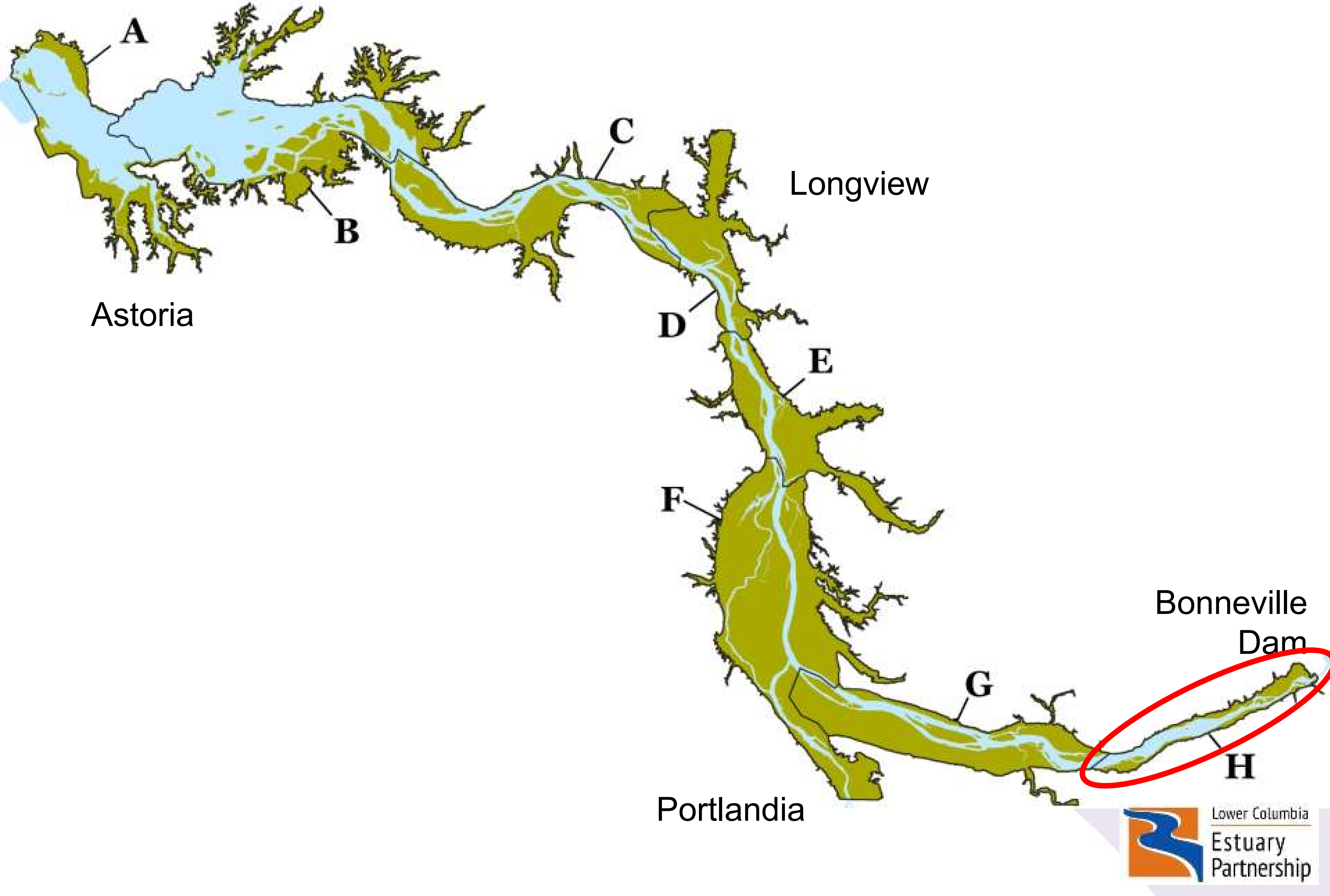
Restoration of Cold Water Refuges in the Columbia River Estuary

**Chris Collins*, Catherine Corbett, Keith Marcoe, Paul Kolp, Matthew Schwartz, Amanda Hanson

Lower Columbia Estuary Partnership

Lower Columbia River Estuary



Mainstem thermal regime during adult return migration

- ~50% of steelhead used thermal refugia when temperatures were 19-21°C.
- *>70% used tributaries when temperatures were > 21°C.*
- Duration of use ex*tended to weeks during the warmest times.*

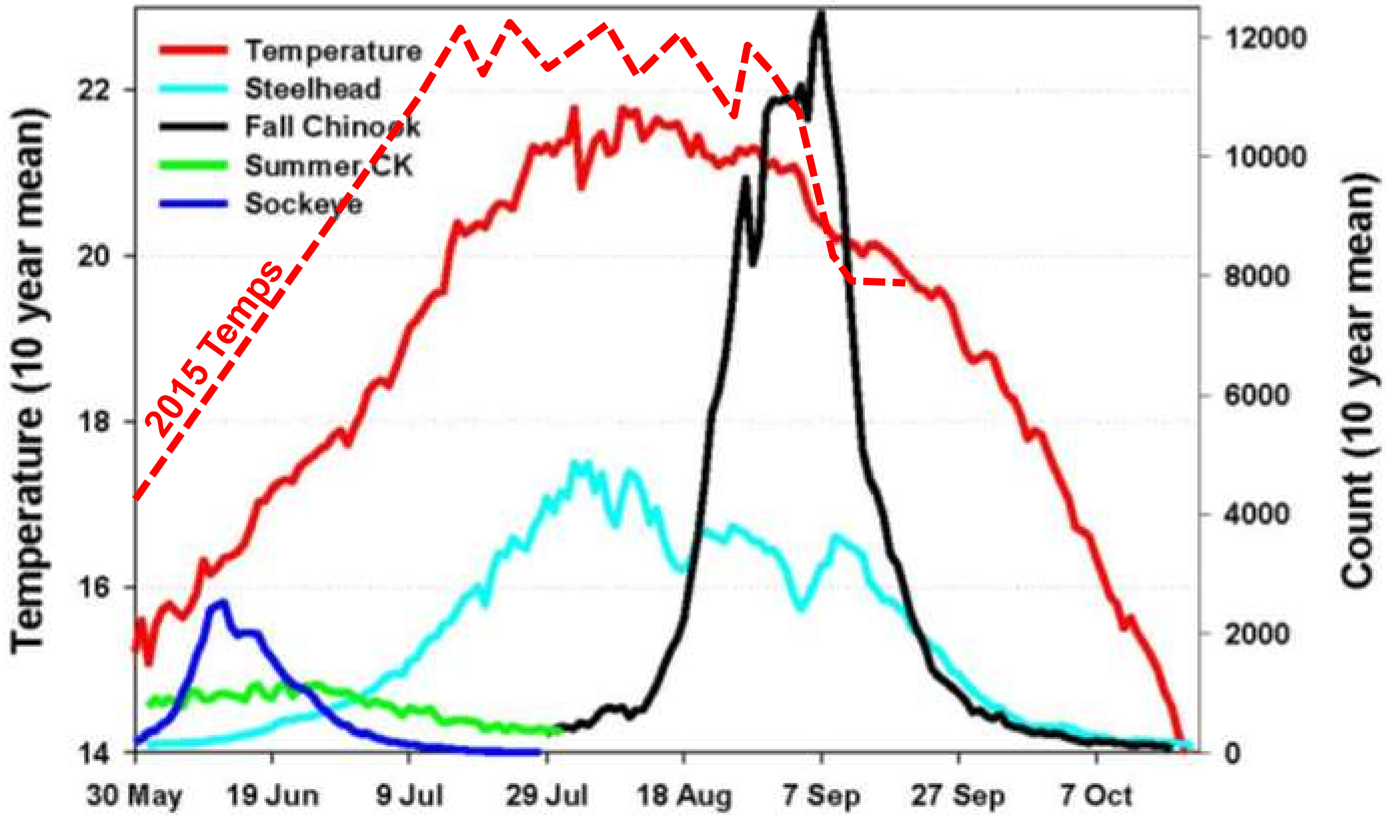
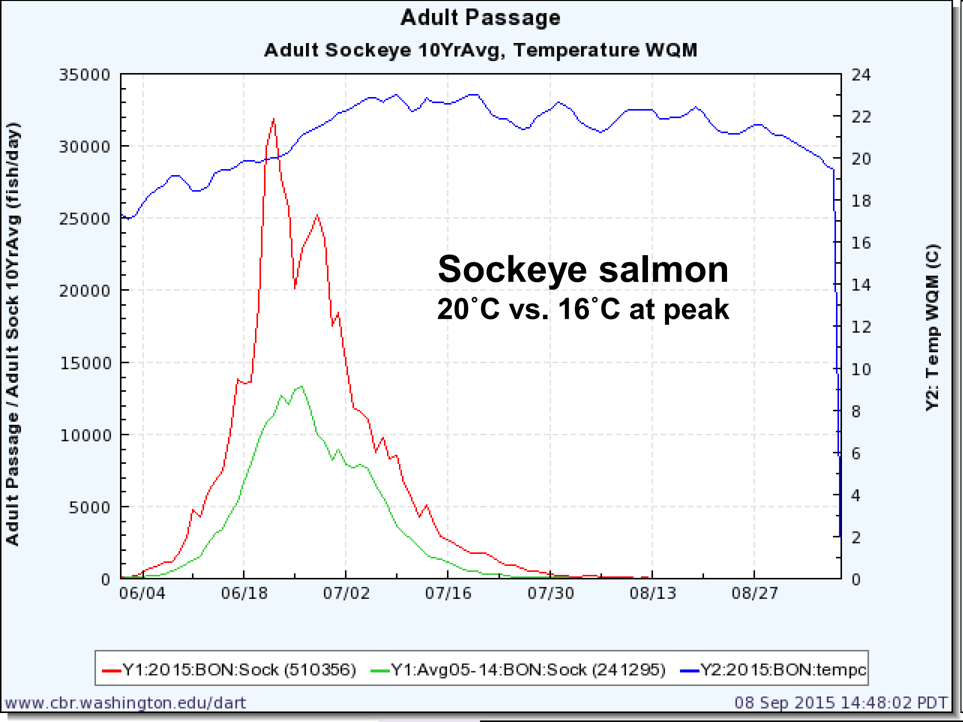
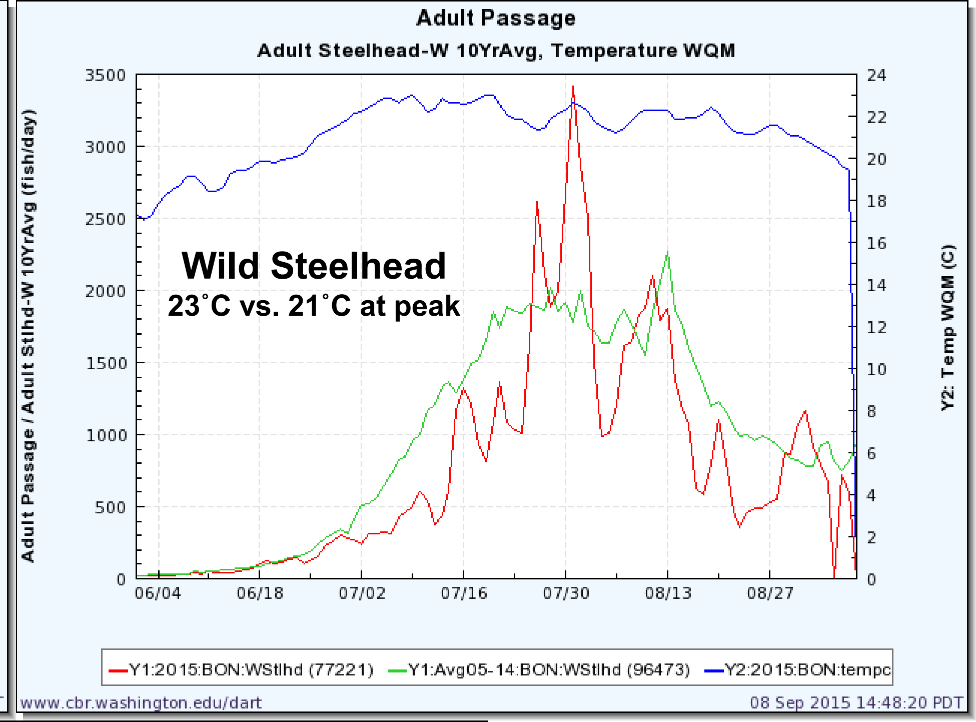
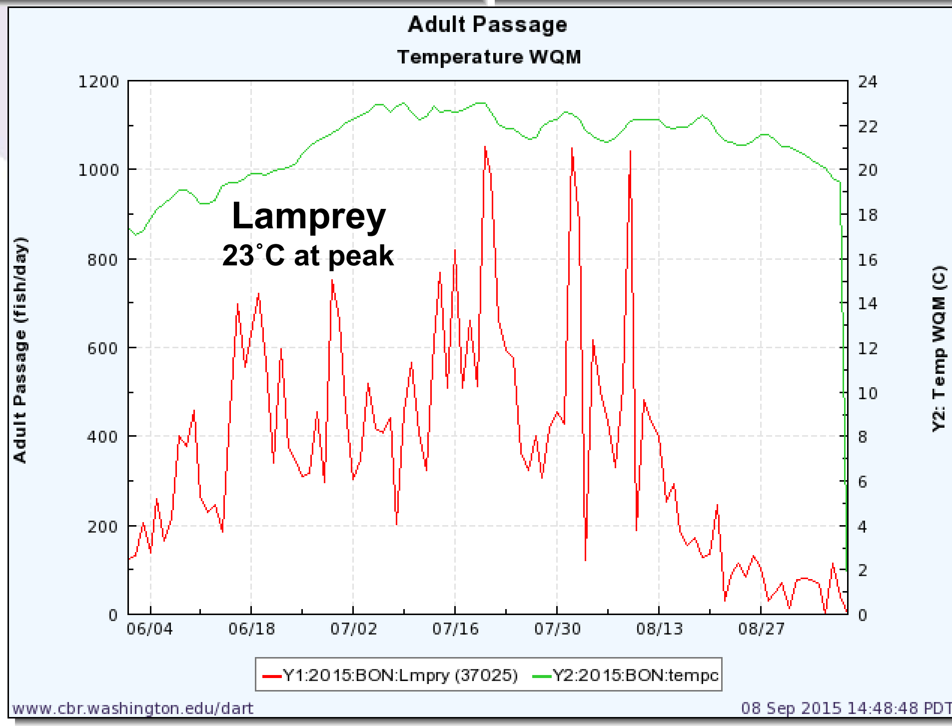


