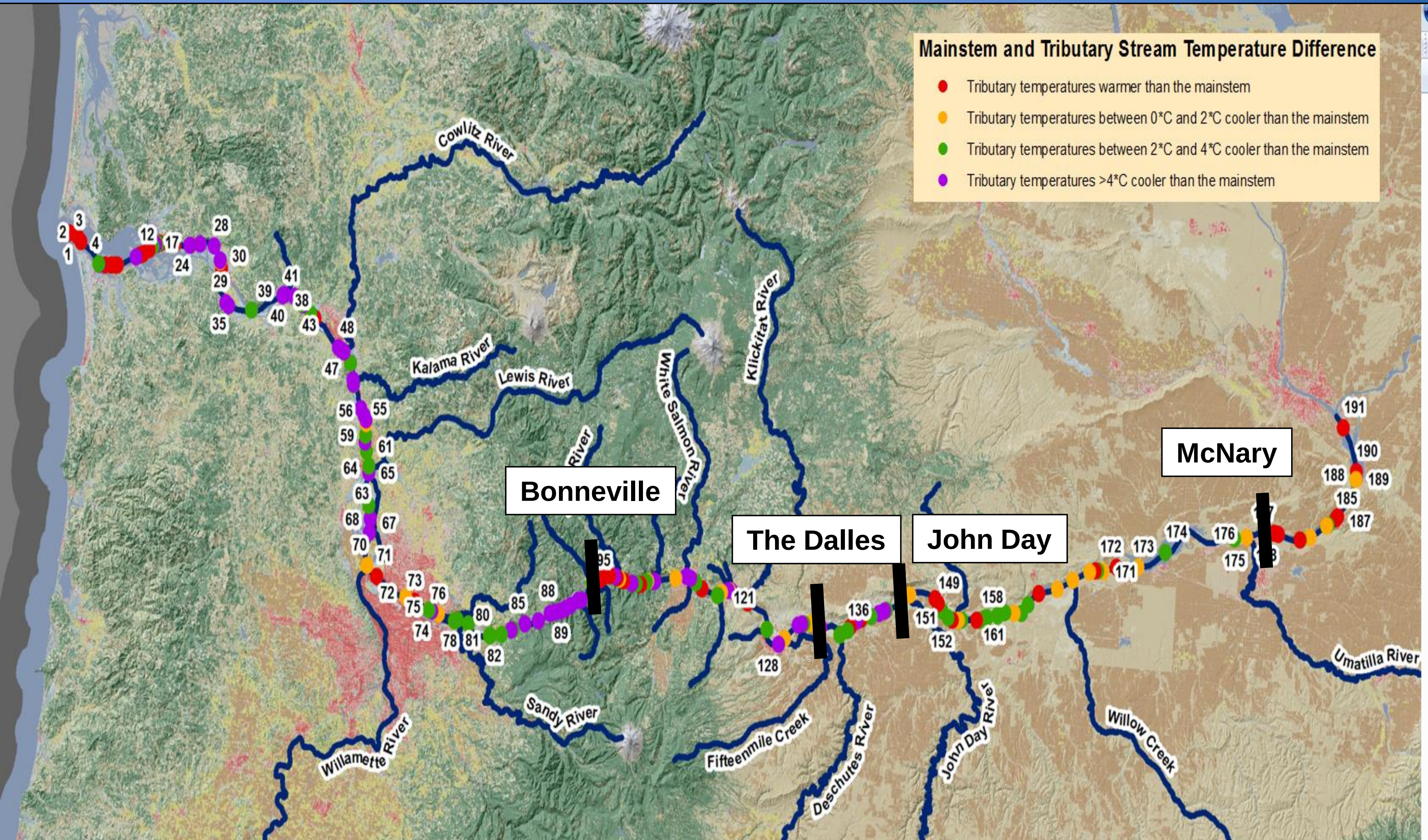
Columbia River
Cold Water Refuges Plan

(All data herein is preliminary)

Lower Columbia Estuary Partnership
February 2017

John Palmer
EPA Region 10

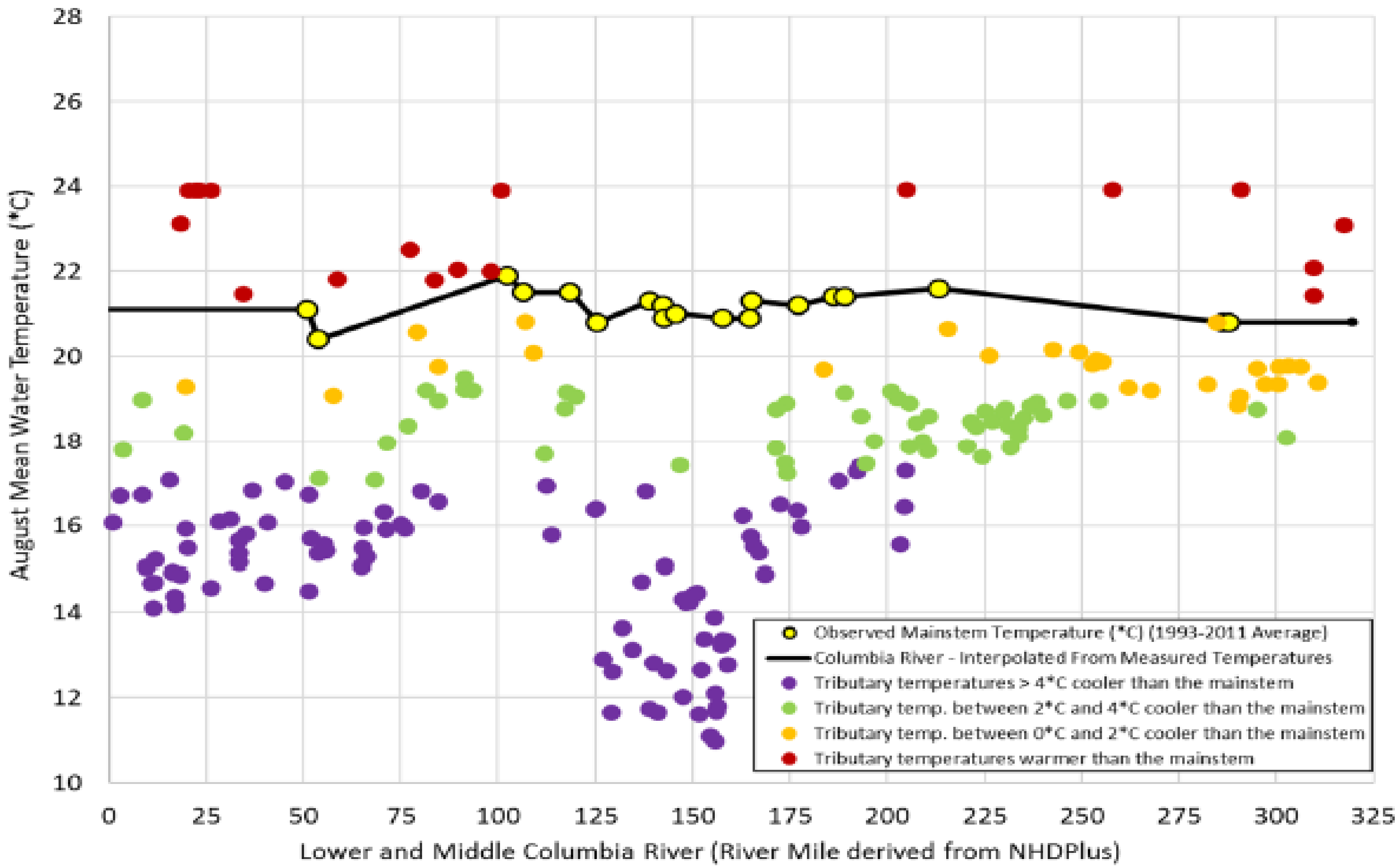
191 Columbia River Tributaries Screened
(NorWest Data, USFS)



