County





Operational Priorities

1. **Water supply for City of Everett**

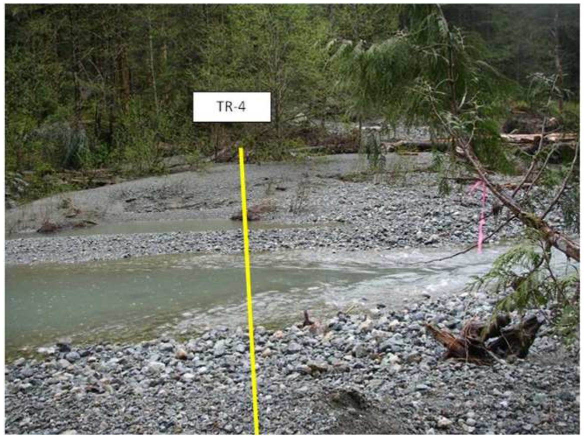
2. **Instream flow needs**
3. **Power generation**

Increases complexity in defining acceptable flow regime

Instream Flow Study:
Project Objectives – Methods

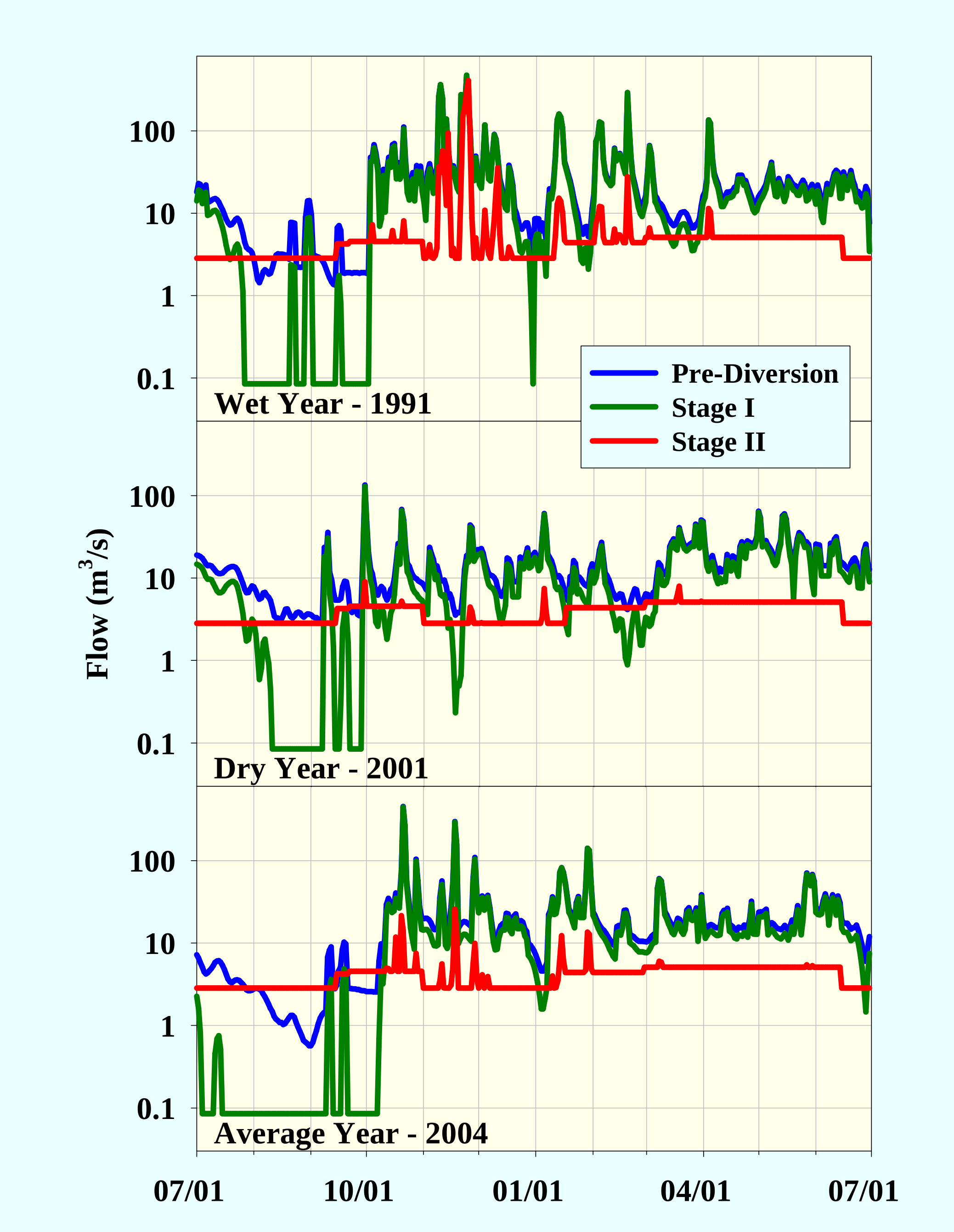
- **Develop reach-specific habitat:flow relationships for target species/lifestages – Apply 1-D PHABSIM modeling.**

**** Develop integrated aquatic habitat model that produces a time series of data over a range of flow conditions and under select alternative operational scenarios.***



