Enhancing Cold Water Refuges at Small Tributaries in the Lower Columbia River

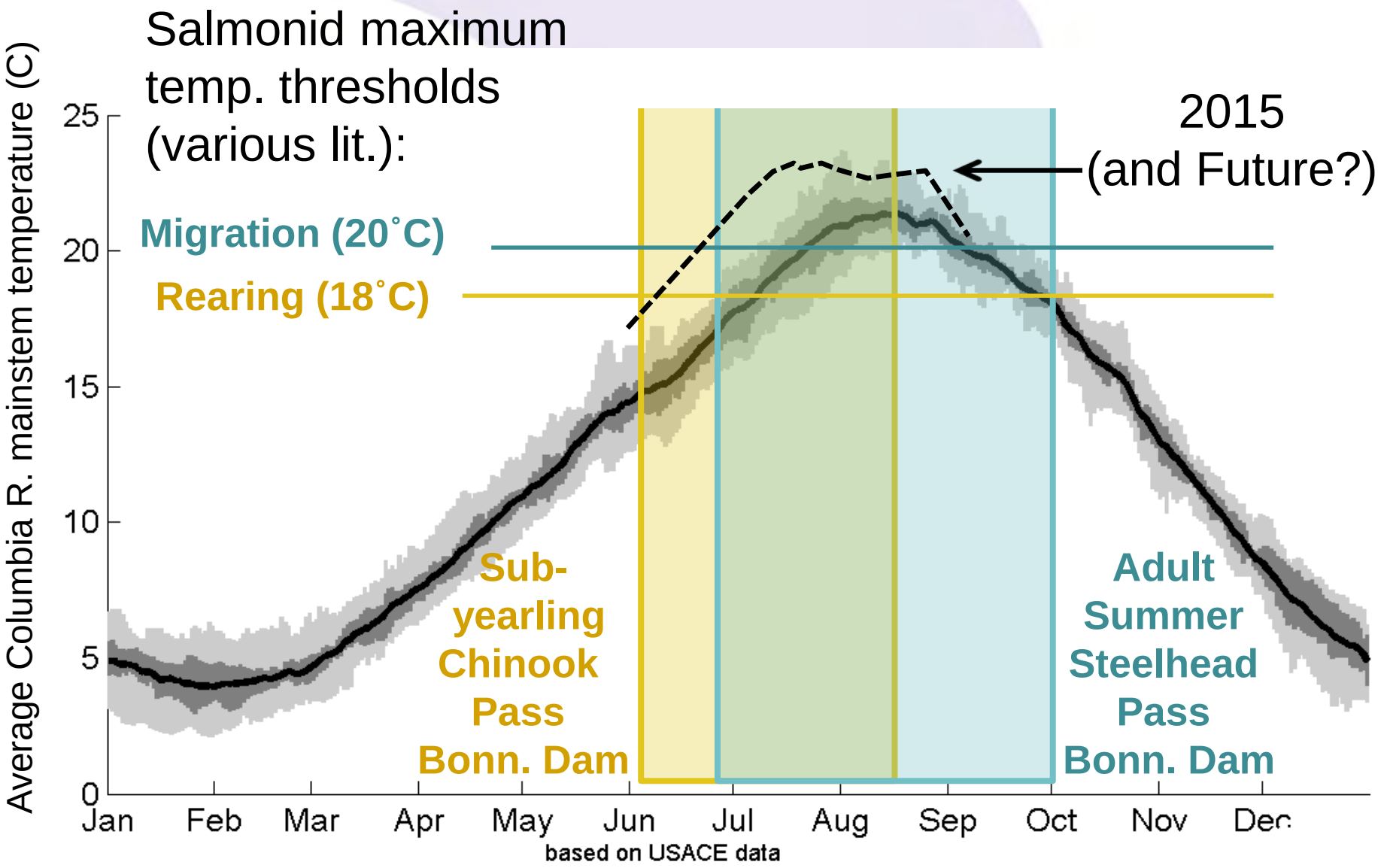
**Keith Marcoe*, Chris Collins, Catherine Corbett, Paul Kolp (LCEP)

Mike Burke (Inter-fluve)