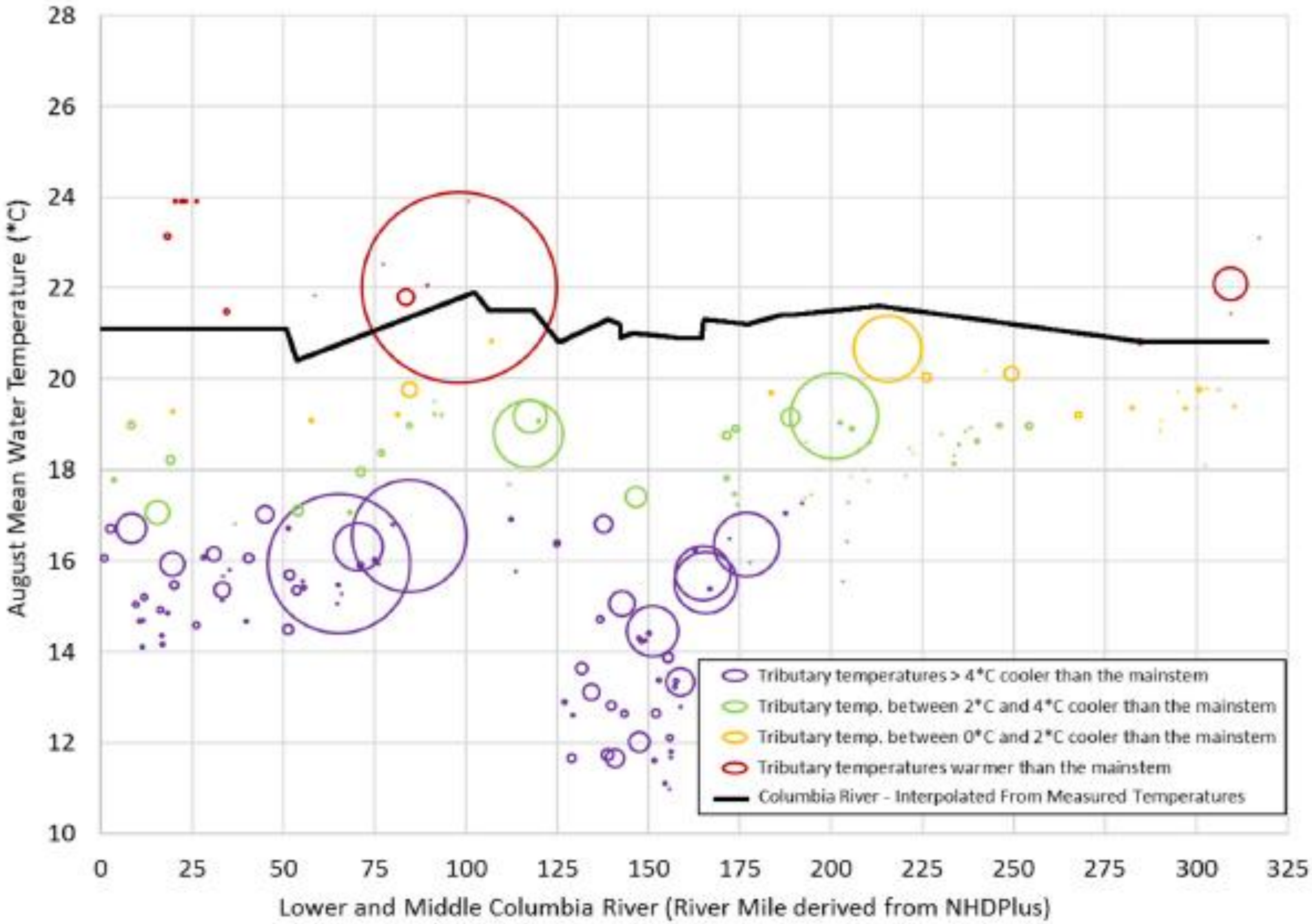
August Mean Tributary Temperature

Figure 2. Modeled August Mean Stream Temperatures within Tributaries that Discharge into the Lower and Middle Columbia River

[The size of the tributary markers in the bottom image is relative to the tributary flow level]



August Mean Temp w/Flow Representation



Columbia River CWR Tributaries
Preliminary Data

Table 1. Observed Average Monthly Temperature Difference (C) between the tributary and the Columbia River (**- CWR at Columbia main channel unlikely)

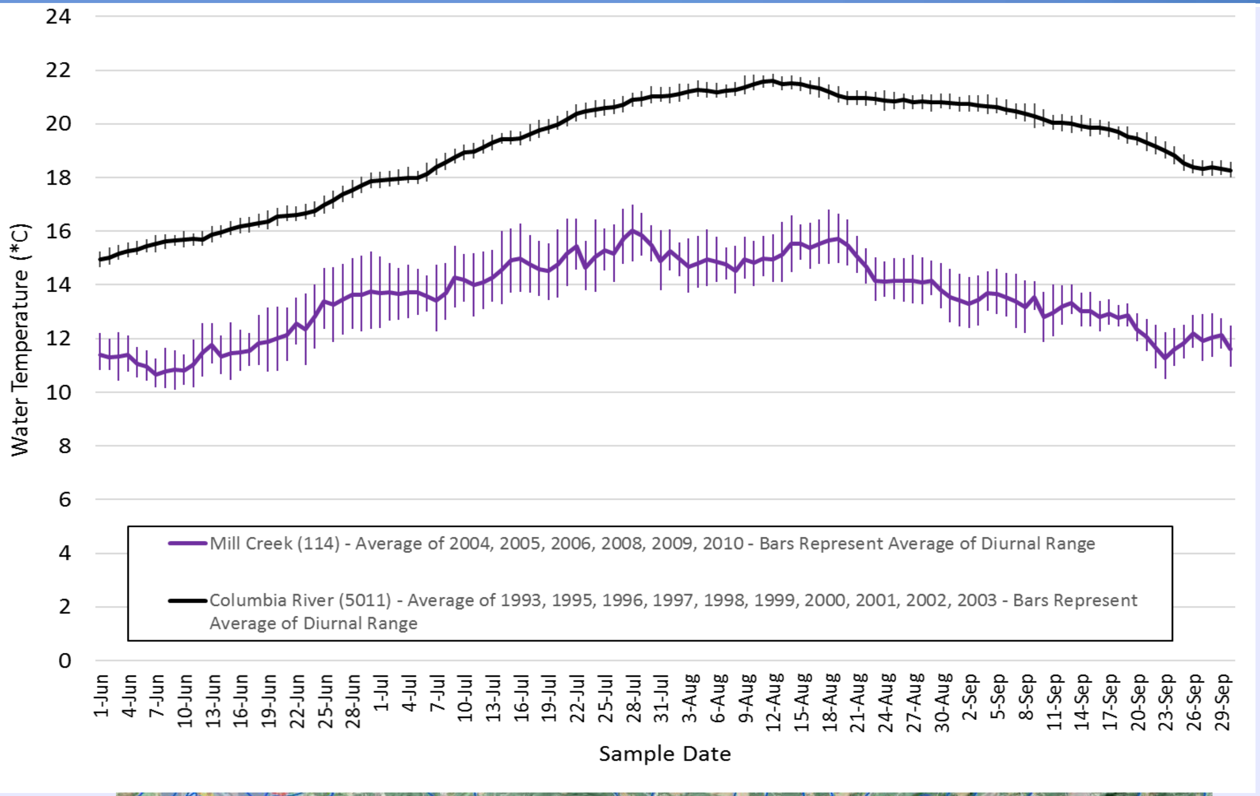
Site Name	June	July	August	September
Tributary #18 – Grays River**	4.2	5.1	6.4	6.4
Tributary #30 – Elochoman River**	0.5	2.0	2.5	4.6
Tributary #37 – Clatskanie River**	No Data	1.8	3.3	5.5
Tributary #38 – **Mill Creek**	4.3	4.9	6.4	7.0
Tributary #40 – **Abernethy Creek**	No Data	4.6	5.5	6.0
Tributary #41 – Germany Creek	3.7	3.7	5.2	6.2
Tributary #49 – **Cowlitz River**	No Data	4.1	5.8	5.8
Tributary #52 – **Kalama River**	4.8	4.1	5.4	6.3
Tributary #63 – **Lewis River**	Data pending			
Tributary #77 – **Sandy River**	1.6	0.9	2.8	3.8
Tributary #78 – Washougal River**	1.8	0.3	2.2	3.8
Tributary #83 – **Bridal Veil Creek**	6.4	7.5	9.0	8.4
Tributary #85 – **Wahkeena Creek**	6.2	8.8	10.9	10.0
Tributary #86 – Oneonta Creek	Data pending			
Tributary #88 – Woodward Creek	4.7	6.2	7.6	6.6
Tributary #88b – Hamilton Creek	4.3	4.9	5.8	5.8
Tributary #91 – **Tanner Creek**	5.8	7.7	9.3	9.2
Tributary #92 – **Eagle Creek**	4.3	3.9	5.2	6.0
Tributary #94 – **Rock Creek**	2.7	2.7	3.7	4.7
Tributary #96 – **Herman Creek**	4.3	7.2	9.2	8.9
Tributary #100 – **Wind River**	2.7	4.6	6.6	7.3
Tributary #112 – **LWS River**	6.3	7.6	9.1	8.4
Tributary #115 – **White Salmon River**	4.7	8.0	10.4	10.2
Tributary #116 – **Hood River**	3.7	4.4	5.8	6.9
Tributary #125 – **Klickitat River**	2.5	2.6	4.7	6.0
Tributary #129 – 15 Mile Creek	-1.1	-0.7	1.8	4.1
Tributary #135 – **Deschutes River**	-1.6	0.4	2.9	3.7
Tributary #147 – John Day River	-5.0	-3.9	-1.2	1.0
Tributary #167 – Willow Creek**	-4.1	-0.5	2.2	4.3
Tributary #176 – **Umatilla River**	-2.7	-3.0	0.0	1.9
Tributary #188 – Walla Walla River	-4.3	-6.0	-2.5	1.3

31 Tributaries > 2C colder than Columbia River (when T > 20C) & flow > 10 cfs

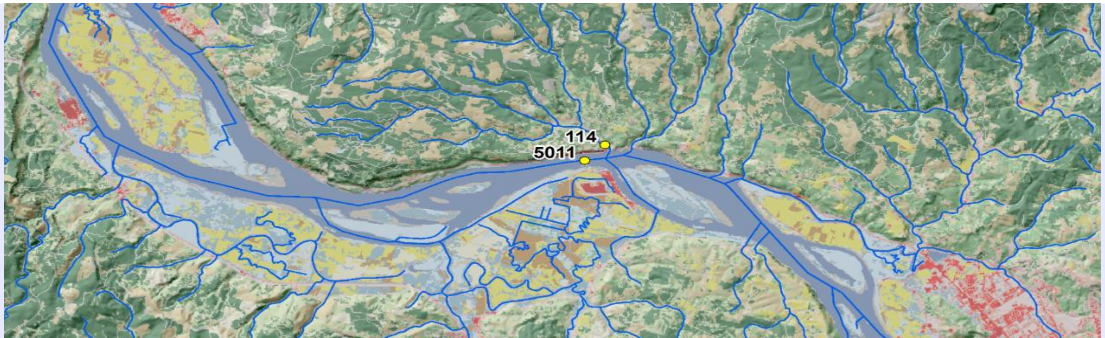
5 unlikely to have CWR at confluence with main channel of Columbia River

19 known or suspected CWR adult salmon use & CWR 18C or less (when Columbia >20C)