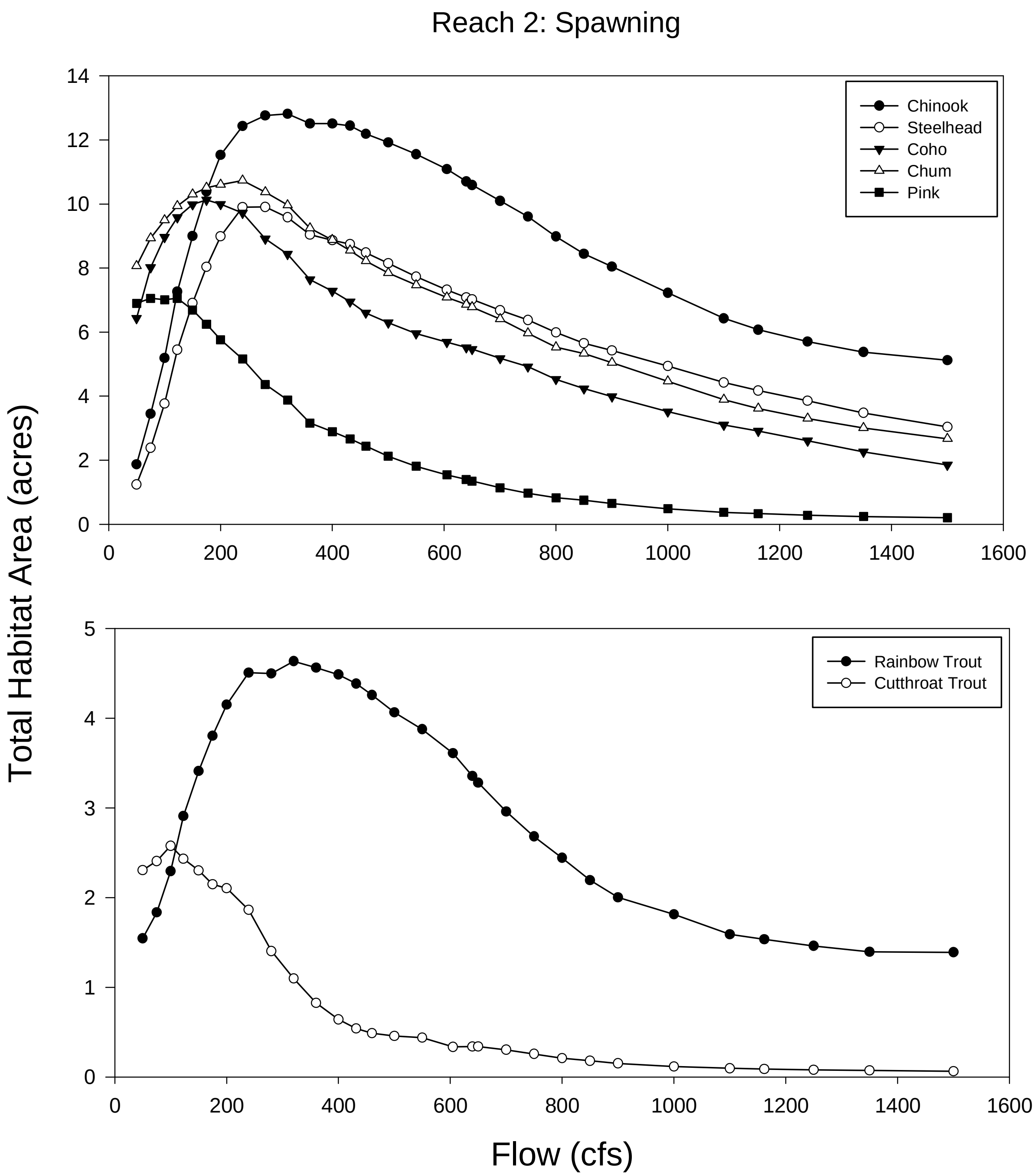
Operations Model

Daily flows at upstream end of Reach 2



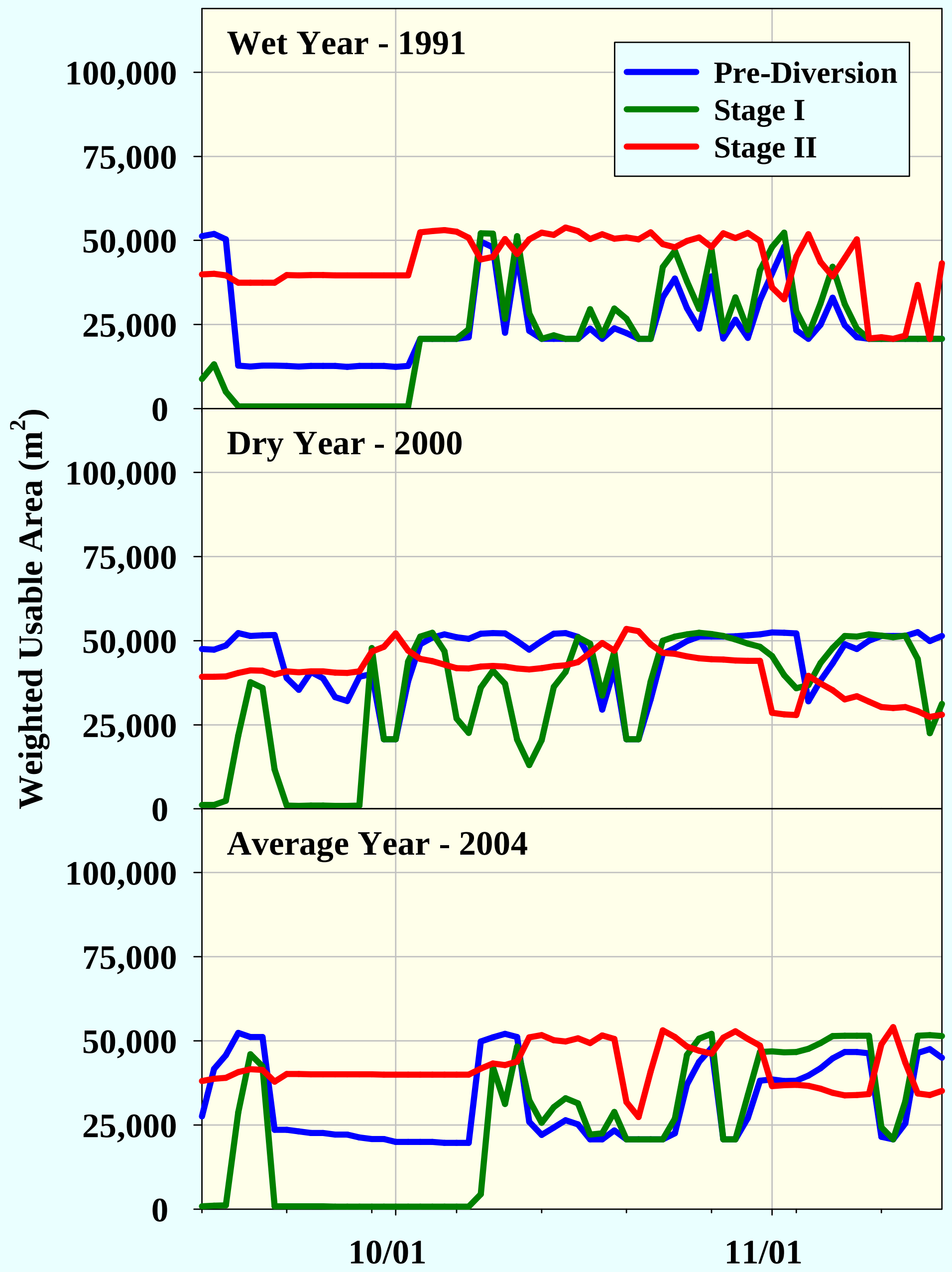
Link to →

PHABSIM Analysis



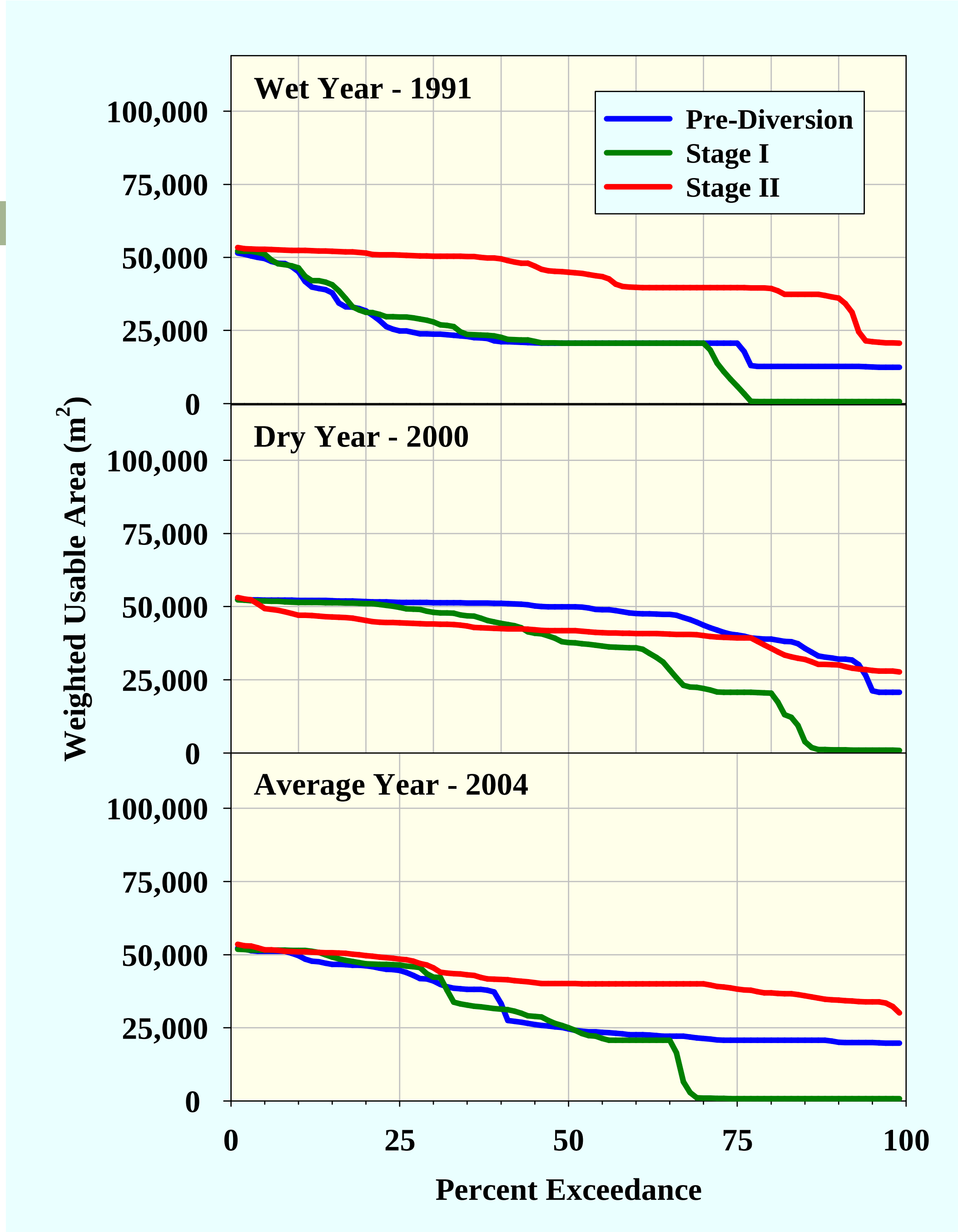
Produce →

Time Series
of Chinook
