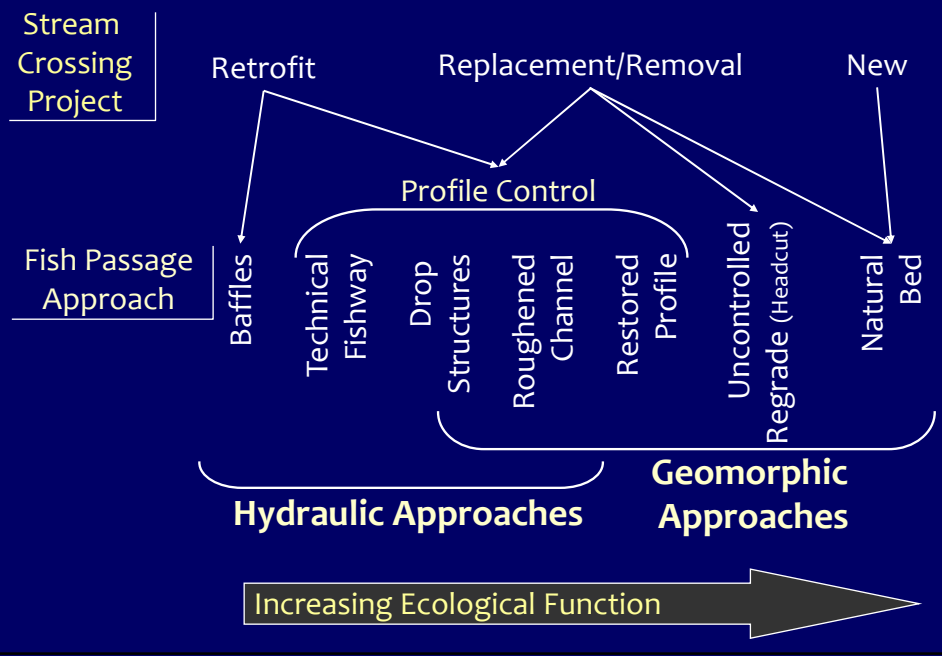
Hydraulic Design Overview




Michael Love P.E.
Arcata, California
mlove@h2odesigns.com
707-822-2411

Design Approaches for Aquatic Organism Passage



Two Design Options - Premises

- Hydraulic: A structure with appropriate hydraulic conditions will allow target species to swim through it.
- Stream Simulation: A channel that simulates characteristics of the adjacent natural channel will present no more of a challenge to movement of organisms than the natural channel.