Mill Creek

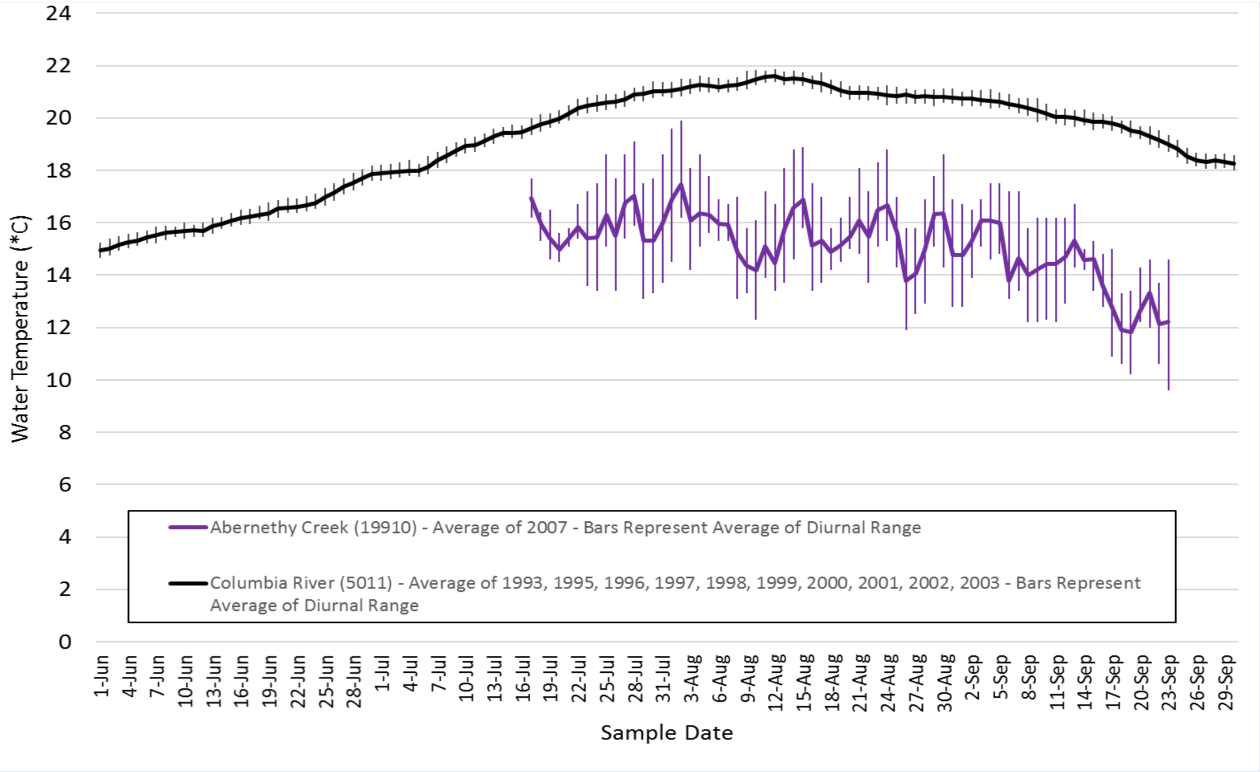


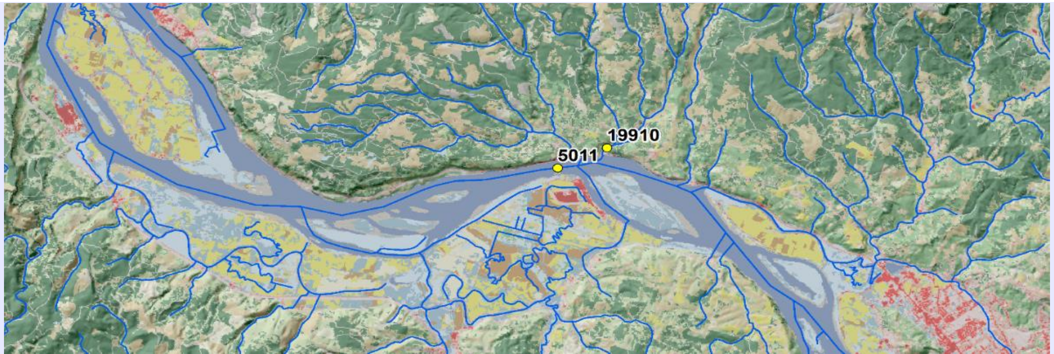
Water Temperature (*C)
Sample Date
Mill Creek (114) - Average of 2004, 2005, 2006, 2008, 2009, 2010 - Bars Represent Average of Diurnal Range
Columbia River (5011) - Average of 1993, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003 - Bars Represent Average of Diurnal Range