spawning
Weighted
Usable Area
in Reach 2

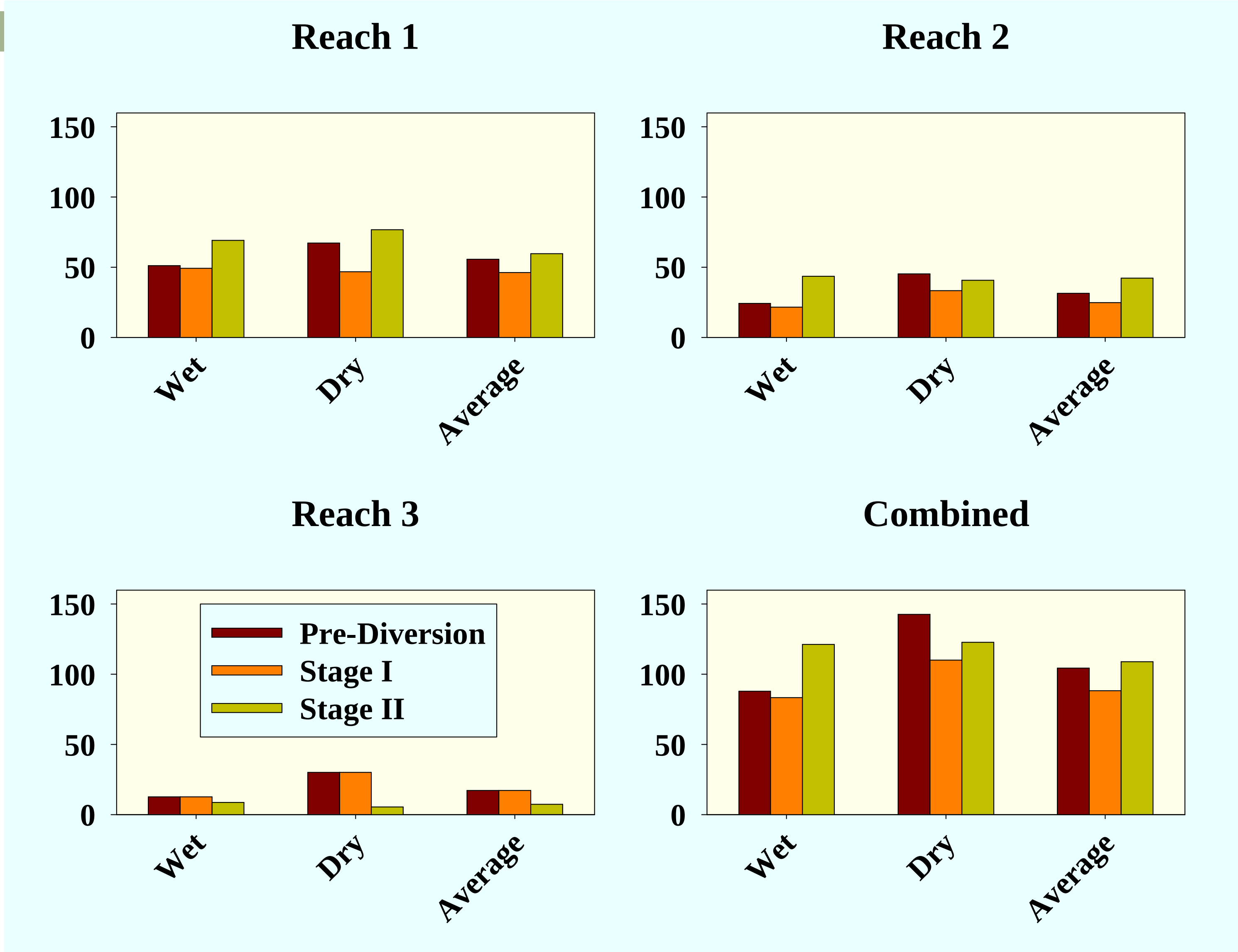


Habitat Duration

Chinook spawning in Reach 2



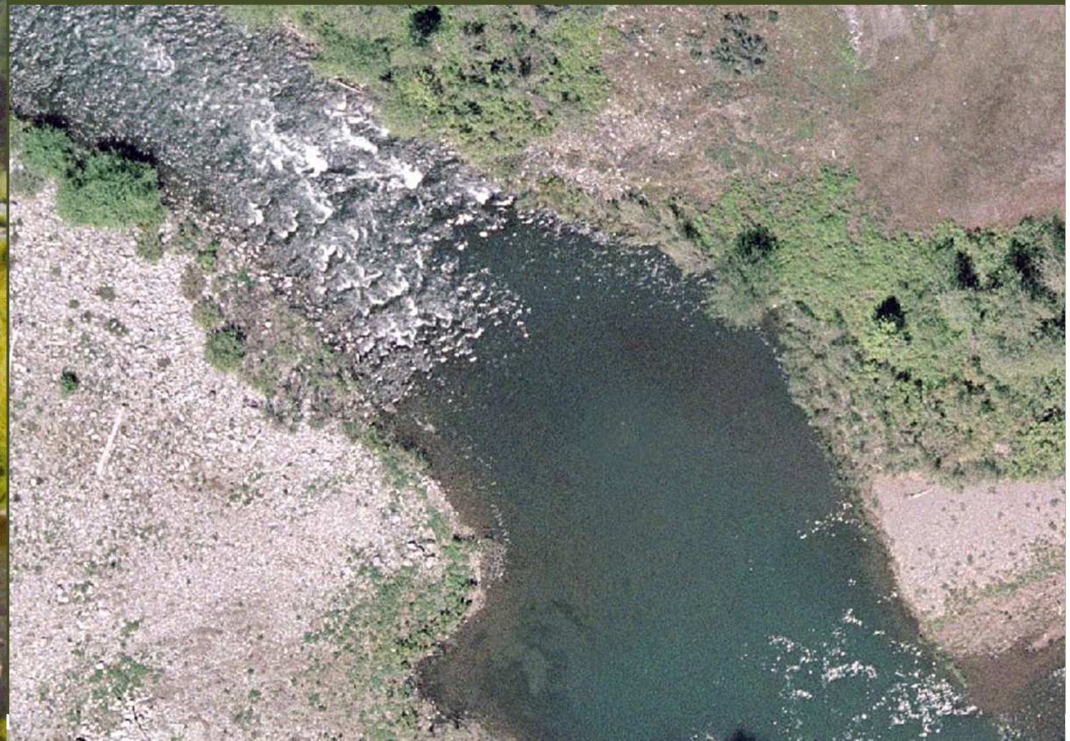
Chinook Spawning Habitat Summary
Average Weighted Usable Area (1,000 m²)



