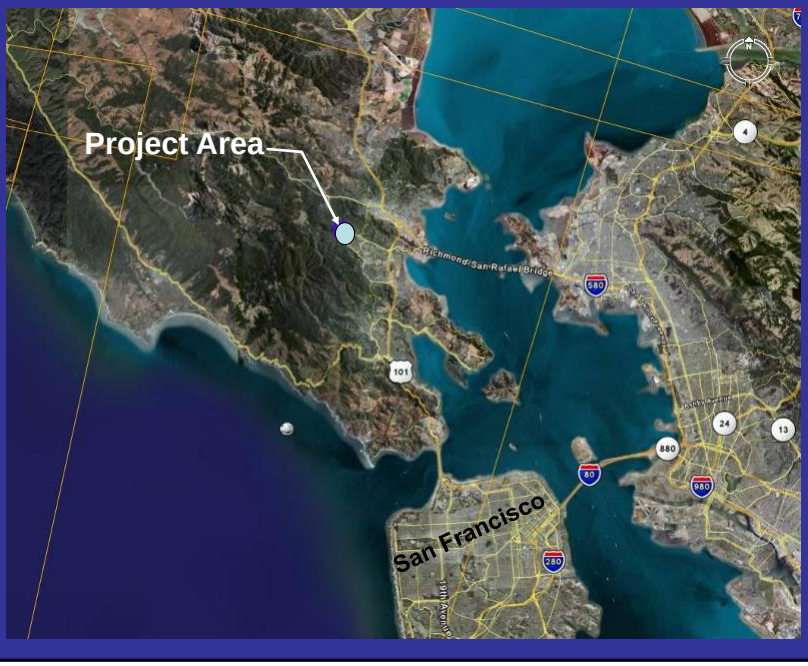
Flood Channels: Developing Fish Resting Pools in a Concrete Channel Using Fish Energetics and Hydrodynamic Modeling

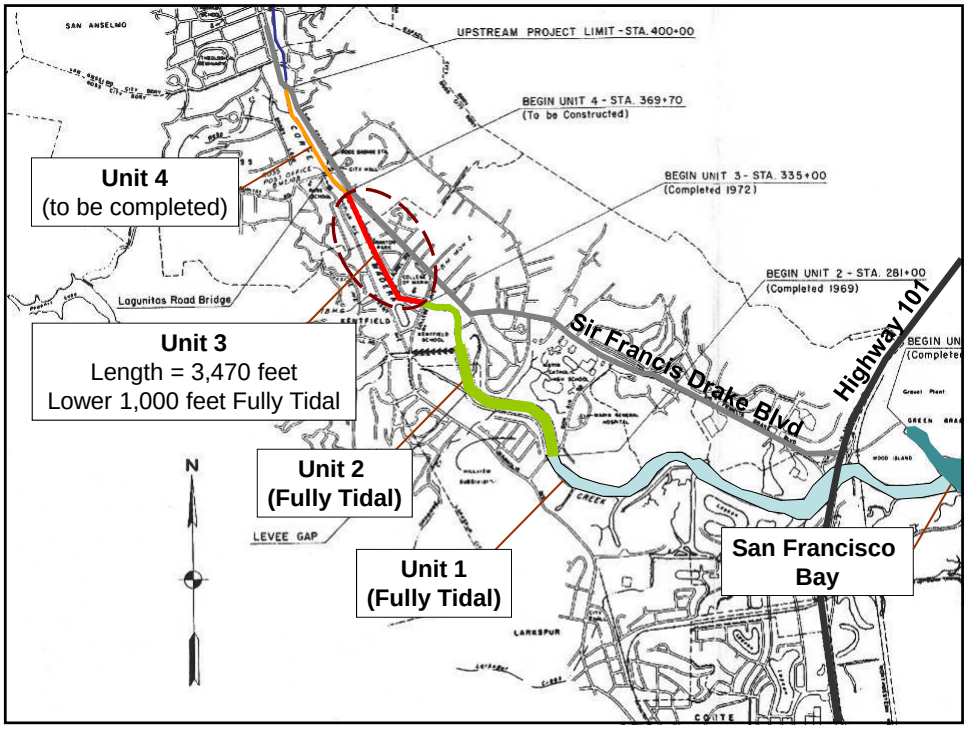
Michael Love P.E.,
Michael Love & Associates Inc., Arcata CA

Michael Love & Associates
Hydrologic Solutions

Friends of
Corte Madera Creek Watershed

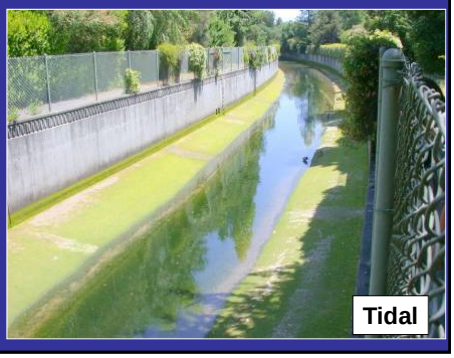
Project Area: Unit 3 of Corte Madera Flood Control Channel