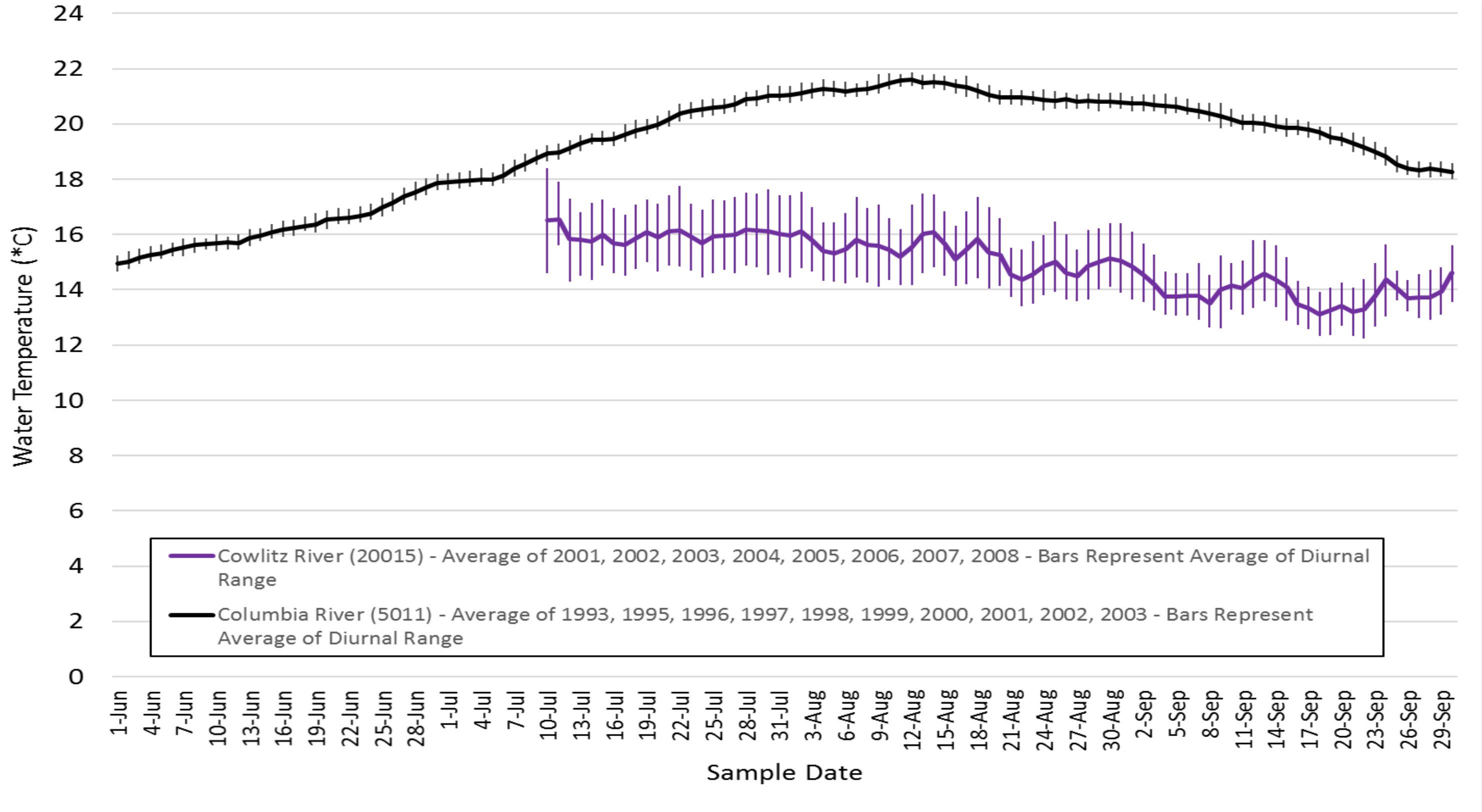
114
5011

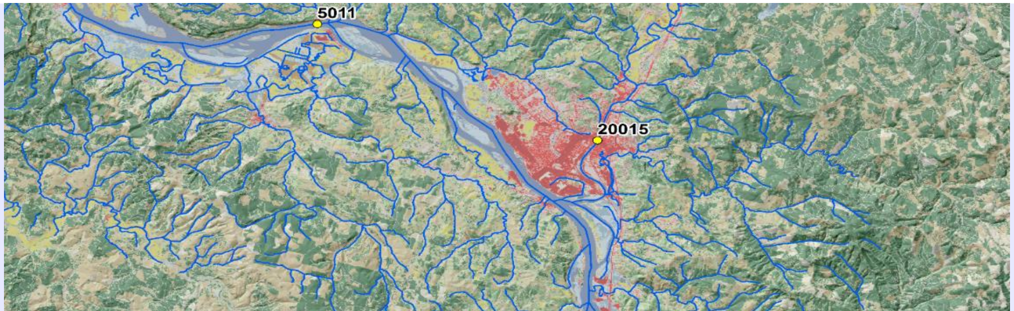
Abernethy Creek



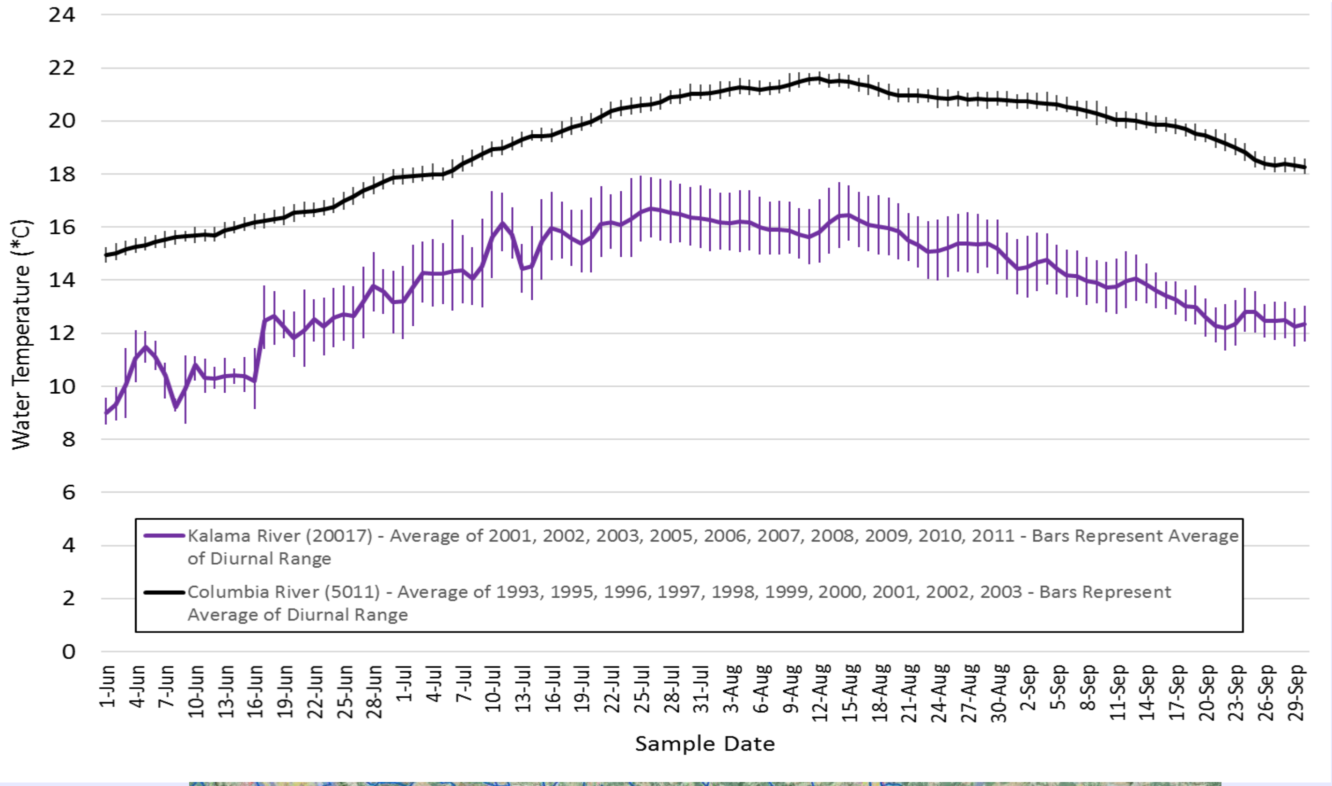


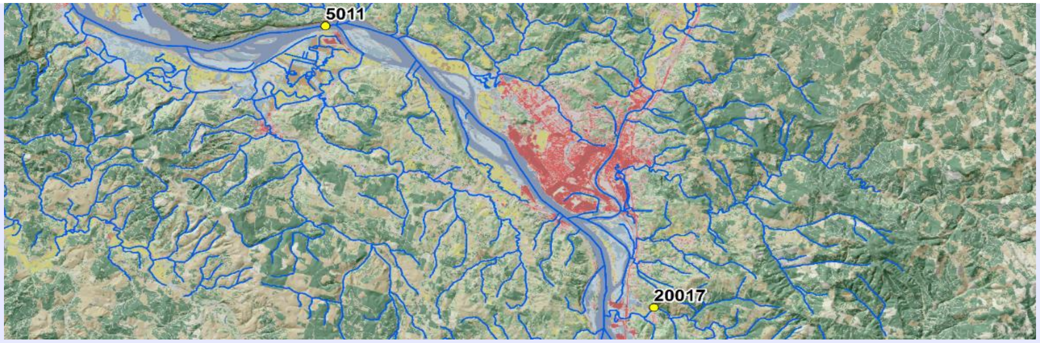
Cowlitz River



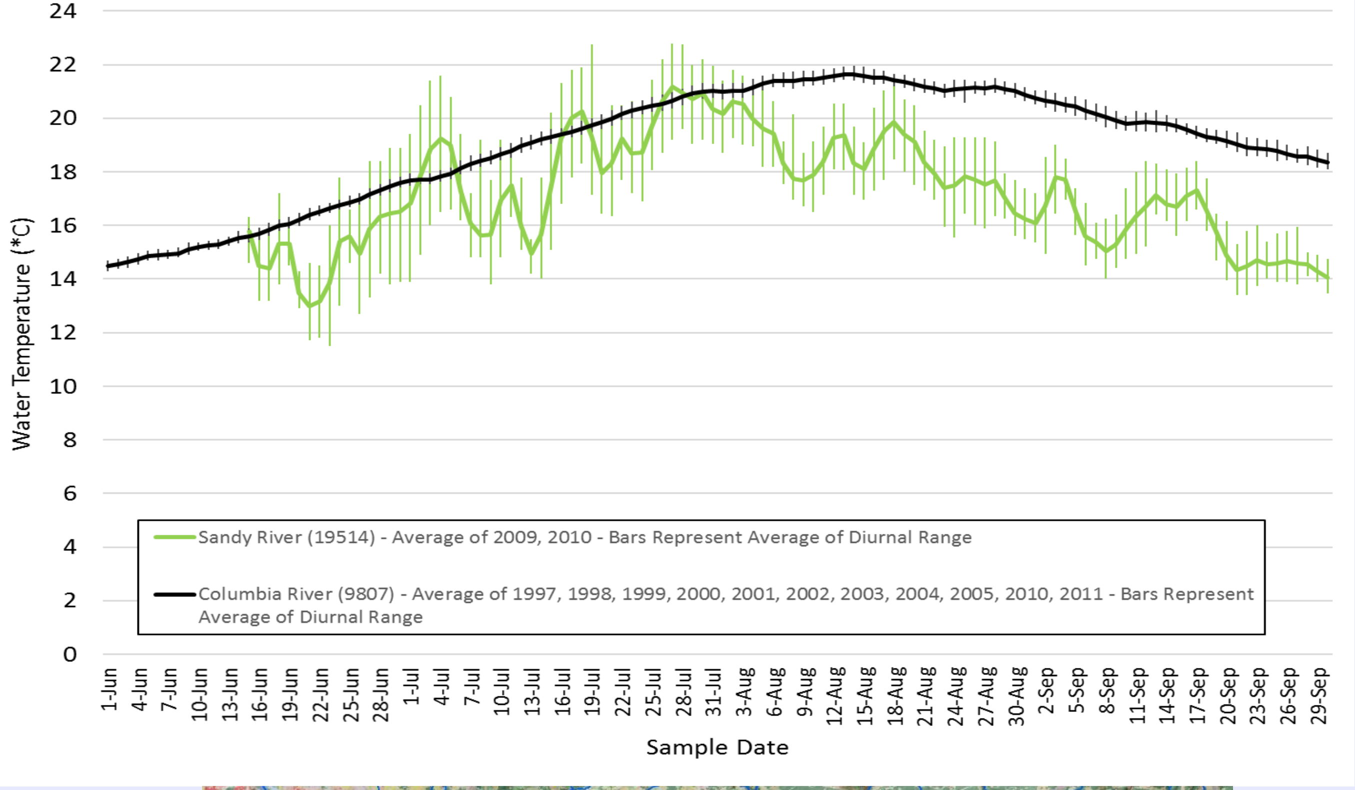


Kalama River

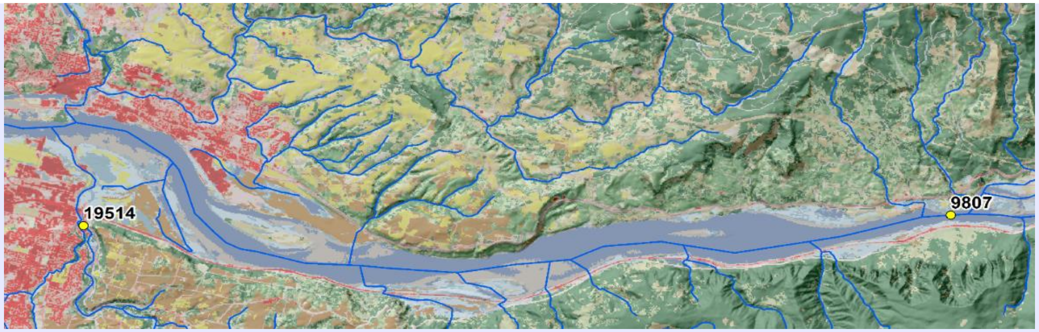




Sandy River

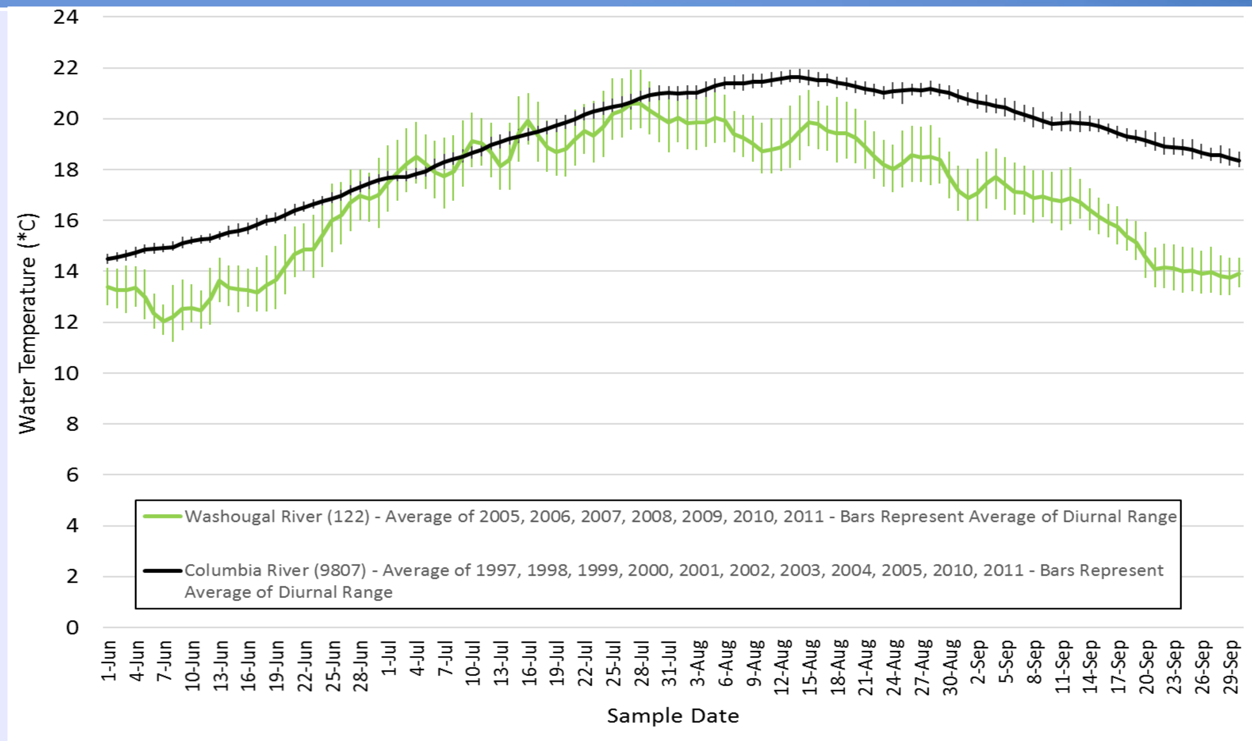


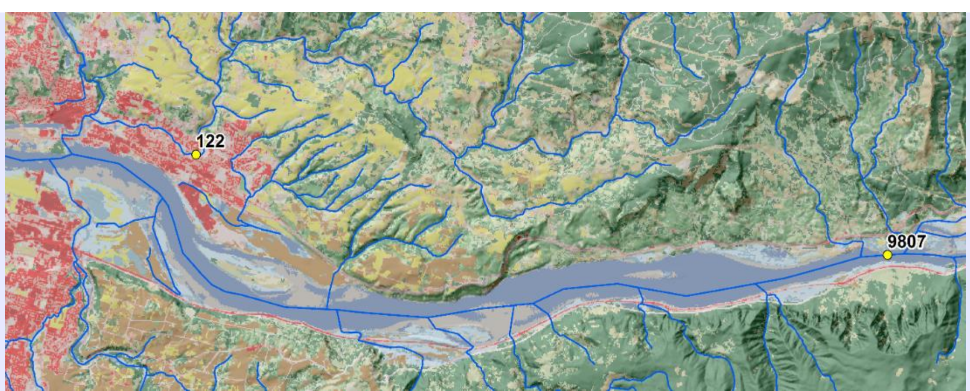
Water Temperature (*C)
24
22
20
18
16
14
12
10
8
6
4
2
0
Sandy River (19514) - Average of 2009, 2010 - Bars Represent Average of Diurnal Range
Columbia River (9807) - Average of 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2010, 2011 - Bars Represent Average of Diurnal Range
1-Jun
4-Jun
7-Jun
10-Jun
13-Jun
16-Jun
19-Jun
22-Jun
25-Jun
28-Jun
1-Jul
4-Jul
7-Jul
10-Jul
13-Jul
16-Jul
19-Jul
22-Jul
25-Jul
28-Jul
31-Jul
3-Aug
6-Aug
9-Aug
12-Aug
15-Aug
18-Aug
21-Aug
24-Aug
27-Aug
30-Aug
2-Sep
5-Sep
8-Sep
11-Sep
14-Sep
17-Sep
20-Sep
23-Sep
26-Sep
29-Sep
Sample Date