Spectrum of Hydraulic Approach


Tide Gates and Bare Culverts

Fish Baffles

Technical Fishways

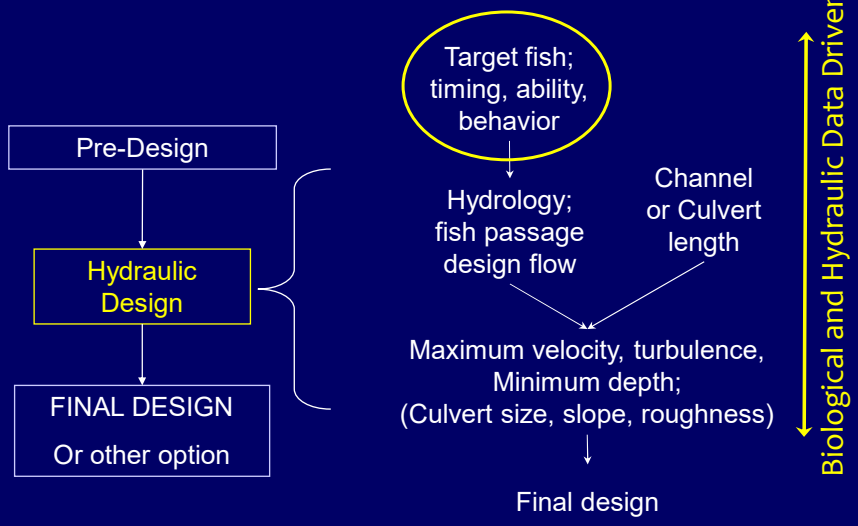
Concrete/Sheetpile Weirs

Log Weirs

Boulder Weirs

Roughened Channel

Hydraulic Design Option



Target Species & Life Stages

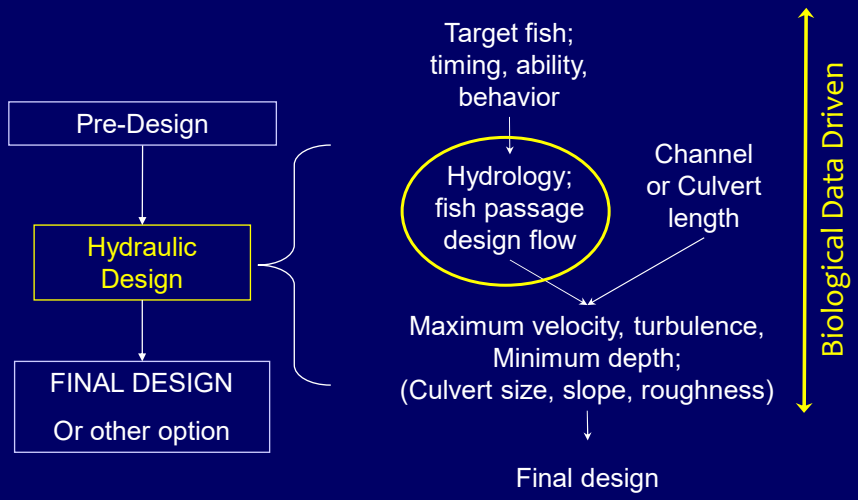
Fish Passage Hydraulic Criteria and Design Flows

- Primarily developed for Salmonids, and Pacific Lamprey to lesser extent
- Consult literature and biologist for non-salmonid target species

List of Fish Species found in one small urban stream in Arcata, CA (from Darren Ward, CPH, 2024)

Common Name	Scientific name
Coho salmon	Oncorhynchus kistuch
Coastal cutthroat trout	Oncorhynchus clarkii clarkii
Threespine stickleback	Gasterosteus aculeatus
Western brook lamprey	Lampetra richasrdosni
Night Smelt	Spirinchus starksi
Pacific staghorn sculpin	Leptocottus armatus
Prickly Sculpin	Cottus asper
Coastrange sculpin	Cottus aleuticus
Starry Flounder	Platichthys stellatus
Tidewater goby	Eucycloglobius newberryi
Yellowfin goby	Acanthogobius flavimanus
Longjaw mudsucker	Gillichthys mirabilis
Flounder sp	Pleuronectidae