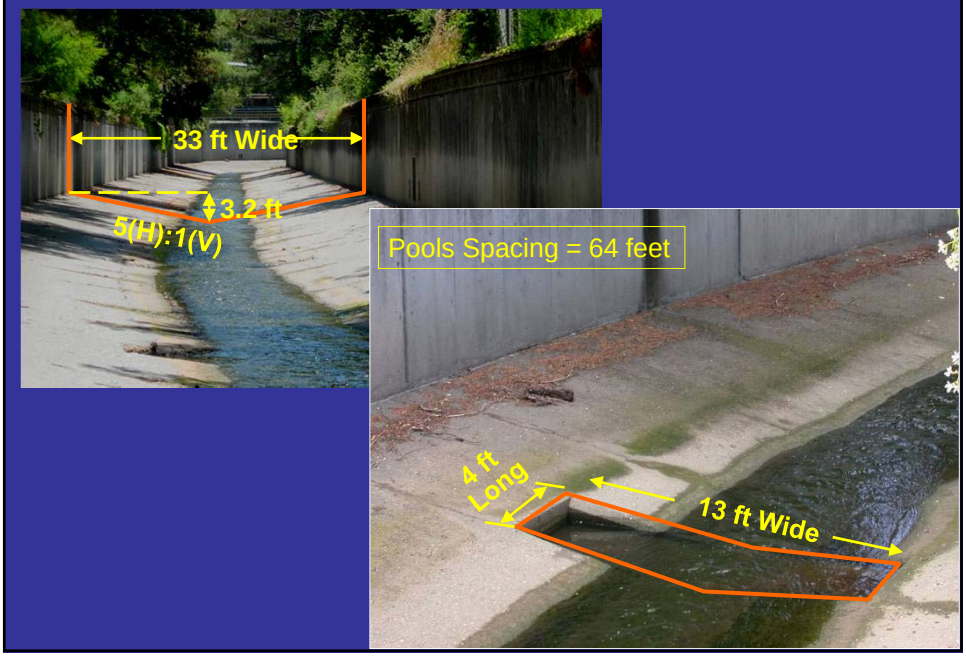


Project Objectives

- Identify exhaustion barriers for **adult steelhead** in Unit 3 channel
- Design shape and spacing of new resting pools for improving steelhead passage