Value

- Integrated Operations Model and Habitat Model used to evaluate tradeoffs between power generation – water supply – habitat.
- **Modeling used to negotiate operating conditions for the next licensing term (2011 to 2061)**

PIT 3, 4, & 5 PROJECT
PACIFIC GAS & ELECTRIC COMPANY



Flow Related Issues

- Instream flows for fish
- Flows for FHYLF
- Microhabitat-Flow Relationships
- Riparian Vegetation Inundation

METHODS

- PHABSIM – 1-D Model (existing model)
- PHABSIM – 2-D Model (PG&E completed in-house)
- Habitat Mapping – R2
- Amphibian Surveys
- Riparian Inundation Surveys

Habitat Mapping Spring Flow Releases / Aerial Photography

- Base, 250, 400, 600, 800, 1200 cfs
- Photograph Entire Pit 3, 4, 5 Reach
- 1:7200 Scale, 10 cm Pixel

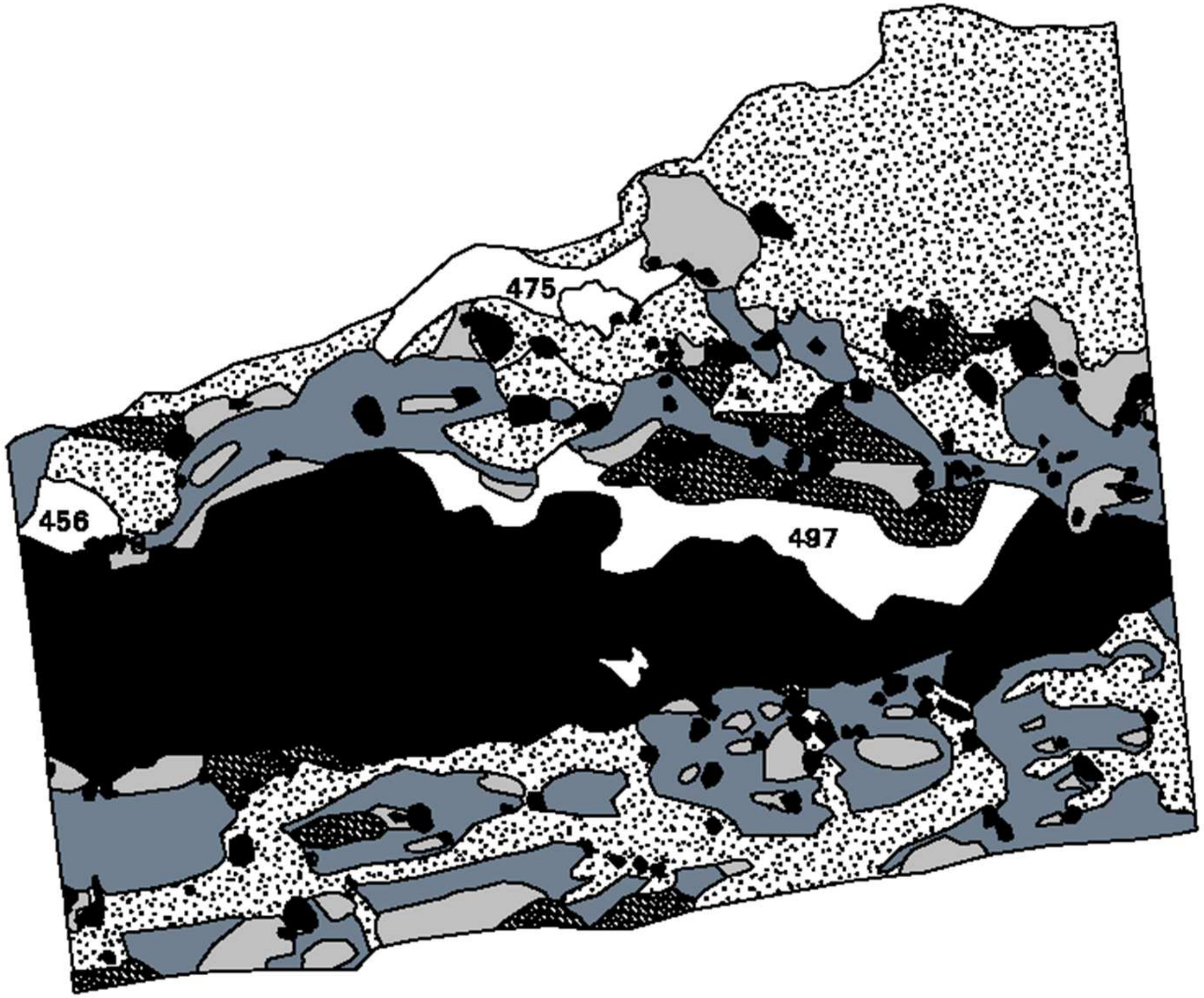
- Goal: Produce Photographs That Could be Used to Map Microhabitat Polygons and Riparian Vegetation