Lower Columbia Estuary Partnership

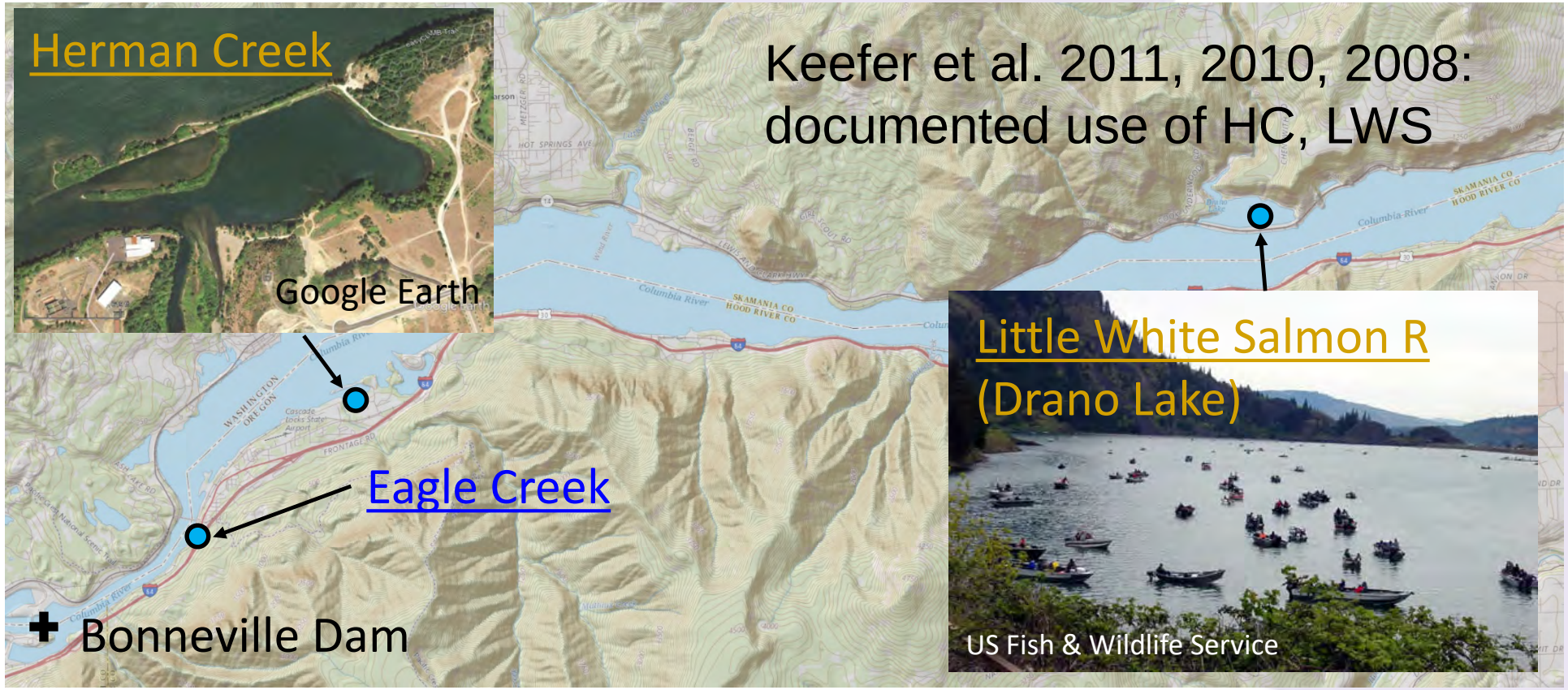
inter·fluve

Purpose: address warm Columbia R. temperature during summer migratory period for salmonids



- How are salmonids responding to high temperatures?

thermal refuge use in mid-Columbia above Bonneville Dam



- **What is happening in the lower Columbia?**

LCEP Thermal Refuge Study, 2015 - 2018

- mapped cold water inputs from Longview to Bonneville

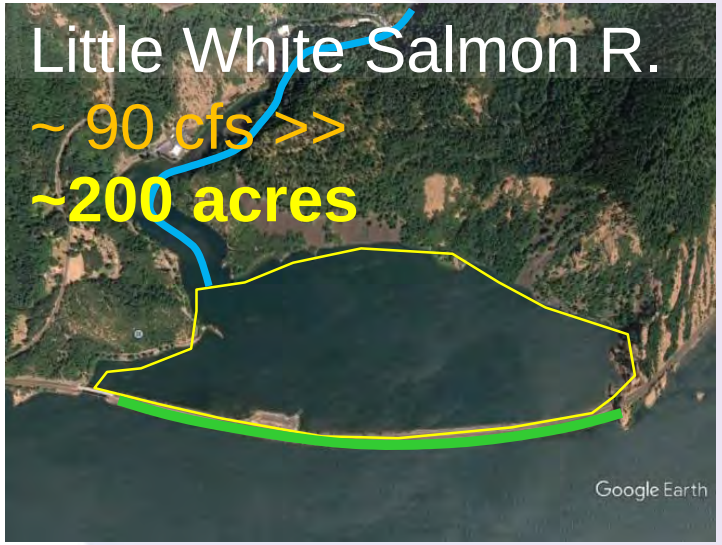
> no suitable thermal refuge from Lewis R. to Eagle Cr. (57 mile gap)

LCEP Thermal Refuge Study, 2015 - 2018

- Feasibility study for enhancing confluences of selected CR Gorge tributaries to create cold water refuges
- Strategy: re-create (on a smaller scale) mid-Columbia refuges through placement of flow diversion structures
- Test using water temperature modeling

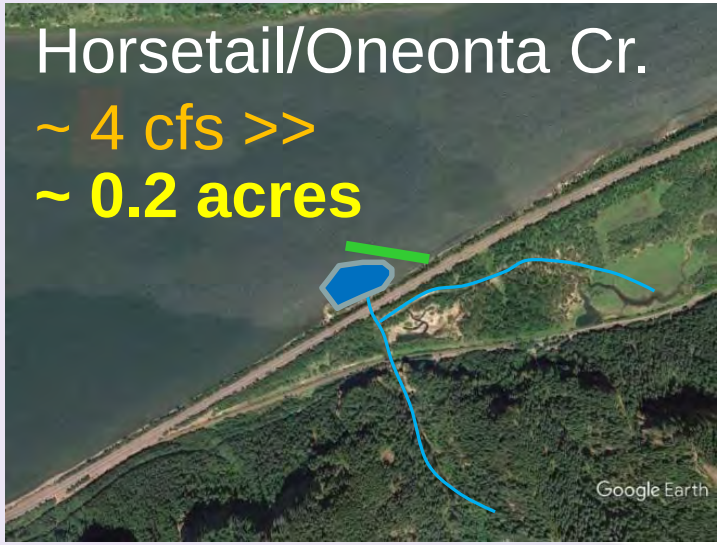
Scale Comparison (existing summer conditions)

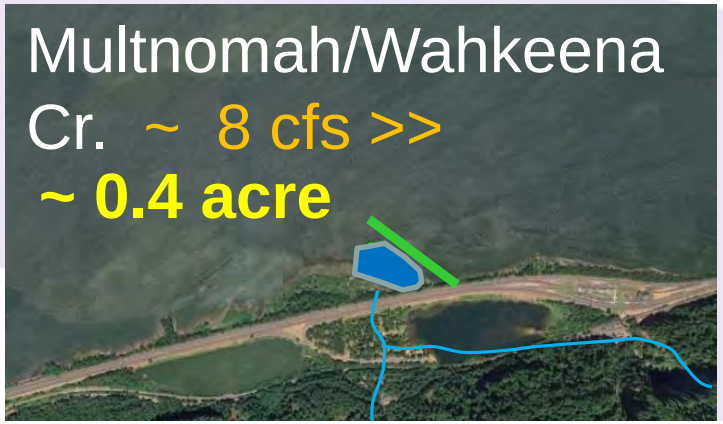
mid-Columbia tribs.