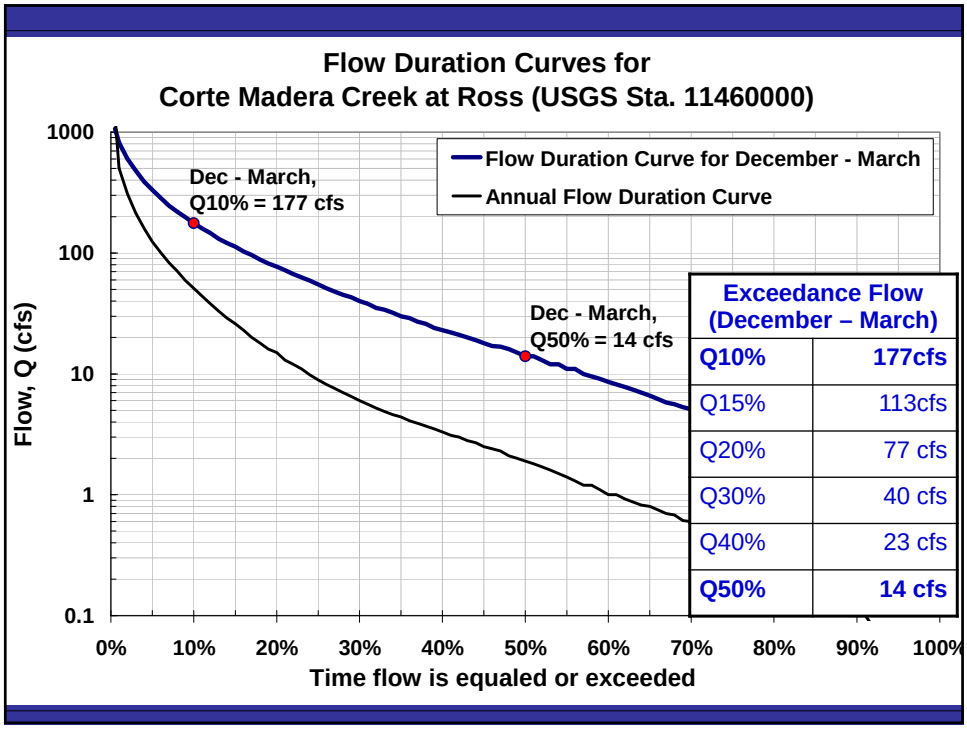


Unit 3 Typical Channel Geometry



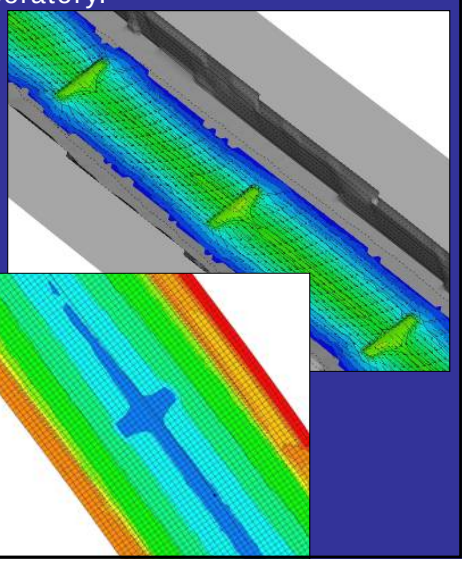
Approach

1. Data Collection & Monitoring
   - Video Monitoring Hydraulics and Fish Movement
   - Stage Observations throughout Channel
2. Numerical Model of Existing Channel Hydarulics
   - Calibrated 2-D Finite Difference Model
   - Simulations for Various Tidal and Flow Conditions
3. Evaluate Passage Using Energetics & Locomotion Model
   - Route Fish through Channel at Migration Flows
   - Conduct multiple simulations to describe variation in fish size and swimming abilities
   - Locate Exhaustion Barriers
4. Develop and Evaluate Resting Pool Alternatives
   - Effectiveness of pool shapes to provide resting areas.
   - Assess Spacing verses Passage Rate for New Pools



2-D MD_SWMS Model

- Background
  - Developed and supported by USGS Geomorphology and Sediment Transport Laboratory.
- Model Grid
  - Channel fitted grid
  - Grid cell size is 1 foot
- Model inputs
  - Topography
  - Downstream tidal elevation
  - Drag coefficient
  - Lateral eddy viscosity
  - Flow rate
- 2-D model outputs
  - Water velocity
  - Water depth
  - Shields stress

