No Fish Left Behind*

Tidal Water Crossings in Washington State

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Washington Department of Fish and Wildlife

- 3000+ miles shoreline
- 2500 miles Puget Sound
- Development is shoreline focused


Richmond
Delta
Langley
Surrey
Gulf of Alaska
Duncan
Bellingham
Saanich
Victoria
Oak Harbor
Seattle
Kent
Tacoma
Olympia
Aberdeen
Astoria
Longview
Hillsboro
Portland
Gresham


Strait of Georgia
Nooksack River
N. Fork
Ross Lake
Baker Lake
S. Fork
Samish River
Skagit River
Strait of Juan de Fuca
Suiattle River
Sauk River
Stillaguamish River
Dungeness R.
Elwha River
Snohomish R.
Puget Sound
Skykomish R.
Snoqualmie River
Lake Washington
Hood Canal
Green River
Cedar R.
White River
Puya llup R.
Nisqually River
Deschutes R.


7/21/2006 10:26 AM


ECONOMY MARKET BUILDING
BEST
FLOWERS
FRESH WHOLE MEDIUM KING SALMON
WE ♥ TIPS!
AIRLINE TRAVEL PACKS!
DELIVER TO ALL DOWNTOWN HOTELS AND TO THE AIRPORT!
SMALL SOCKEYE GIFT BOX



Pacific salmon and steelhead are much more than essential elements of a healthy Pacific Coast ecosystem; they are cultural icons woven into the fabric of local communities and economies –

NOAA Fisheries





Pacific Salmonids

Species	**Species Name**
Chinook Salmon	*Oncorhynchus tshawytscha*
Coho Salmon	*Oncorhynchus kisutch*
Sockeye Salmon	*Oncorhynchus nerka*
Chum Salmon	*Oncorhynchus keta*
Pink Salmon	*Oncorhynchus gorbuscha*
Coastal Cutthroat Trout	*Oncorhynchus clarki clarki*
Steelhead Trout	*Oncorhynchus mykiss*
Bull Trout	*Salvelinus confluentus*


10
20
30
40
50
60
70

Nisqually River Estuary, South Puget Sound

Status of ESA Listings & Critical Habitat Designations for West Coast Salmon & Steelhead

PUGET SOUND DOMAIN

- Puget Sound Chinook (T) [FCH 9/2/05]
- Hood Canal Summer Chum (T) [FCH 9/2/05]
- Ozette Lake Sockeye (T) [FCH 9/2/05]
- Puget Sound Steelhead (T) [CH under dev.; ANPR 1/10/11]

WILLAMETTE/LOWER COLUMBIA DOMAIN

- Columbia River Chum (T) [FCH 9/2/05]
- Lower Columbia River Coho (T) [CH Under dev.; ANPR 1/10/11]
- Lower Columbia River Chinook (T) [FCH 9/2/05]
- Lower Columbia River Steelhead (T) [FCH 9/2/05]
- Upper Willamette River Chinook (T) [FCH 9/2/05]
- Upper Willamette River Steelhead (T) [FCH 9/2/05]

OREGON COAST DOMAIN

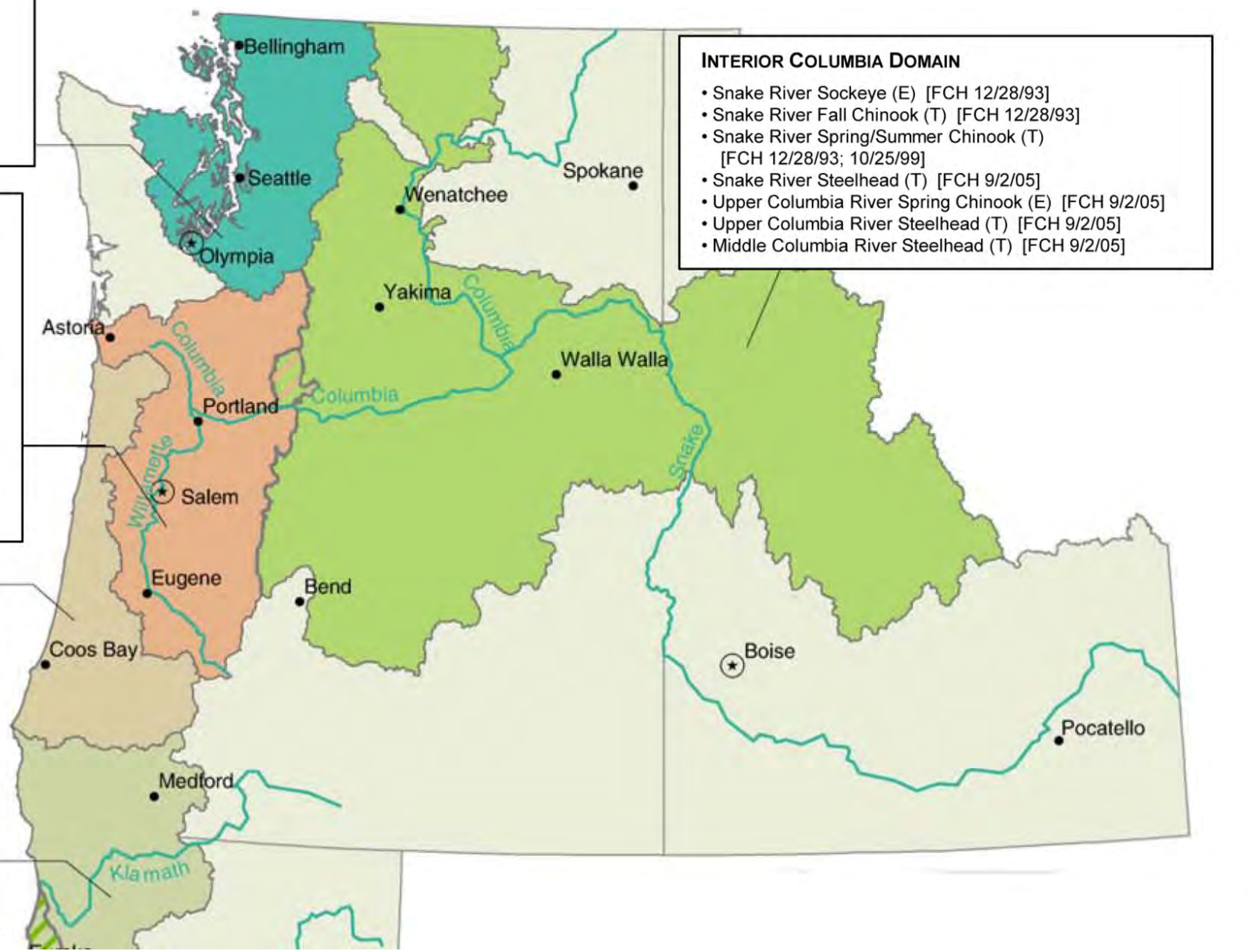
- Oregon Coast Coho (T) [FCH 2/11/08]

SOUTHERN OREGON/NORTHERN CALIFORNIA COAST DOMAIN

- Southern Oregon/Northern California Coast Coho (T) [FCH 5/5/99]

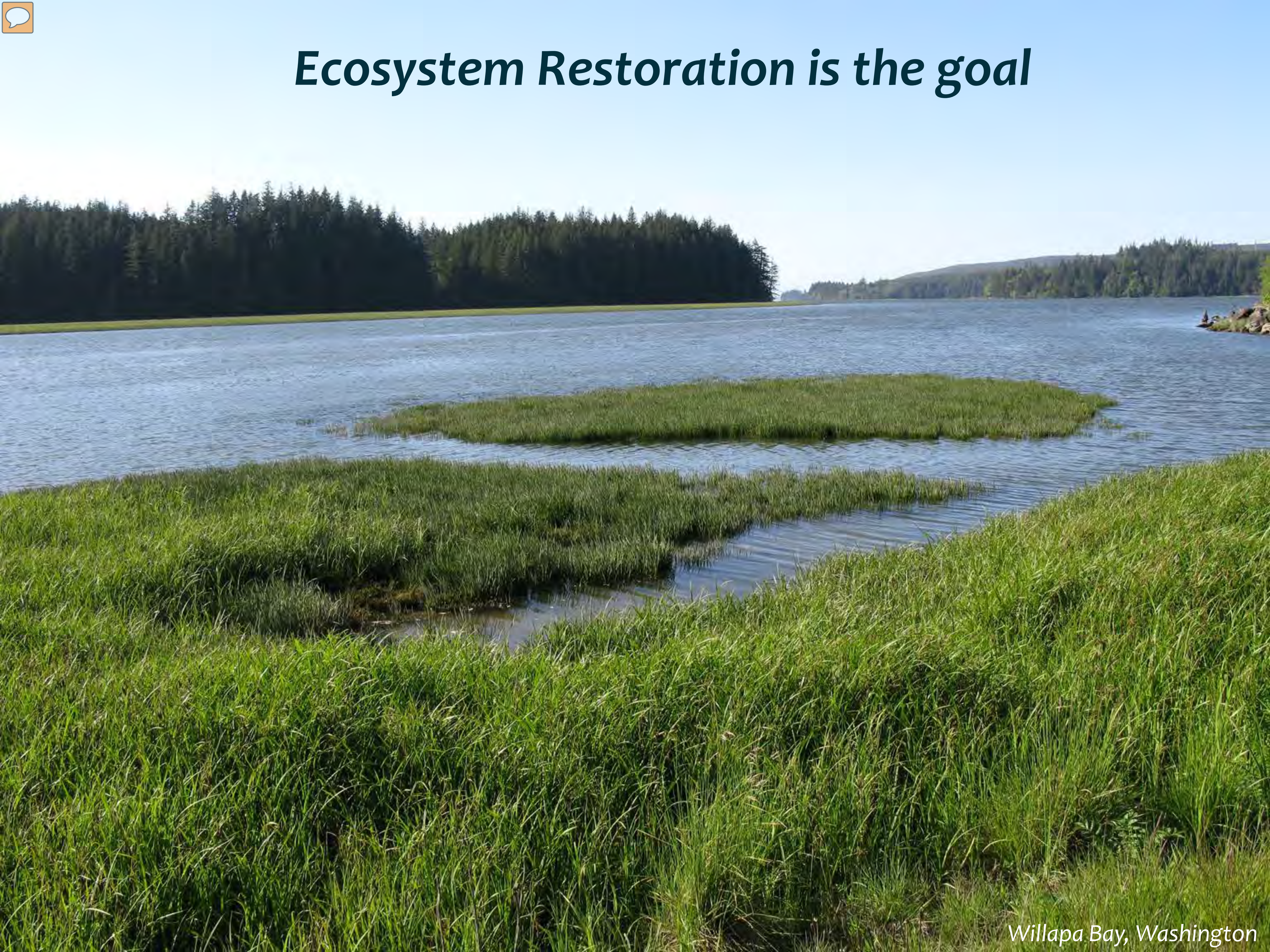
INTERIOR COLUMBIA DOMAIN

- Snake River Sockeye (E) [FCH 12/28/93]
- Snake River Fall Chinook (T) [FCH 12/28/93]
- Snake River Spring/Summer Chinook (T) [FCH 12/28/93; 10/25/99]
- Snake River Steelhead (T) [FCH 9/2/05]
- Upper Columbia River Spring Chinook (E) [FCH 9/2/05]
- Upper Columbia River Steelhead (T) [FCH 9/2/05]
- Middle Columbia River Steelhead (T) [FCH 9/2/05]



NOAA Fisheries 2012

Ecosystem Restoration is the goal



Willapa Bay, Washington

Elwha River, Strait of Juan de Fuca

Duckabush River, Hood Canal

Farms, Fish & Floods Initiative

Skagit Bay


Carpenter Creek estuary, Kitsap Peninsula

Whiteman Cove, South Puget Sound

Salmon Recovery

SRFB distributes funds to local groups

Early push to recognize marine role in salmon life history

Salmon Stronghold also emphasized to avoid future listings

Pitship marsh, Sequim

Fish Passage Projects

Long recognized as effective projects

Johns River Wildlife Area, Grays Harbor

Chico Creek estuary

But, there is a risk of Salmon Fatigue…


FOLLOW SR 304
BREMERTON BOARDWALK
LODGING
TOURIST ACTIVITIES
Puget Sound Navy Museum
BUG MUSEUM

Included:	Not included:
Culverts	Bridges or other crossing structures
Puget Sound watersheds and most of the coastal watersheds (gray area on map) except Columbia River and Willapa Bay	Columbia River drainages & Willapa Bay
State-owned lands	Local, federal or private lands
FW & tidal	