Field Mapping

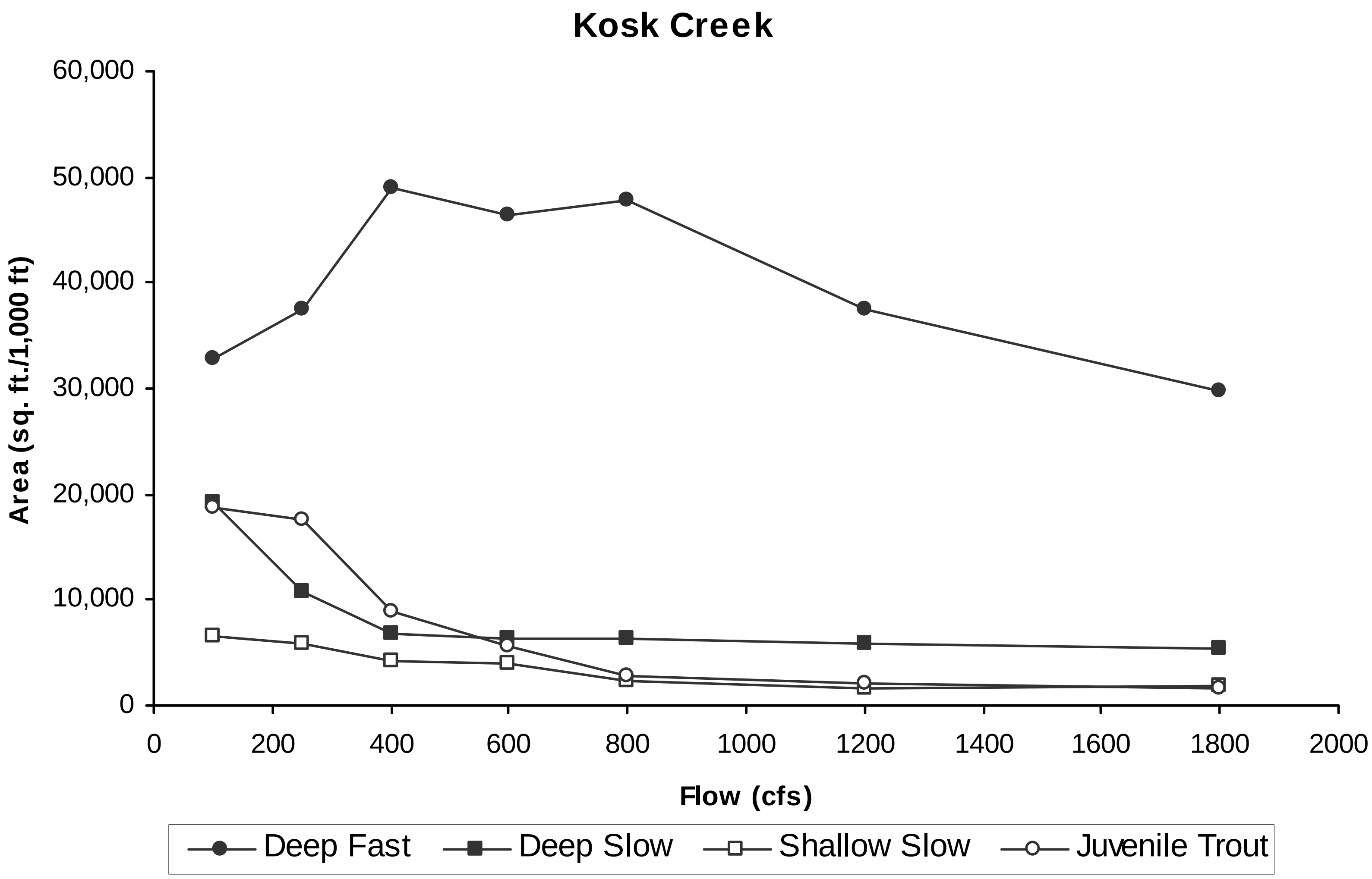
Complex Small-Boulder Gardens (Riffles/Pocket Water) Distinguished by Geomorphic and Hydraulic Features, →Heterogeneous Polygons With %'s


R2 Resource Consultants
Phone: 425-556-1288
R2 #1346 * map_pitorthos_field.aml * 26 Jul 02
Weir Creek
400 cfs
Pacific Gas and Electric
Pit River Aquatic Habitat
Sheet 1
0
40
80
1 Inch = 40 Feet

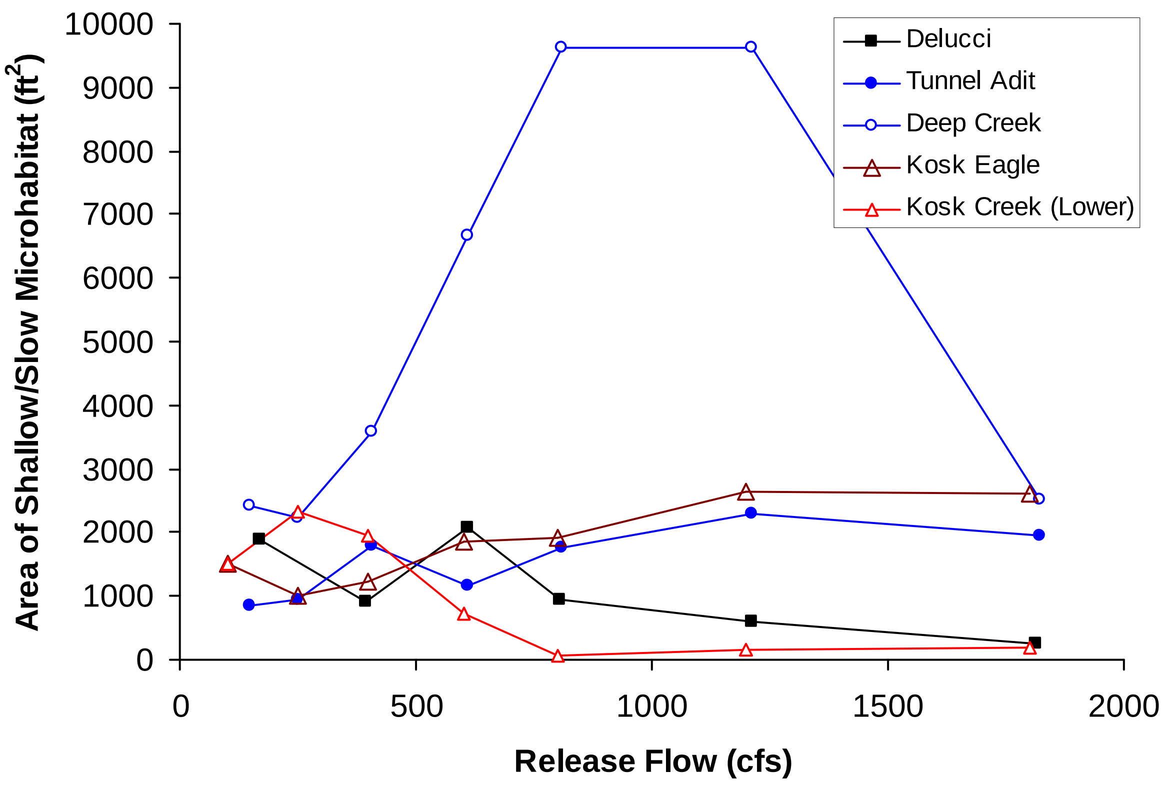
Digitized Maps (detail)



Microhabitat-Flow Curves: By Site



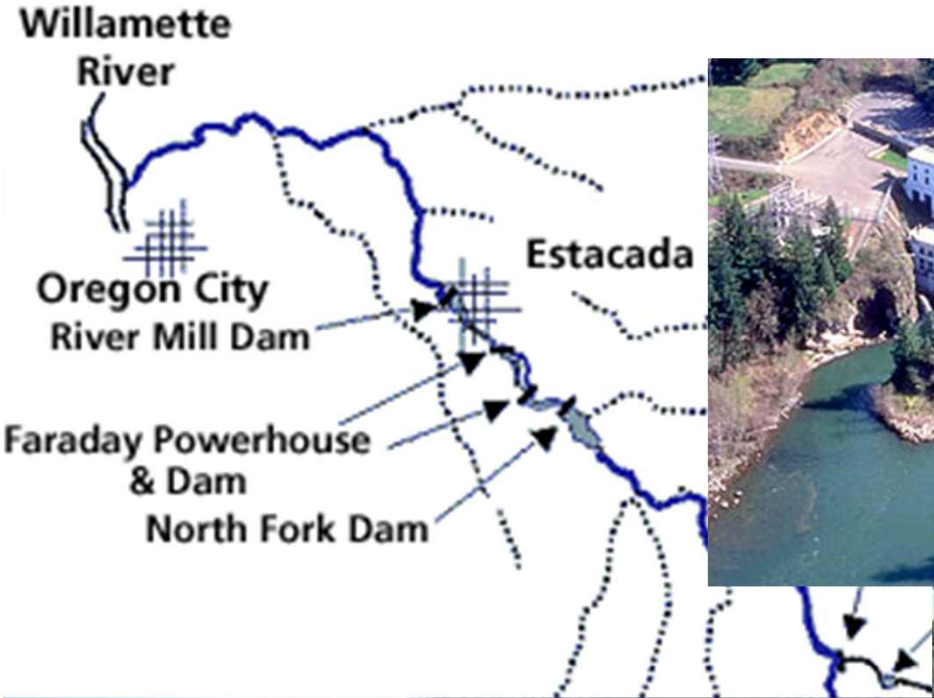
Eagle Foraging:
Pool Tail Habitat



Value

- Habitat Mapping analysis was coupled with results from other modeling efforts to derive “agreed-to” flow regime.