Hydraulic Design Option

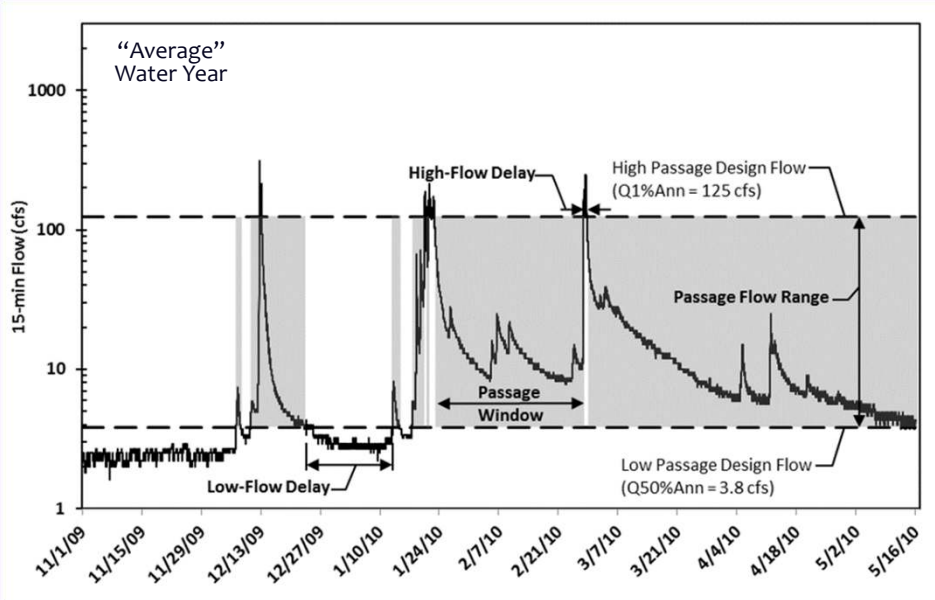


Fish Passage Flow Considerations

Migration Timing

- **Purpose of upstream movement**
  - spawning
  - foraging
  - thermal refugia
  - pop. density
- **Sensitivity to delay**
  - wet year
  - dry years
- **Hydrologic Characteristics**
  - peaky
  - spring feed
  - long duration (spring runoff)
  - infrequent events

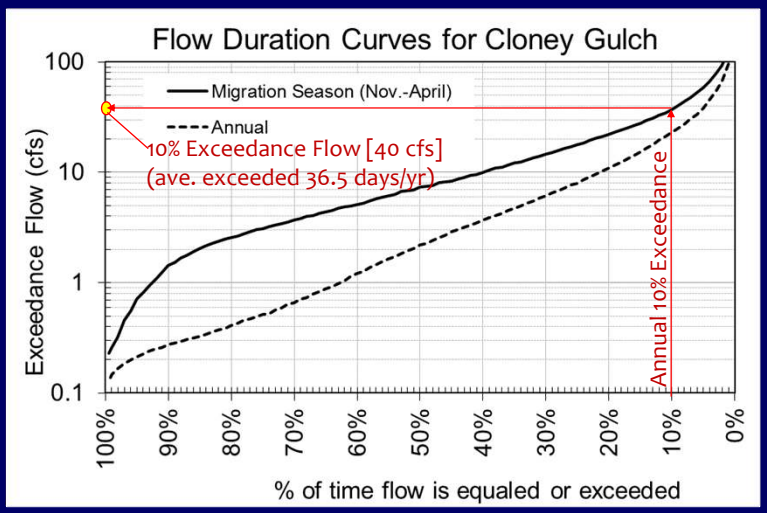
Considering Delay when Selecting Fish Passage Design Flows



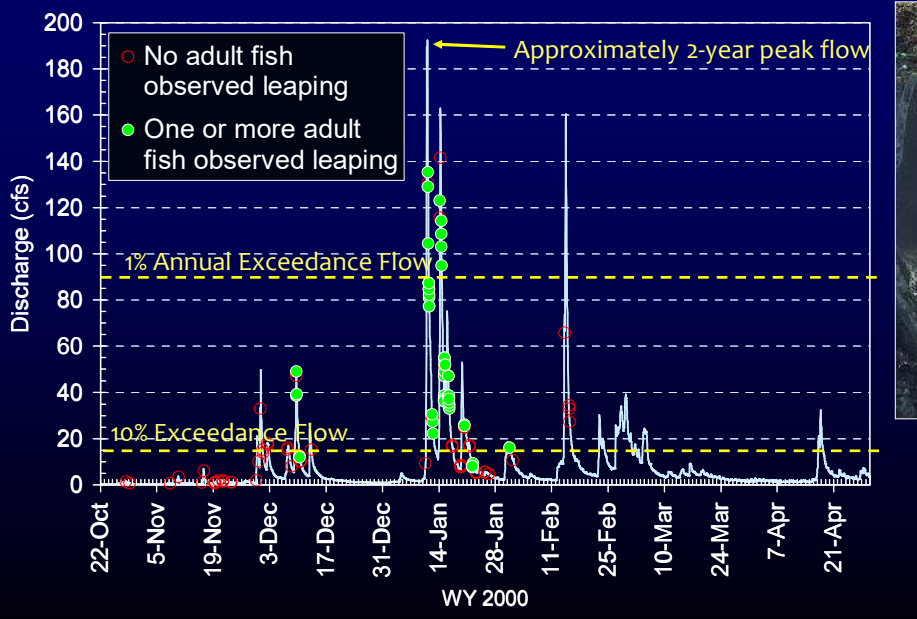
From: Lang and Love (2014)