Mid-Columbia: artificial landforms have created thermal refuge zones

Lower Gorge tribs.



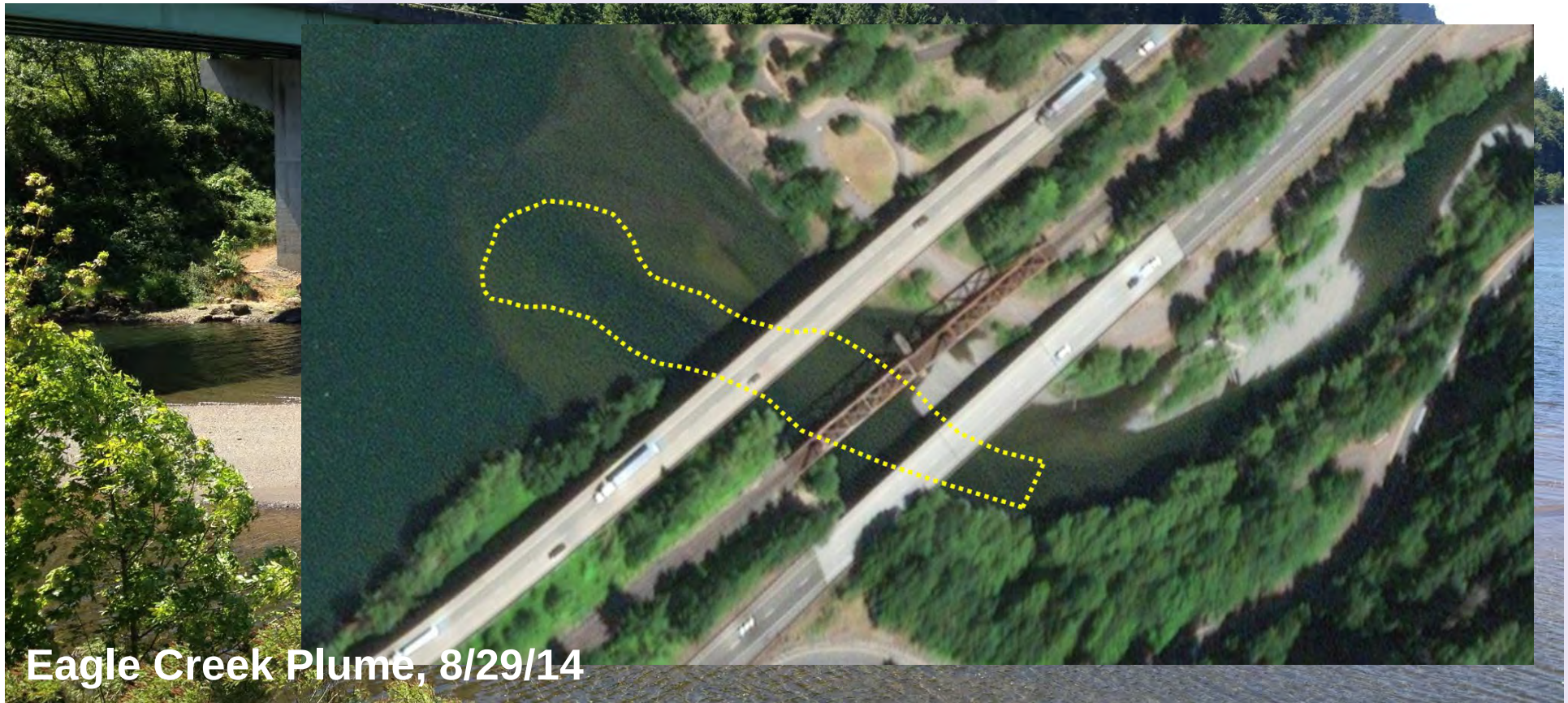


Can we do the same in lower Columbia?

Cold water refuge – LCEP Criteria

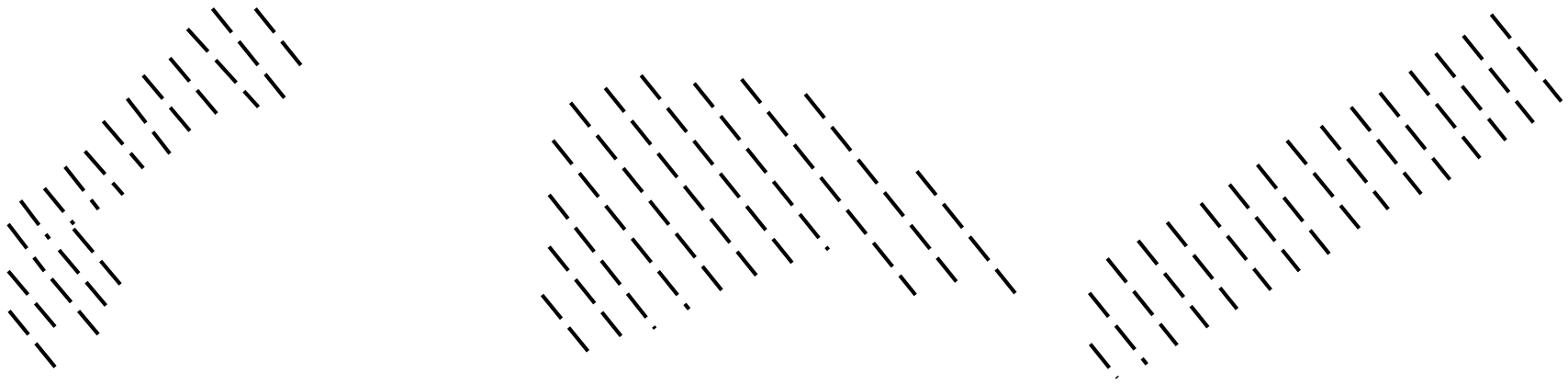
Suitable for juvenile and adult salmonid use