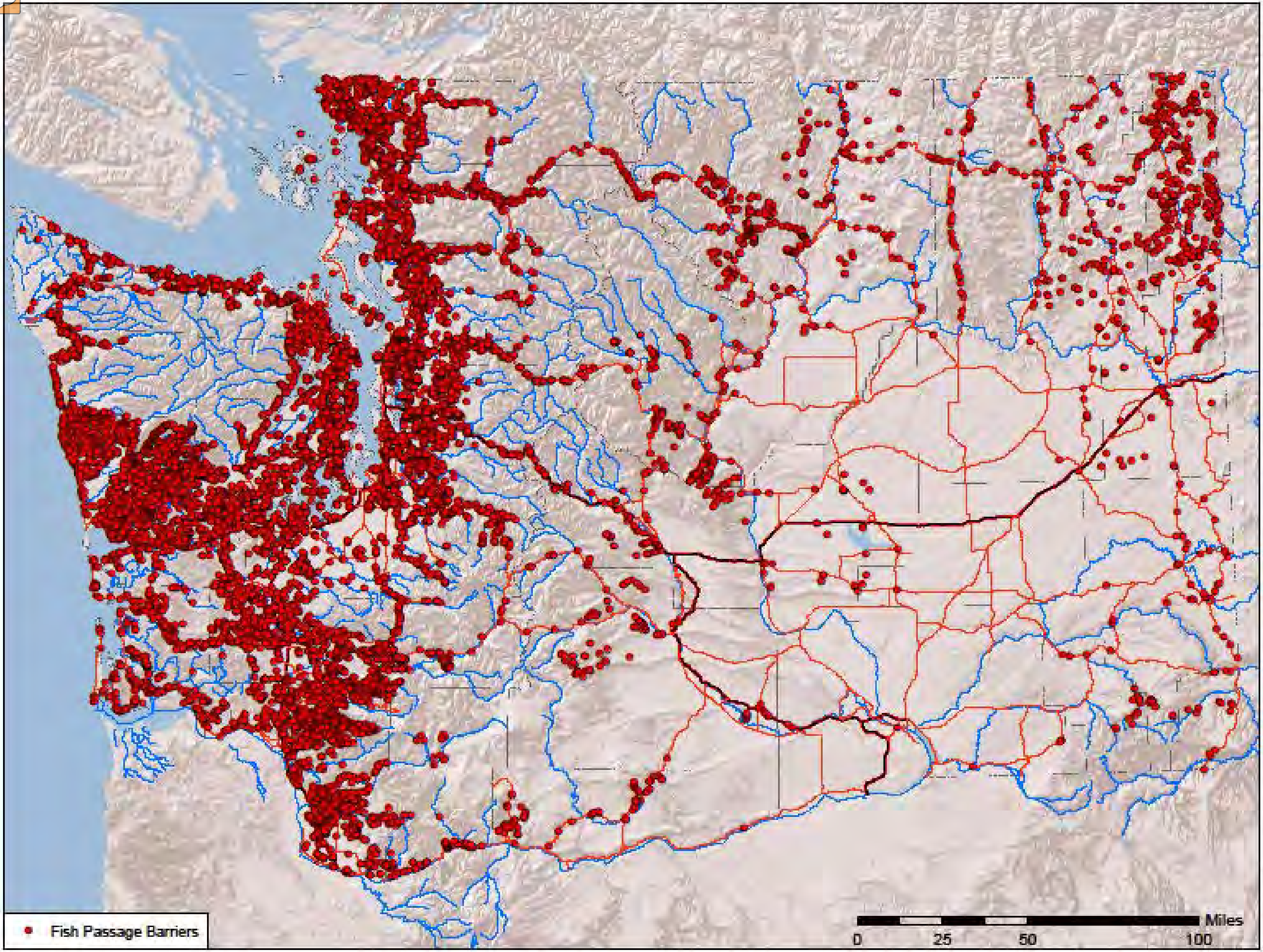
Magnitude of Effort

State Parks, Dept. of Natural Resources & Dept. Fish & Wildlife — Oct 2016

WSDOT — 2030

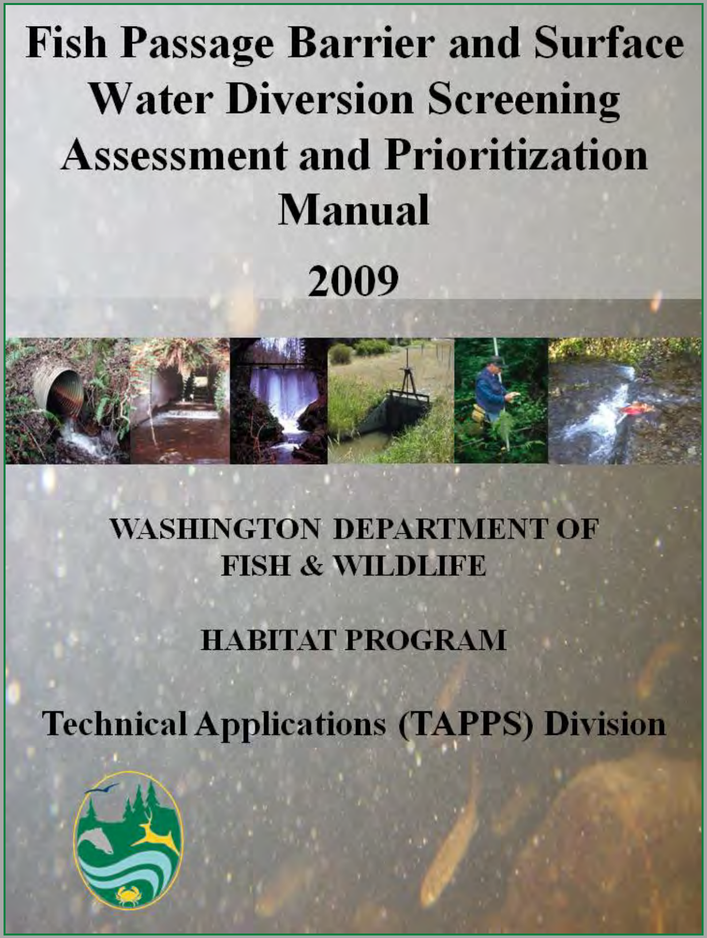
978 total culverts, with 825 with 'significant habitat' (gain of 200m)

Replacement structures – bridges or other "geomorphic" design



Fish Passage Barriers
Miles
0
25
50
100

Standardized fish passage assessment and habitat survey methodologies



* Methods developed in 1998 to support fish passage barrier prioritization
* Currently standardized protocols that are used throughout the state of Washington.
* Data is collected and entered into a Fish Passage Barrier Database by dedicated fish passage inventory staff.

Washington Department of Fish and Wildlife. 2009. **Fish Passage and Surface Water Diversion Screening Assessment and Prioritization Manual.** Washington Department of Fish and Wildlife. Olympia, Washington.

http://wdfw.wa.gov/publications/pub.php?id=00061

Existing barrier assessment / Prioritization

Barrier assessments physically identify migration barriers and help to prioritize investment. Set up to address riverine systems well, but no criteria established for tidal and estuarine systems.

Prioritizing ensures that projects with the greatest benefits are constructed first; More efficiently utilizes limited funds; Helps identify projects when funding becomes available

Fish Passage Barrier Culvert Conditions:

Excessive Water Surface Drop

High Velocity

Shallow Water Depth

WDFW Barrier Assessment Protocols

Current Criteria

- Criteria based on fish swimming and leaping capabilities and culvert hydraulics
- Velocity and Hydraulic Drop are targeted for 6” trout
- Depth for adult Chinook, coho, sockeye, and steelhead
- Criteria creates a minimum standard for passing fish 90% of the time during adult migration

Adult Fish Passage Requirements

Velocity criterion varies with the length of the culvert:

- **< 30 m (100‘) long, max velocity is 1.2 mps (4.0 fps)**
- **30 m – 60 m (100-200‘) long, max velocity is 0.9 mps (3.0 fps)**
- **> 60 m (200‘) long, max velocity is 0.6 mps (2.0 fps)**

These velocity limits should not be exceeded during 10% exceedance flows, or ‘High Fish Passage Design Flow’

Adult Fish Passage Requirements

Hydraulic drop is an abrupt change in water surface

Hydraulic drop may not exceed 0.24 m (0.8') at any point within or at the inlet or outlet of the culvert

The maximum hydraulic drop criteria must be satisfied at all flows between the low and high fish passage design flow criteria (Low = 2-year 7-day low flow; High = 10% exceedance flow)

Adult Fish Passage Requirements

Water depth at any location within culverts as installed <u>and without a natural bed</u> shall not be less than 0.30 m at the low flow design (2-year, 7-day low flow)

WAC 220-110-070 (3)(A)

High Fish Passage Design Flow

- The flow that is exceeded only 10% of the time during fish presence
- Calculated using basin area, regional precipitation, and elevation

Low Fish Passage Design Flow

- The 2-year 7-day low flow
- Calculated using regression equations

Scope of the problem…

Prioritization

* Ensures that projects with the greatest benefits are constructed first
* More efficiently utilizes limited funds
* Helps identify projects when funding becomes available
* Could be advantageous when applying for grant funding

The Priority Index

* Provides a numerical ranking system to prioritizing fish passage corrections that is a first cut for identifying projects.

* The index considers:
  * Potential improvement in fish passage
  * Species expected to benefit and their productivity
  * The quantity and quality of habitat upstream
  * Modified by the importance of the species in salmon recovery efforts and the cost of the project

The Priority Index (PI)

$$PI = \sum_{\text{all species}} \sqrt[4]{(BPH)MEC}$$

Where:

- PI = Priority Index
- B = Passage improvement
- P = Annual adult production potential per m^2
- H = Habitat gain in m^2
- M = Mobility Modifier
- E = ESA Status Modifier
- C = Cost Modifier

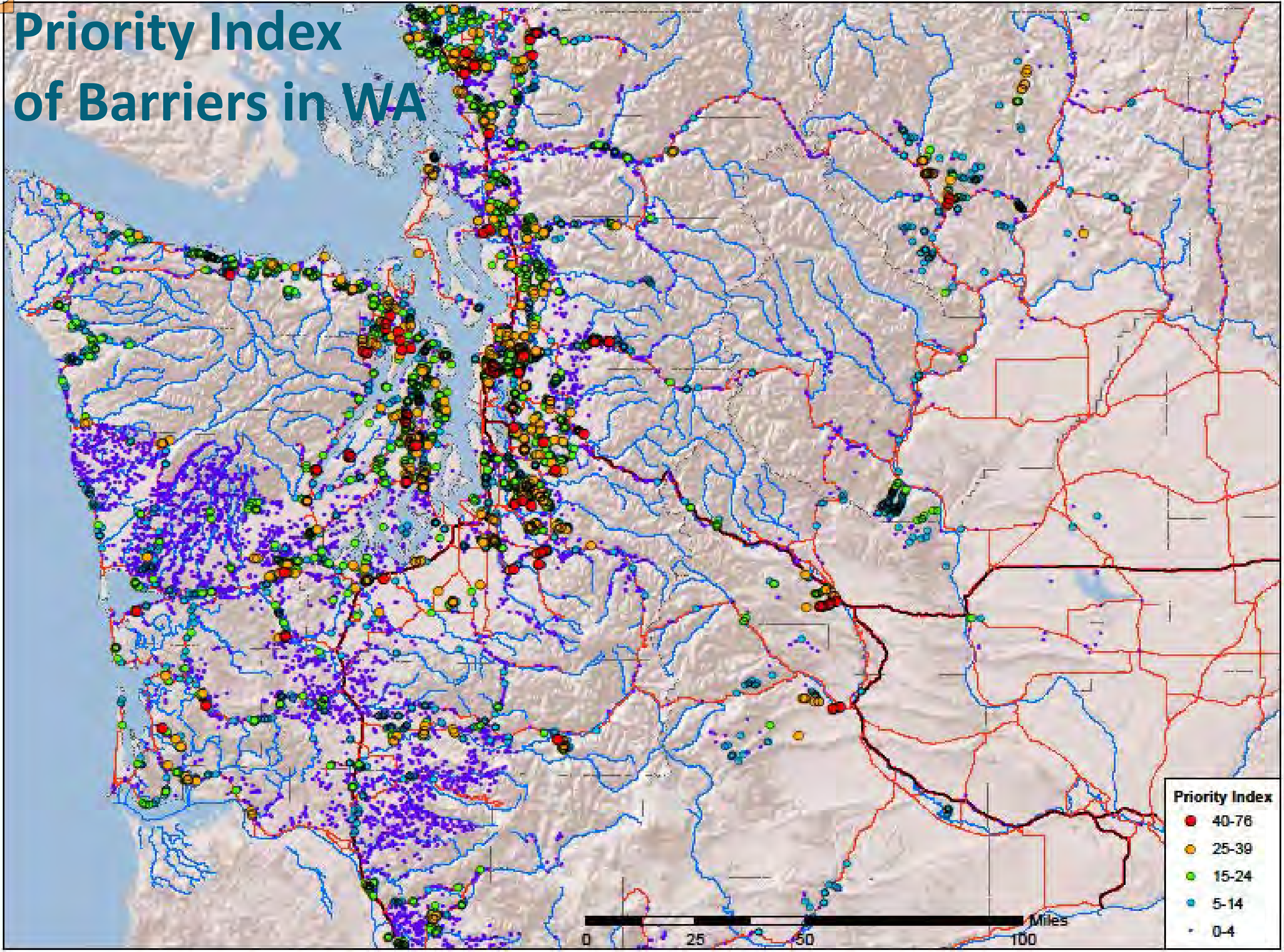
Purdy Creek - An example

Purdy Creek – An example:

$$PI = \sum_{\text{all species}} \sqrt{(BPH)MEC}$$

Species	Proportion of Passage Improvement	Annual Adult Production Potential per m^2	Habitat gain in m^2	Mobility Modifier	ESA Status Modifier	Cost Modifier	Priority Index per species
	B	**P**	**H**	**M**	**E**	**C**	
Sockeye/Kokanee	**0.67**	3.0000	-	2	1	**1**	0.00
Chum	**0.67**	1.2500	8,045	2	1	**1**	10.77
Pink	**0.67**	1.2500	-	2	1	**1**	0.00
Coho	**0.67**	0.0500	17,960	2	2	**1**	7.00
Chinook	**0.67**	0.0160	3,931	2	3	**1**	3.99
Steelhead	**0.67**	0.0021	18,300	2	3	**1**	3.53
Sea-run Cutthroat	**0.67**	0.0370	18,300	2	1	**1**	5.49
Resident Trout	**0.67**	0.0400	20,996	1	1	**1**	4.87
Bull Trout	**0.67**	0.0007	-	1	1	**1**	0.00
						Total PI:	**35.65**