Figure 2. Ten-year (1996-2005) mean lower Columbia River water temperature (°C) and mean run size and timing of adult summer Chinook salmon, fall Chinook salmon, sockeye salmon, and summer steelhead at Bonneville Dam. Thermal refugia use by many adult populations has been associated with

Graph and text copied from Keefer et al. 2011, which included results from Herman and Eagle Creeks.







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Mainstem thermal regime during adult return migration

Steelhead returns – run timing by population

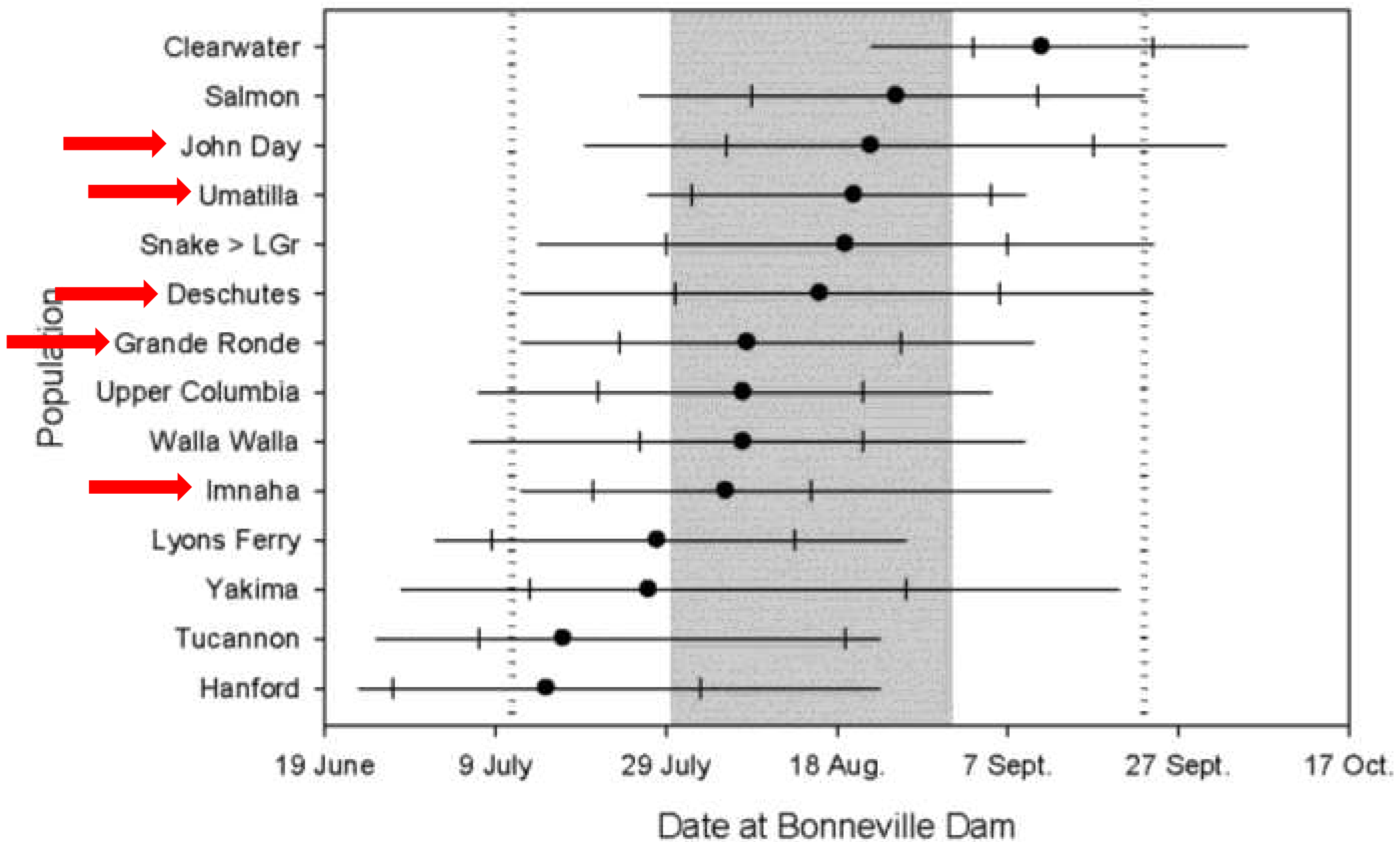
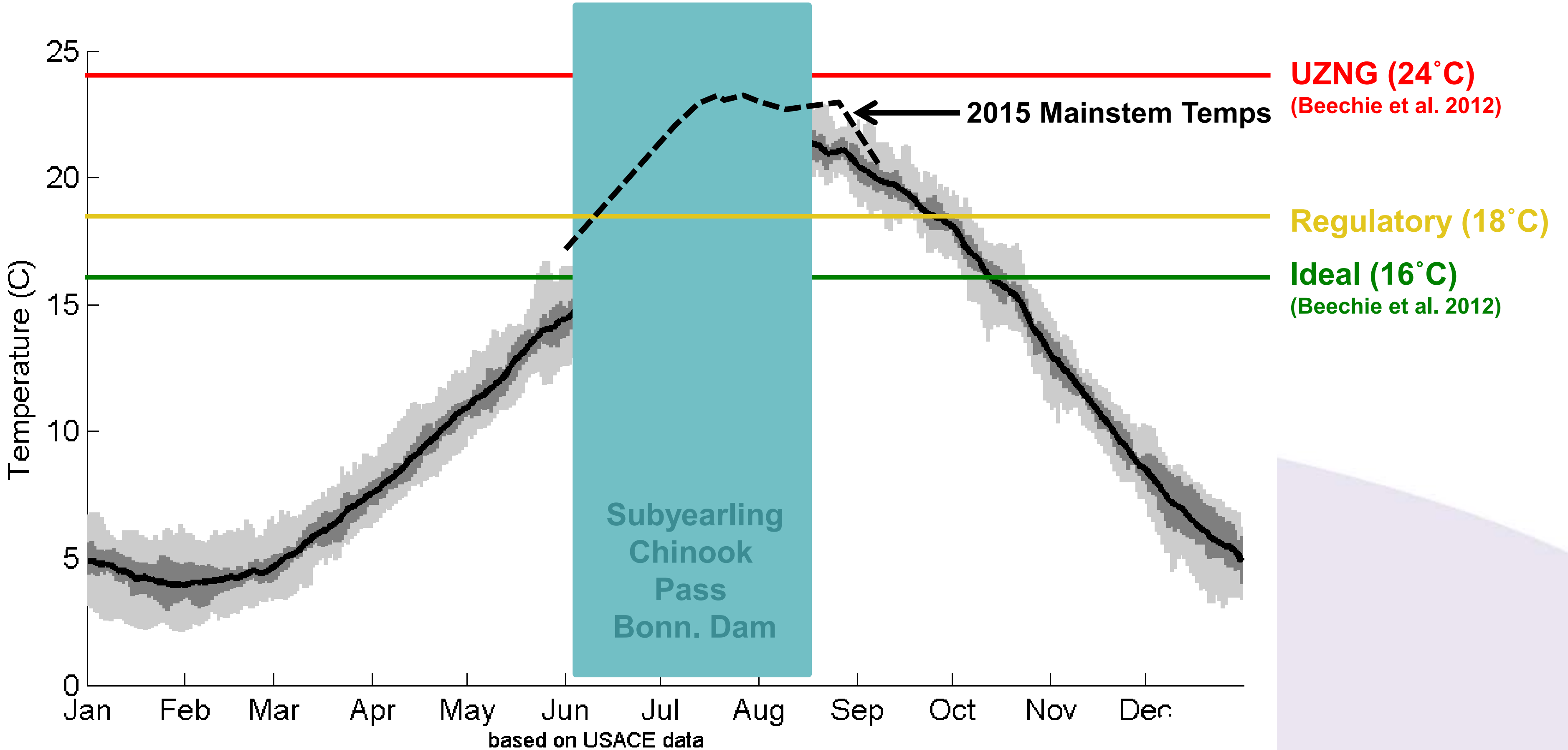


Figure 9. Migration timing distributions (median, quartiles, and 10th and 90th percentiles) at Bonneville Dam for steelhead that successfully returned to tributaries or hatcheries across study years. Vertical dotted lines show mean first and last dates that Columbia River water temperature was 19 °C; the shaded area shows dates with mean temperature ≥21 °C. From Keefer et al. (2009).