- **Temperature:** > 2°C colder than mainstem (Keefer et al. 2011)
- **Depth:** 0.5m minimum for juveniles (Bottom et al. 2005)
  2m minimum for adults (Johnson et al. 2010)
- **Area:** ~1 acre (smallest plume reported above Bonneville Dam)



Tributary Potential To Meet Suitability Criteria

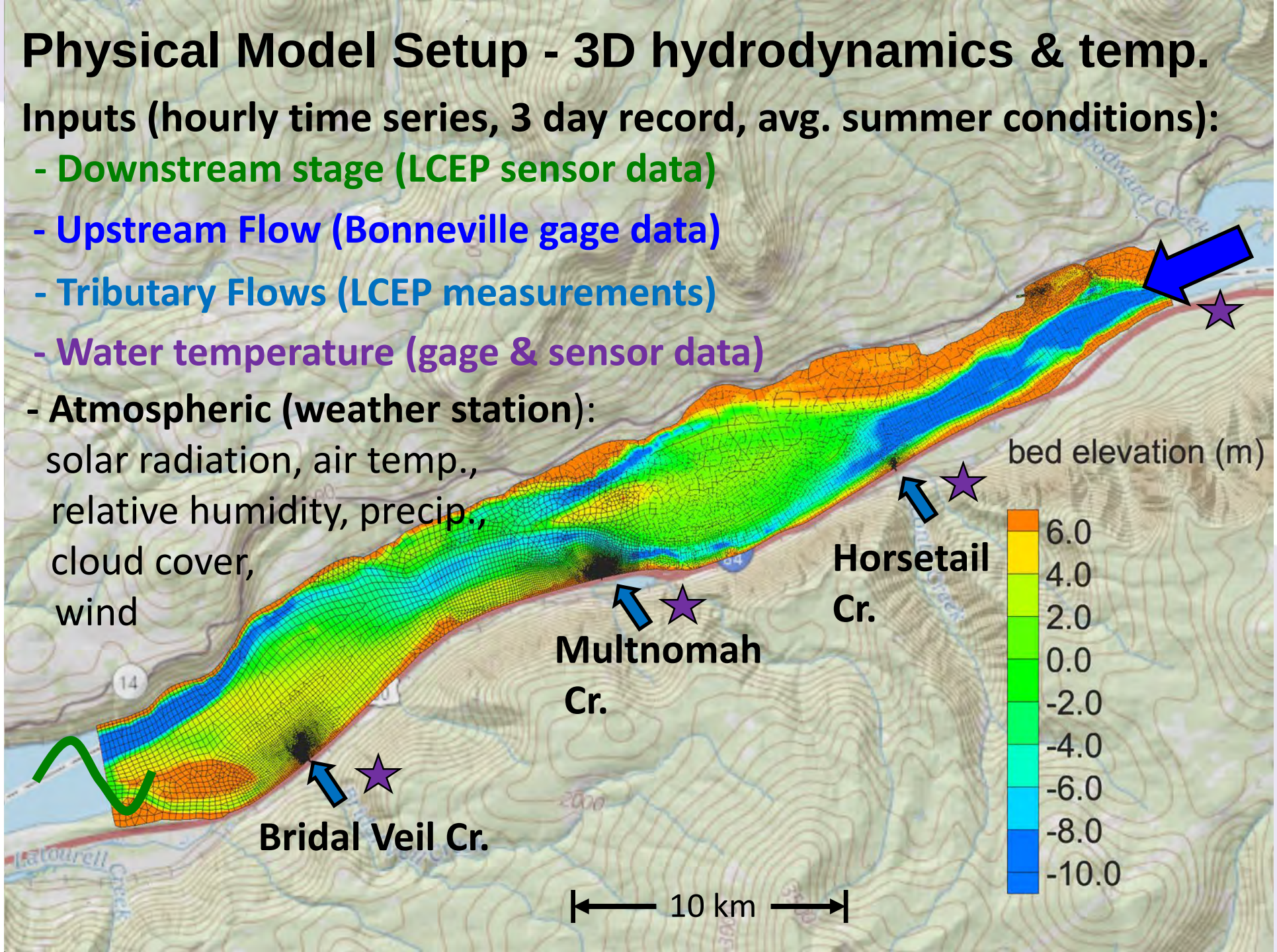
Criteria	Bridal Veil	Multnomah	Horsetail
confluence depth	1-2 m	1-2 m	0.5-1 m
temperature (avg,°C)	13.5	13.3	17.2
flow (area)	10–14 cfs	7-11 cfs	3-7 cfs
*detectible by fish?	juv./ad.	juv./ad.	juv./ad.