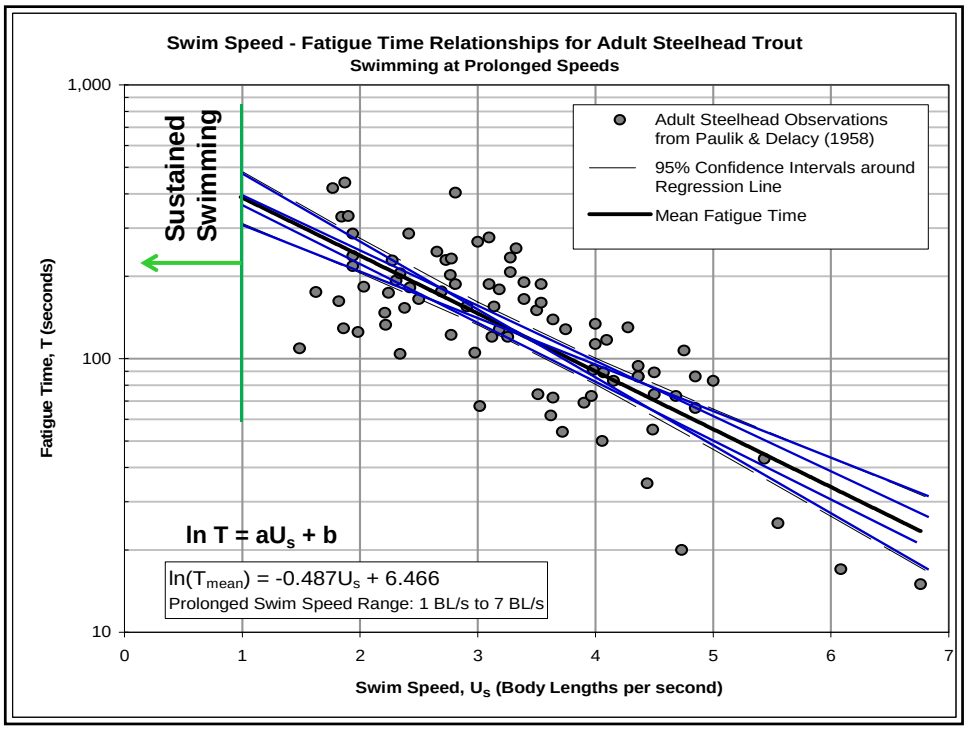


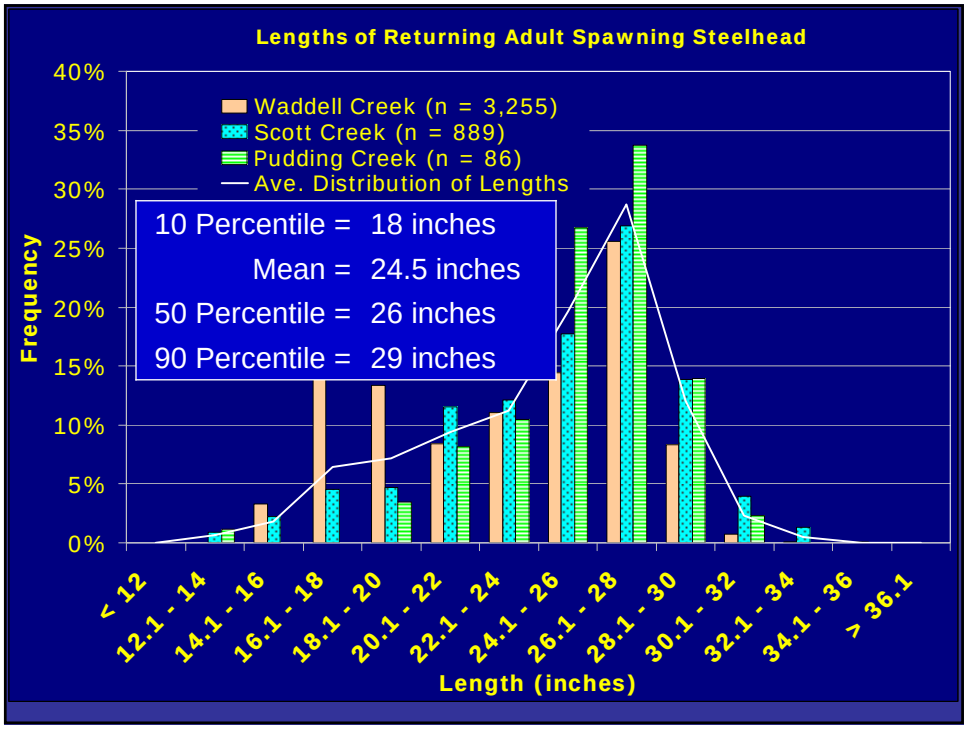
Fish Routing Model

Modes of Swimming:

- **Sustained Swimming** - Completely aerobic activity and can be maintained indefinitely.
- **Prolonged Swimming** - Combination of aerobic and anaerobic metabolic activity, maintained between 20 seconds and 60 minutes before fatigue.
- **Burst Swimming** - Fastest swimming mode uses anaerobic muscles almost exclusively and only maintainable between 1 and 20 seconds before fatigue.

(Beamish, 1978).





Fish Passage Model Approach

For Each Flow and Tidal Condition:

1. Route fish through channel based on 2-D results
   - Determine velocities and depths along route
2. Stochastic simulations of swimming along route
   - Randomly select fish length and swim speed from distributions
   - Conduct ~1,000 simulations.
   - Estimate proportion of Steelhead able to ascend concrete channel.

Parameters for Modeling Steelhead Locomotion

1. Requires 0.6 ft depth to swim or rest
   - Approximate depth required to submerge large (32") steelhead (*FishBase, 2006*)
   - Swim speed equations only useful if submerged
2. Swim-route follows path of least resistance
   - Lowest water velocities where depth is sufficient
   - Width of path is 2 feet (account for swimming motions)
3. Swims at distance optimizing speed
   - Furthest distance before becoming fatigued (Castro-Santos, 2005)
4. Sustained Swimming allows for recovery from fatigue (holding/resting)
   - Water velocity $\leq$ 1 BL/s

Fish Locomotion and Energetics

Swim Speed Equation:

$\mathbf{\ln (T) = aU_s + b}$ (swim speed-fatigue time relationship)

Tracking Fatigue of Fish Swimming through Channel:

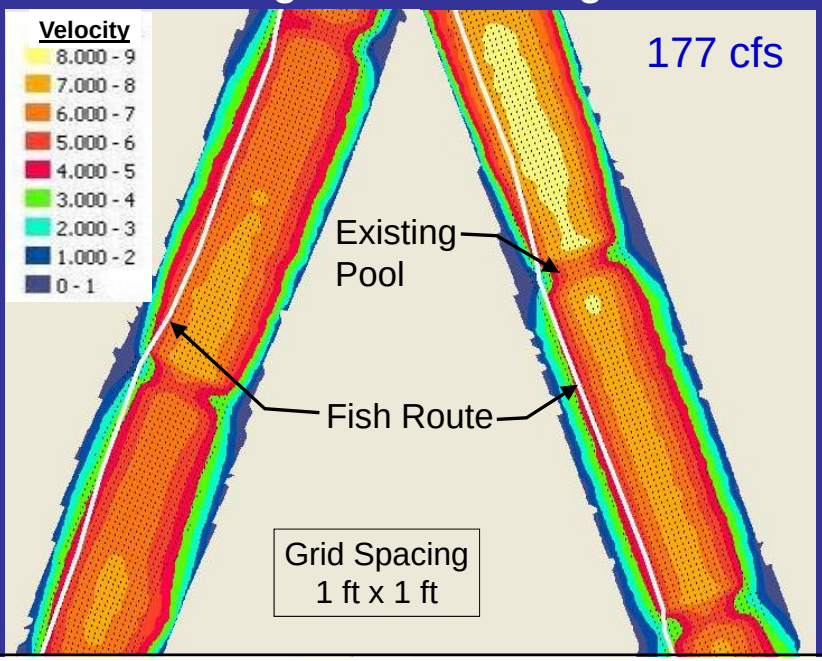
$$F\% = 100 \times \sum \frac{t_{U_S}}{T_{U_S}}$$