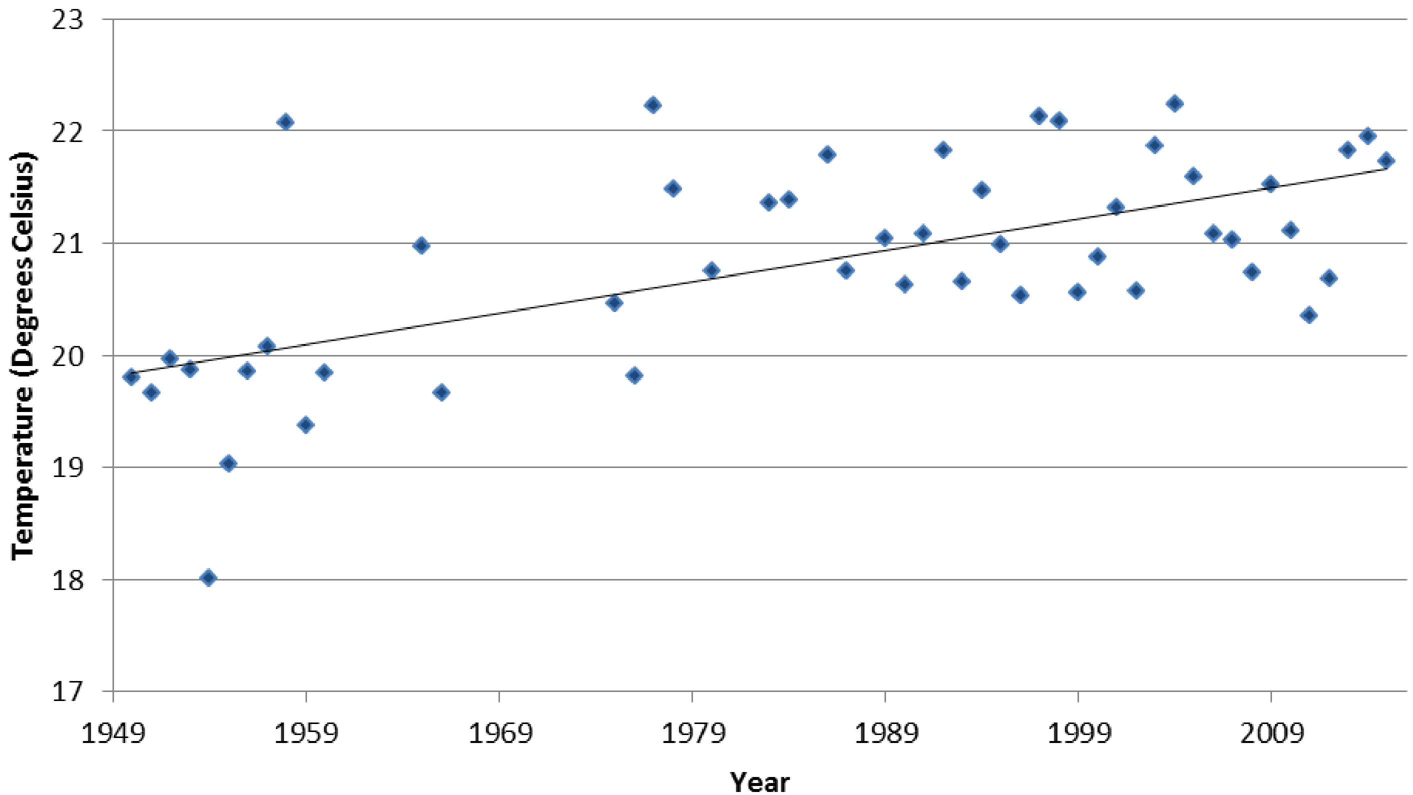
Graph and text copied from Keefer et al. 2011

Mainstem thermal regime during juvenile outmigration



Mainstem thermal regime

1. **Mainstem Columbia temperatures have increased over the last 70 years**
2. **Mainstem temperatures predicted to increase by 2-3˚C over the next ~70 years** (Source: NorWest)
3. **Most natural systems have spatially variable thermal profiles, i.e., not homogenous and not linear (Fullerton et al. 2015)**



Average August Water Temperature at Bonneville (1950-2015)
Columbia River DART, Columbia Basin Research, University of Washington

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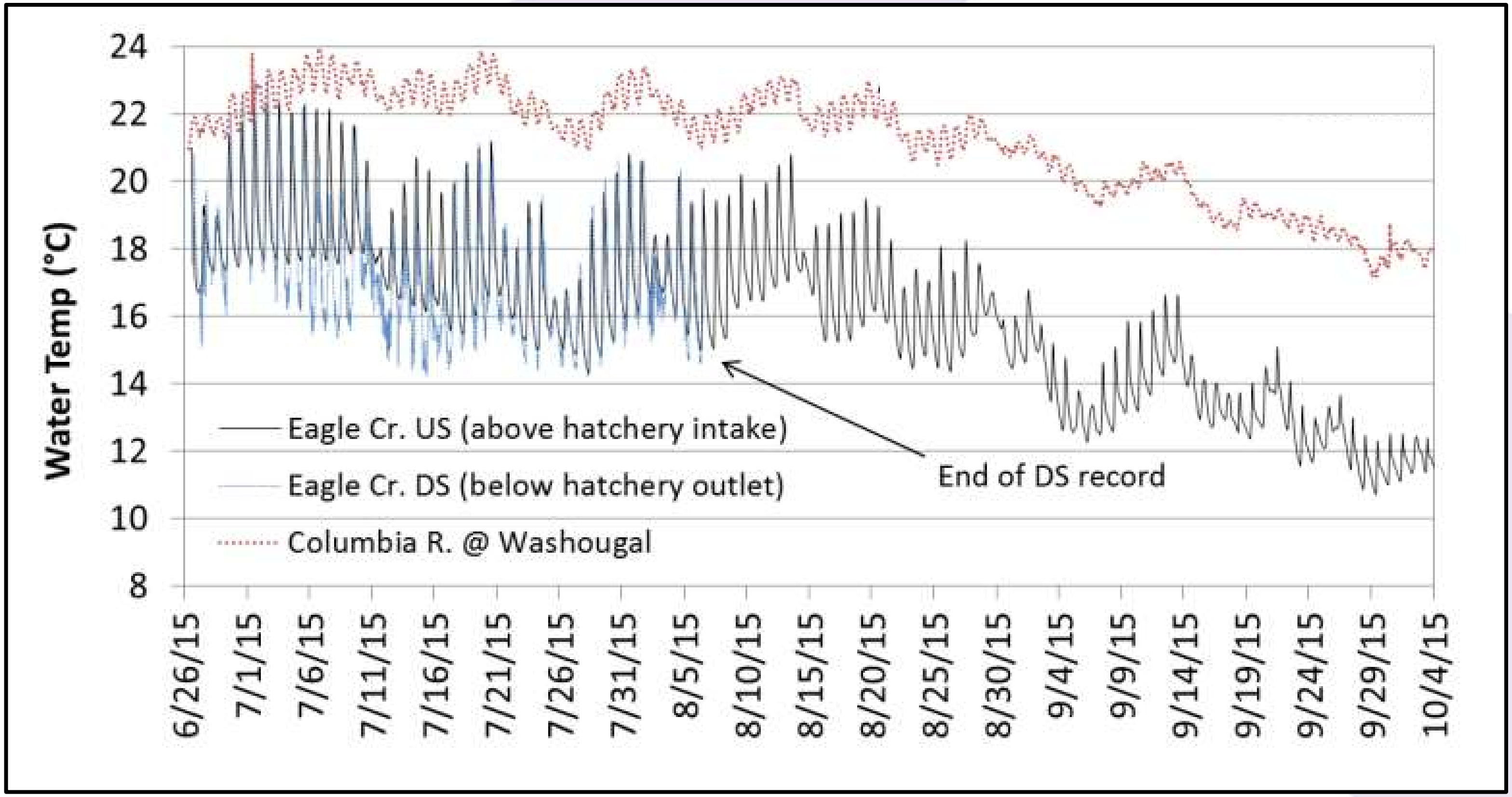
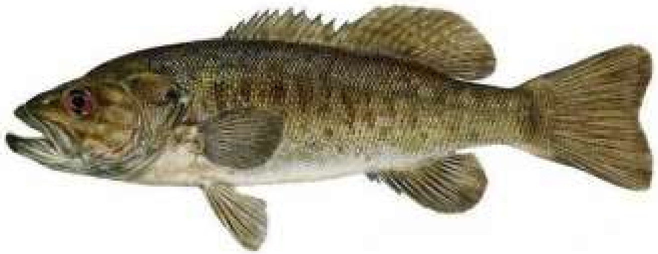
3. **Most natural systems have spatially variable thermal profiles, i.e., not homogenous and not linear (Fullerton et al. 2015)**
4. **Mainstem Columbia has minimal diurnal fluctuations in temperature**

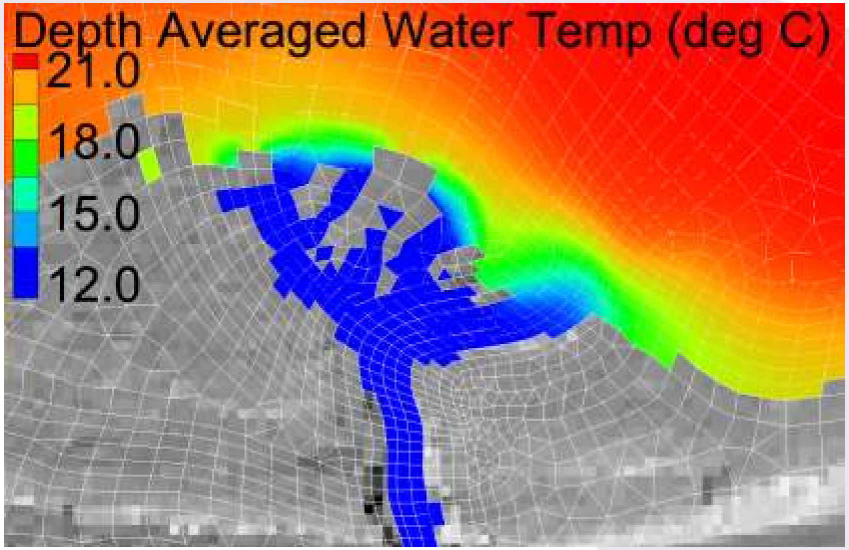


Question 1: What are the potential pros and cons of thermal refuge?

- ❖ Numerous potential benefits and impacts associated with thermal refugia, e.g. disease and predation.

- ❖ *Diversity & Resilience*:
  - Species: *Five life history strategies* documented in single populations of Chinook and coho (Reimers 1973; Craig 2010).
  - Habitats: A diversity of habitats (including varied thermal conditions), supports a variety of life history strategies, which is important for population resilience.



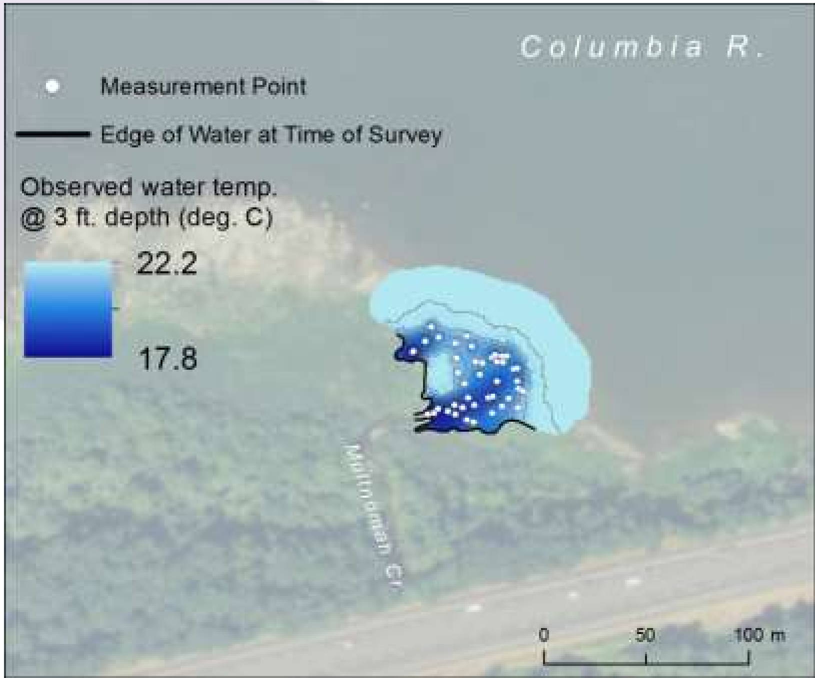


Question 2: What are the characteristics of thermal refuge?