Priority Index of Barriers in WA

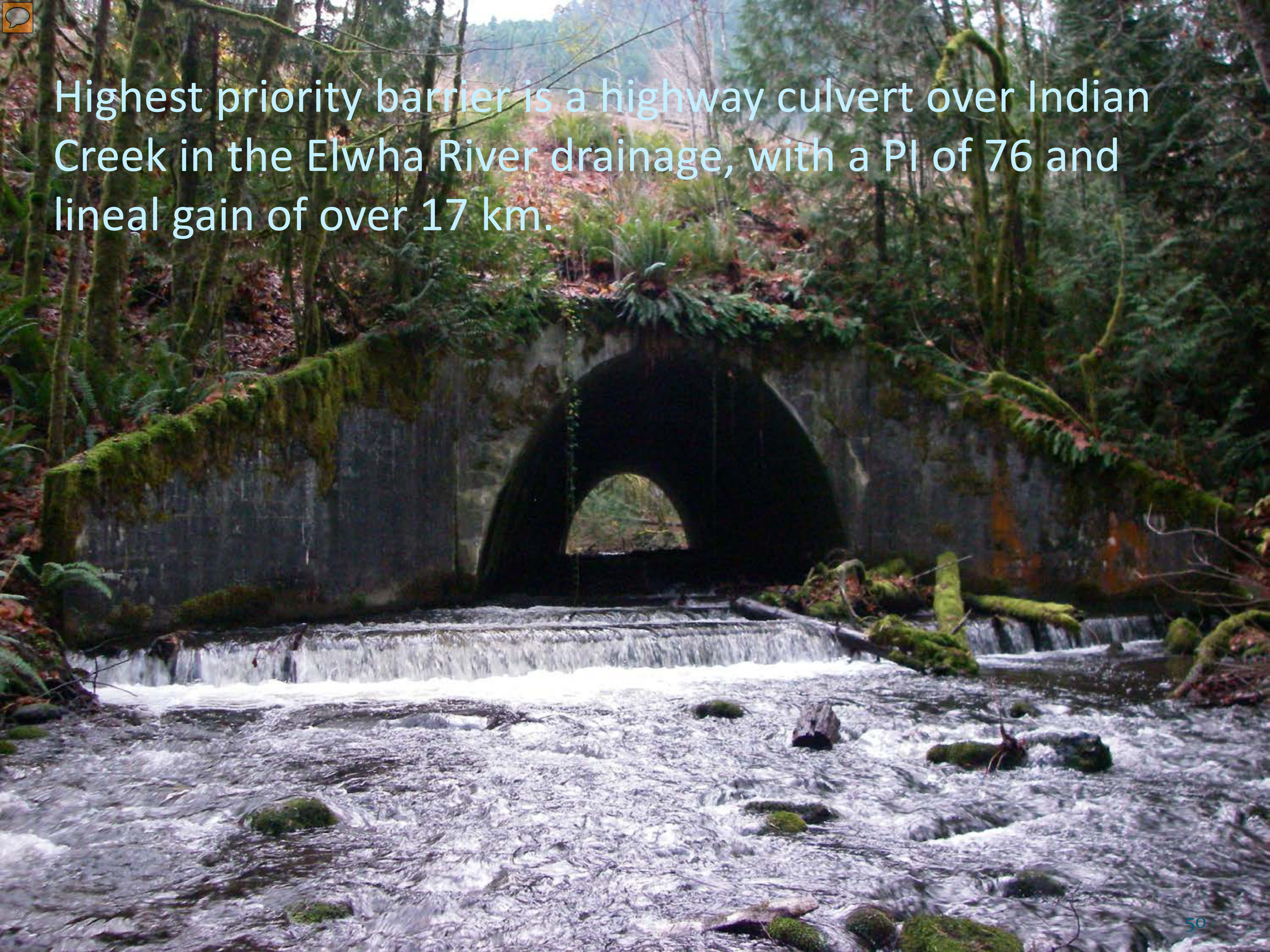


Limitations to the PI model

* Expensive and time consuming due to the need to walk the stream.
* Habitat surveys become outdated.
* Assumes all manmade barriers upstream are temporary such that it only considers potential habitat, which may not be immediately realized.
* Only calculated on streams that can be surveyed (walkable).
* Relies on estimated adult productivity, which is biased towards highly productive species such as chum.
* Regionally biased towards areas with multiple anadromous species, such as coastal streams.
* Barriers are only identified based on jurisdictional investments.

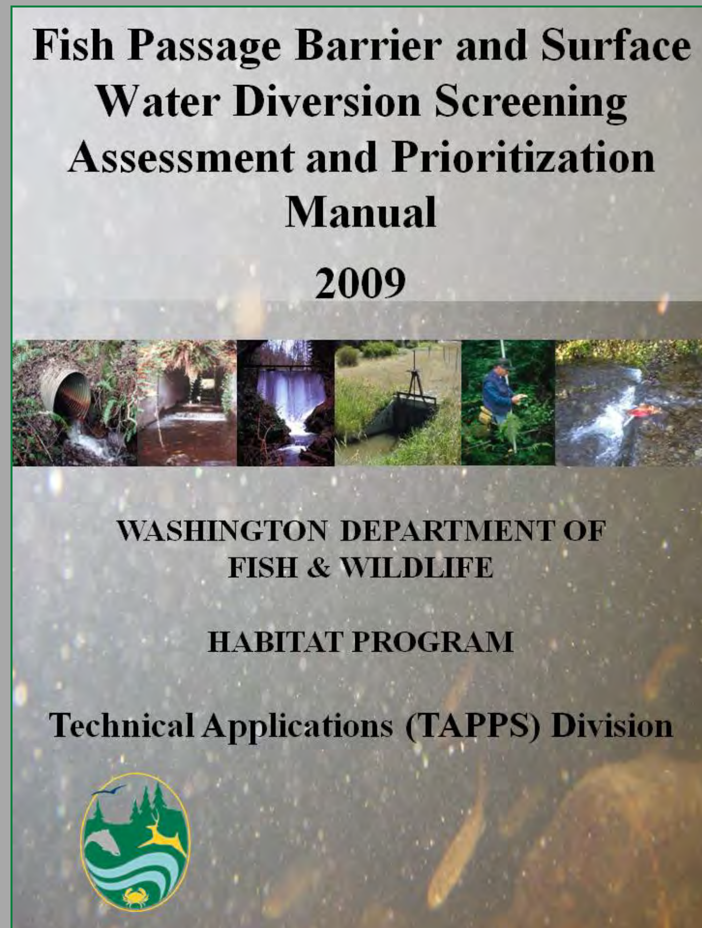
Highest priority projects in the WDFW Fish Passage Database

PI	Stream	Tributary to	Feature	Passability	Lineal Gain	Spawning Area	Rearing Area	Owner
76	Indian Cr	Elwha R	Culvert	33	17,109	11,854	115,344	State
71	Big Soos Cr	Green R	Dam	0	130,439	192,677	735,357	State
71	Little Bear Cr	Sammamish R	Culvert	33	45,990	32,627	99,905	City
66	NF Nemah R	Willapa Bay	Dam	67	64,048	265,892	212,036	State
64	Minter Cr	Henderson Bay	Dam	67	36,061	36,373	104,400	State
63	May Cr	Wallace R	Other	33	12,256	18,343	41,864	State
60	Issaquah Cr	Lake Sammamish	Dam	67	86,501	117,152	296,146	State
60	Big Quilcene R	Hood Canal	Dam	33	5,584	13,766	33,376	Federal
59	Little Bear Cr	Sammamish R	Culvert	67	45,736	32,022	98,633	City
59	Friday Cr	Samish R	Dam	67	66,239	69,569	282,460	State



Highest priority barrier is a highway culvert over Indian Creek in the Elwha River drainage, with a PI of 76 and lineal gain of over 17 km.

For more info on prioritization methods:



Washington Department of Fish and Wildlife. 2009. **Fish Passage and Surface Water Diversion Screening Assessment and Prioritization Manual.** Washington Department of Fish and Wildlife. Olympia, Washington.

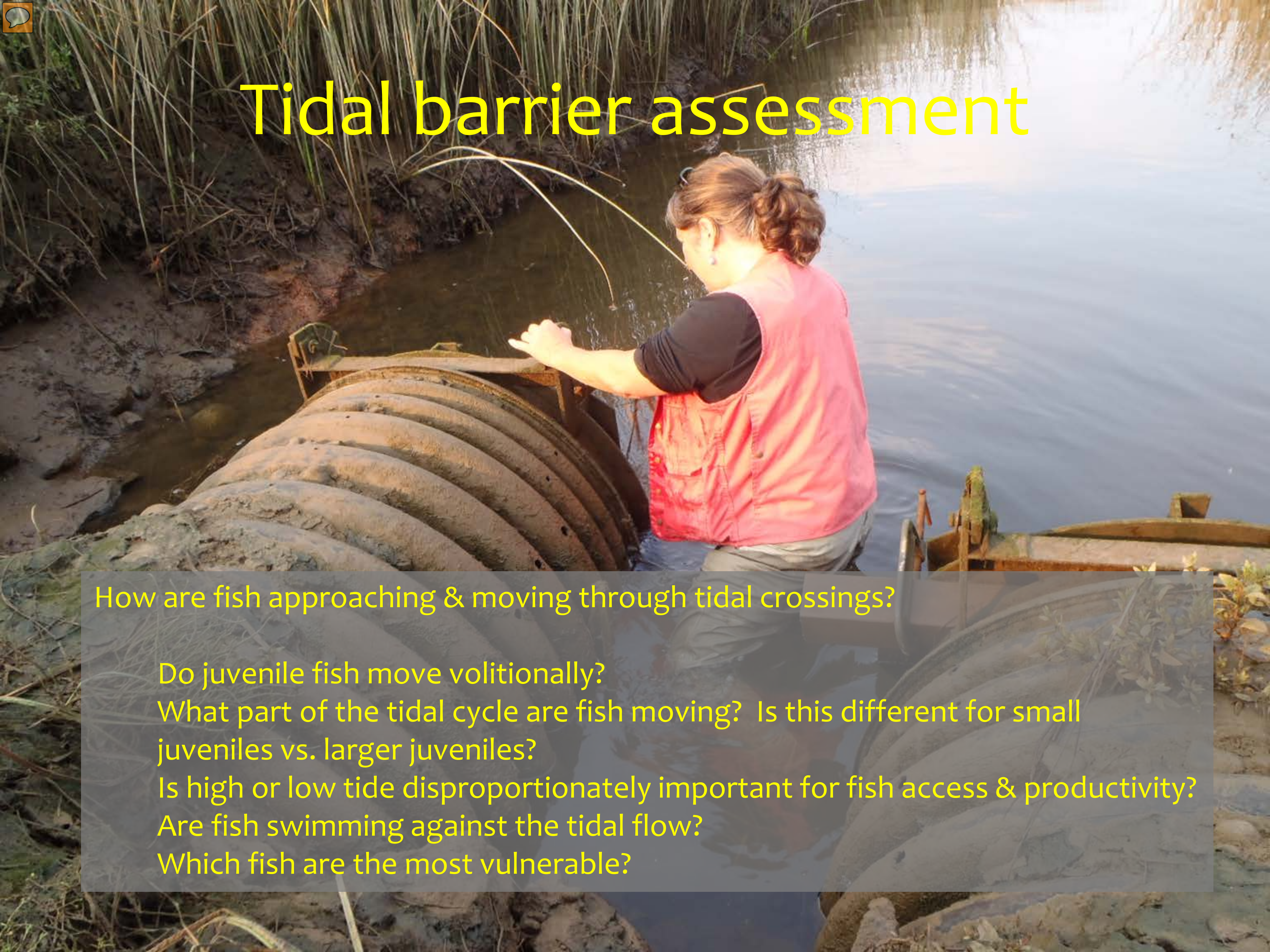
http://wdfw.wa.gov/publications/pub.php?id=00061