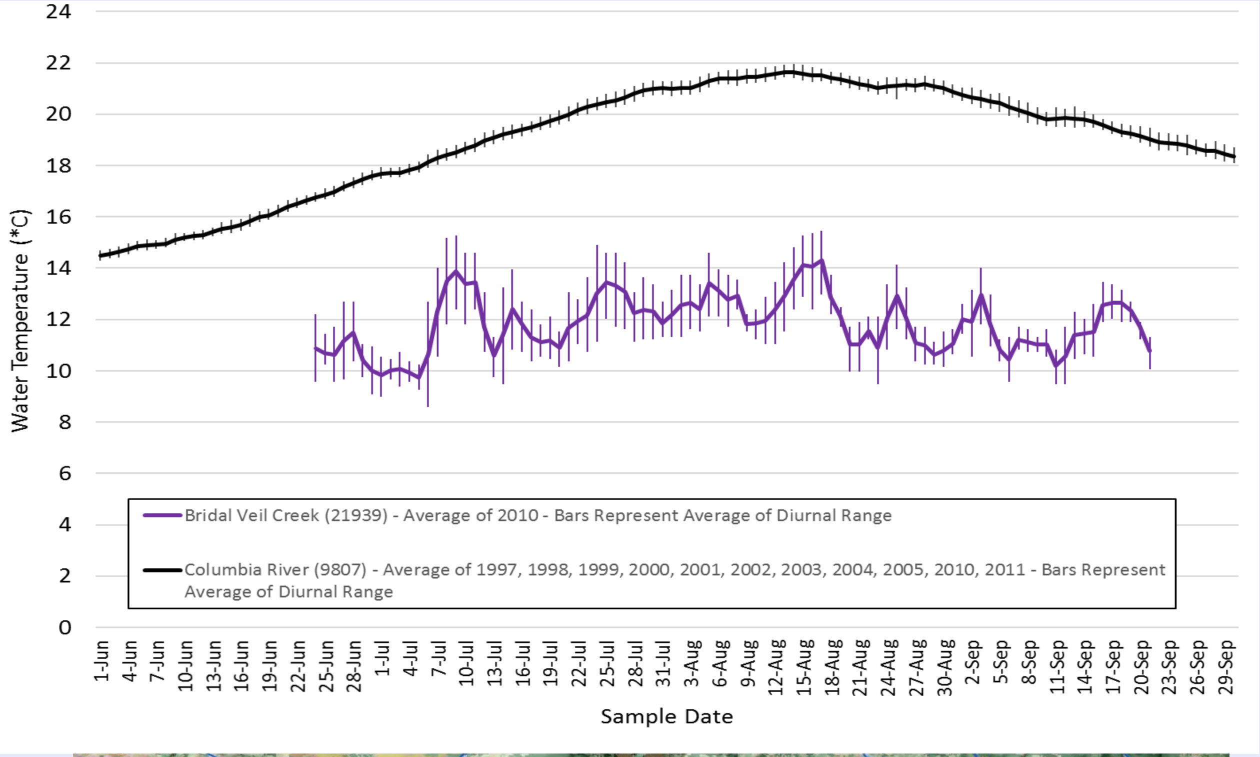
19514
9807

Washougal River

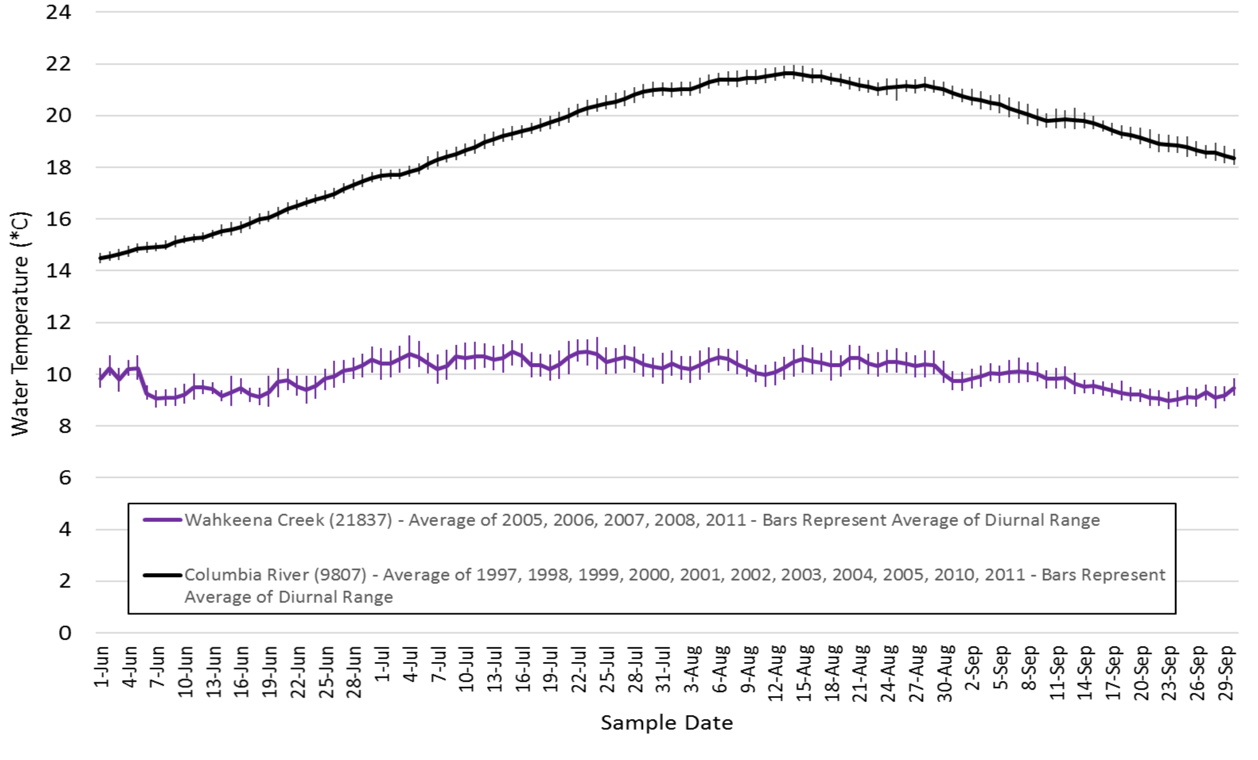




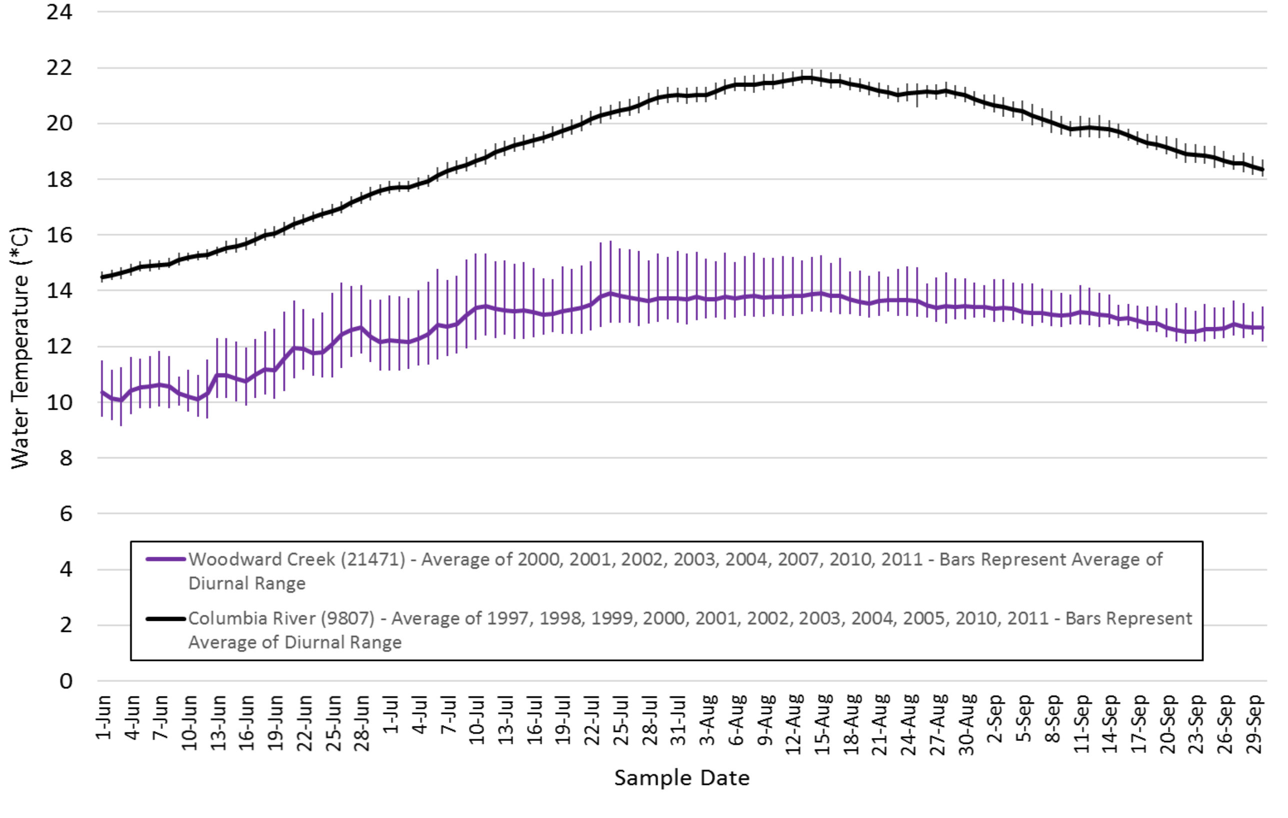
Bridal Veil Creek

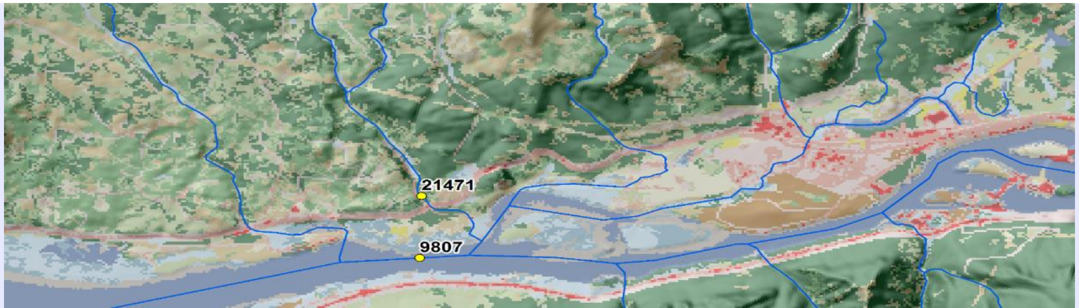


Wahkeena (& Multnomah) Creek

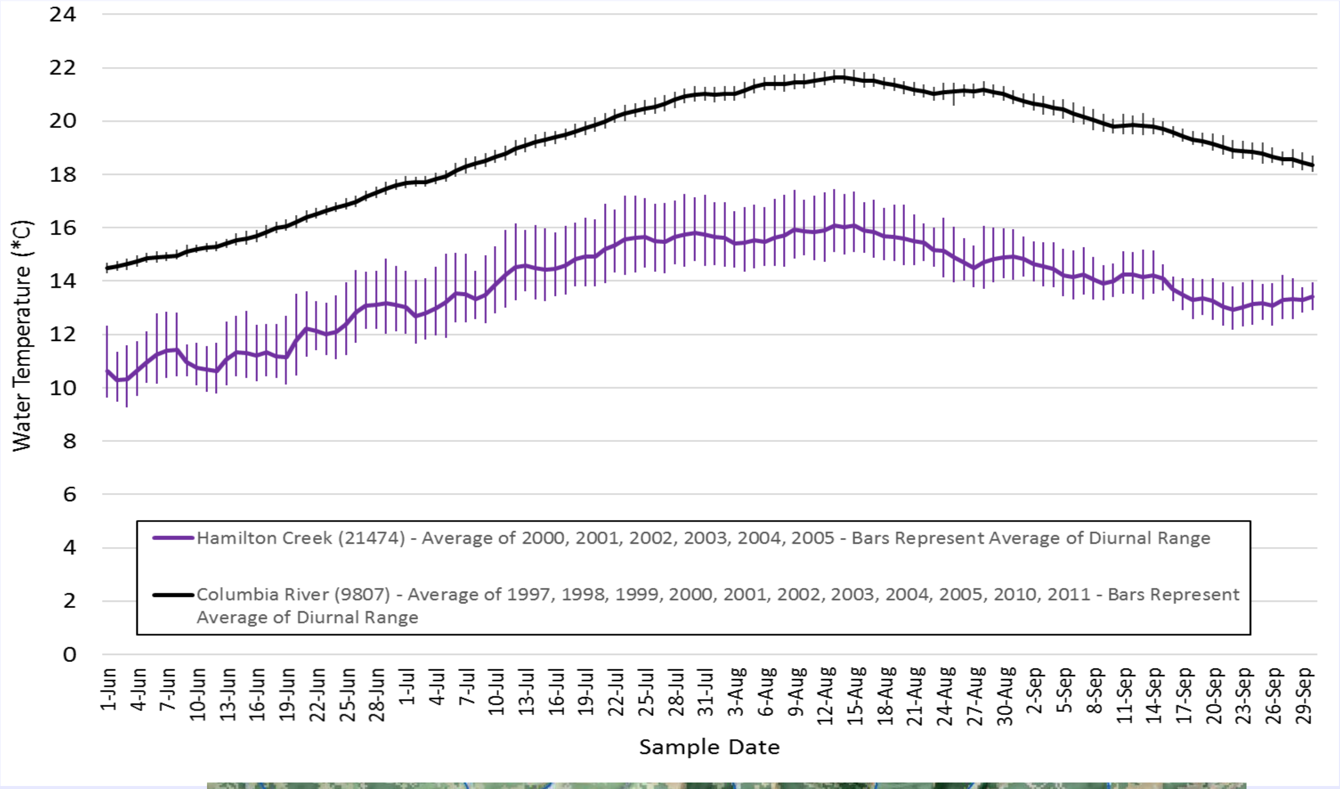


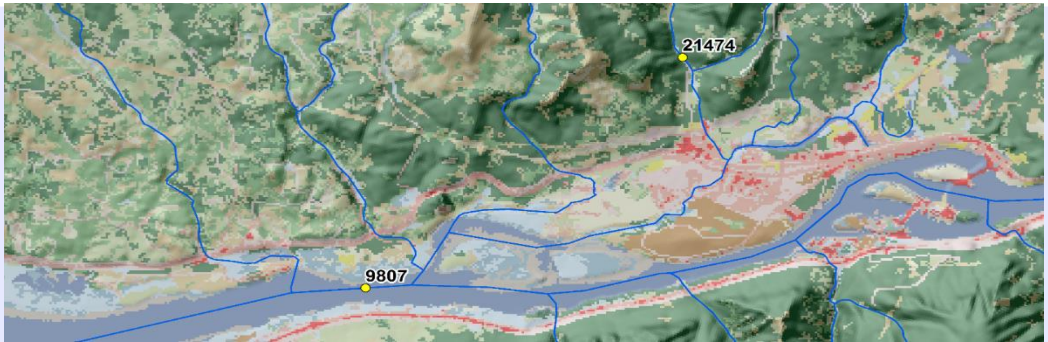
Woodard Creek



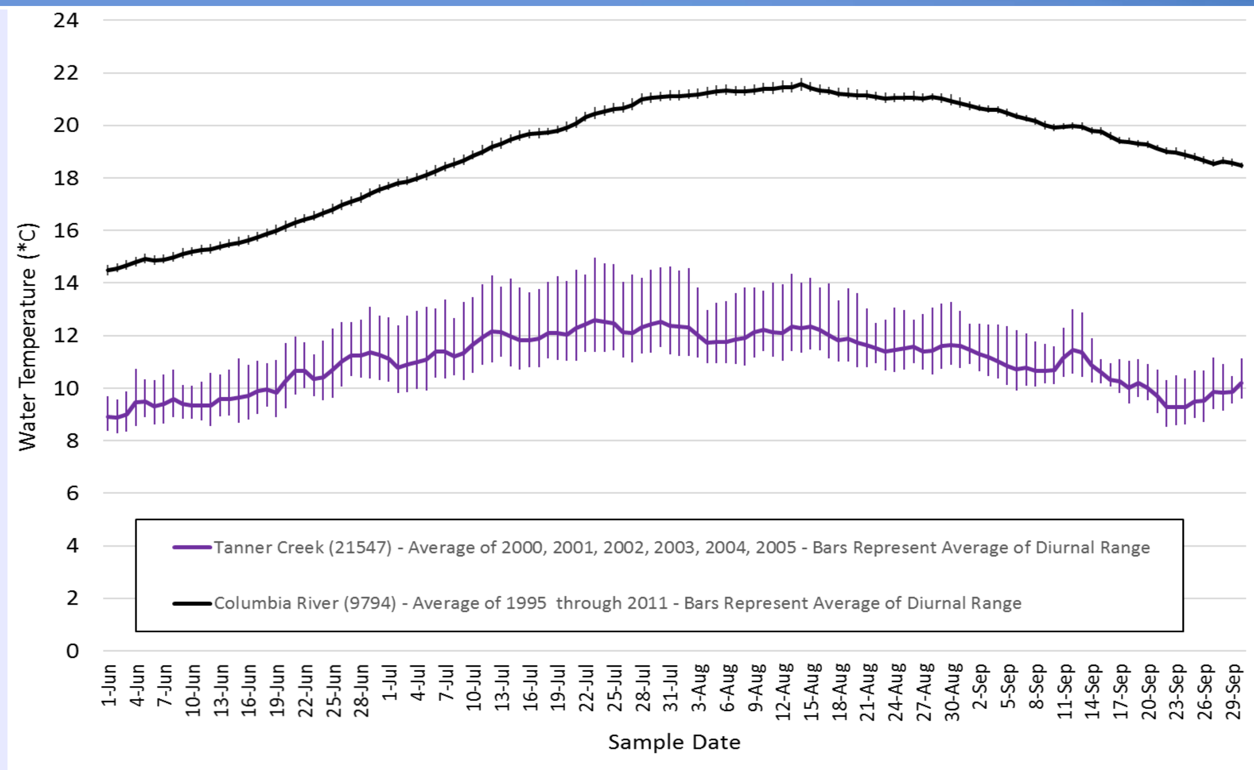


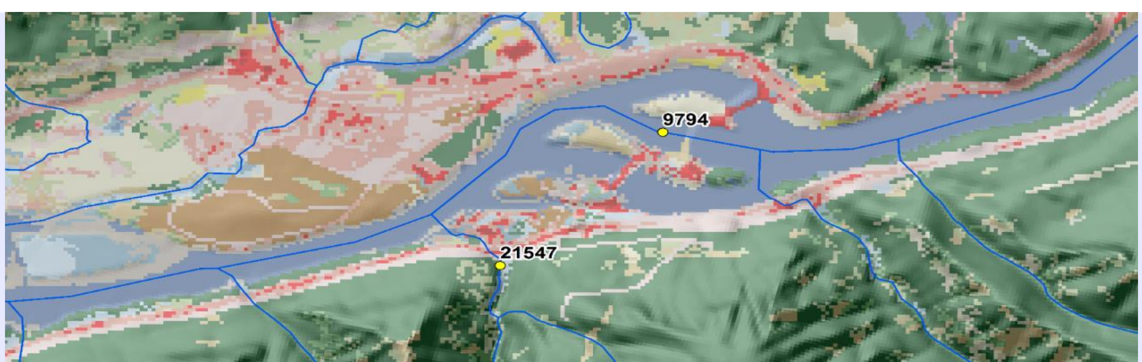