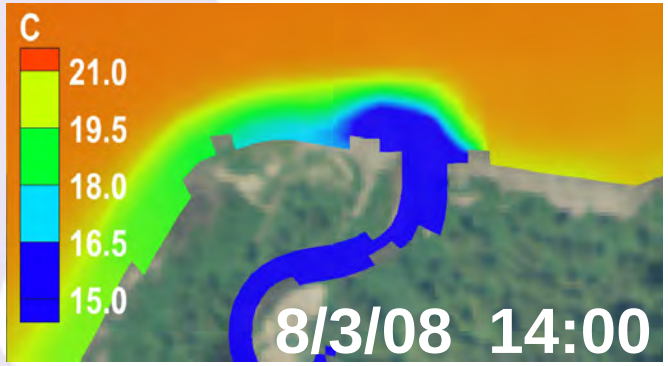
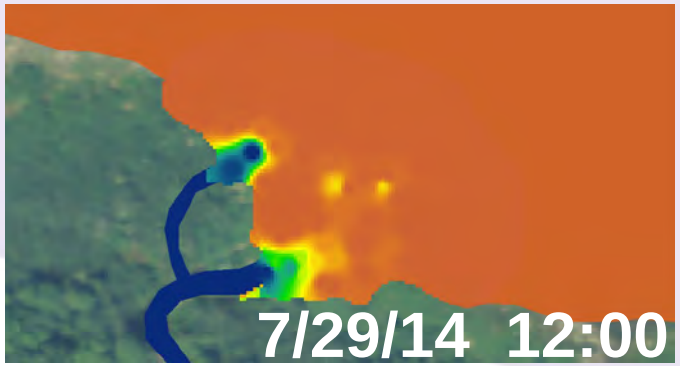
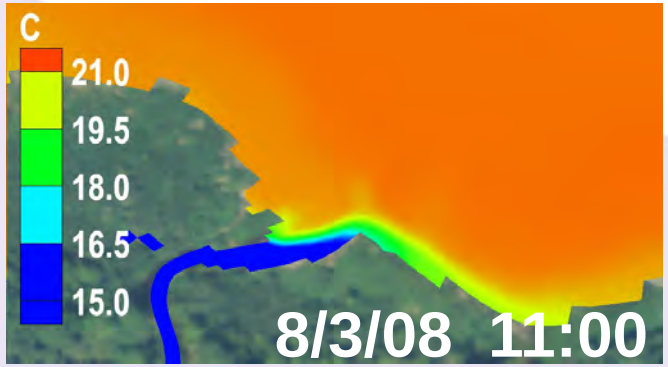
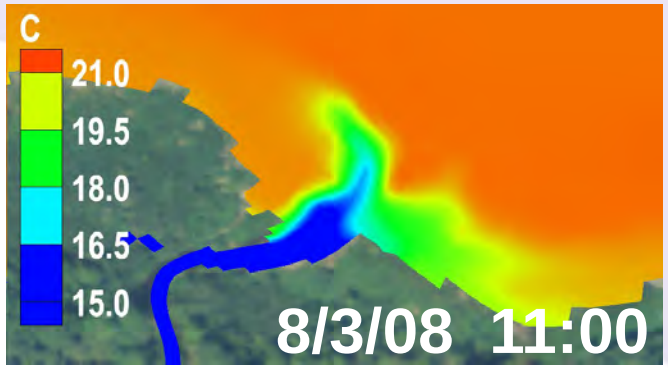
Physical Model Setup - 3D hydrodynamics & temp.

Inputs (hourly time series, 3 day record, avg. summer conditions):

- Downstream stage (LCEP sensor data)
- Upstream Flow (Bonneville gage data)
- Tributary Flows (LCEP measurements)
- Water temperature (gage & sensor data)
- **Atmospheric (weather station)**:
  solar radiation, air temp.,
  relative humidity, precip.,
  cloud cover,
  wind

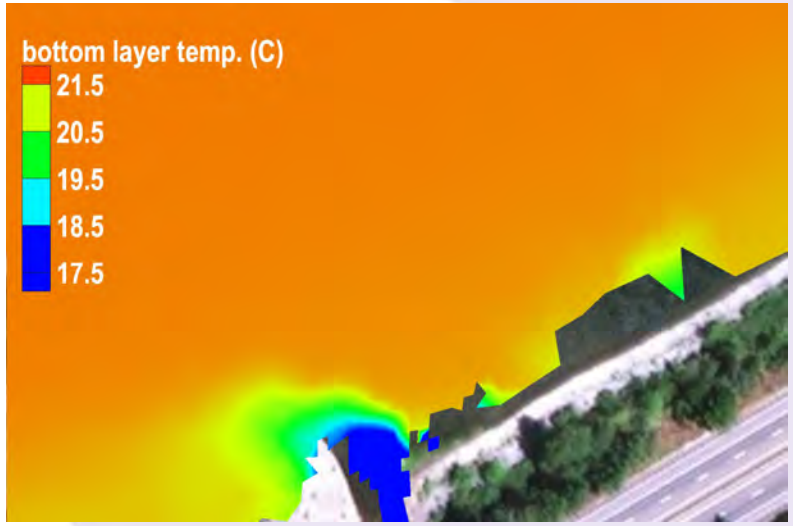


Model Validation

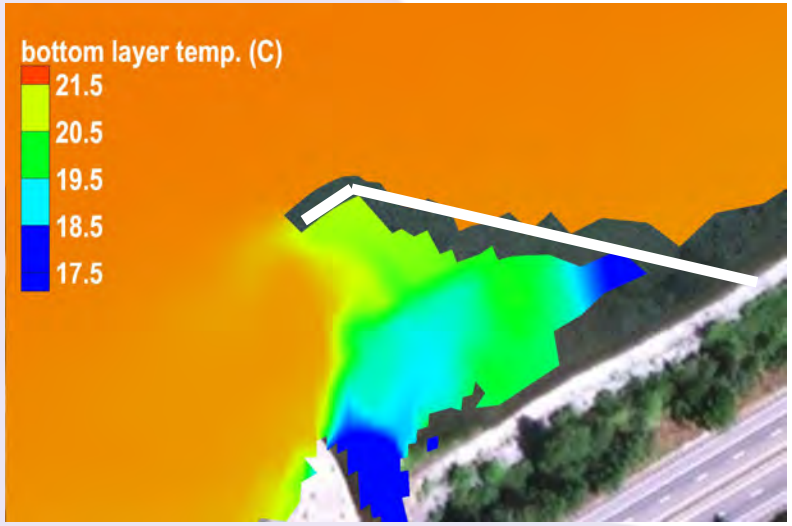
Stream confluence	observed temperature	model temperature
Bridal Veil Cr. (@ surface)		
Multnomah Cr. (@ surface)		
Multnomah Cr. (@ max. depth)		