Organized by attributes presented in *Ecological Assessment Criteria for Restoring Anadromous Salmonid Habitat in Pacific Northwest Estuaries* (Simenstad and Cordell, 2000)

- **Opportunity/Access**:
  - Adjacent to mainstem
  - Detection: - Plume must extend into the migratory corridor
    - Temp. differential (2-7˚C cued adults above Bonneville) (Keefer et al. 2011)
- **Capacity**:
  - Temperature: - physiological: <19˚C (Bottom et al. 2011)
    - protection from predators: <19˚C (Moyle 2002)
  - Depth: minimum of ~0.5m for juveniles (Bottom et al. 2005)
  - Horizontal extent: uncertain

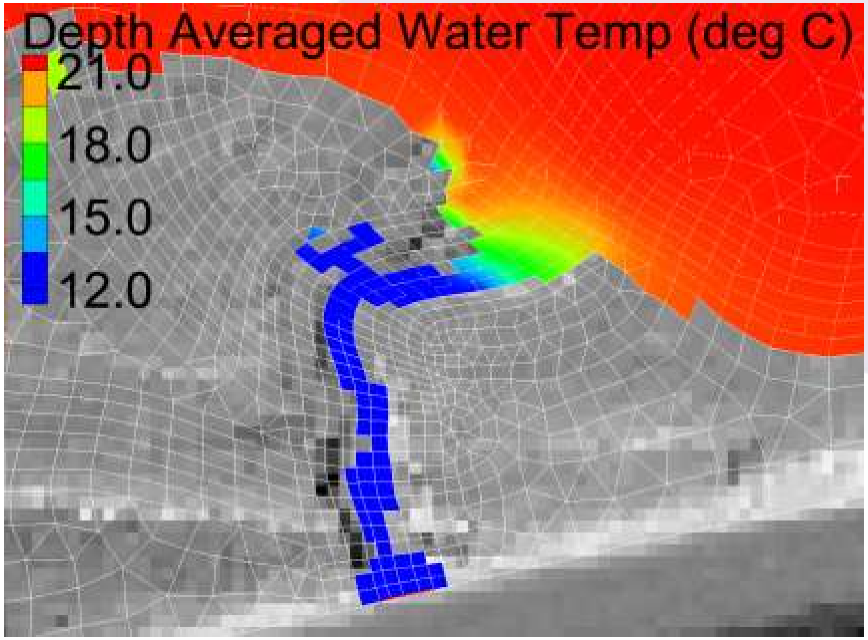
Design Criteria: - 2°C temperature difference
- 19°C max. tributary temp.
- >0.5m depth
- max. spatial extent practical



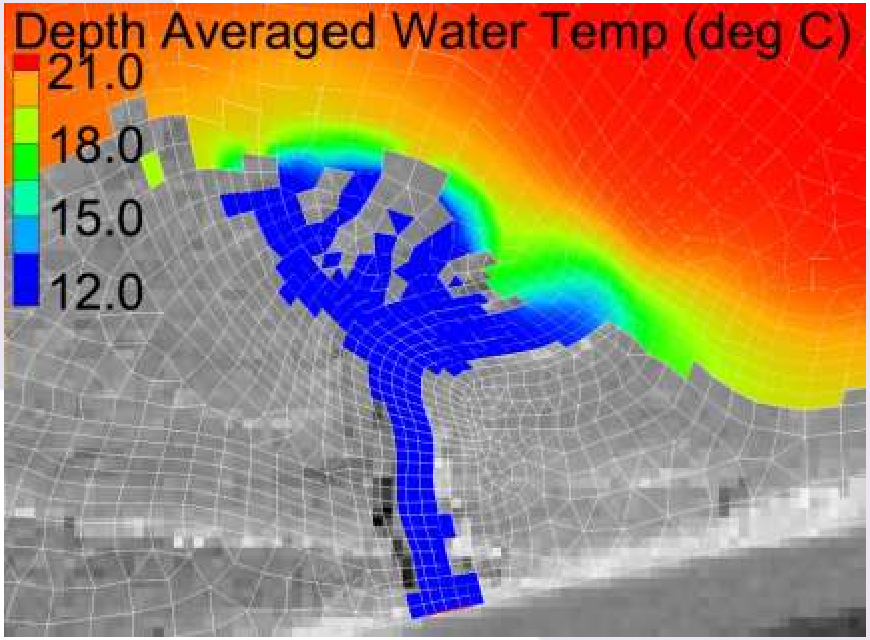
Question 3: What factors influence formation of thermal refuge?

The likelihood of a plume to form at a tributary confluence is influenced by:

1. **Water temperature** (tributary and mainstem Columbia R.)
   - Temp. differential b/t Columbia River and tributary varies from 2 to 11˚C
2. **Discharge** (tributary and mainstem Columbia R.)
   - Columbia River = 100,000 – 150,000 cfs
   - Gorge tributary = 1 – 50 cfs



Q_{TRIB} = 10 cfs



Q_{TRIB} = 50 cfs

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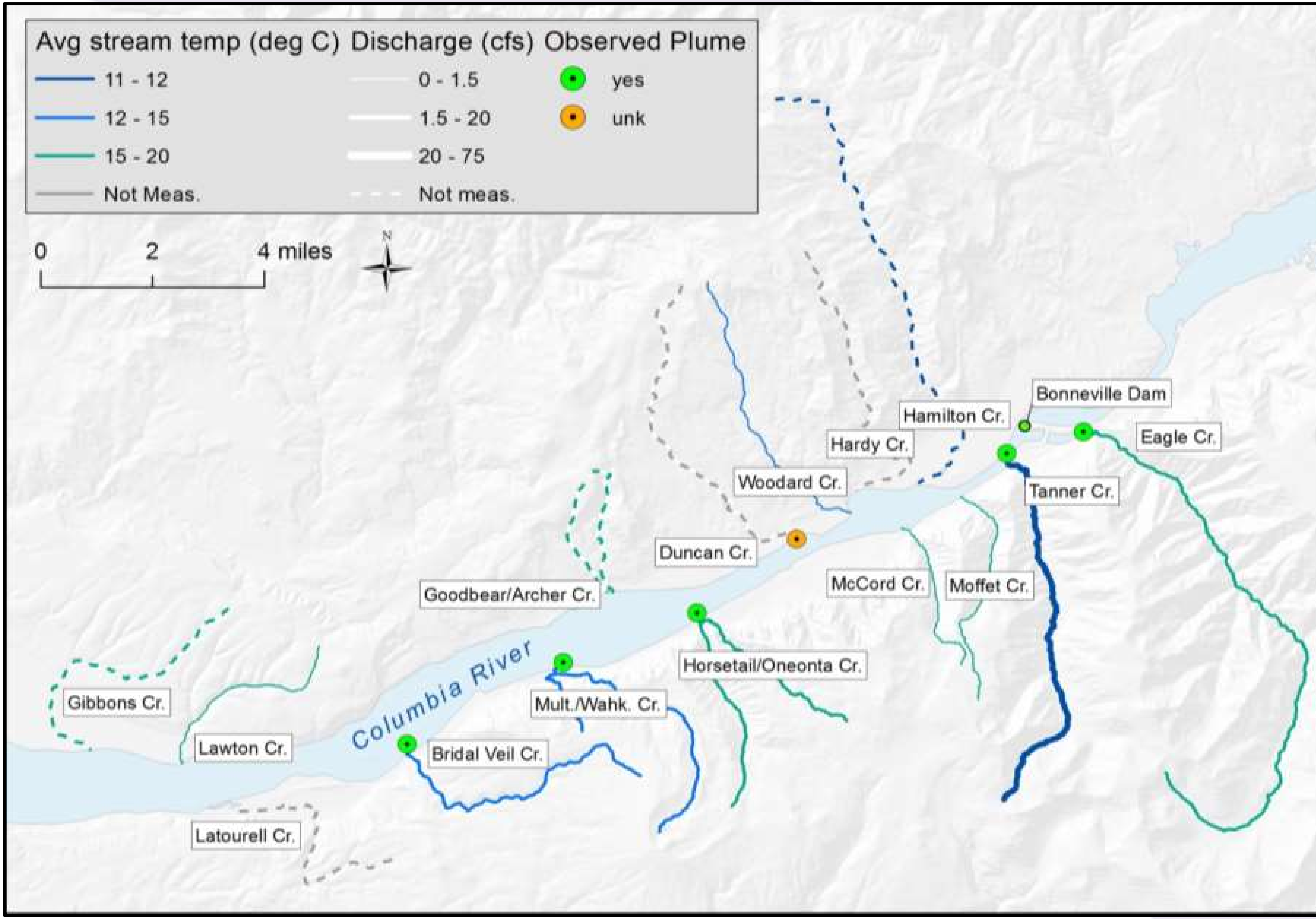
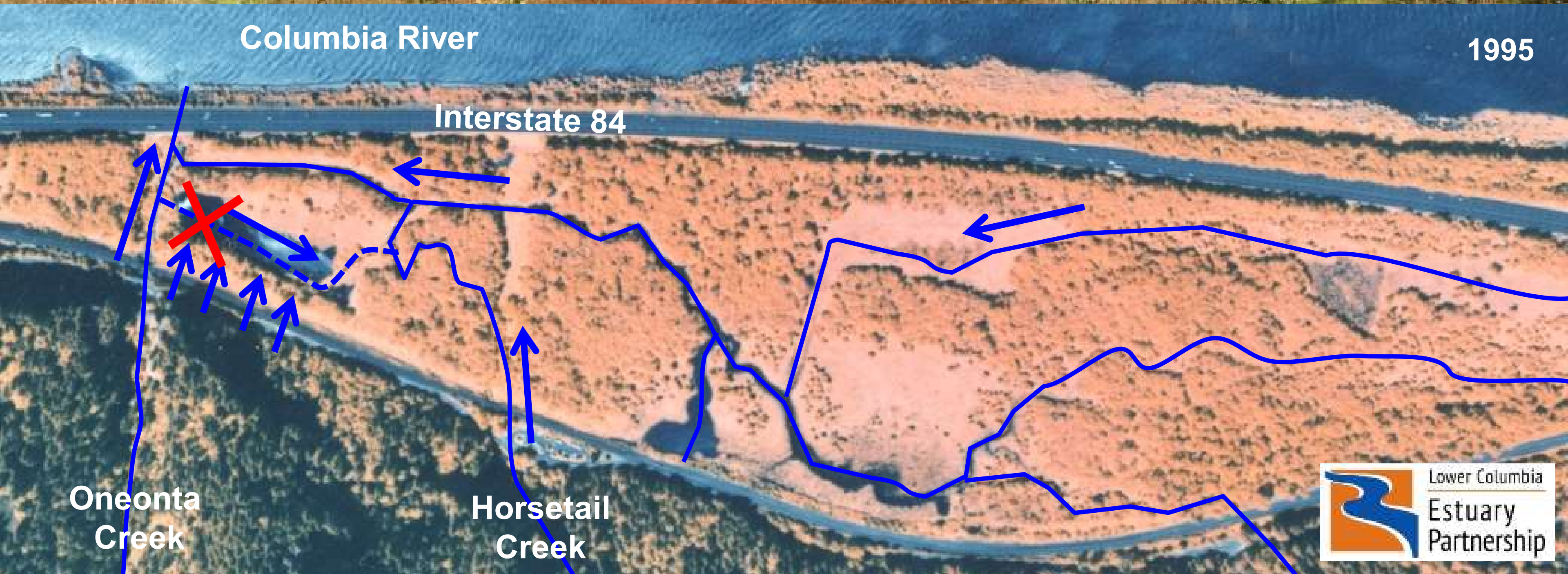
   - Columbia River = 100,000 – 150,000 cfs
   - Gorge tributary = 1 – 50 cfs
3. **Bathymetric profile** (eddy formation)
4. **Atmospheric effects** (solar radiation, wind)

Question 4: What streams have the potential to provide thermal refuge?