Portland General Electric – Clackamas River Project

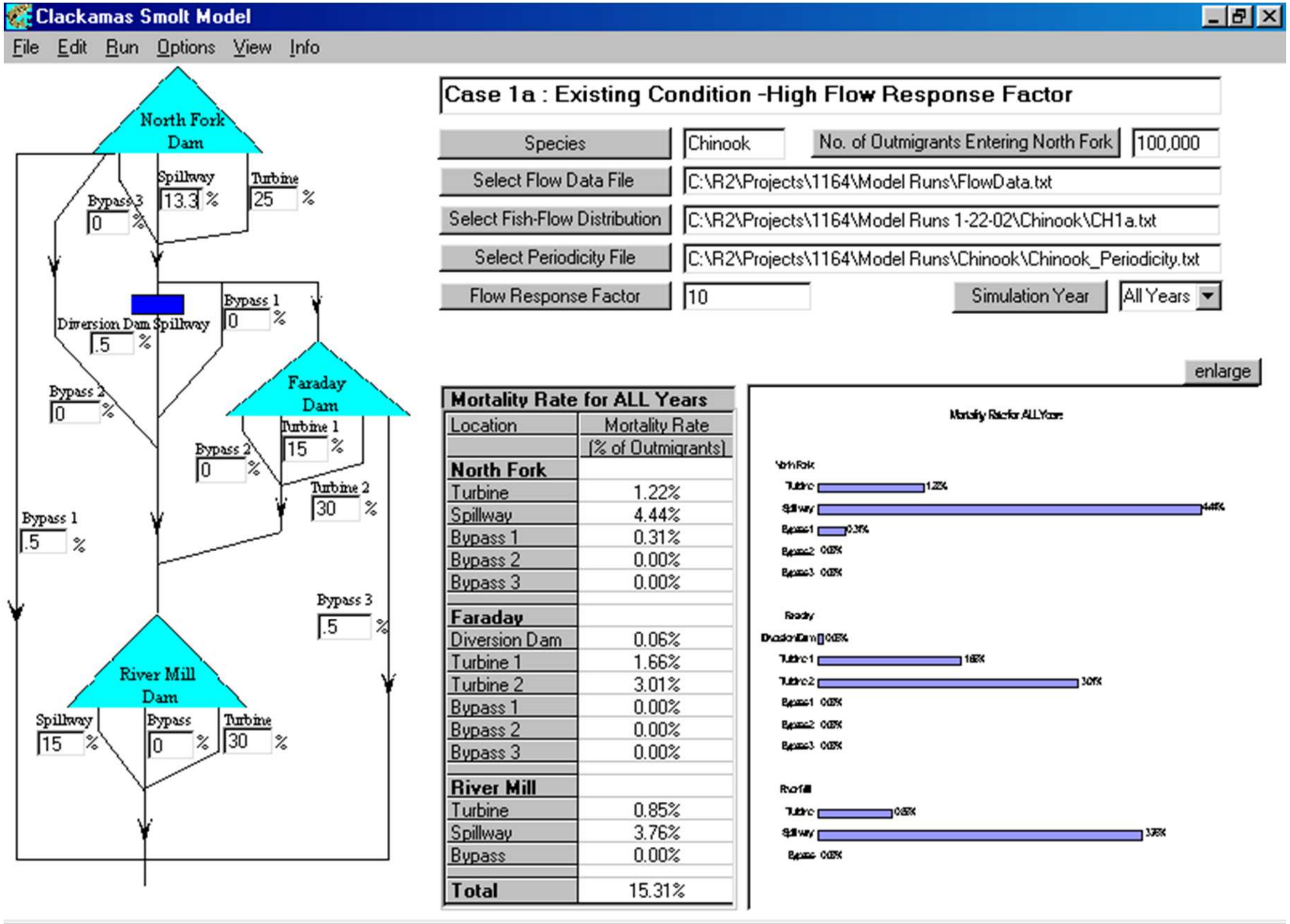


ISSUE – Downstream Fish Passage Mortality

Smolt Mortality Model

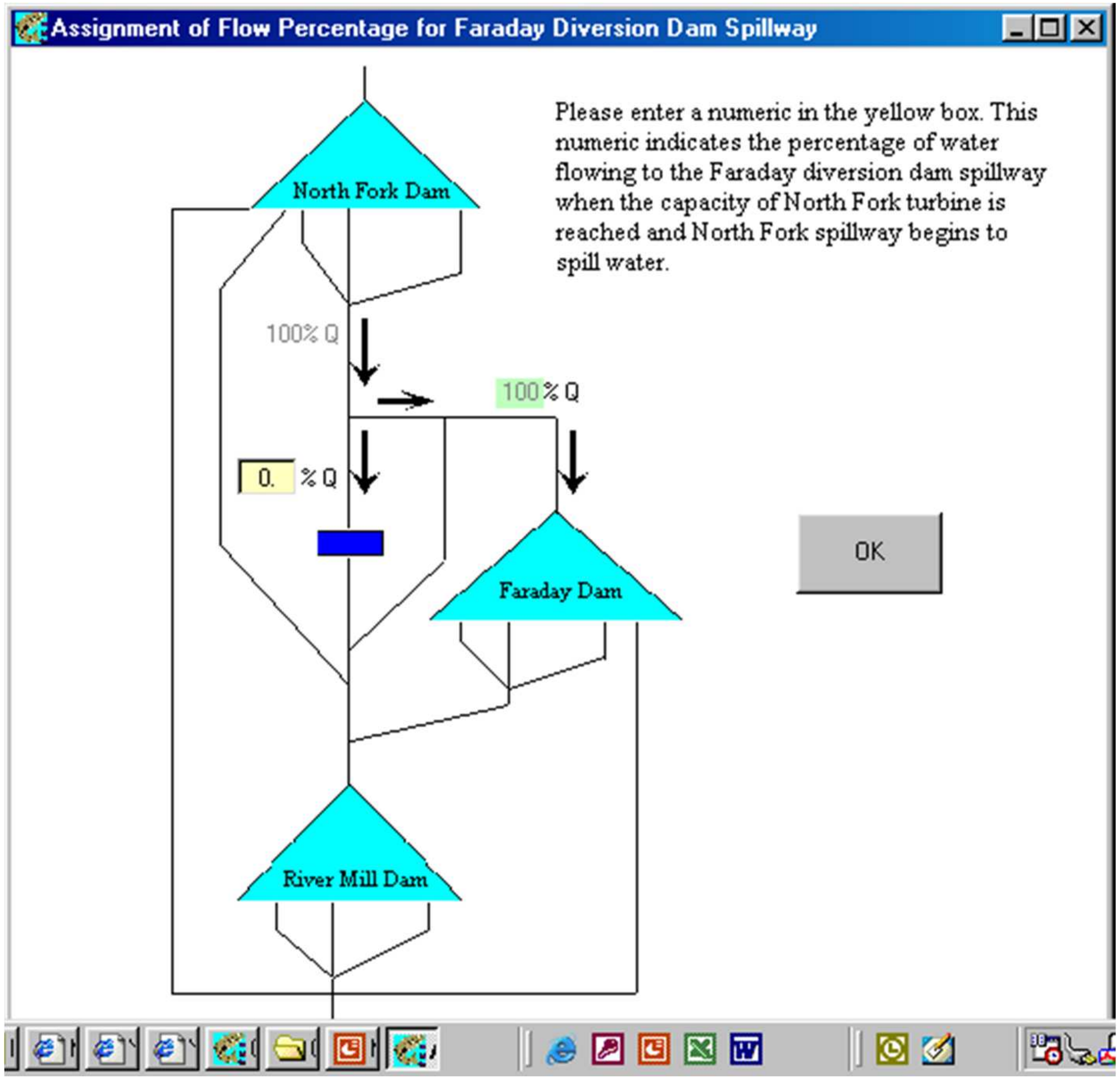
- Model used to investigate system level alternatives
  - Case 1: Existing conditions
  - Case 2: Full turbine exclusion screens at North Fork
  - Case 3: Full turbine exclusion screens at all projects
  - Case 4: Full screens at NF, Spill at FD, surface collector at RM
  - Case 5: Barrier net at NF, Full screens at FD, surface collector at RM with partial turbine guidance deflector
  - Cases 6 & 7 : Investigate route specific mortality for fry passage