(Castro-Santos 2006)

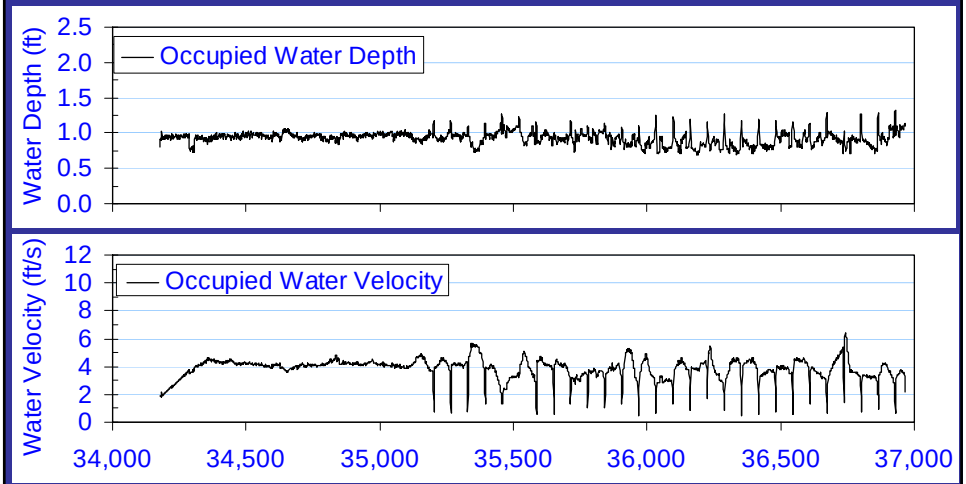
where:

F%	Percent fatigued
t_{U_s}	Swim time from one node to another node
T_{U_s}	Time to fatigue at given swim speed, U_s from swim speed equation