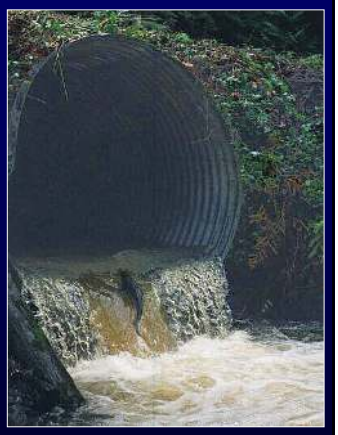
Fish Passage Design Flows

- Typically based on Flow Duration Curves constructed using daily average discharge
- CA salmonid criteria based on entire year,
  - Sometime projects also examine migration period, or most extreme month(s) of year (wet or dry)



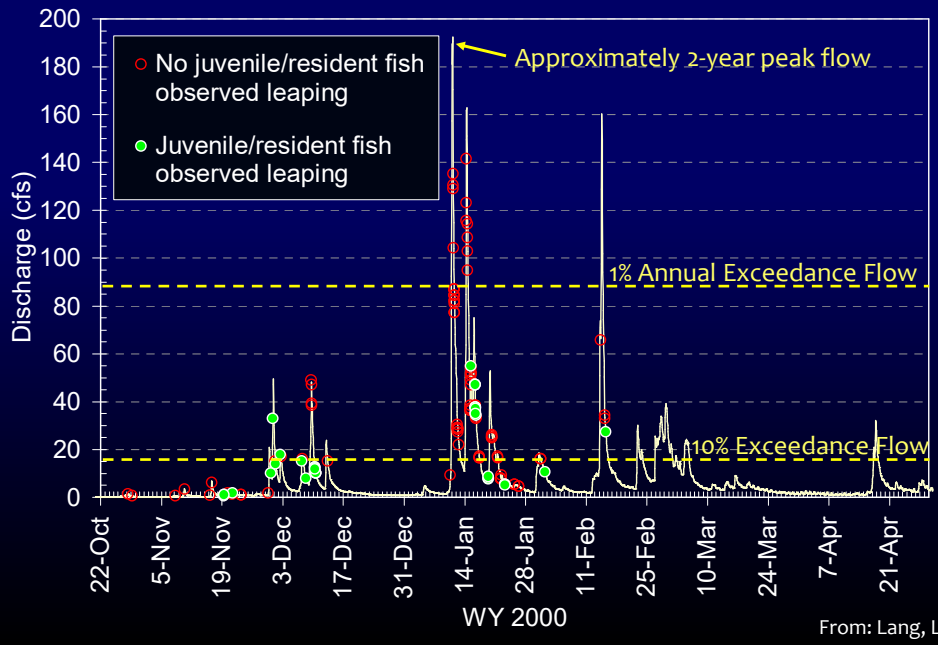
Observations of Adult Salmon Leaps at Sullivan Gulch





From: Lang, Love Trush, (2002)

Observations of Juvenile (<5") Leaps at Sullivan Gulch



From: Lang, Love Trush, (2002)

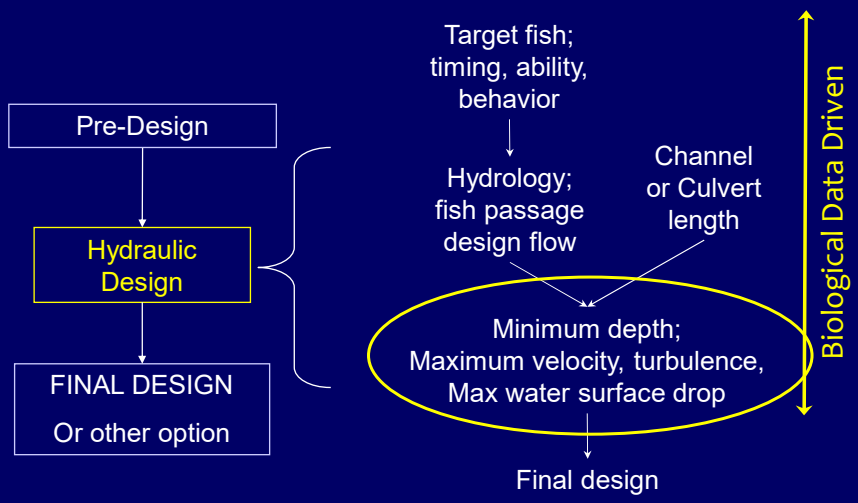
Fish Passage Flows for Hydraulic Designs