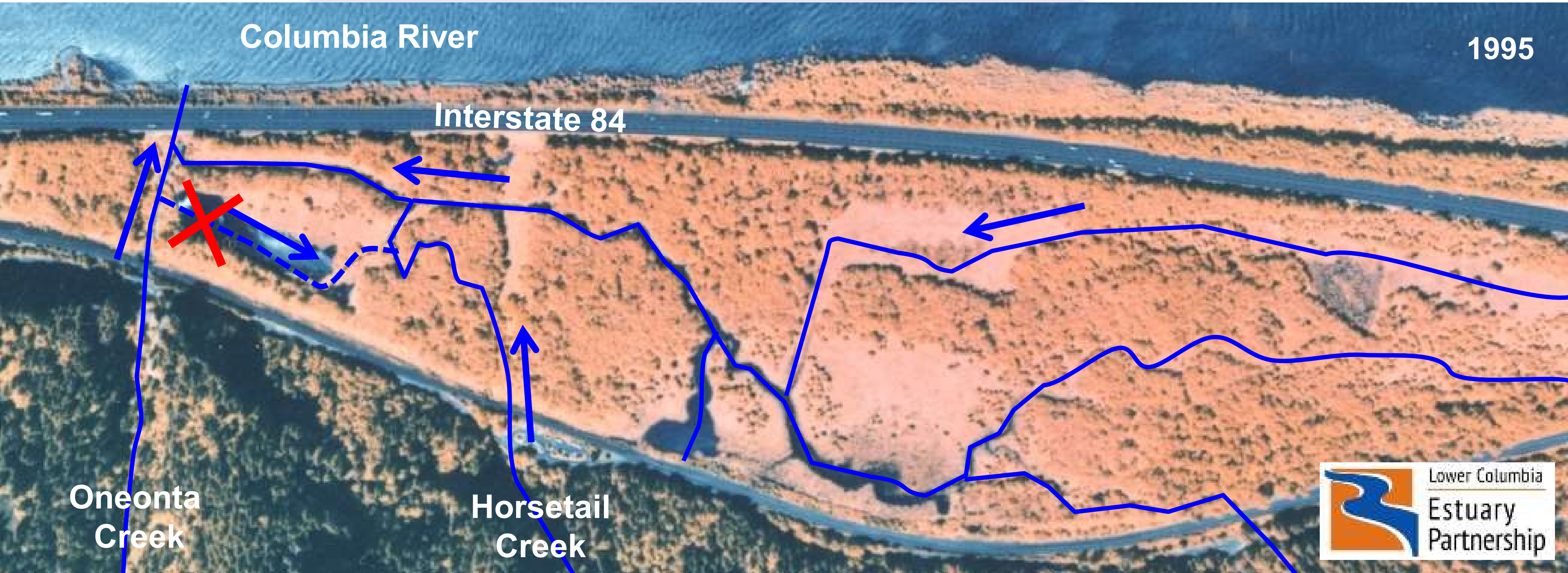


Restoration Actions – Example 1: restore instream flow (eliminate stream diversions)

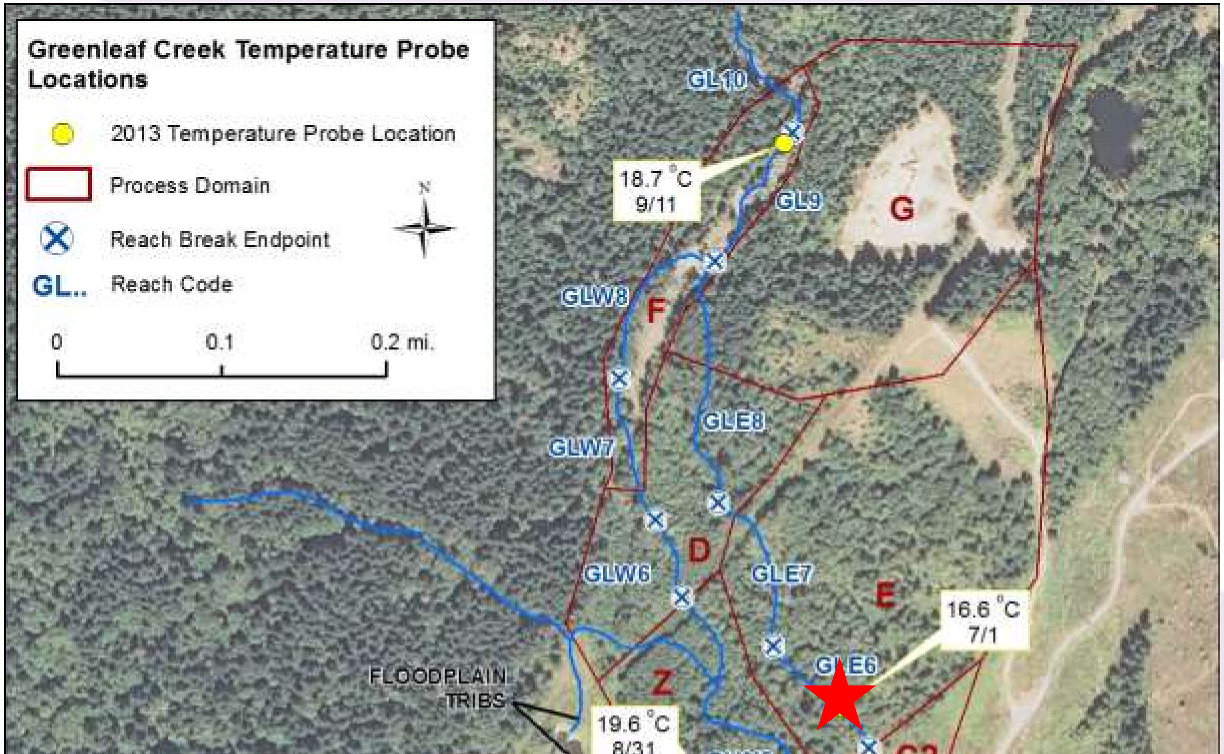
Restoration Actions – Example 2: restore floodplain hydrology

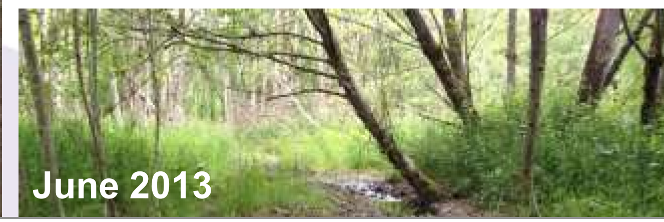


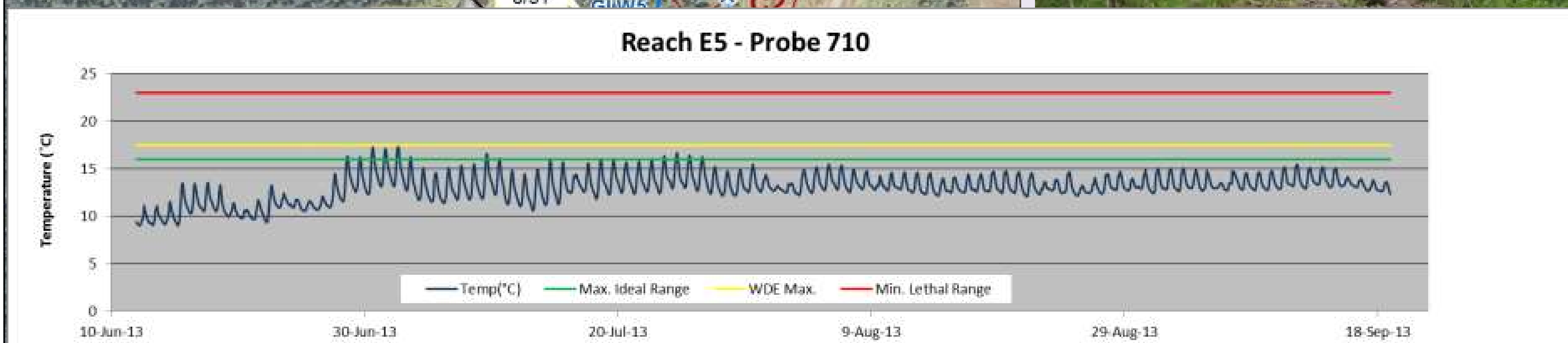
Restoration Actions – Example 3: improve riparian vegetation



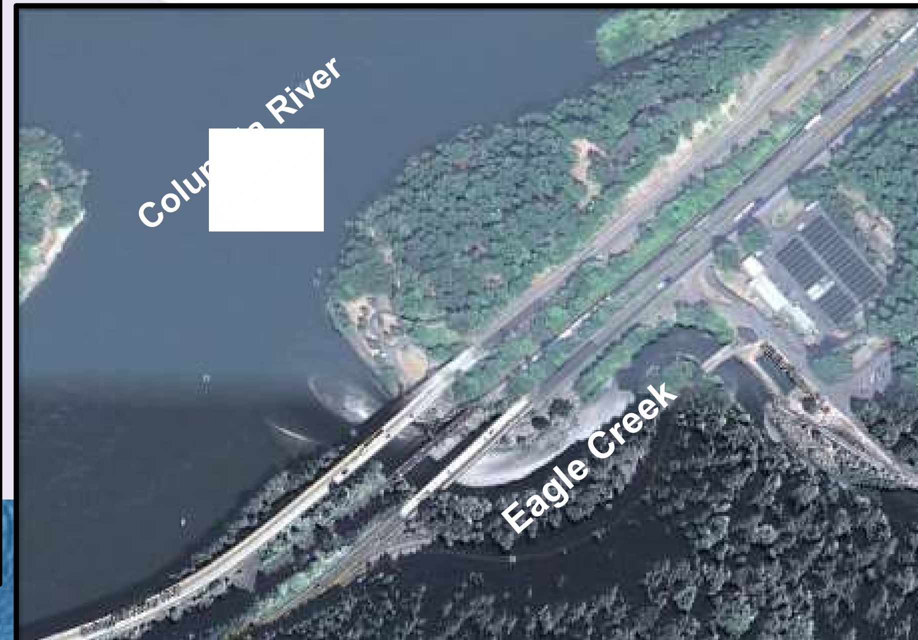
Restoration Actions – Example 4: increase hyporheic exchange