Hamilton Creek





Tanner Creek





Plume Characterization

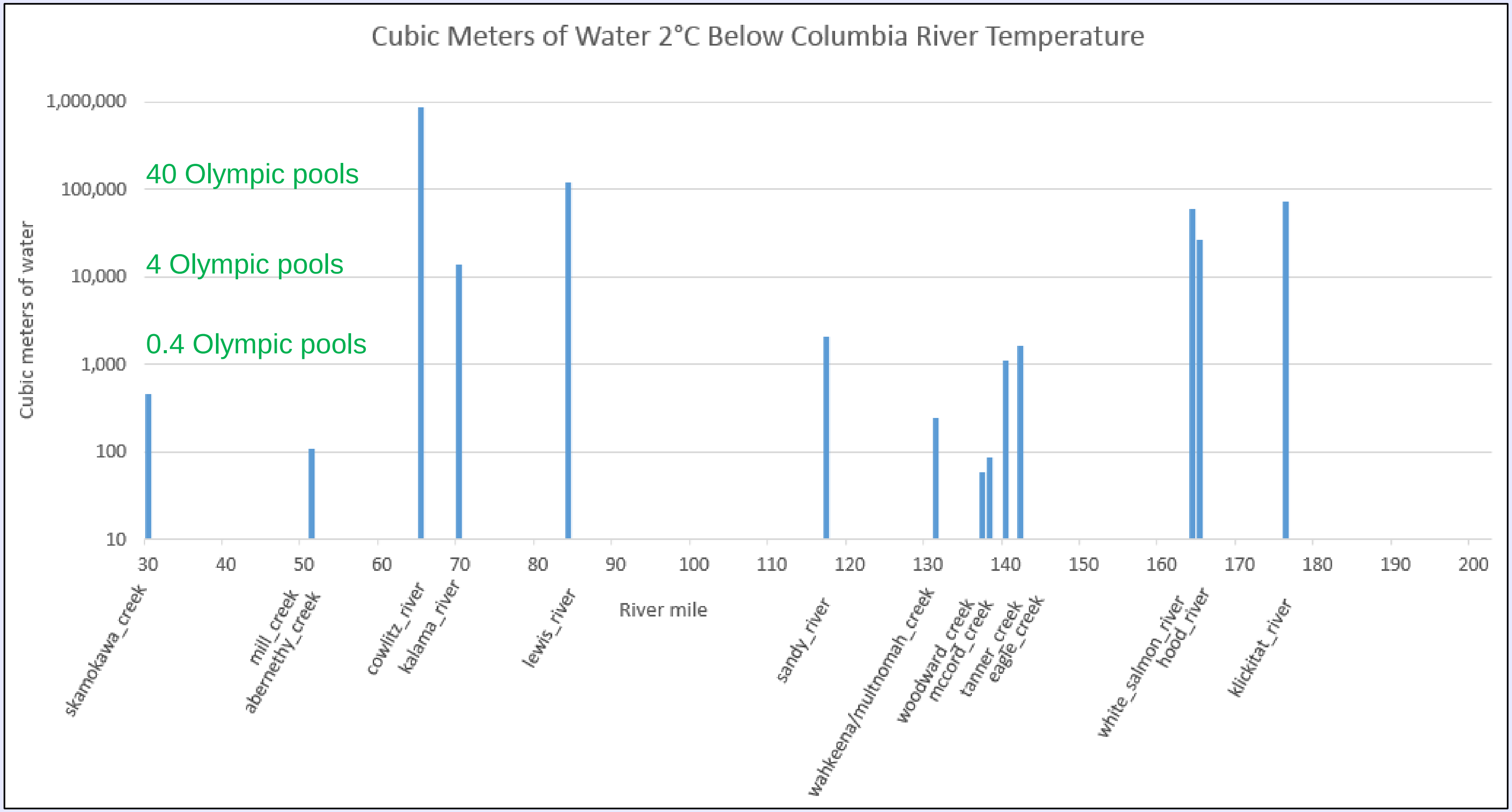
- EPA CORMIX Modeling
  - 26 tributaries confluences modeled
    - Cooler than Columbia River and greater than 10 cfs
    - Simple direct entry into Columbia River
  - 17 tributaries had plumes colder than Columbia

- EPA 2016 Plume monitoring study
  - Elochoman, Washougal, Wind, Rock, Little White Salmon