Fish Access Assessment in Tidal Systems

Fish Access Assessment in Tidal Systems

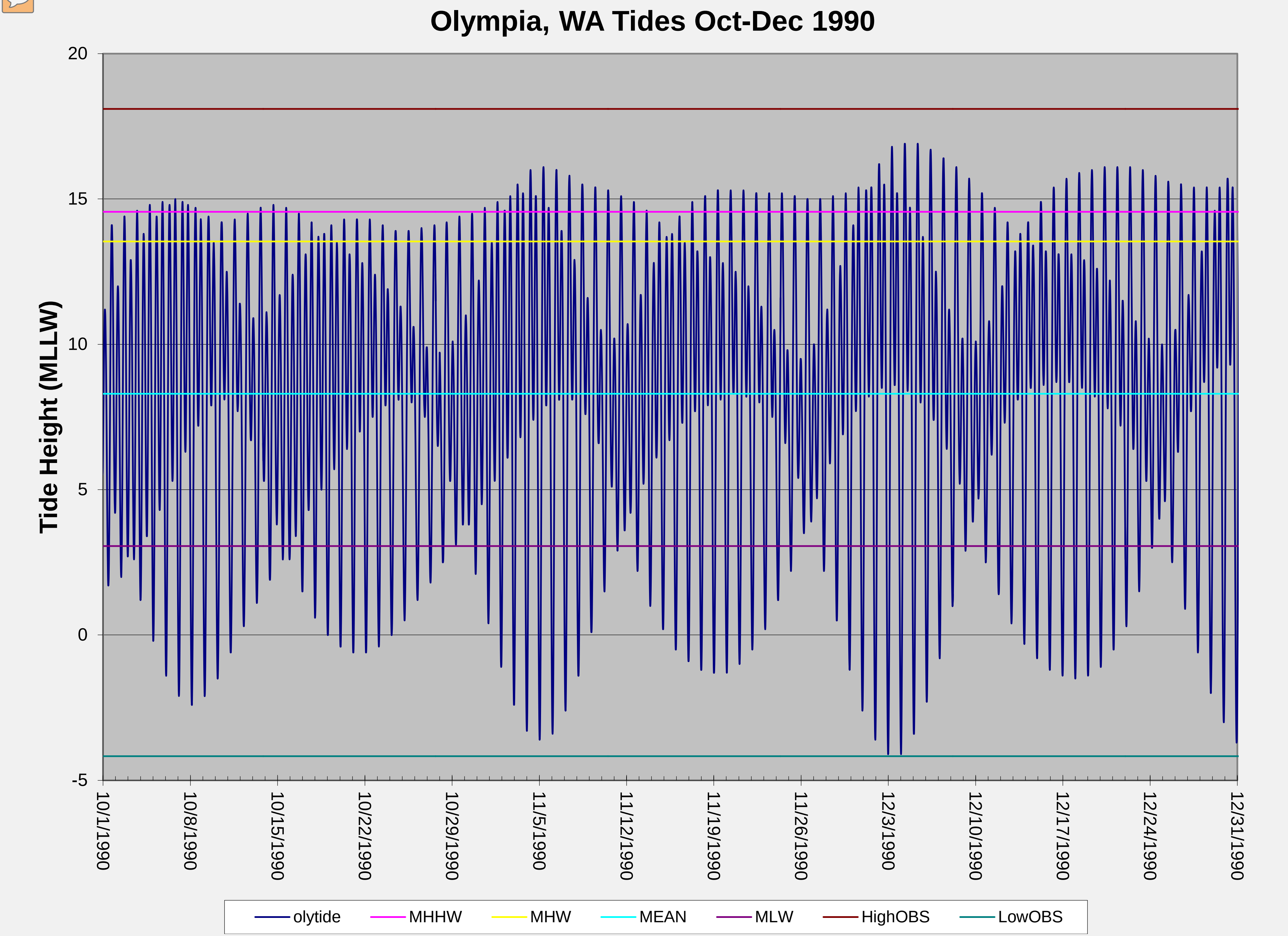
Field Assessment

Tidal barrier assessment

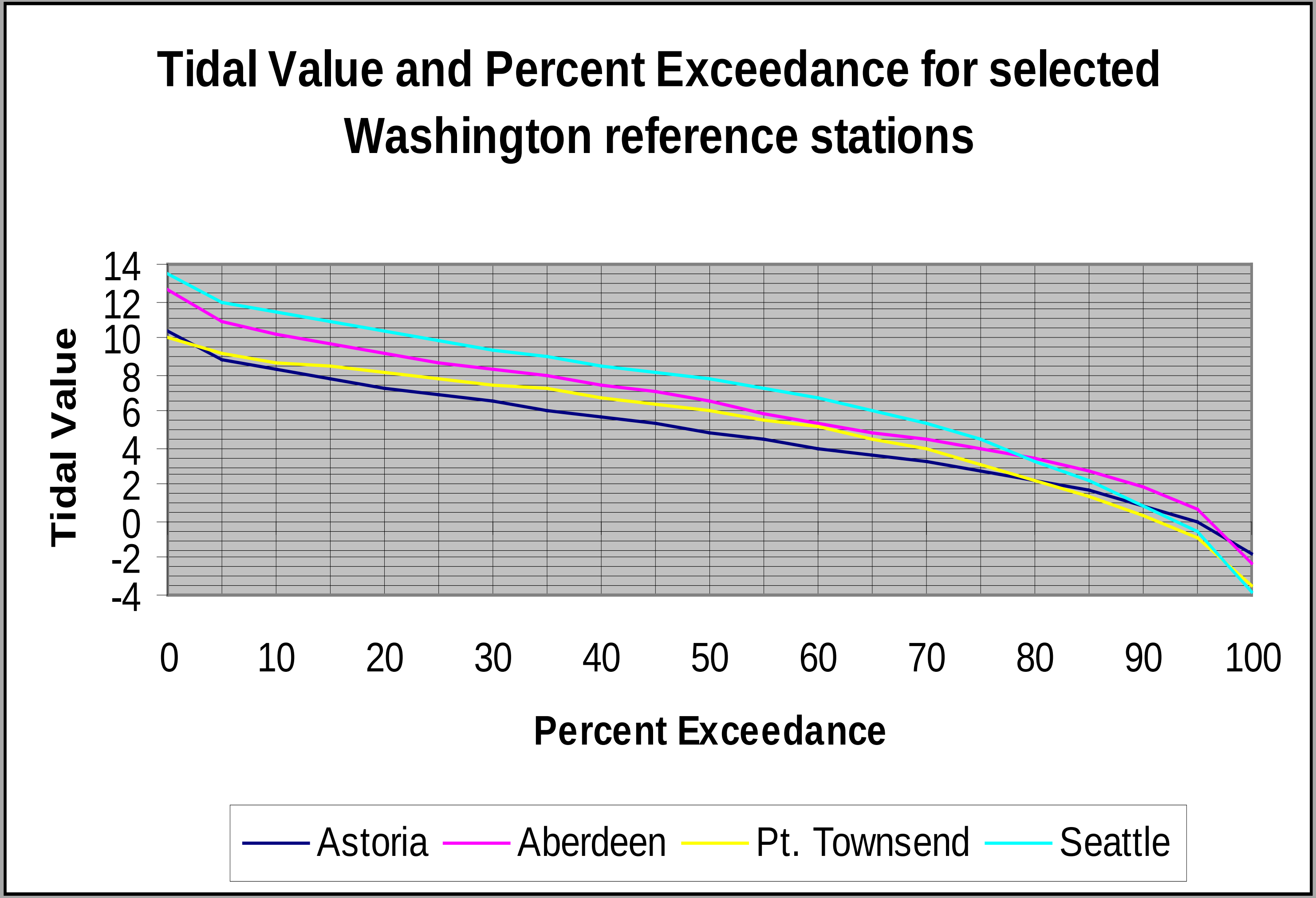


How are fish approaching & moving through tidal crossings?

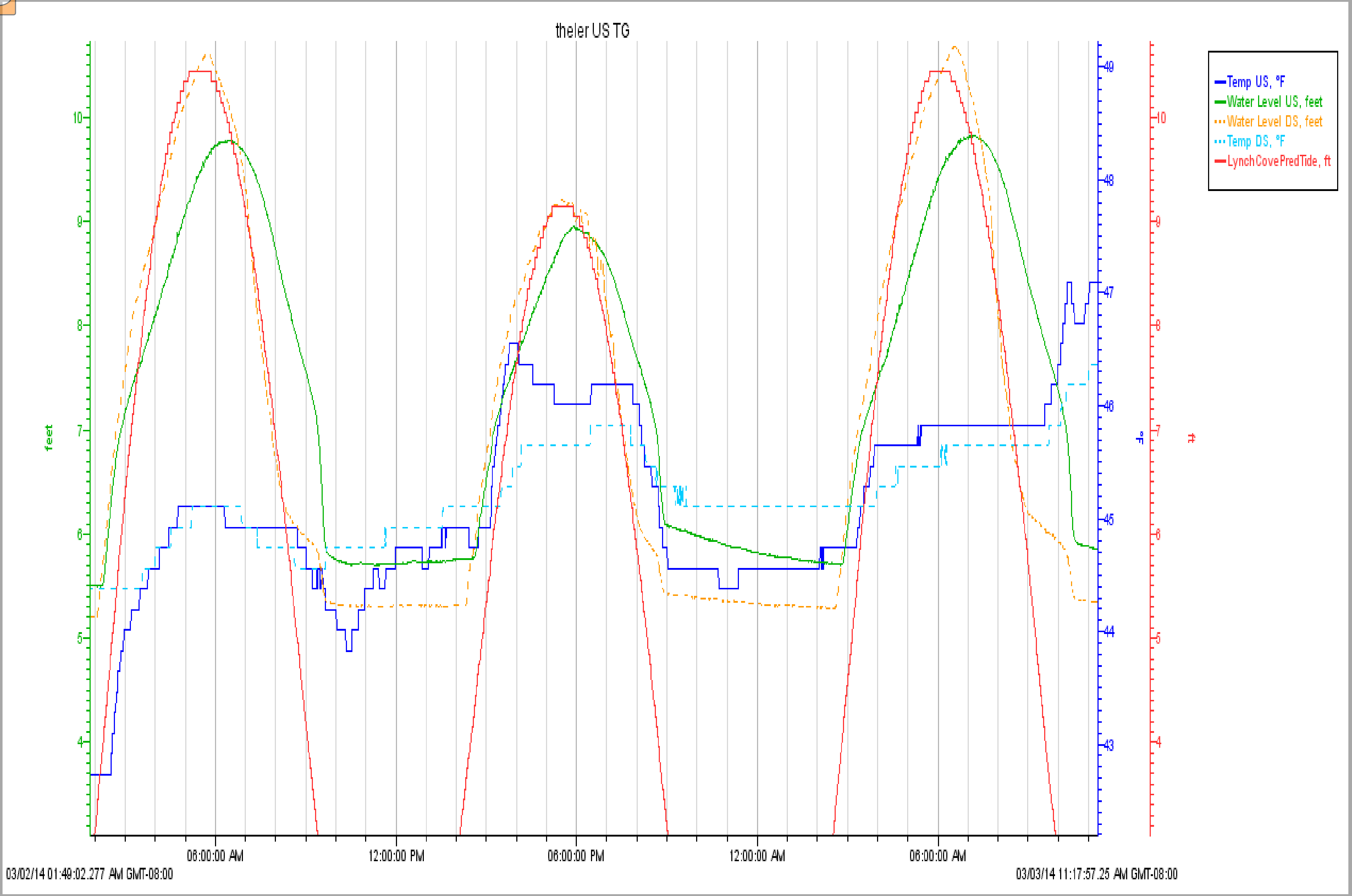
- Do juvenile fish move volitionally?
- What part of the tidal cycle are fish moving? Is this different for small juveniles vs. larger juveniles?
- Is high or low tide disproportionately important for fish access & productivity?
- Are fish swimming against the tidal flow?
- Which fish are the most vulnerable?



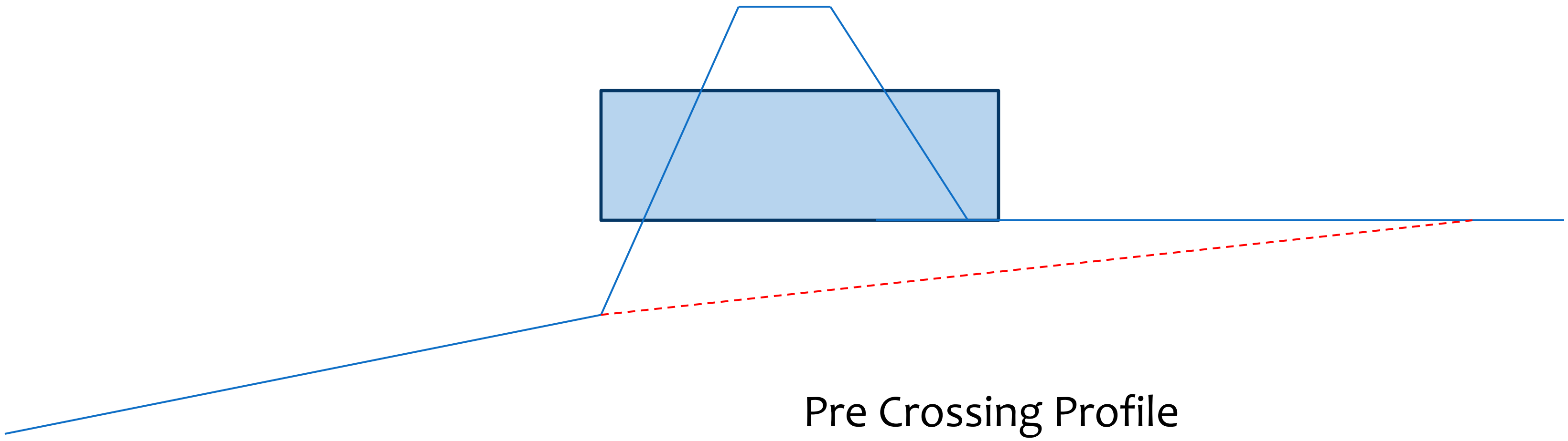
Olympia, WA Tides Oct-Dec 1990
Tide Height (MLLW)
20
15
10
5
0
-5
10/1/1990
10/8/1990
10/15/1990
10/22/1990
10/29/1990
11/5/1990
11/12/1990
11/19/1990
11/26/1990
12/3/1990
12/10/1990
12/17/1990
12/24/1990
12/31/1990
olytide
MHHW
MHW
MEAN
MLW
HighOBS
LowOBS



Tidal Station	MHHW	MLLW	10% Exceedance	90% Exceedance
Astoria	8.42	0	8.3	0.9
Aberdeen	10.07	0	10.2	1.8
Port Townsend	8.45	0	8.7	0.3
Seattle	11.35	0	11.4	0.8