California Fish Passage Flow Requirements (CDFW, 2001; NMFS, 2002 and 2019)

Species/Lifestage	Low Passage Design Flow		High Passage Design Flow	
	Annual Exceedance Flow	Alternative Minimum Flow	Annual Exceedance Flow	Based on 2-year Flow*
Adult Anadromous Salmonids	50%	3 cfs	1%**	50% of Q2-yr
Adult Non-Anadromous Salmonids#	90%	2 cfs	5%	10% of Q2-yr
Juvenile Salmonids	95%	1 cfs	10%	5% of Q2-yr
Non-Native Salmonids#	90%	1 cfs	5%	N/A
Desirable Non-Native Species#	90%	1 cfs	10%	N/A

* Refer to NMFS (2019) Fish Passage Addendum #1 for to determine when to use.
** NMFS (2019) uses migration season rather than annual for adult anadromous salmonids
# Non anadromous design flows from CDFW, 2001.

Hydraulic Design Approach



Hydraulic Approach: Minimum Depth

NOAA Fisheries West Coast Region and CDFW allowable velocities

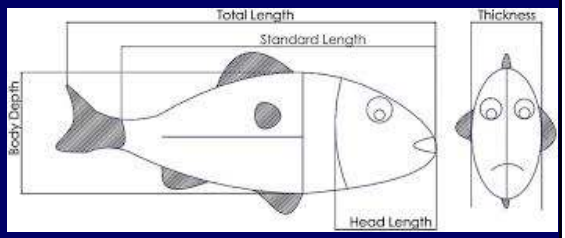
Species/Lifestage	Minimum Flow Depth (ft)
Adult Anadromous Salmonids	1.0
Adult Non-Anadromous Salmonids	0.67
Juvenile Salmonids	0.5
Native Non-Salmonids Non-Native Species	Species specific swimming performance data is required for the use of the hydraulic design option for non-salmonids. Hydraulic design is not allowed for these species without this data.

Excerpt from the Morphometric Data Table:

Common name	Family	Genus	Species	BD/TL	TL/SL	TL/FL
broad whitefish	Salmonidae	Coregonus	nasus	0.232	1.165	1.099
humpback chut	Cyprinidae	Gila	cypha	0.224	1.252	1.134
humpback whitefish	Salmonidae	Coregonus	pidschian	0.196	1.142	1.078
inconnu	Salmonidae	Stenodus	leucichthys	0.174	1.146	1.080
lake sturgeon	Acipenseridae	Acipenser	fulvescens	0.118	1.186	1.096

Where: BD = Body Depth, TL = Total Length, SL = Standard Length, FL = Fork Length

from FishXing User Manual, 2006 and Fishbase (fishbase.org)



from Machavaram, Sahu, and Paradkar, 2019

What do we know about Fish Energetics?

Swim Speed Variable

- Fish Size
- Water Temperatures
- Swimming Mode and Length:
  Aerobic (sustained swimming)
  Anaerobic (burst swimming)
  Mixed Mode (prolonged swimming)
- Method of Testing:
  Lab settings, method of capture…
- Stressors:
  Chemical, lack of depth, distance traveled, time spent in fresh water…


Treadmill


Flume (volitional)