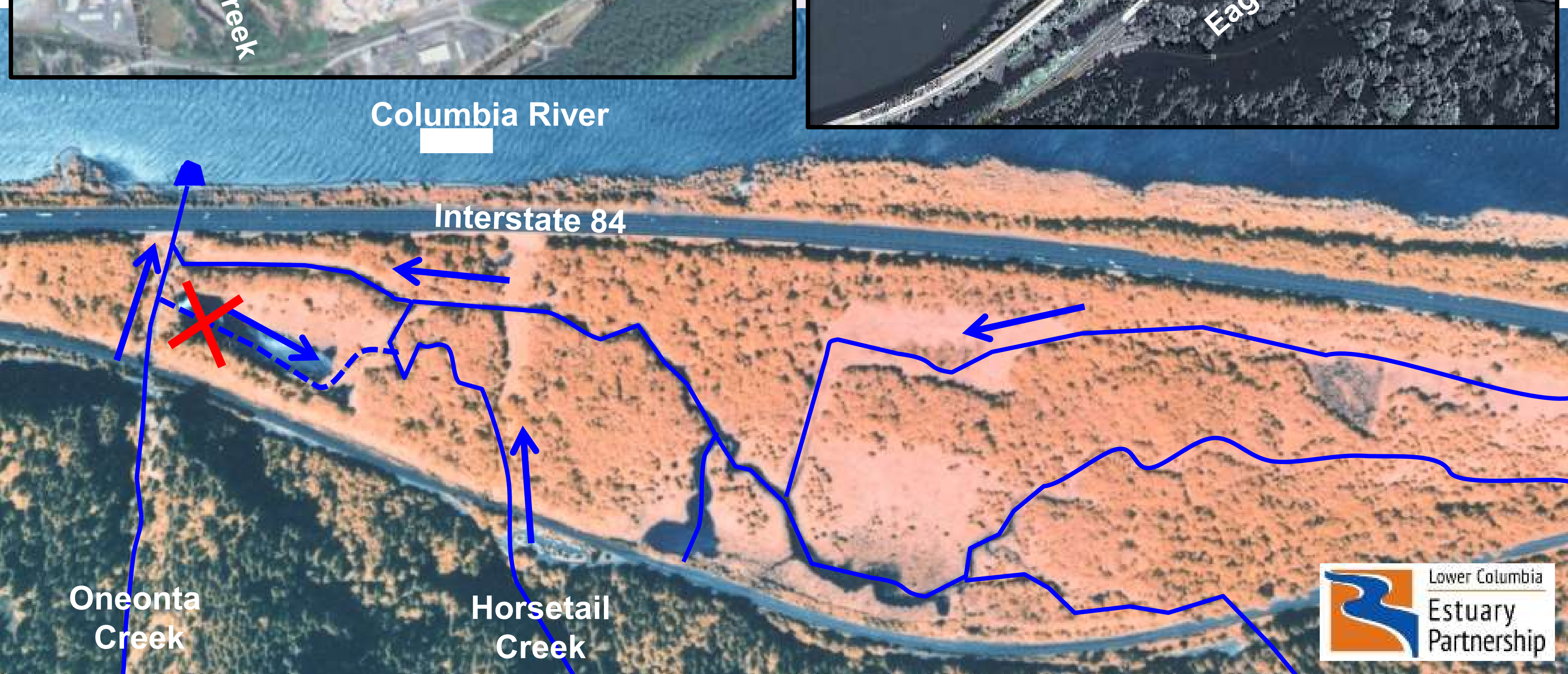






Restoration Actions – Example 5: increase localized hydraulic shadow





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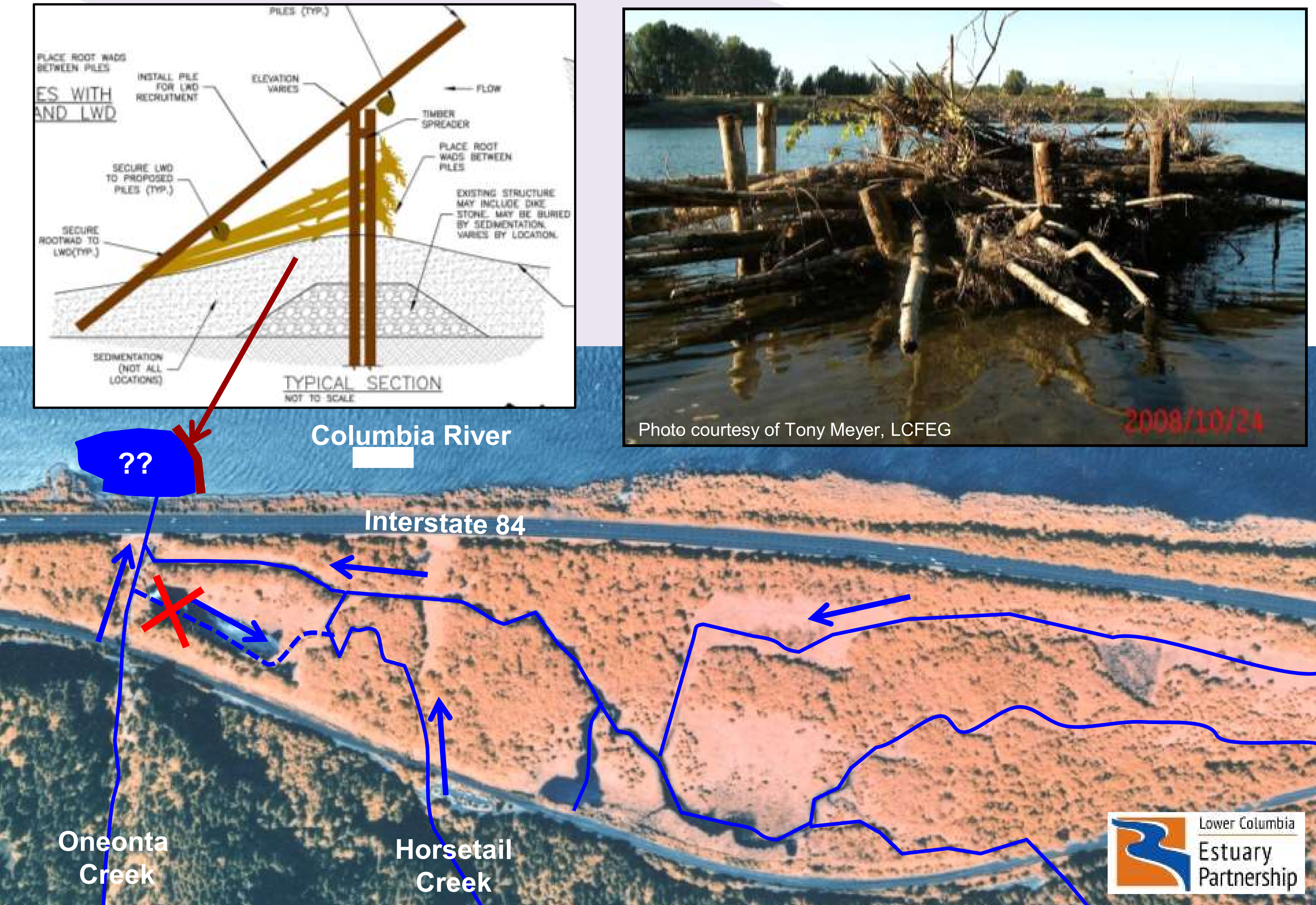
Restoration Actions – Example 5: increase localized hydraulic shadow




Questions…
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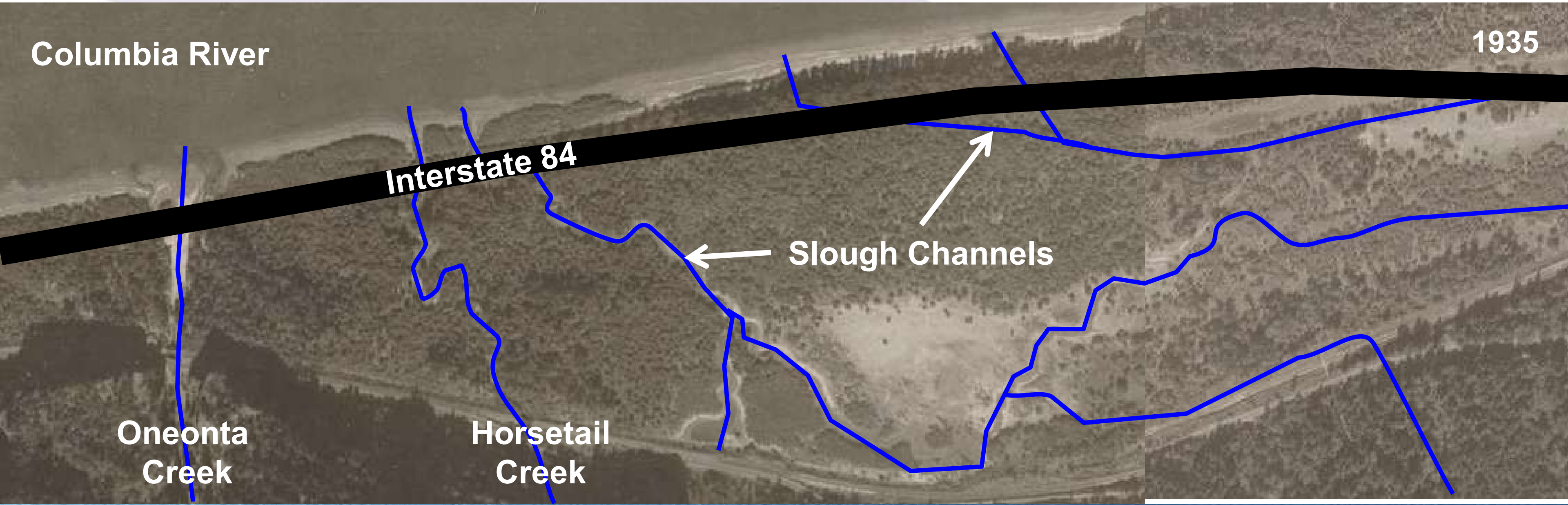
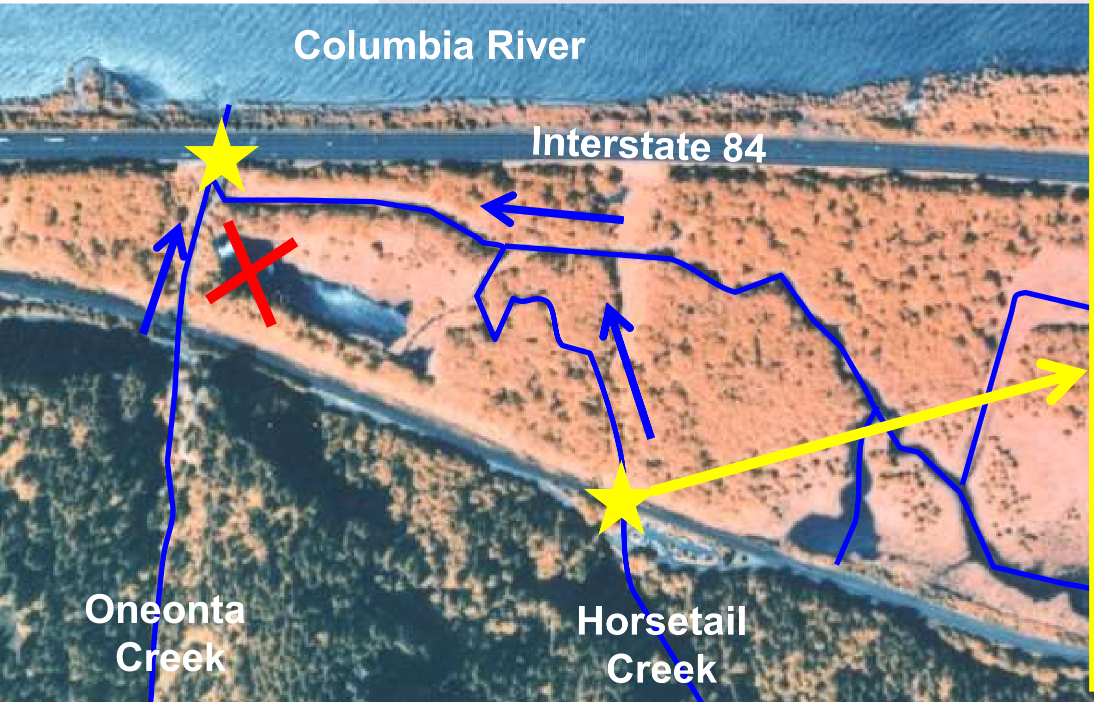
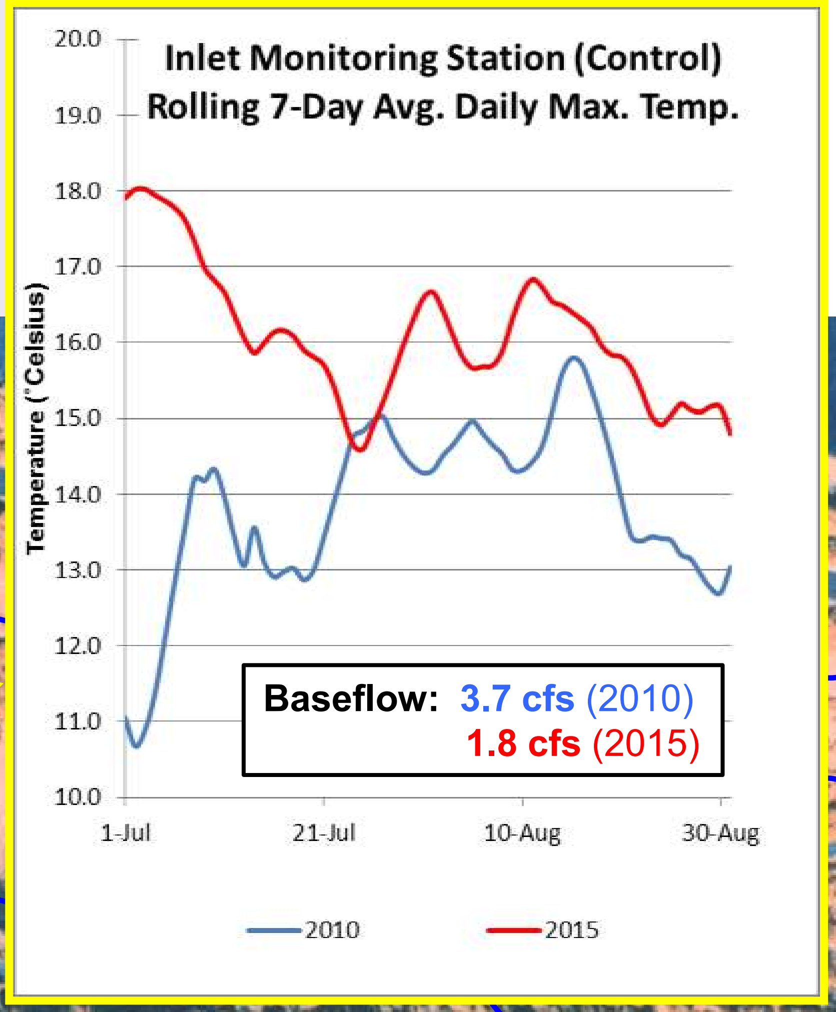
Example Project



Preliminary Monitoring Results – thermal loading within the site

- Two years of monitoring data: 2010 & 2015
  - 2015 *monitoring period* was…..
    - 2.8˚C warmer
    - 5.8 inches less rain
- Peak temperatures in the restored gravel pond decreased by 5.1˚C (from 23.6˚C to 18.5˚C).
- Mean increase in temperature between inlet (reference) and outlet monitoring stations was constant between years (2.7˚C vs. 2.9˚C).