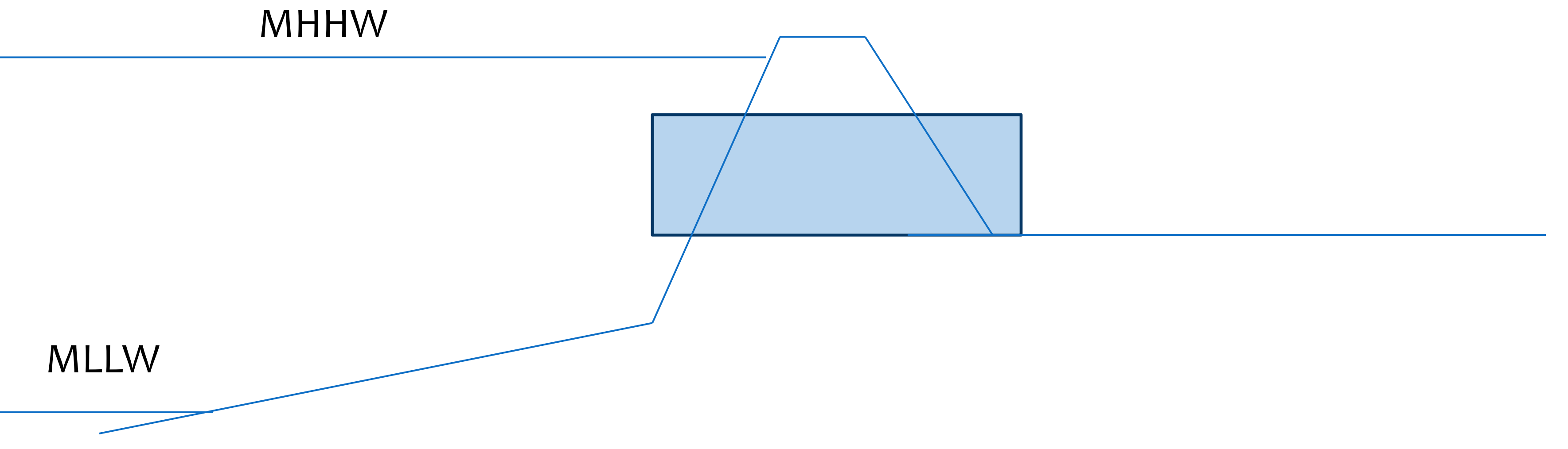

theler US TG
Temp US, °F
Water Level US, feet
Water Level DS, feet
Temp DS, °F
LynchCovePredTide, ft
feet
°F
ft
06:00:00 AM
12:00:00 PM
06:00:00 PM
12:00:00 AM
06:00:00 AM
03/02/14 01:49:02.277 AM GMT-08:00
03/03/14 11:17:57.25 AM GMT-08:00

Assessing tidal culverts



Pre Crossing Profile

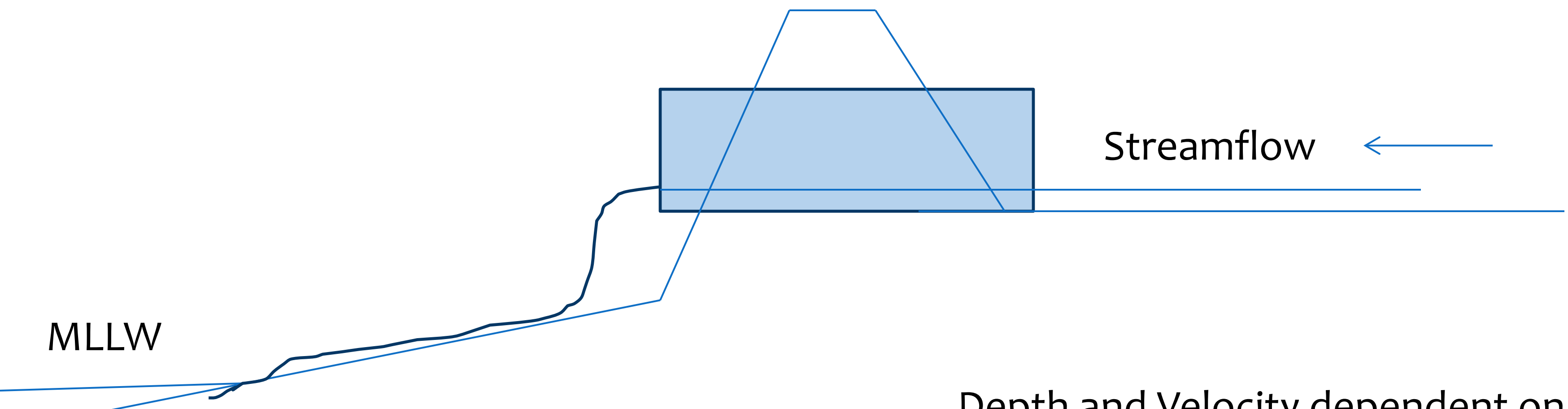
Assessing tidal culverts



Assessing tidal culverts At MLLW

Slack Low Tide

Outfall Drop exceeds limits of compliance

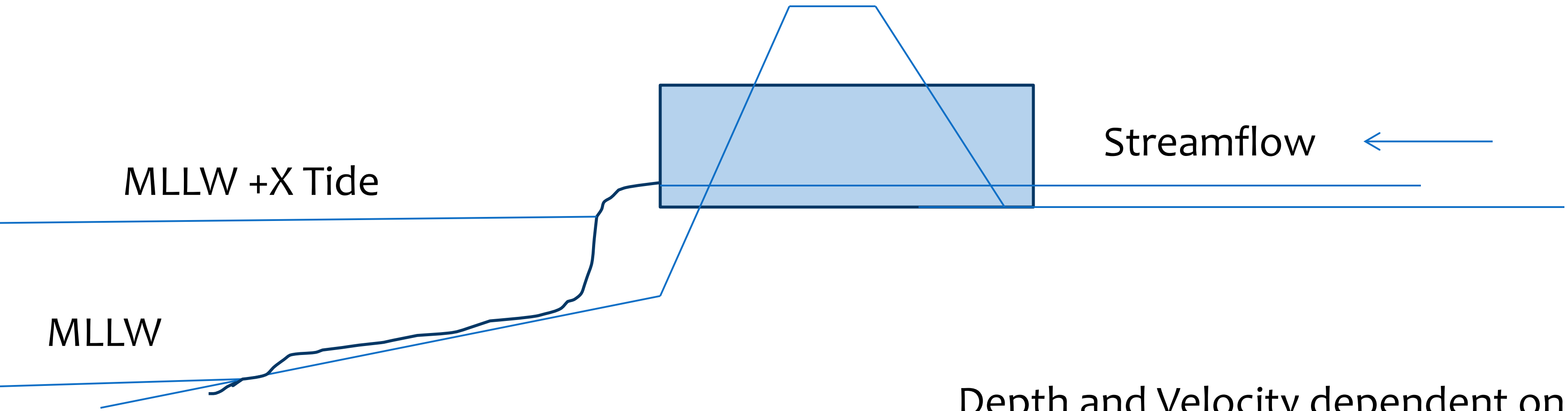


Depth and Velocity dependent on inflow hydrology and culvert geometry.

Assessing tidal culverts At MLLW + X Tide

Flood (incoming) Tide

Outfall Drop beginning to be backwatered by incoming tide and at limits of compliance

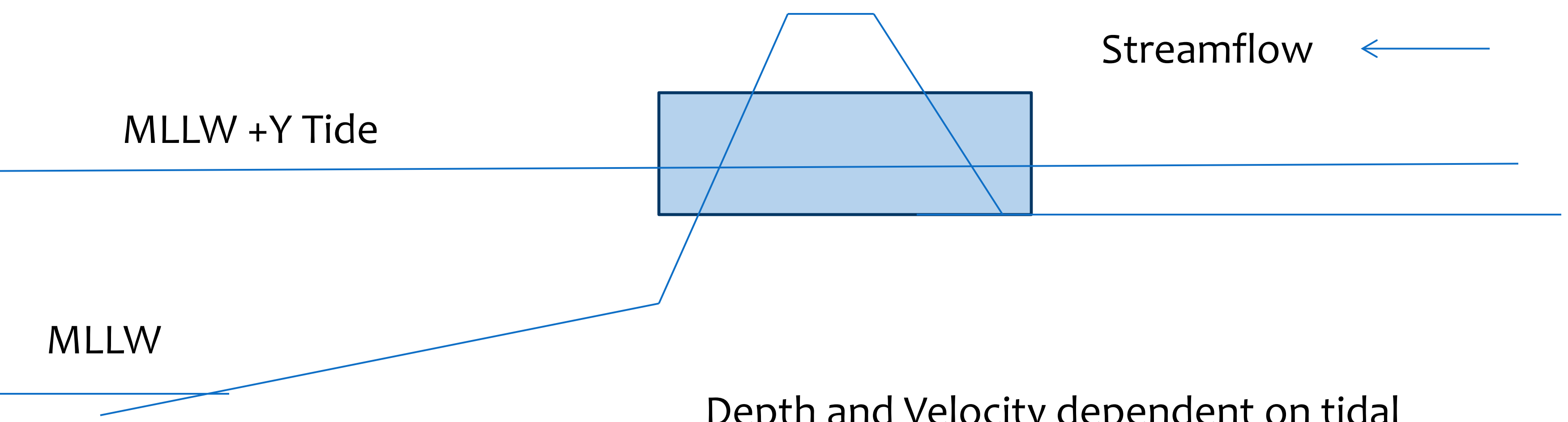


Depth and Velocity dependent on inflow hydrology and culvert geometry.

Assessing tidal culverts At MLLW + Y Tide

Flood Tide

Outfall Drop completely backwatered by incoming tide and within limits of compliance

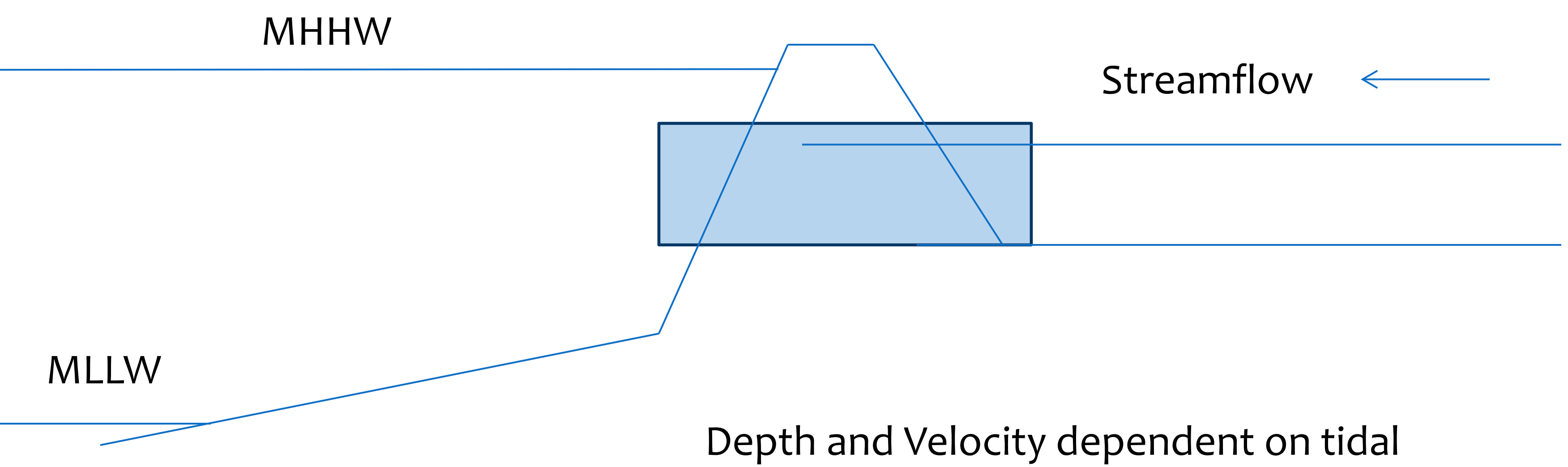


Depth and Velocity dependent on tidal backwater, inflow hydrology and culvert geometry.

Hydraulic impacts from tidal culverts MHHW

Slack High Tide

Outfall Drop completely backwatered by incoming tide and within limits of compliance

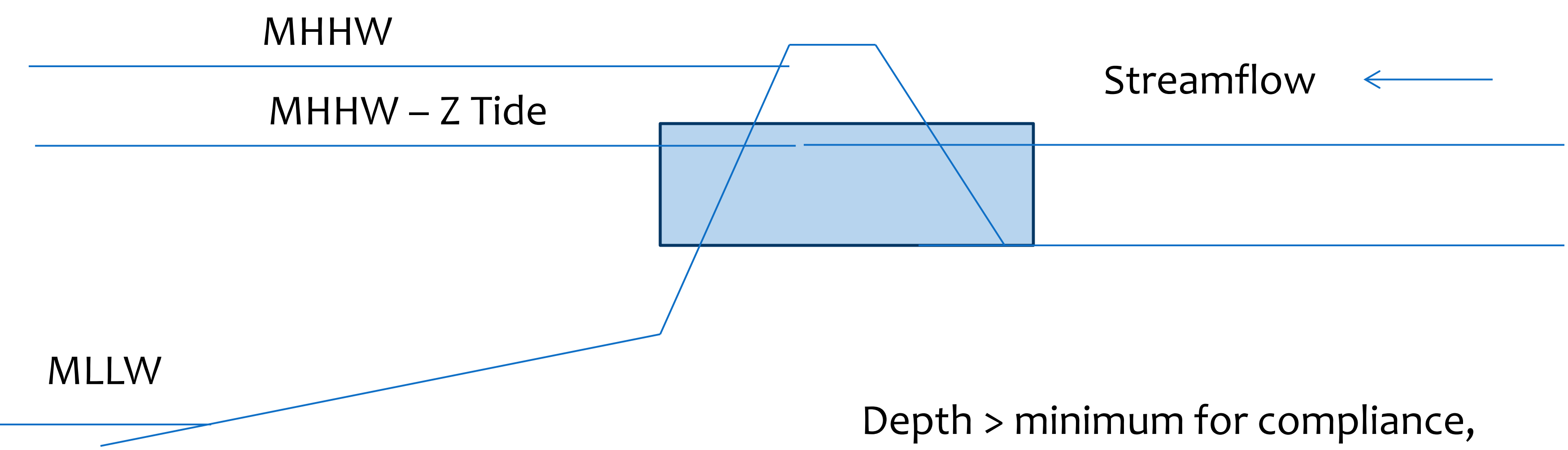


Depth and Velocity dependent on tidal backwater, inflow hydrology and culvert geometry.