Respirometer

Hydraulic Approach: Allowable Velocities

NOAA Fisheries West Coast Region and CDFW allowable velocities

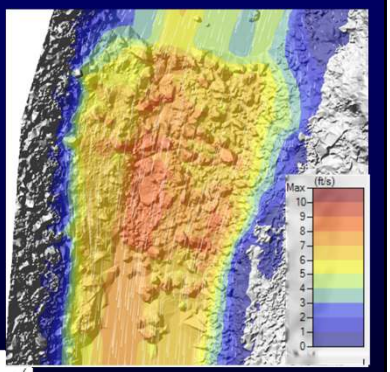
Culvert Length vs Maximum Average Water Velocity for Adult Salmonids		
Culvert Length (ft)	Adult Non-Anadromous Salmonids (fps)	Adult Anadromous Salmonids (fps)
<60	4	6
60-100	4	5
100-200	3	4
200-300	2	3
>300	2	2
Juvenile salmonids*		1

* 2 fps allowable for short distances

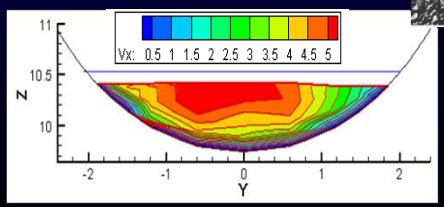
Hydraulic Approach
Roughness and Slope Controls Velocity

- Culvert walls
- Bed material
- Baffles
  - Limitations of turbulence, debris, maintenance
- Roughened channel
  - Bed stability
  - Variety of migration pathways
  - Turbulence limitation though higher than baffles

Powers, 1996



Rowdy Creek Roughened Channel 2D RAS Results

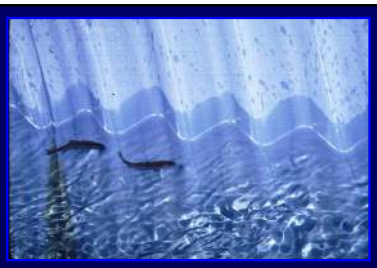


Battelle & DOE, 2003

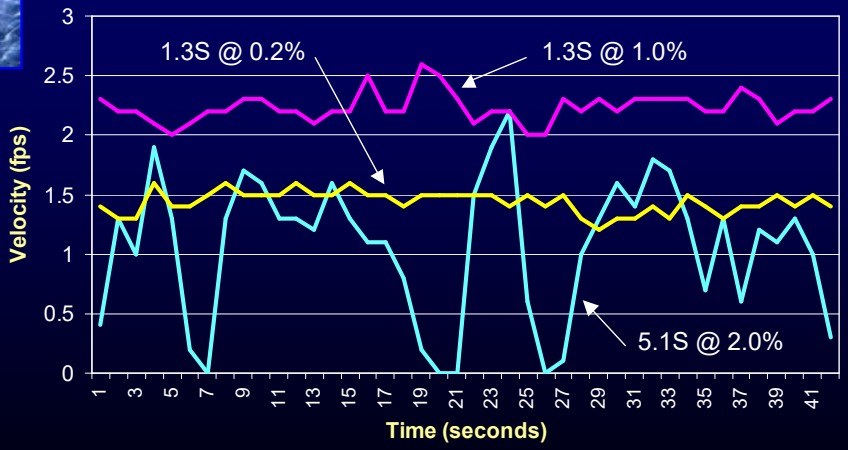
Turbulence

- Measured by Energy Dissipation Factor (EDF)
- Limits fish passage

For Technical Fishways:	Max EDF
Adult Anadromous Salmonids	4 ft-lb/s/ft^3 (765 W/m^3)
Adult Resident Salmonids	3 ft-lb/s/ft^3 (575 W/m^3)



Turbulence in $V_{occupied}$



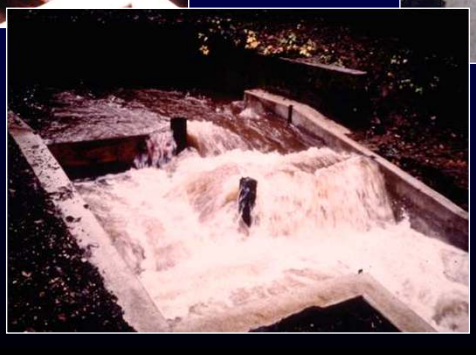
(3S) 1/2" Spiral Corrugations, 36" CMP
(1S) 1"x3" Spiral Corrugations, 36" CMP