Visual Basic

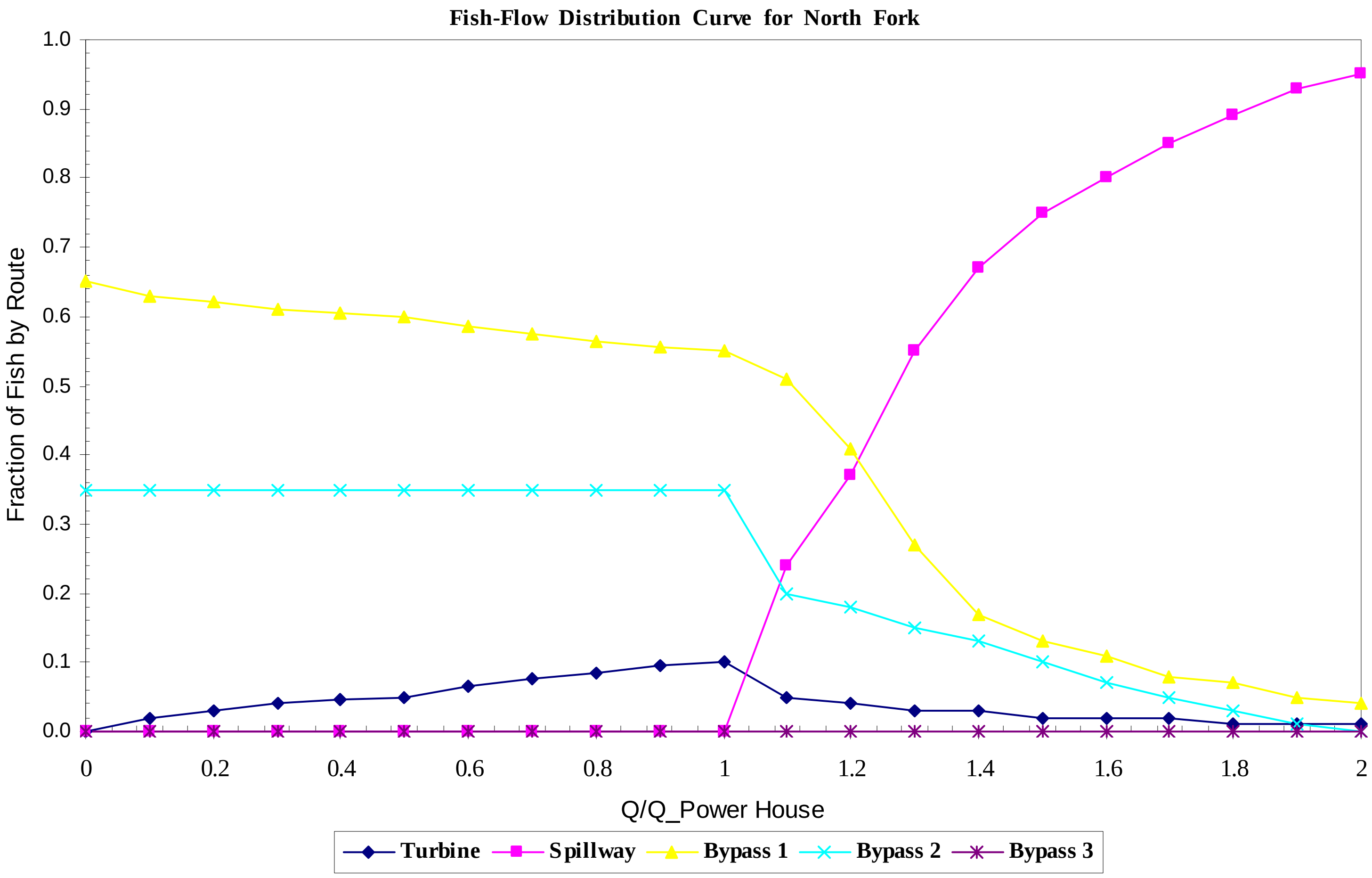


Smolt Mortality Model
Data Sources – Chinook

- Periodicity
  - Based on last 5 years data from the North Fork collection/bypass system
- NF Bypass Efficiency vs. Flow
  - Interpreted from Cramer & Assoc. Report
- NF Turbine Passage
  - Interpreted from 2001 Acoustic tag study by Normandeau & HTI
- NF spillway mortality
  - Interpreted for 2001 Normadeau Assoc. Report
- RM surface collection bypass
  - Interpreted from 2001 Obermeyer weir passage study by Normandeau
- Remaining variable estimated – model used for sensitivity


Assignment of Flow Percentage for Faraday Diversion Dam Spillway
Please enter a numeric in the yellow box. This numeric indicates the percentage of water flowing to the Faraday diversion dam spillway when the capacity of North Fork turbine is reached and North Fork spillway begins to spill water.
North Fork Dam
100% Q
100% Q
0. % Q
Faraday Dam
OK
River Mill Dam