Assessing tidal culverts MHHW – Z Tide

Ebb Tide

Outfall Drop completely backwatered by incoming tide and within limits of compliance

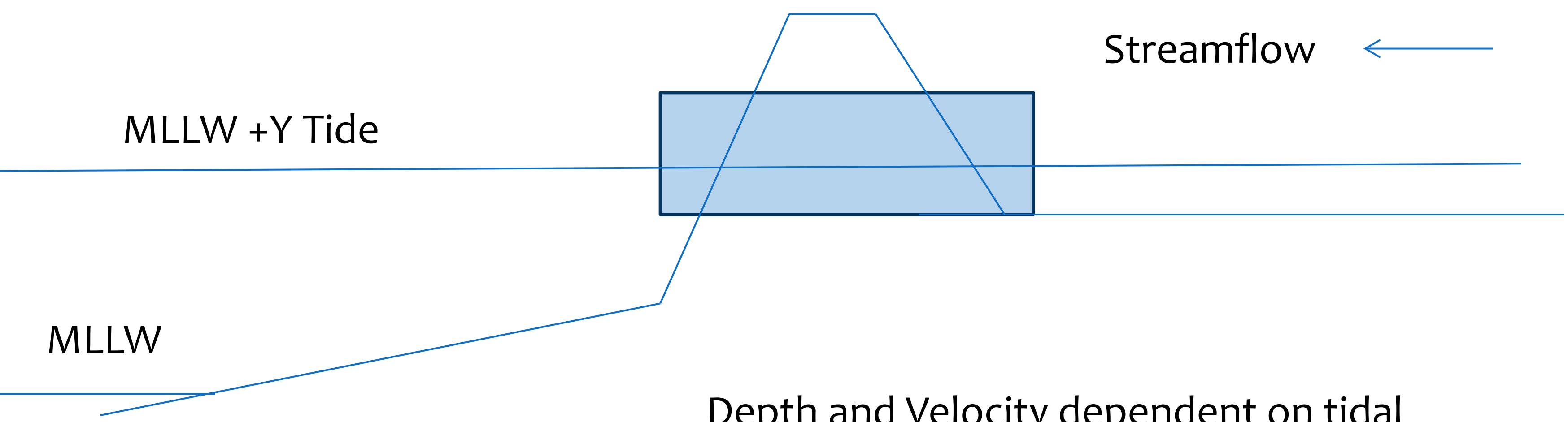


Depth > minimum for compliance, instantaneous Velocity = O

Assessing tidal culverts At MLLW + Y Tide

Ebb Tide

Outfall Drop completely backwatered by incoming tide and within limits of compliance

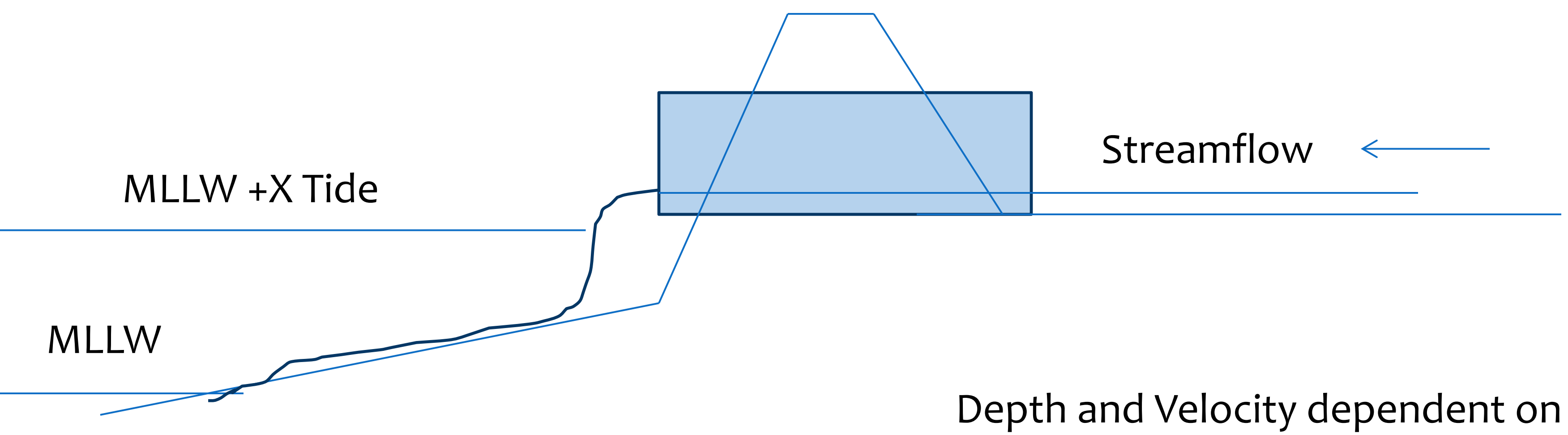


Depth and Velocity dependent on tidal backwater, inflow hydrology and culvert geometry.

Assessing tidal culverts At MLLW + X Tide

Ebb Tide

Outfall Drop beginning to be backwatered by incoming tide and at limits of compliance

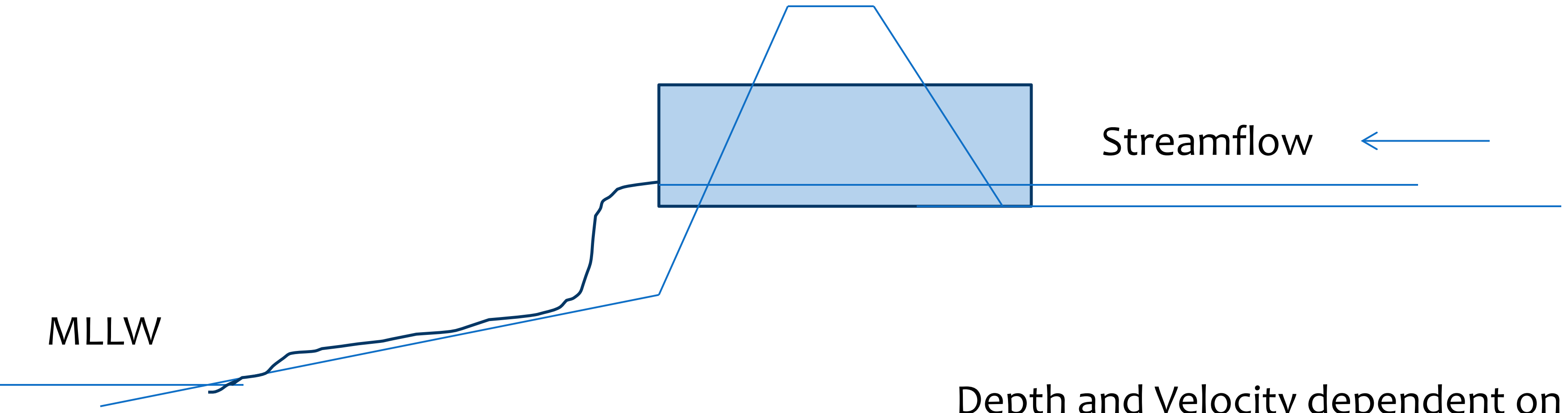


Depth and Velocity dependent on inflow hydrology and culvert geometry.

Assessing tidal culverts At MLLW

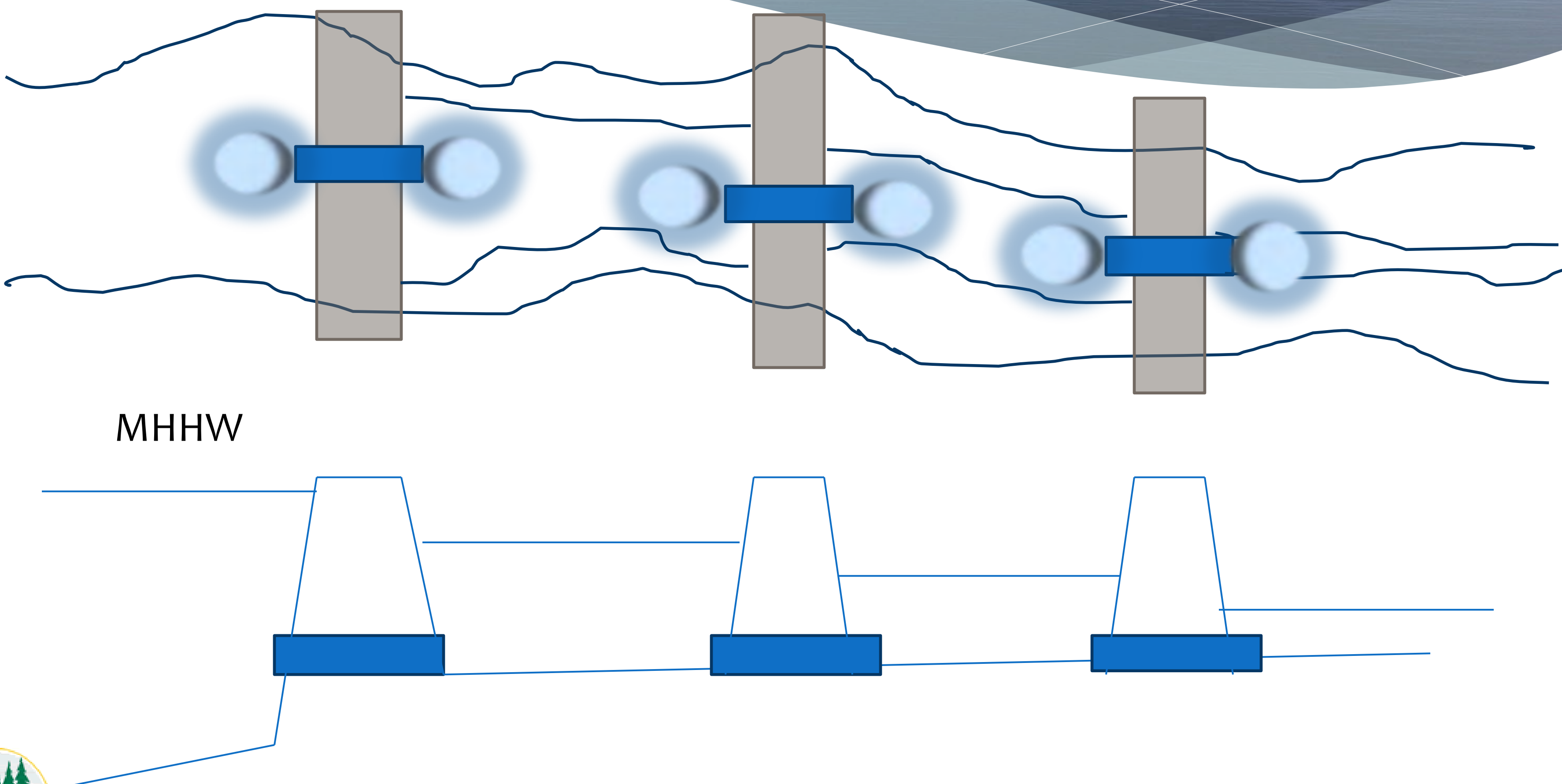
Slack Low Tide

Outfall Drop exceeds limits of compliance



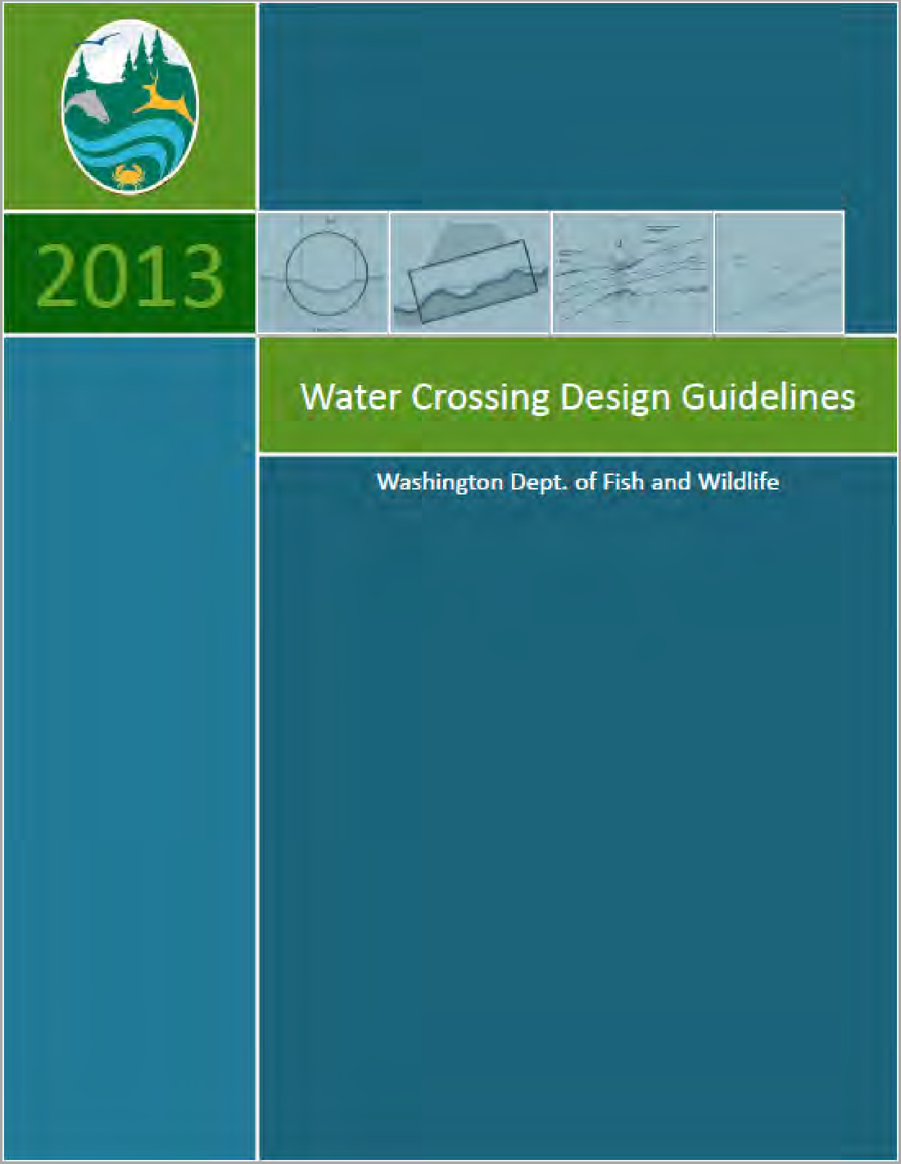
Depth and Velocity dependent on inflow hydrology and culvert geometry.