From Powers (1997)

Example of Turbulence, EDF

Low Flow

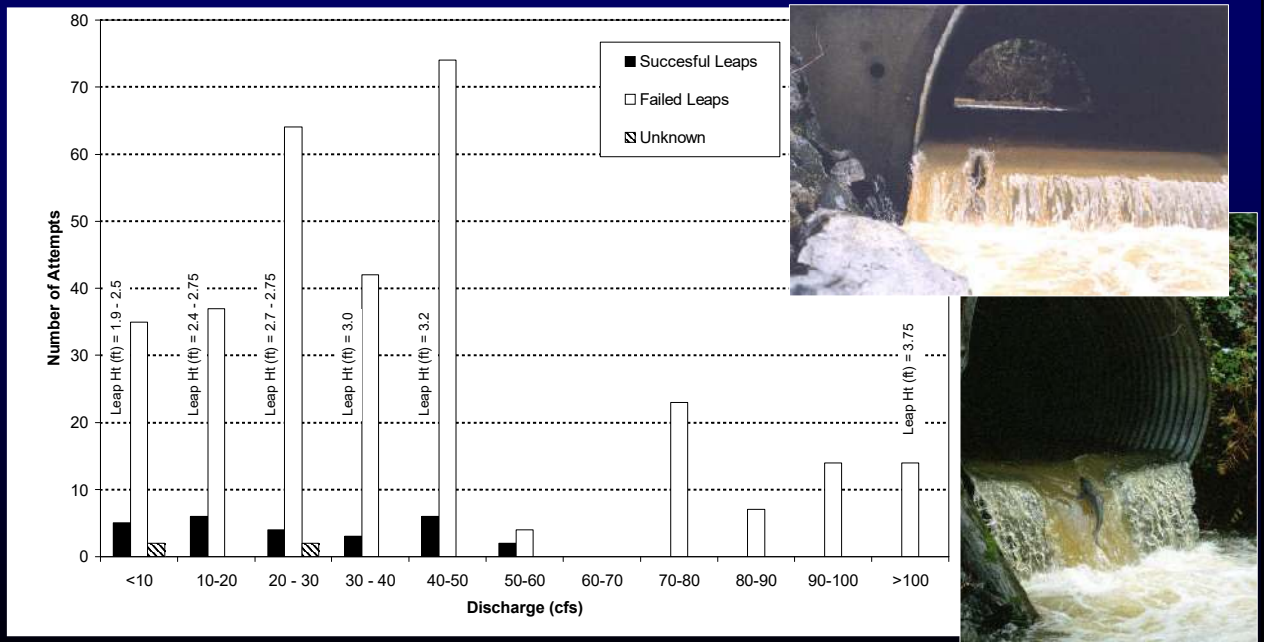
Fish passage design flow
(for Pacific salmon)
EDF = 4 ft-lb/sec/ft3



Two times fish
passage design flow
EDF = 8 ft-lb/sec/ft3

From Kozmo Bates

Adult Salmon Leaping Success vs Leap Height?



Hydraulic Approach: Maximum Drop

NMFS West Coast Region and CDFW Maximum Water Surface Drops

Species/Lifestage	Maximum Drop (ft)
Adult Anadromous Salmonids	1
Adult Non-Anadromous Salmonids	1
Juvenile Salmonids*	~~0.5~~ 1.0 (NMFS, 2019)
Native Non-Salmonids	Where fish passage is required for native non-salmonids no hydraulic drop shall be allowed at the culvert outlet unless data is presented which will establish the leaping ability and leaping behavior of the target species of fish.
Non-Native Species	

* CDFW guidelines allow 1 ft drop for boulder weirs, 0.5 ft drops at other weirs. Consult with CDFW if considering using 1.0 ft rather than 0.5 ft in design

** Drop height criteria does not apply to stream simulation designs. Instead, drops should not exceed those found in the reference/natural channel reach.