Selecting a Swimming Route

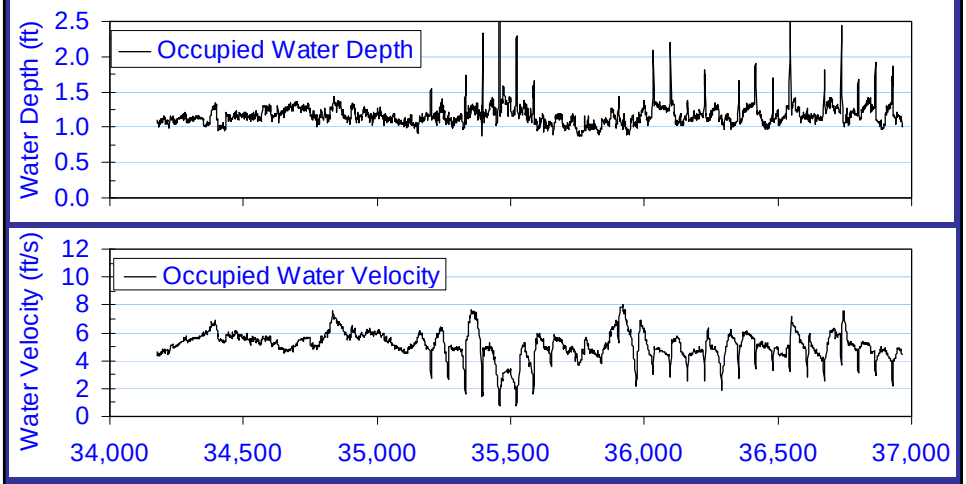


Results:
Occupied Velocity & Depth at 23 cfs

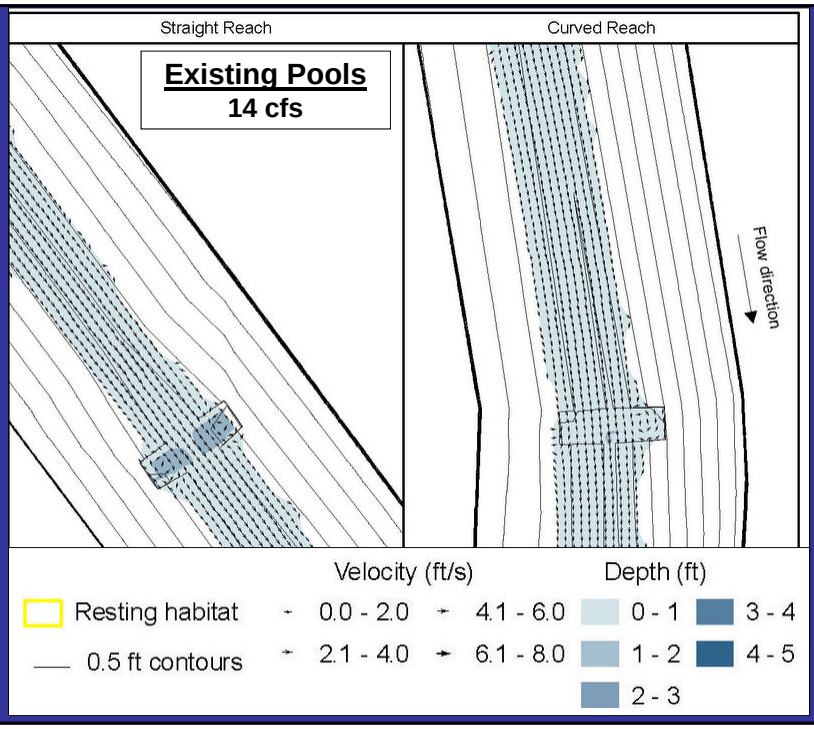


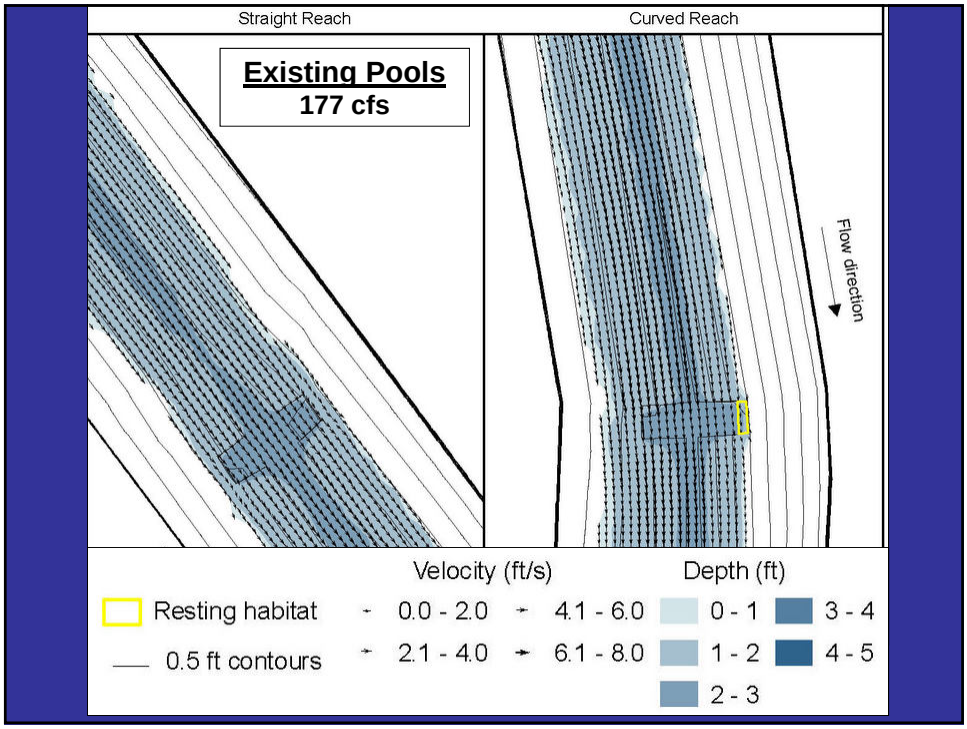
Conditions at MLLW (Low Tide)

Results:
Occupied Velocity & Depth at 177 cfs



Conditions at MLLW (High Tide)