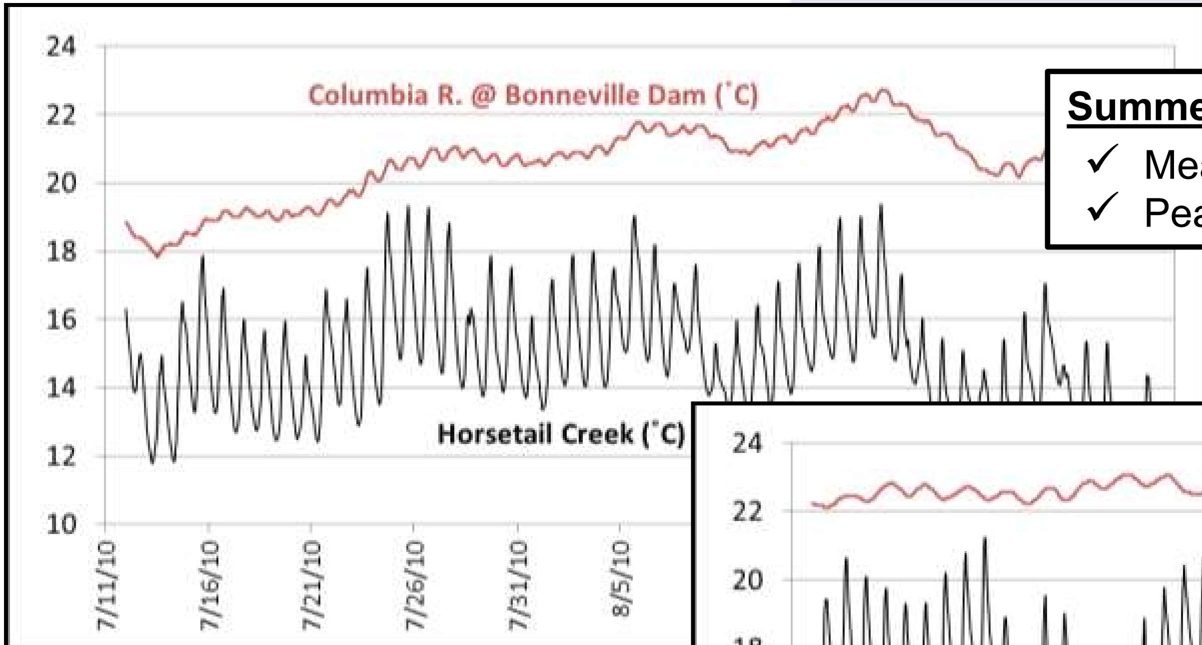




Preliminary Monitoring Results – thermal refugia in the mainstem

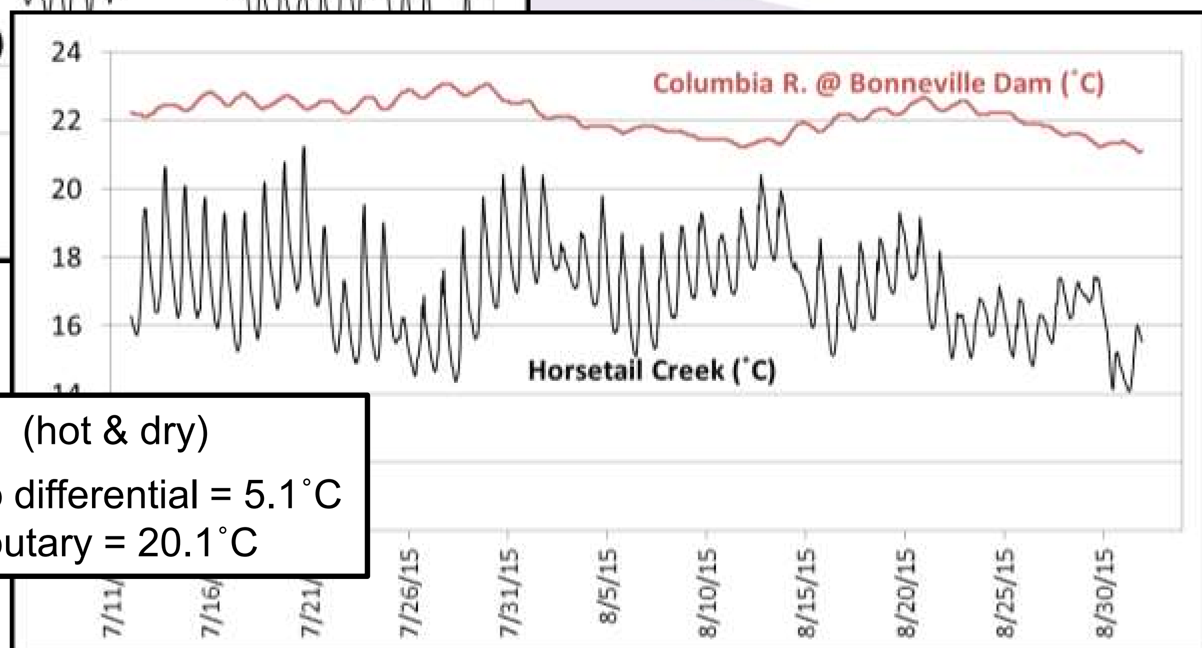
***Preliminary* Temperature Criteria**:

- Temperature differential b/t mainstem and tributary = >2˚C (Keefer et al., 2011)
- Peak tributary temperature = 19˚C (Bottom et al., 2011; Moyle 2002)



Summer 2010: (cool & wet)

✓ Mean temp differential = 5.8˚C
✓ Peak in tributary = 18.3˚C

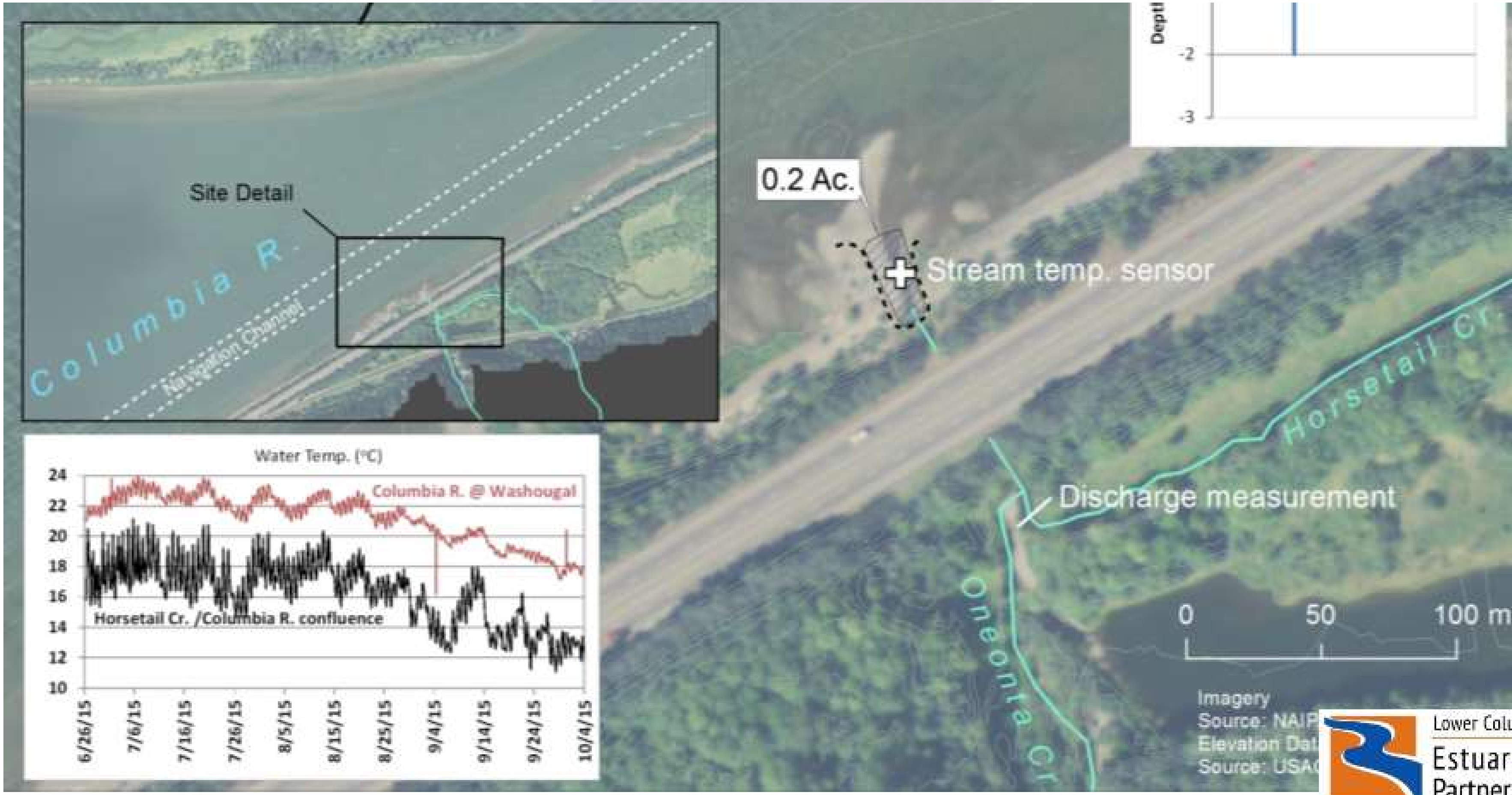


Summer 2015: (hot & dry)

✓ Mean temp differential = 5.1˚C
X Peak in tributary = 20.1˚C

Preliminary Monitoring Results – thermal refugia in the mainstem

- **Thus far, restoration has focused on increasing tributary discharge and decreasing tributary temperatures.**
- **Questions:**
  - **What are the plume dimensions at the tributary/mainstem confluence?**
  - **Are there direct actions we could take to improve conditions there? (e.g., would modifying localized bathymetry or atmospheric conditions increase plume size?)**