Model Results: Horsetail Cr. confluence temperature

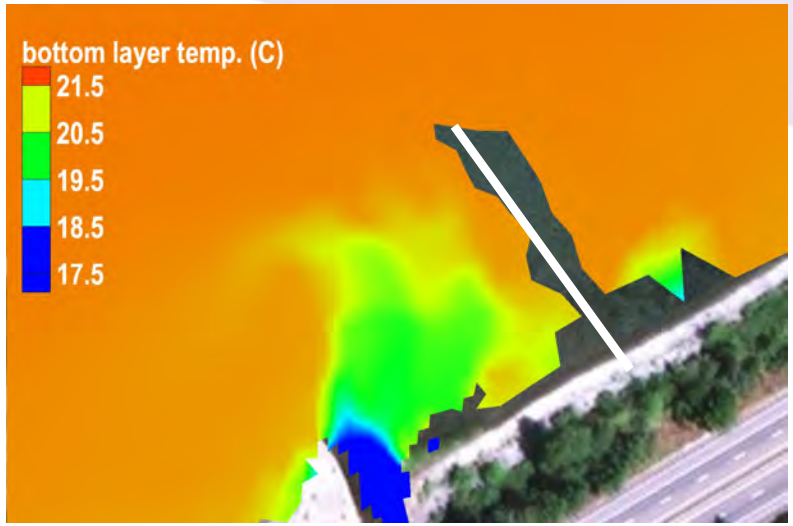
existing condition



upstream structure



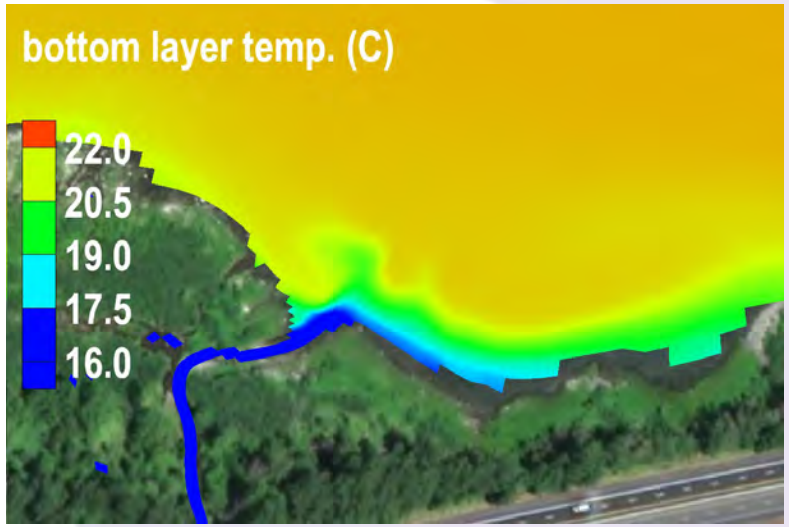
upstream, perpendicular



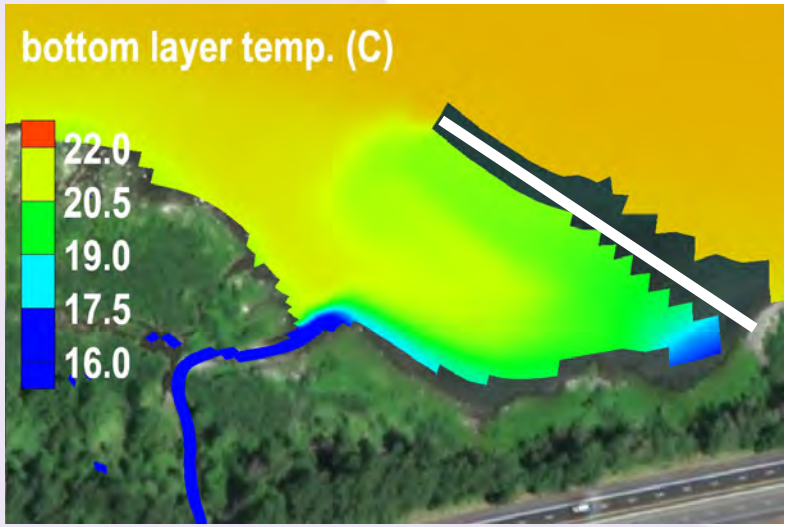
maximum enclosure

Model Results: Multnomah Cr. confluence temperature

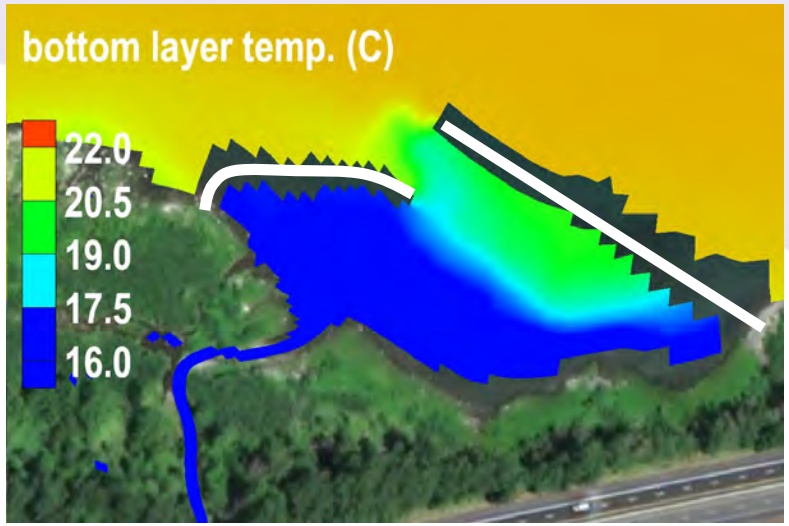
existing condition



upstream structure



max. enclosure



Model Results: Temperature Variability

$\Delta\, T$ vs. time @ Bridal Veil Cr.

$$T_{max.\,enclosure} - T_{existing\ condition}$$

Variations are due to time varying:

- mainstem flow
- atmospheric heating/cooling
- wind strength

blue shades: areas of cold water enhancement

Model Results – Thermal Enhancement Potential

- smaller mid-Columbia refuges (reference):

  Eagle Creek: ~ 1.2 ac.