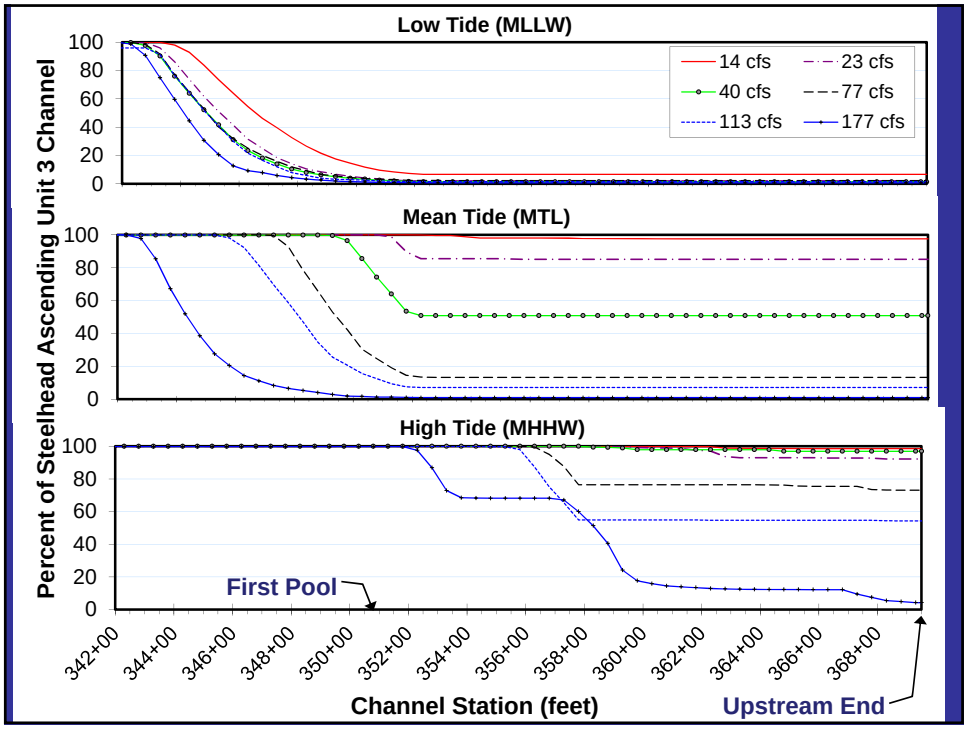




Existing Fish Passage Conditions

	Percent of Steelhead able to Ascend Unit 3					
Tide/Flow	14 cfs	23 cfs	40 cfs	77 cfs	113 cfs	177 cfs
MLLW	7	2	2	2	2	1
MTL	98	85	51	13	7	1
MHHW	99	92	97	73	54	4

MLLW Mean Lower Low Water (Low Tide)
MTL Mean Tide Level
MHHW Mean Higher High Water (High Tide)



Criteria for New Resting Pools

Objectives:

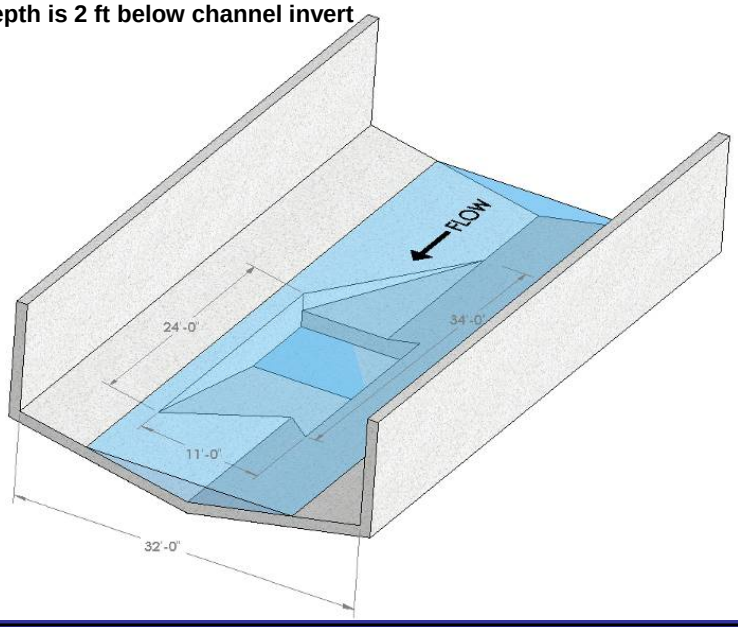
- Improve steelhead passage efficiency at all migration flows and tidal conditions
- Minimize risk of sedimentation
- Minimize impact on channel capacity

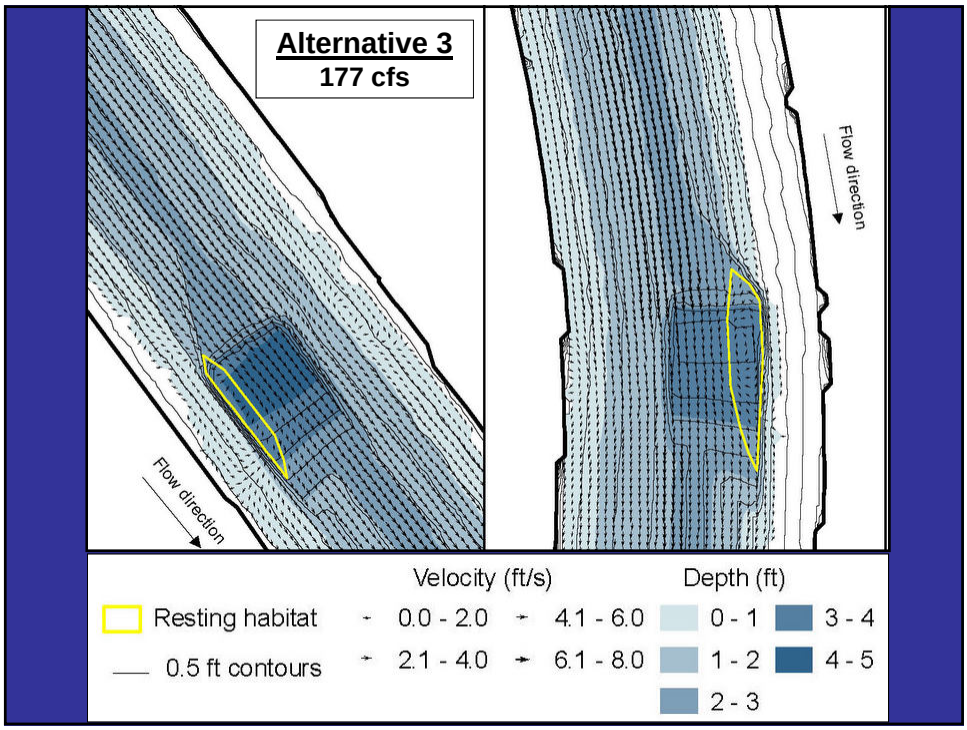
Resting Habitat Criteria:

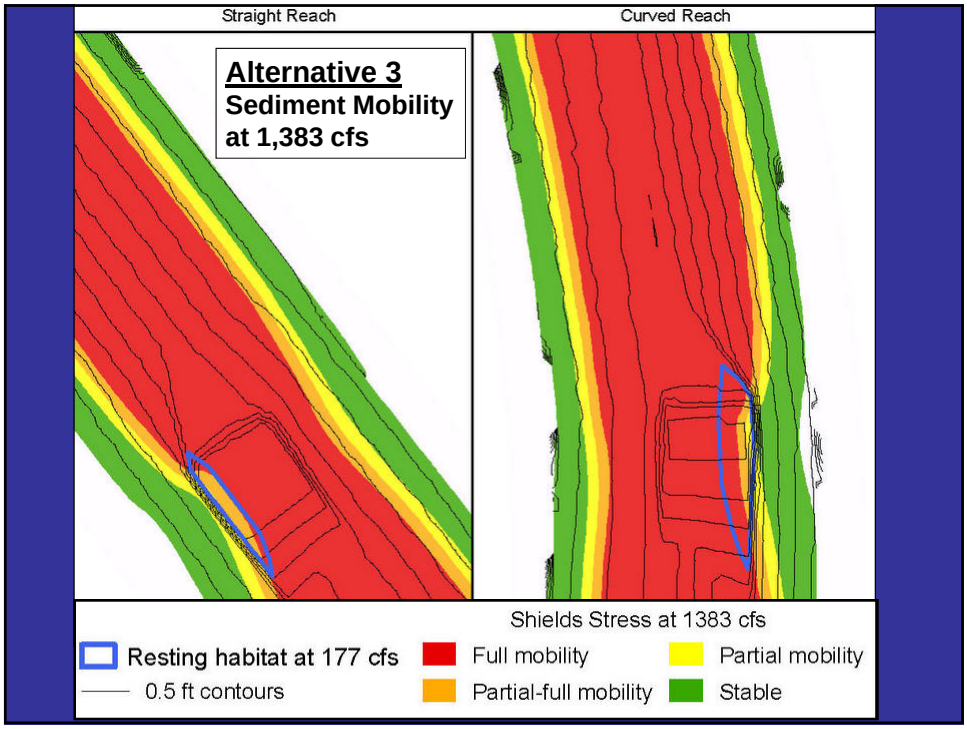
- Water Velocities ≤ 1 BL/s at passage flows
- Water Depth > 2 ft deep (provides cover)
- Minimum Resting Area is:
  2 ft wide x 2 ft long x 2 ft deep

Resting Pool Alternative 3

Pool depth is 2 ft below channel invert







Pool Spacing vs. Passage Success

FLOW	Percent of Steelhead able to Ascend Unit 3 at MLLW				
	Existing Pools	300 ft Spacing	200 ft Spacing	150 ft Spacing	100 ft Spacing
77 cfs	2	40	65	78	87
177 cfs	1	25	53	65	74

Passage Success for 150 ft Spacing

Tide	Percent of Steelhead able to Ascend Unit 3 150 ft Pool Spacing (Existing Conditions) 14 cfs	23 cfs	40 cfs	77 cfs	113 cfs	177 cfs
MLLW	95 (7)	85 (2)	81 (2)	78 (2)	74 (2)	65 (1)
MTL	98 (98)	86 (85)	81 (51)	79 (13)	75 (7)	64 (1)
MHHW	99 (99)	95 (92)	98 (97)	86 (73)	80 (54)	64 (4)

Conculsions

- Resolution provided by 2-D hydraulics simulations better describes hydraulic environment experienced by the fish.
- Evaluating passage performance for the entire fish population more accurately describes passage conditions and impacts to fisheries
- For exhaustion barriers, providing suitable resting pools can greatly improve passage success.