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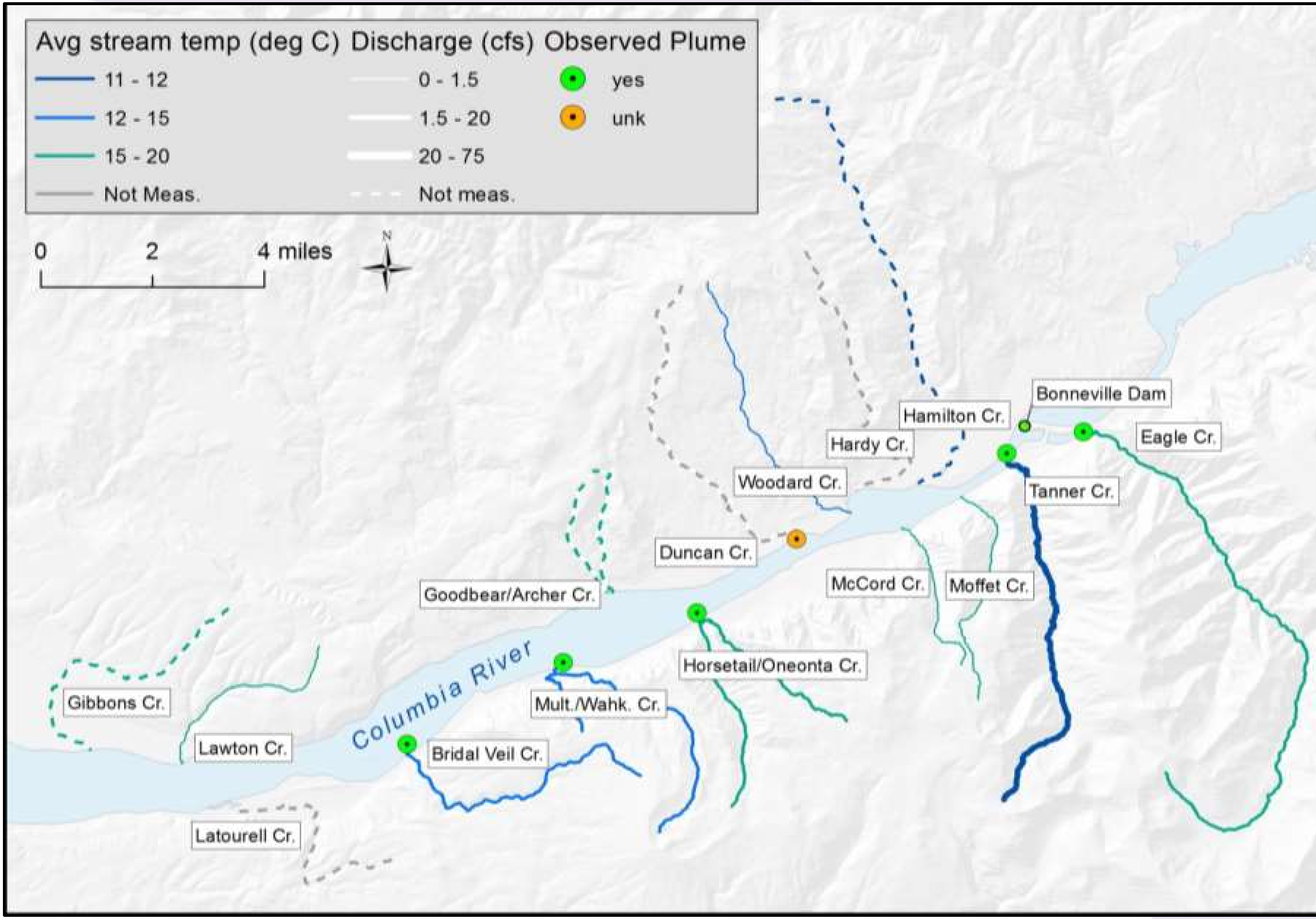
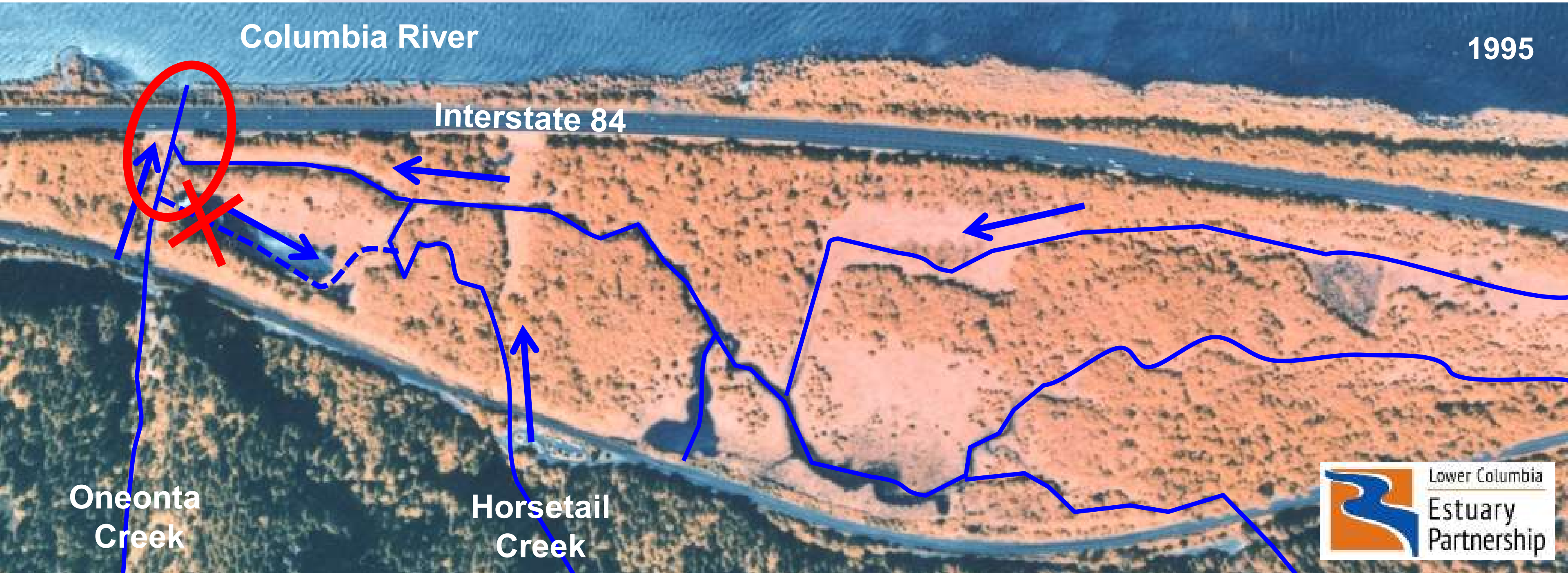
Feasibility Study



Restoration Actions – Example 4: provide access (longitudinal connectivity)



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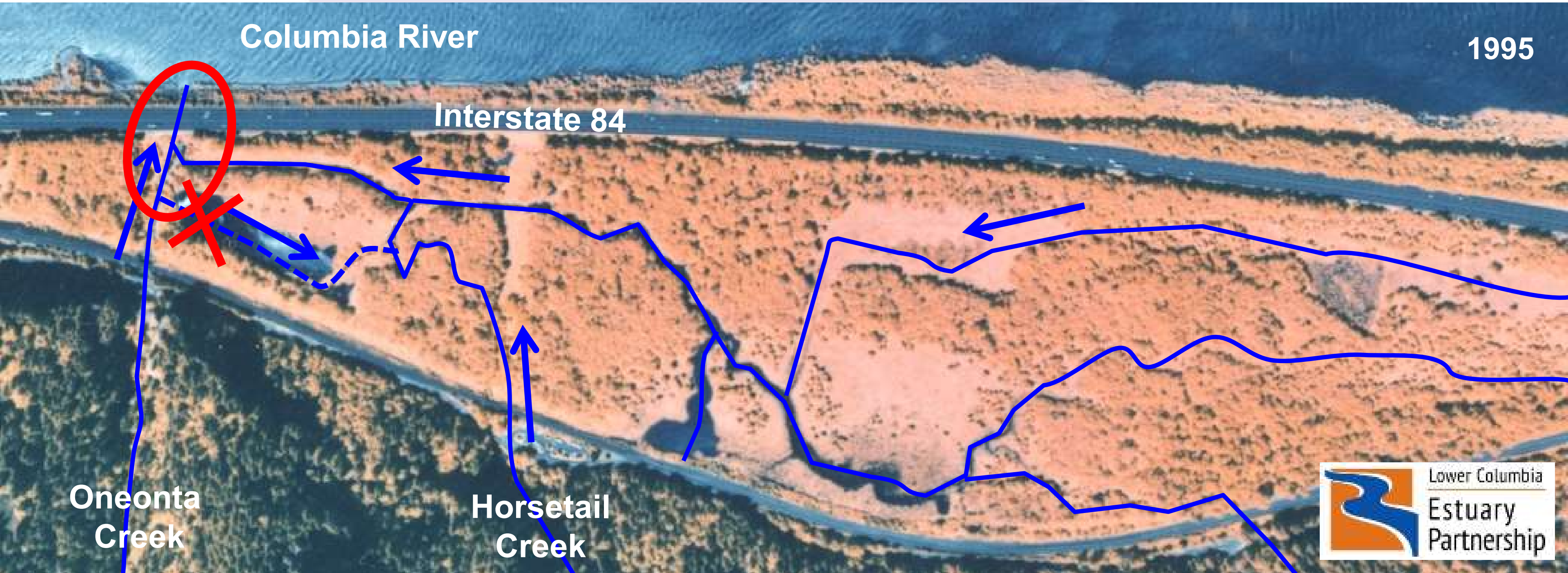


Gorge Tributaries Discussion – *Tanner, Eagle and Herman Creeks* VIDEO

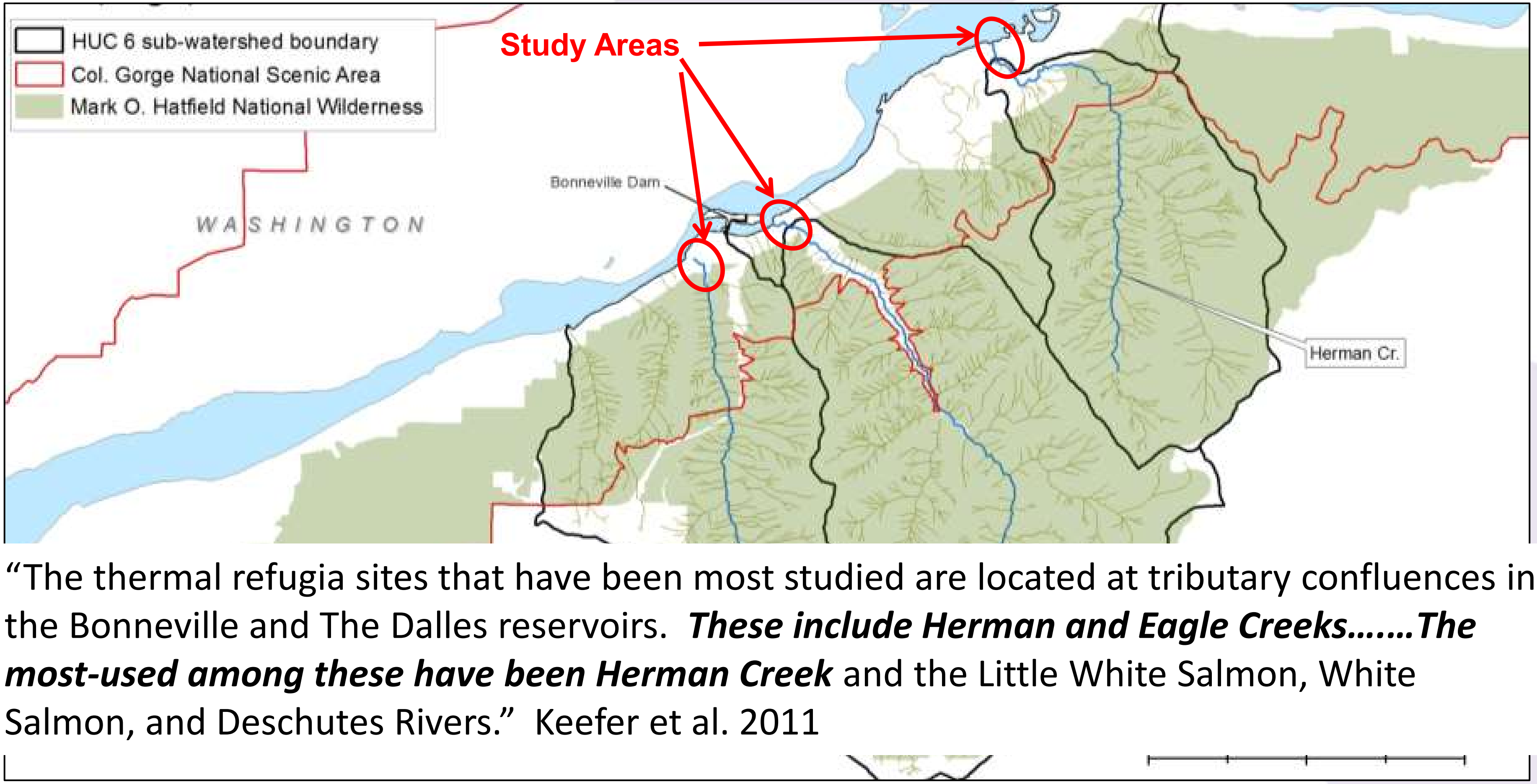
Landscape setting - Last good habitat before highly degraded reach.

Undeveloped watersheds - Intact processes therefore high potential for long-term success

Protected watersheds - Public ownership, wilderness designation, NSA regulations

Cost/benefit - Entire watersheds can be restored through one or two projects

Public Education - Excellent opportunities to educate the public on habitat restoration.



"The thermal refugia sites that have been most studied are located at tributary confluences in the Bonneville and The Dalles reservoirs. ***These include Herman and Eagle Creeks…….The most-used among these have been Herman Creek*** and the Little White Salmon, White Salmon, and Deschutes Rivers." Keefer et al. 2011