Fish – Flow Distributions



Annual Mortality

Mortaliy Statistics for All years

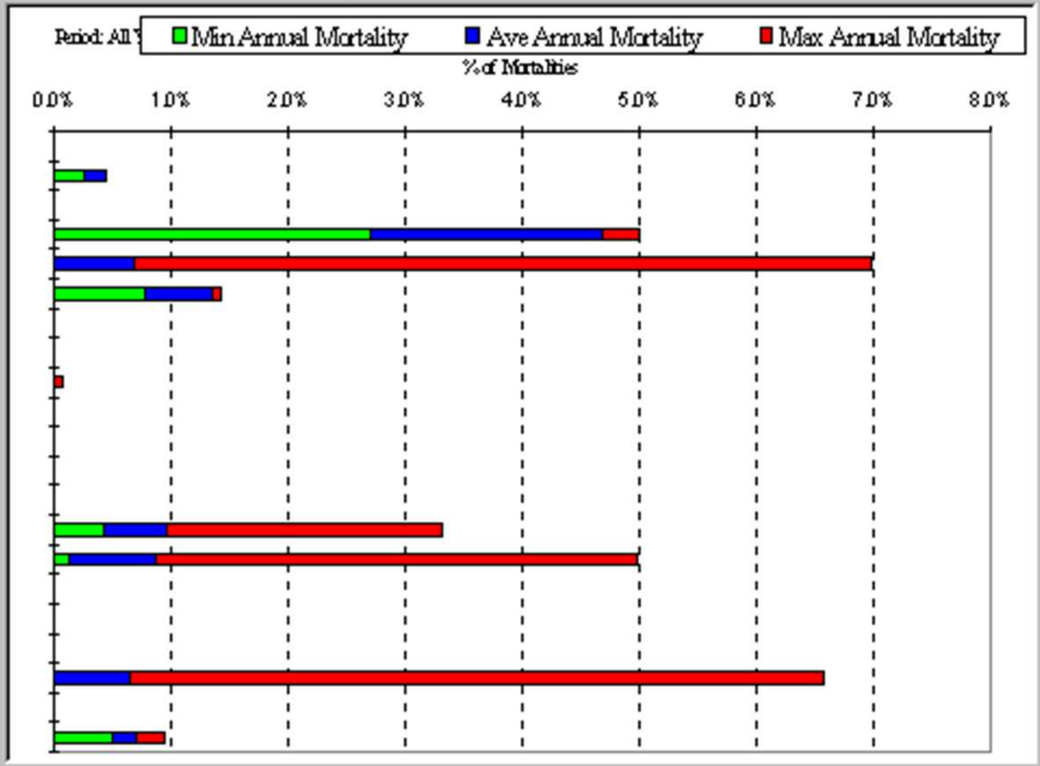
Copy Close

Case COHO 1 , Existing Conditions

Select View Period: All Years

Select View: Passage Mortality Rate

Passage	Min Annual Mortality	Ave Annual Mortality	Max Annual Mortality	Standard Deviation
North Fork				
Reservoir	0.0%	0.0%	0.0%	0.0%
Bypass 1	0.259%	0.432%	0.45%	0.034%
Bypass 2	0.0%	0.0%	0.0%	0.0%
Bypass 3	2.709%	4.692%	5.0%	0.508%
Spillway	0.0%	0.682%	6.977%	1.276%
Turbine	0.782%	1.352%	1.43%	0.135%
Faraday				
Spillway	0.0%	0.004%	0.061%	0.008%
Bypass 1	0.0%	0.0%	0.0%	0.0%
Reservoir	0.0%	0.0%	0.0%	0.0%
Bypass 2	0.0%	0.0%	0.0%	0.0%
Bypass 3	0.0%	0.0%	0.0%	0.0%
Turbine 1	0.416%	0.966%	3.307%	0.529%
Turbine 2	0.122%	0.859%	4.98%	1.02%
River Mill				
Reservoir	0.0%	0.0%	0.0%	0.0%
Spillway	0.0%	0.646%	6.583%	1.149%
Bypass	0.0%	0.001%	0.001%	0.0%
Turbine	0.489%	0.693%	0.95%	0.067%
System	8.541%	10.326%	26.557%	3.328%

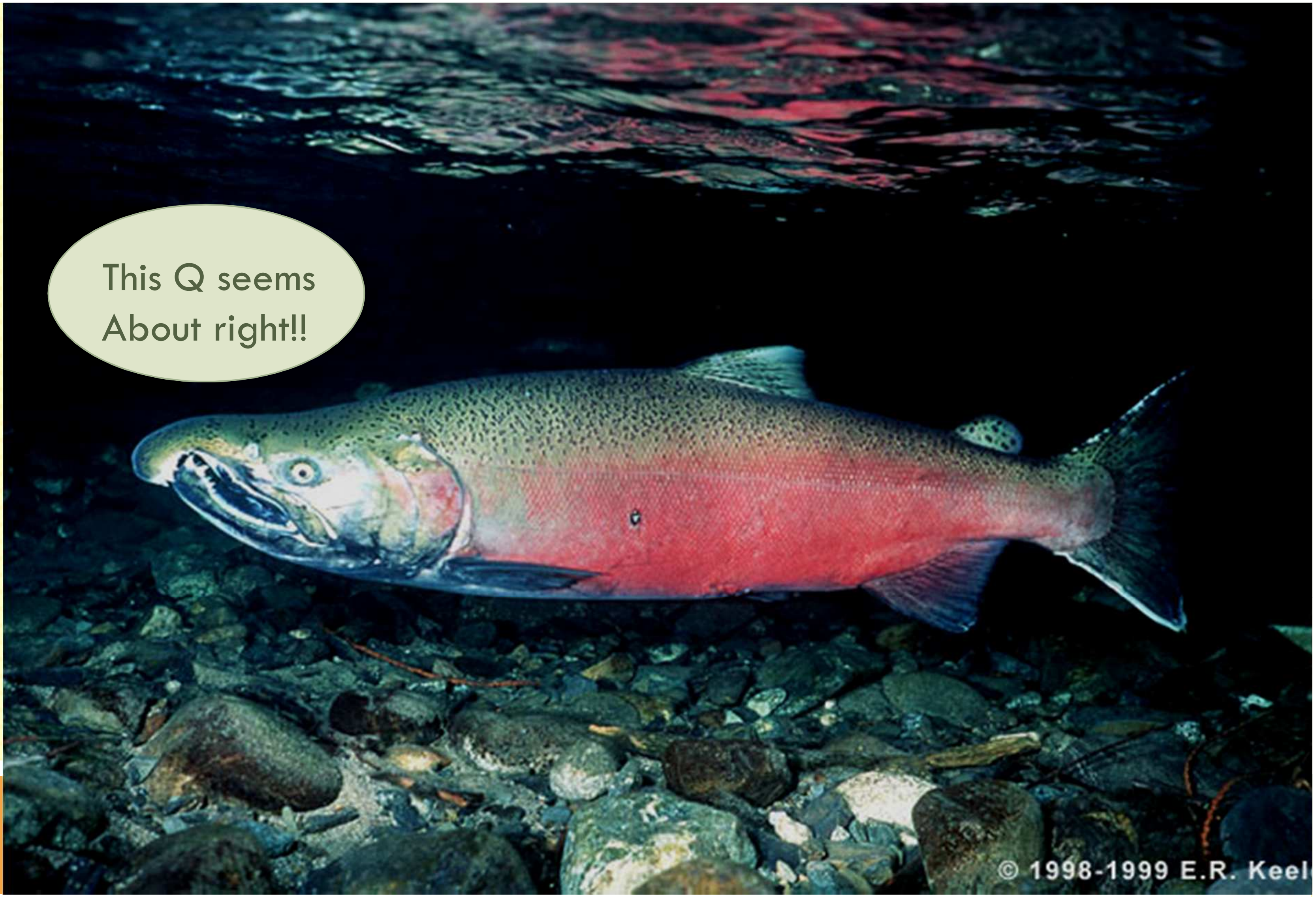


Value

- Survival goals established in settlement will be evaluated with DM3

POPULATION MODELING?

"ALL MODELS ARE WRONG; BUT SOME ARE USEFUL." – GEORGE EP BOX



- Can we predict fish population responses from hydro related project effects?

How about population responses to “Incremental Q changes”?

Some Existing Population Models

- EDT – Ecosystem Diagnosis and Treatment
- FLUSH/CRISP – downstream passage
- SLAM – Salmon Life Cycle Analysis – NFMS/ODFW
- SHIRAZ – Stochastic Model
- OBAN – Oncorhynchus Bayesian Analysis

Guidelines in Selecting Techniques

- Consider project site specificity in Methods Selection – One Size DOES NOT FIT ALL
- Tailor methods to address specific resource issues/questions
- Consider methods selection based on resource sensitivity to flow modifications and resource value and other considerations?
- Collaboration in methods selection (Debate the Results not the Methods)
- Helps when Resource Agencies have established "a priori" resource goals and objectives

THANK YOU

QUESTIONS ?