Assessing tidal culverts compounding attenuation



Standardized design guidelines for fish passage structures

* **Removal** – determine if structure is actually needed
* **Bridge** – channel-spanning bridges facilitate natural in-stream processes and habitat connectivity for fish and wildlife
* **Stream simulation culvert** – culvert wider than and placed at the same gradient as the stream channel and includes a bed throughout to mimic natural in-stream processes.
* **No-slope culvert** – small culvert set at a flat gradient used for simple installations.
* **Retrofit or fishway** – Used only for situations where other options are not feasible.

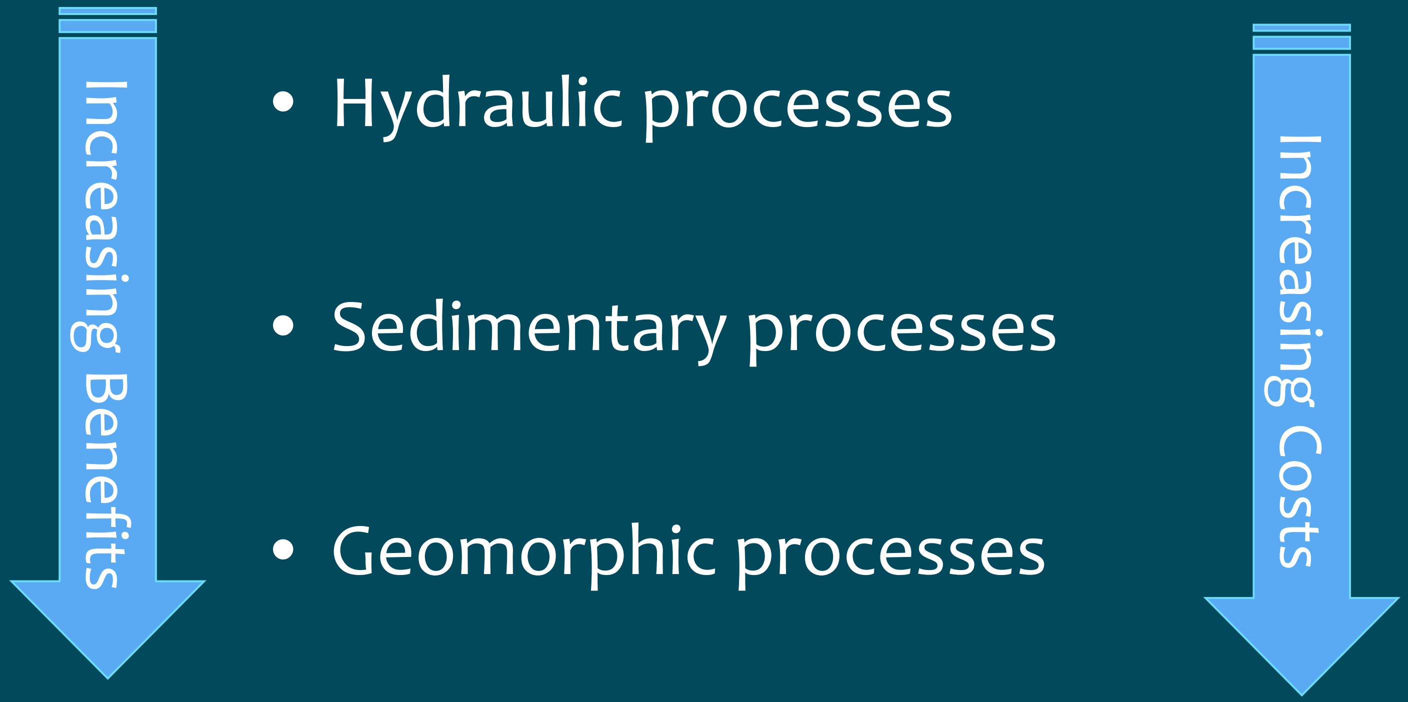


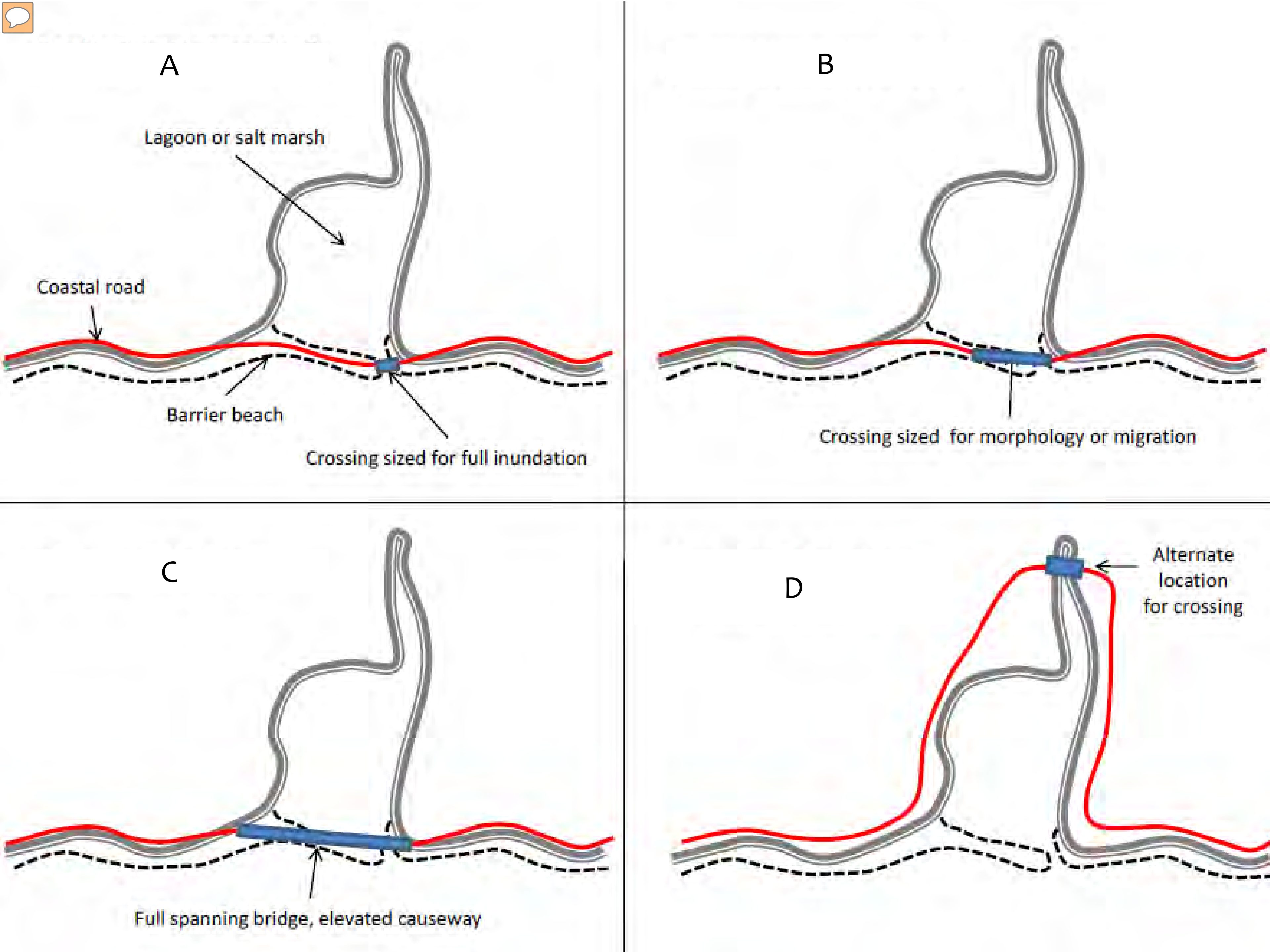
Barnard, R. J., J. Johnson, P. Brooks, K. M. Bates, B. Heiner, J. P. Klavas, D.C. Ponder, P.D. Smith, and P. D. Powers (2013), **Water Crossings Design Guidelines,** Washington Department of Fish and Wildlife, Olympia, Washington.

http://wdfw.wa.gov/hab/ahg/culverts.htm

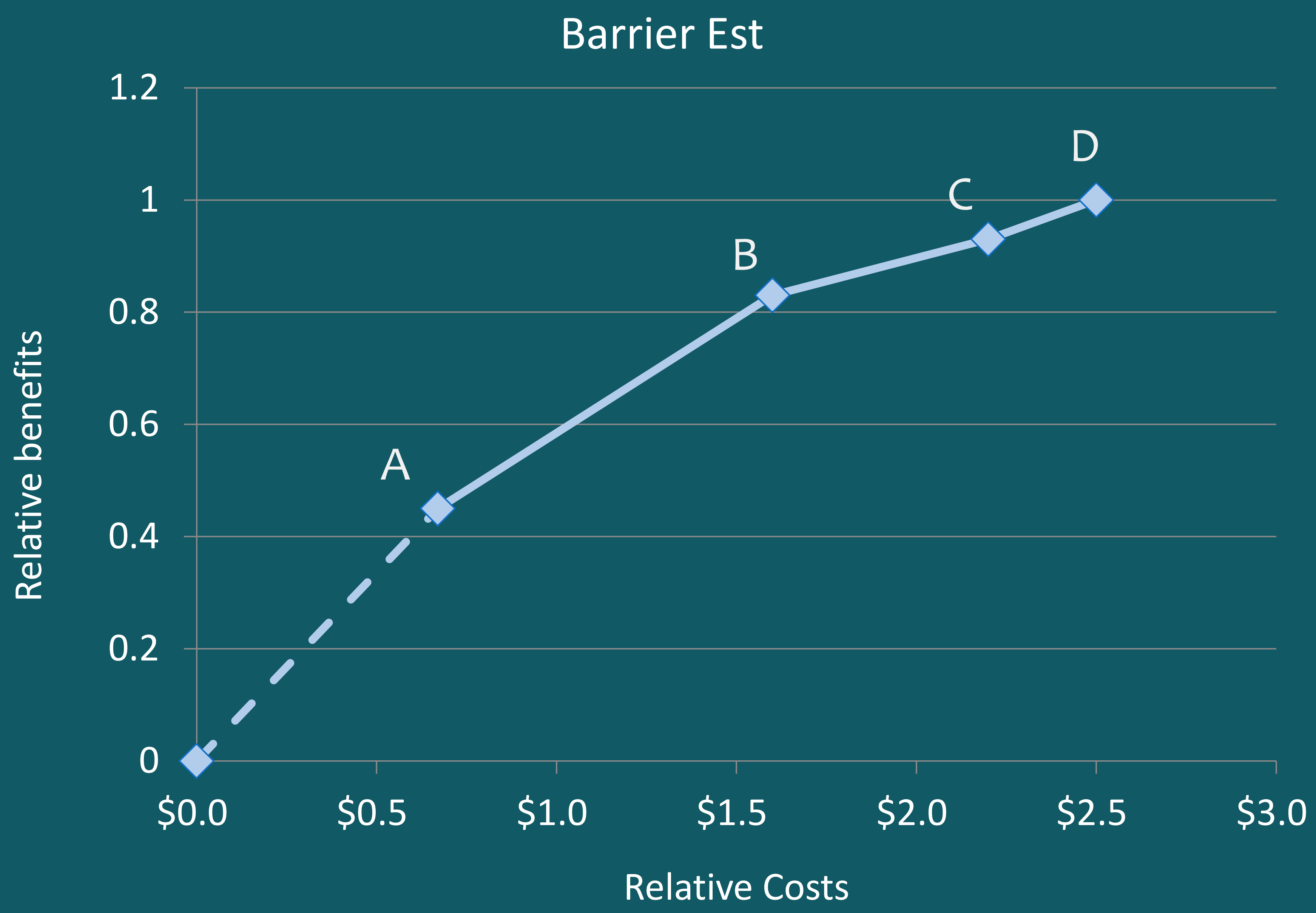
Appendix D: Tidally Influenced Crossings

Alternative analysis using a hierarchy of benefits





A
Lagoon or salt marsh
Coastal road
Barrier beach
Crossing sized for full inundation
B
Crossing sized for morphology or migration
C
Full spanning bridge, elevated causeway
D
Alternate location for crossing

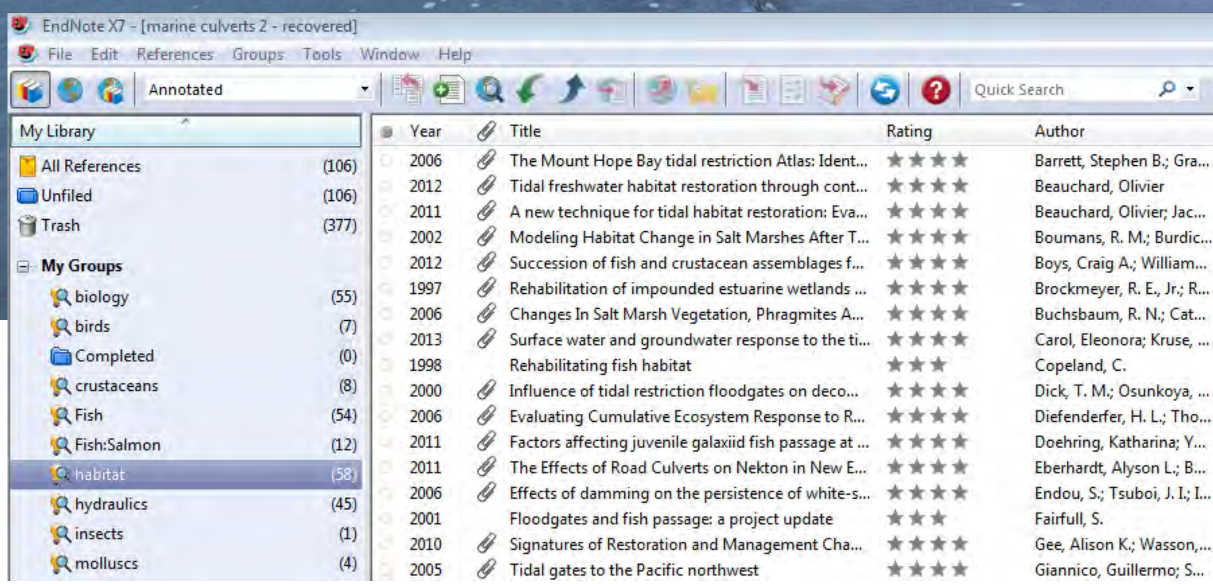

Barrier Est
1.2
1
0.8
0.6
0.4
0.2
0
A
B
C
D
Relative benefits
$0.0
$0.5
$1.0
$1.5
$2.0
$2.5
$3.0
Relative Costs