  Herman Creek: ~ 20 ac.

- lower Columbia model results:

	~Existing Plume Size	~Enhanced Plume Size*
Horsetail Cr.	0.2 ac.	1.2 ac.
Multnomah Cr.	0.4 ac.	6.2 ac.
Bridal Veil Cr.	0.6 ac.	7.4 ac.
	Sum:	14.8 ac.

* Enhanced plume sizes can likely be increased, but cost and other factors must be considered.

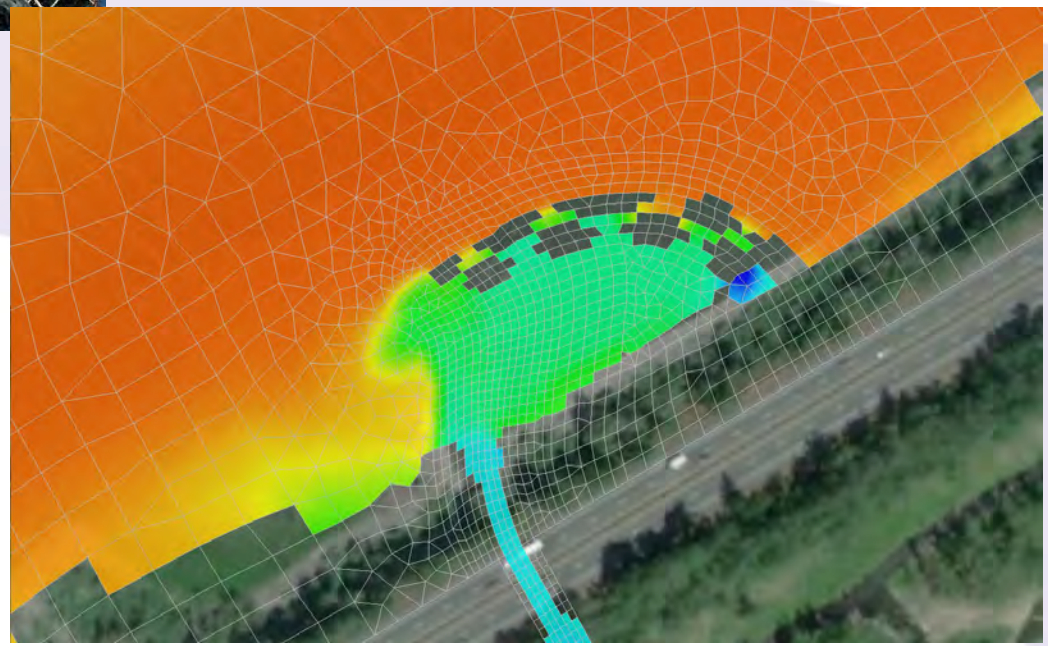
Model Results – Conclusions

- Based on model results, lower Gorge tributary confluences could provide summer refuge for migrating salmonids, with enhancement.
- Sizes of created refuges in the lower Gorge would be comparable to smaller mid-Columbia refuges with documented salmonid use.
- Structures are needed to divert mainstem flows. Existing landforms are not enough by themselves.
- Plume characteristics (size and temperature) are dynamic due to multiple forcing factors (flows, water temperatures, atmospheric effects)

Next Steps – Phase 2 Feasibility

- Structure Intensity: ***LWD Jam*** → ***Landform***

Model temperature effects for porous structures:

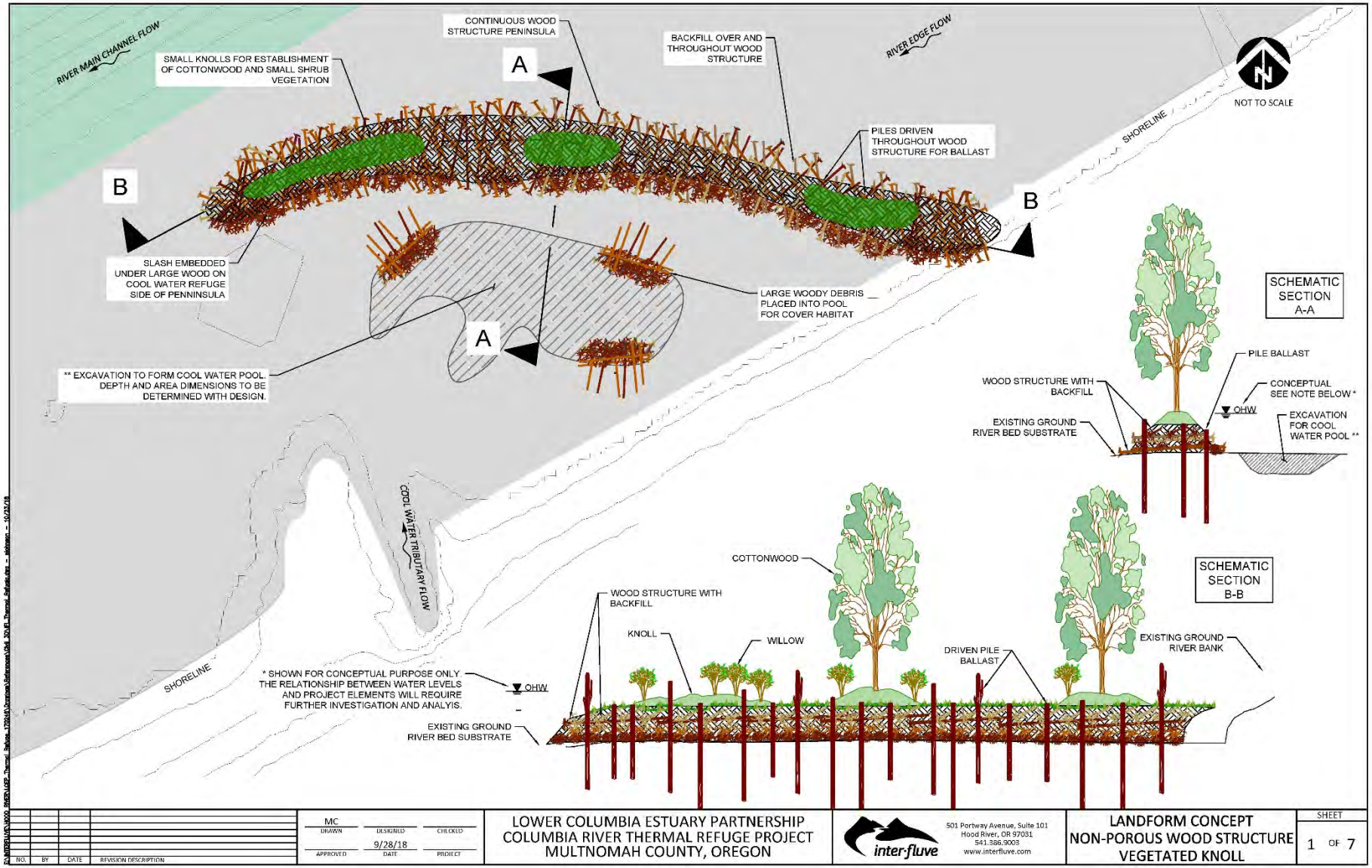


Next Steps – Phase 2 Feasibility

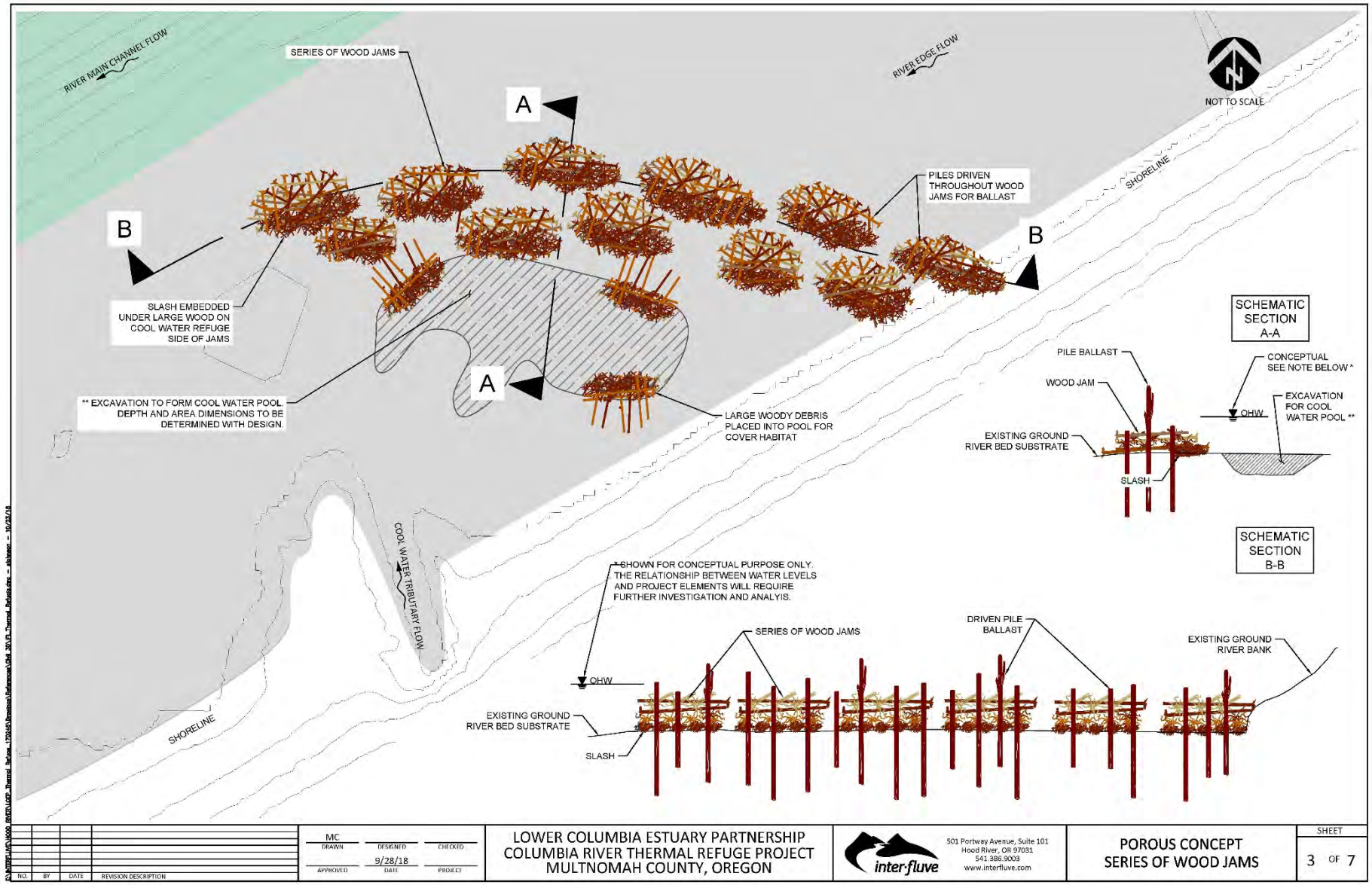
- Structure Intensity
- Geomorphic processes (sediment concerns)
- Impacts to existing alluvial fan processes/habitats
- Life span of structures
- Required maintenance, etc.
- Address potential negative impacts (i.e. predation)

- **Focus on Horsetail as pilot project**
  – most straightforward
  – complements ongoing LCEP floodplain restoration

Horsetail Cr. Thermal Refuge Concept – solid, vegetated landform



Horsetail Cr. Thermal Refuge Concept – series of wood jams



Acknowledgements

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EPA

Questions

Keith Marcoe
Lower Col. Estuary Partnership
(503) 226-1565 x230
kmarcoe@estuarypartnership.org

Horsetail Creek, Lower Columbia Gorge, OR