Next steps for technical work

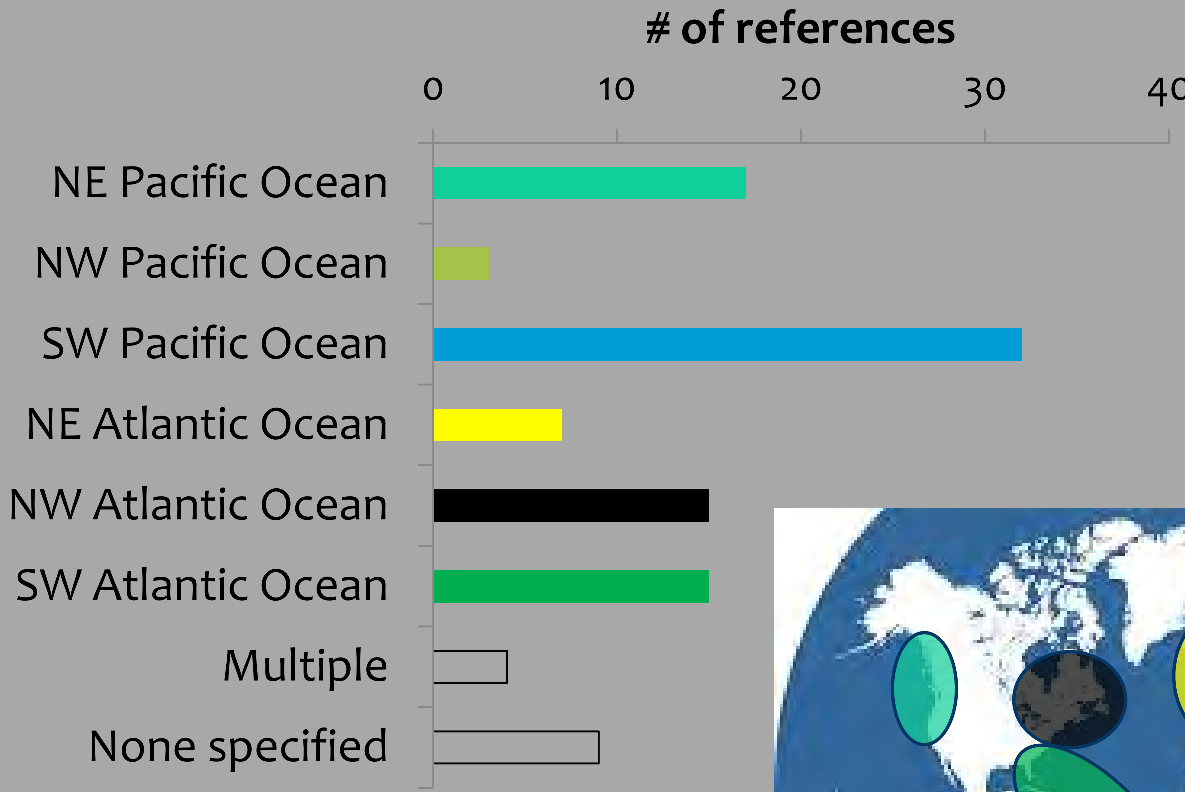
- **Define fish passage in tidal areas**
  - Which fish? What life stage? What time of year? Where in the system? When in the tidal stage?
- **Revise protocol for barrier assessment**
  - Field crew & engineering assessment
- **Revise Priority Index to address tidal areas**
- **Revise technical guidelines for design in tidal areas**
  - Fish passage design criteria as baseline
  - Habitat restoration design criteria for fish access to tidal areas
  - Is there a geomorphic approach for design (e.g. stream sim for freshwater areas) that makes sense for tidal areas?

Literature review for marine culverts and other structures

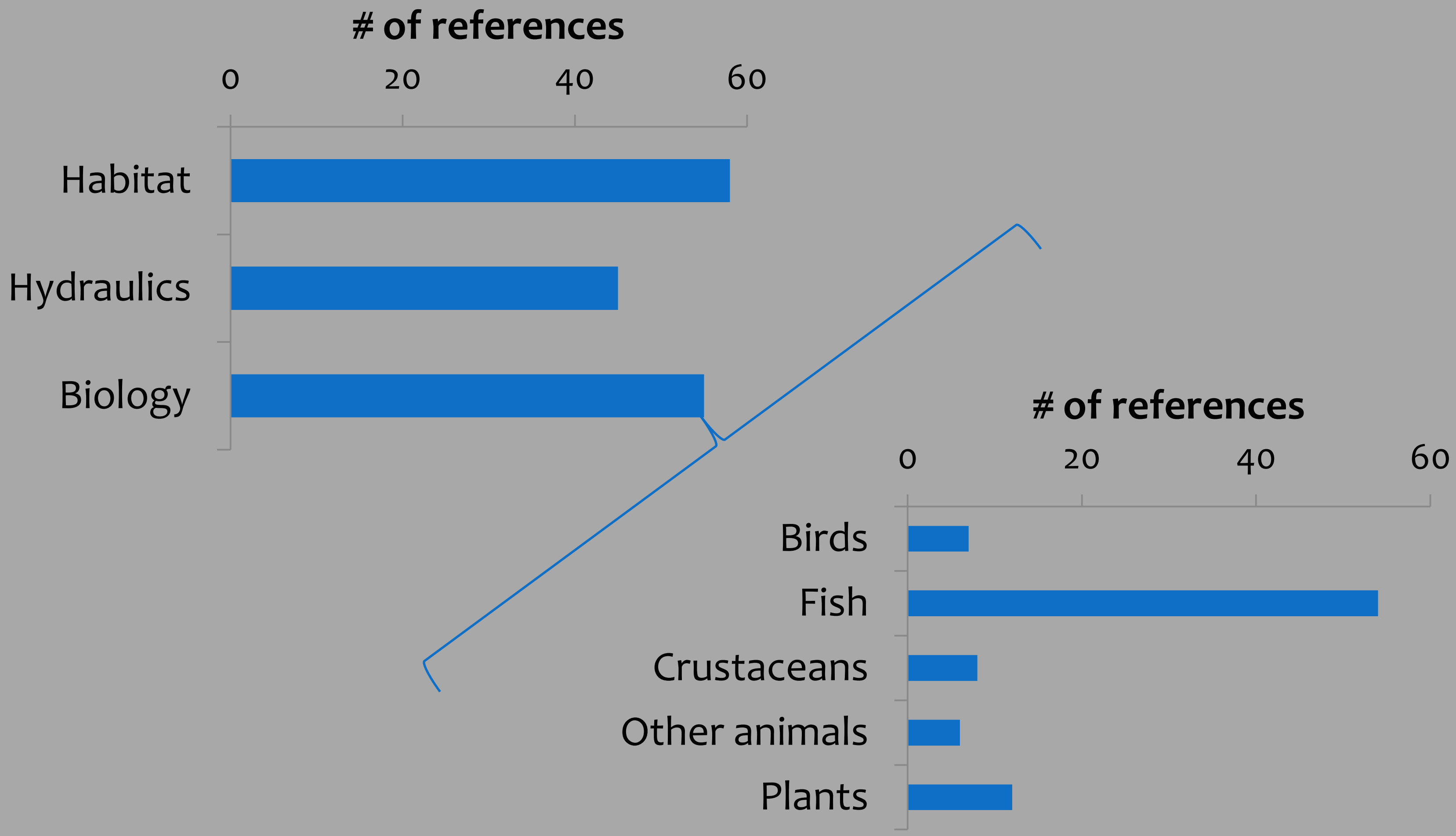
- Comprehensive Endnote database
  - with pdfs
  - groupings by keywords
- Peer-reviewed literature
- Over 100 references



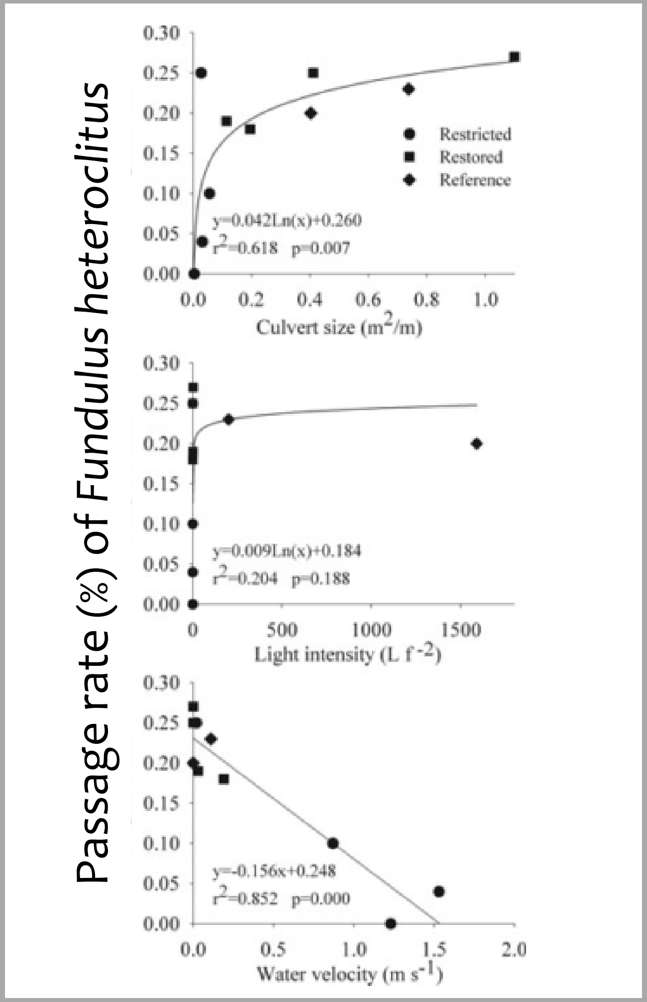
International distribution of references



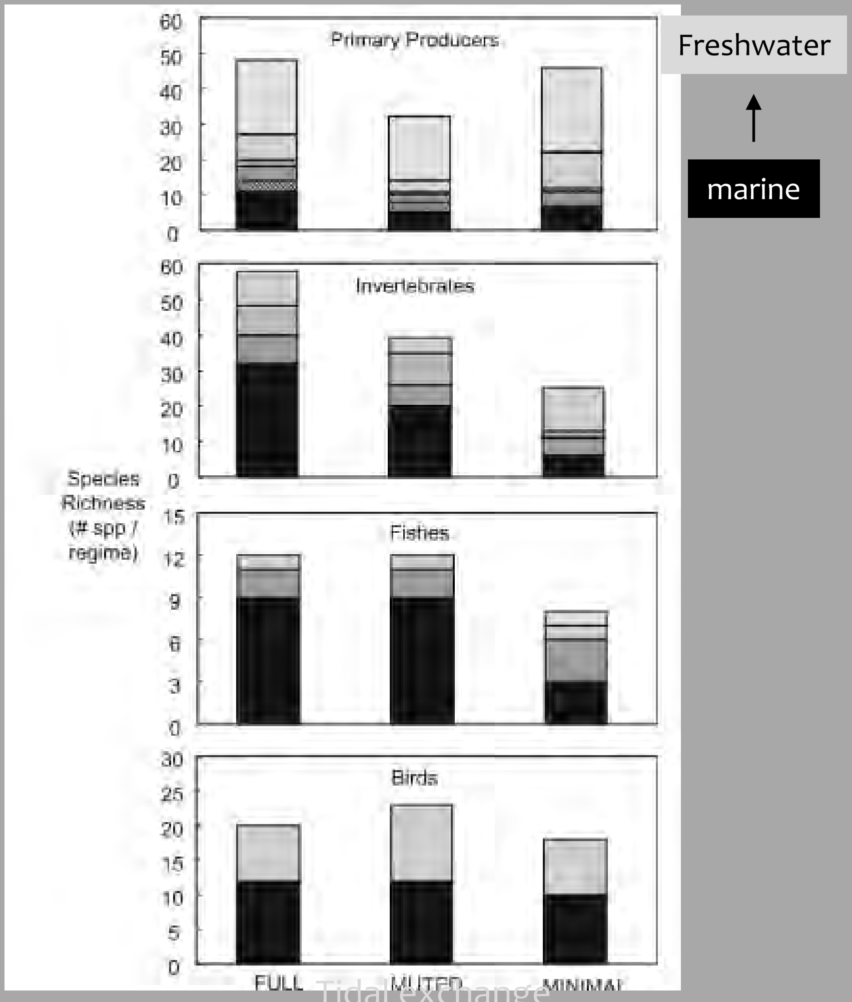
Topics covered by references



Goal: provide guidance on structure design, operation, and management supporting biota



Eberhardt et al. 2010



Ritter et al. 2008

Next steps

- Add “gray” literature
- Add additional literature to assist guidance
  (e.g., flow thresholds affecting fish, reference conditions)
- Determine information gaps
- Produce review of the literature

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Thank you!

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