CORMIX Modeled Tributaries

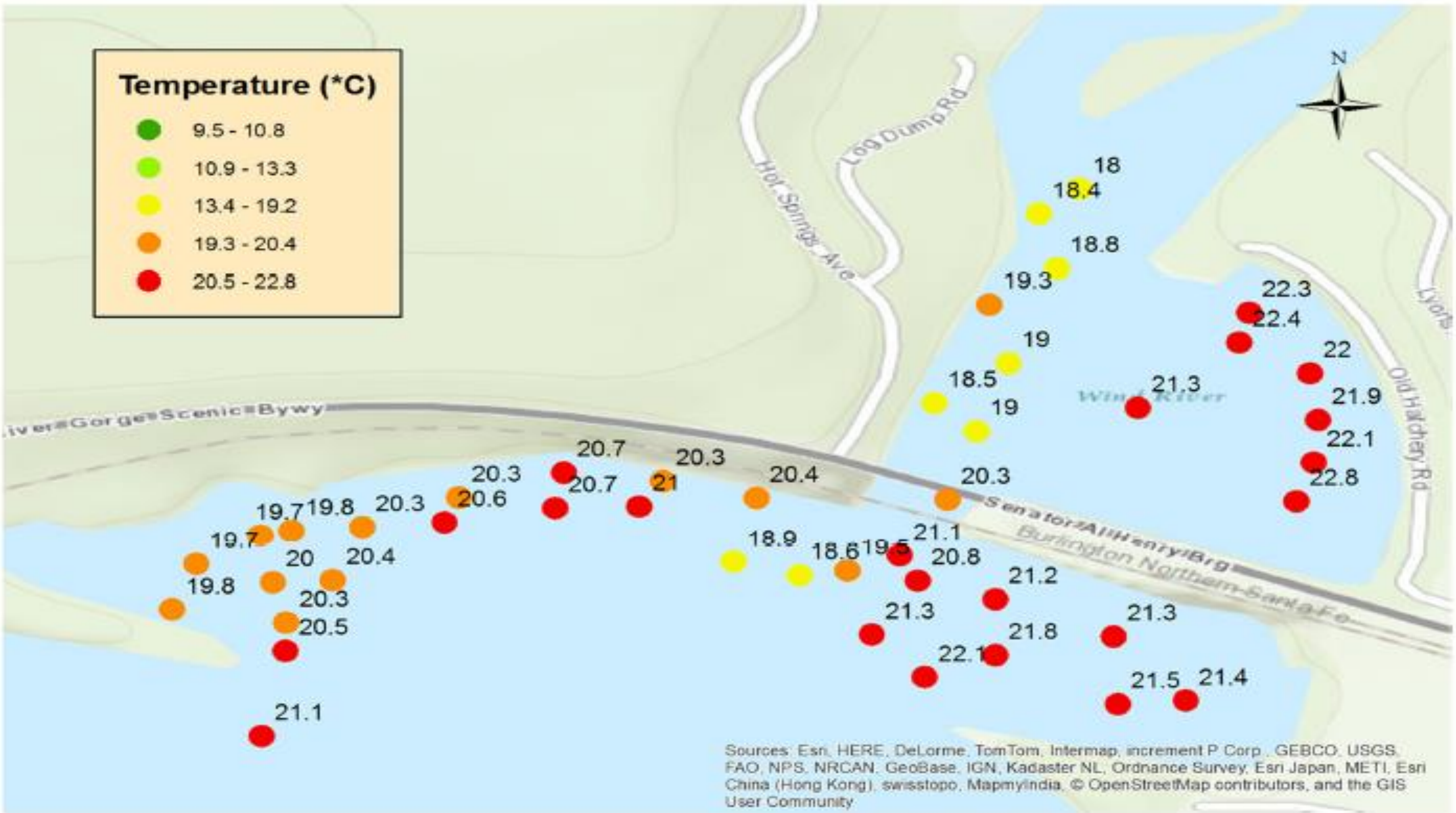
Tributary Code	River Mile	Tributary Name	State	Temperature Difference °C	Flow (cfs)
28	30.9	Skamokawa Creek	WA	5.1	23
37	45.0	Clatskanie River	OR	4.4	33
38	51.3	Mill Creek	WA	6.5	10
40	51.7	Abernethy Creek	WA	5.6	10
49	65.2	Cowlitz River	WA	5.4	3635
52	70.5	Kalama River	WA	5.0	264
63	84.4	Lewis River	WA	4.7	1417
77	117.1	Sandy River	OR	2.7	469
85	131.7	Wahkeena/Multnomah Creek	OR	8.2	15
88	137.7	Woodward Creek	OR	4.8	34
89	138.8	McCord Creek	OR	5.8	15
91	140.9	Tanner Creek	OR	8.5	38
92	142.7	Eagle Creek	OR	5.2	72
115	164.9	White Salmon River	WA	5.1	692
116	165.7	Hood River	OR	5.5	374
125	176.8	Klickitat River	WA	5.0	852
135	200.8	Deschutes River	OR	2.1	3447

Volume of CWR in modeled tributary plumes (Aug mean conditions)



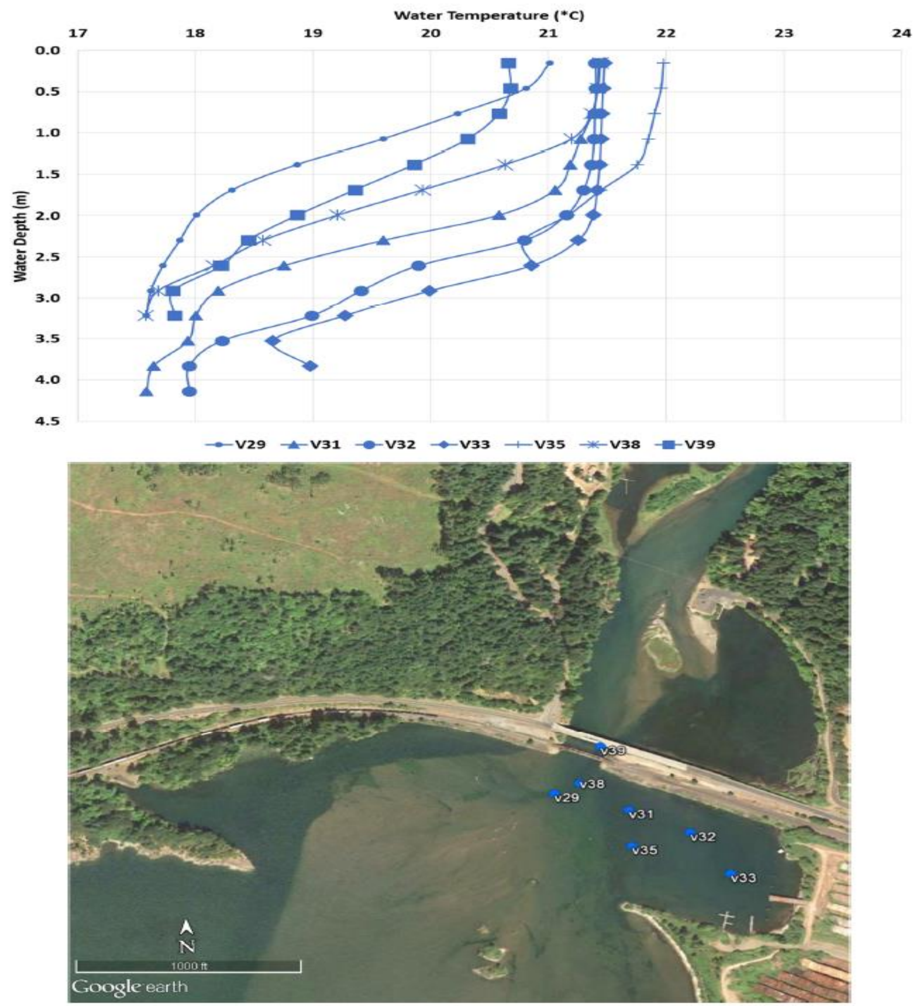
Wind River Confluence

Figure 2. Water Temperature at a 1 meter depth at the Wind and Columbia River Confluence (8/15/16)



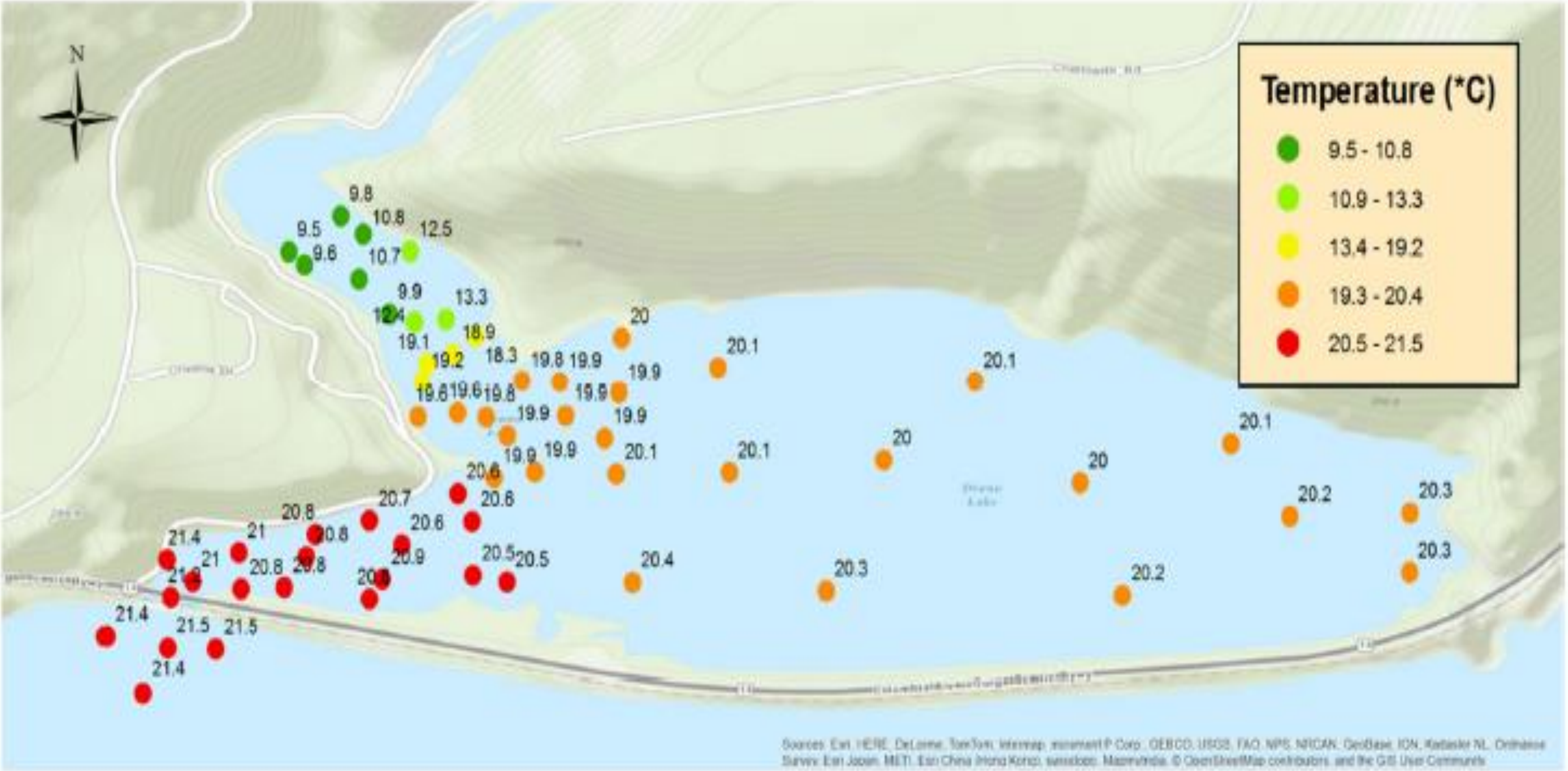
Wind River Confluence Con't

Figure 6. Measured Water Temperature Profile at Selected Wind and Columbia River Confluence Locations on August 15, 2016



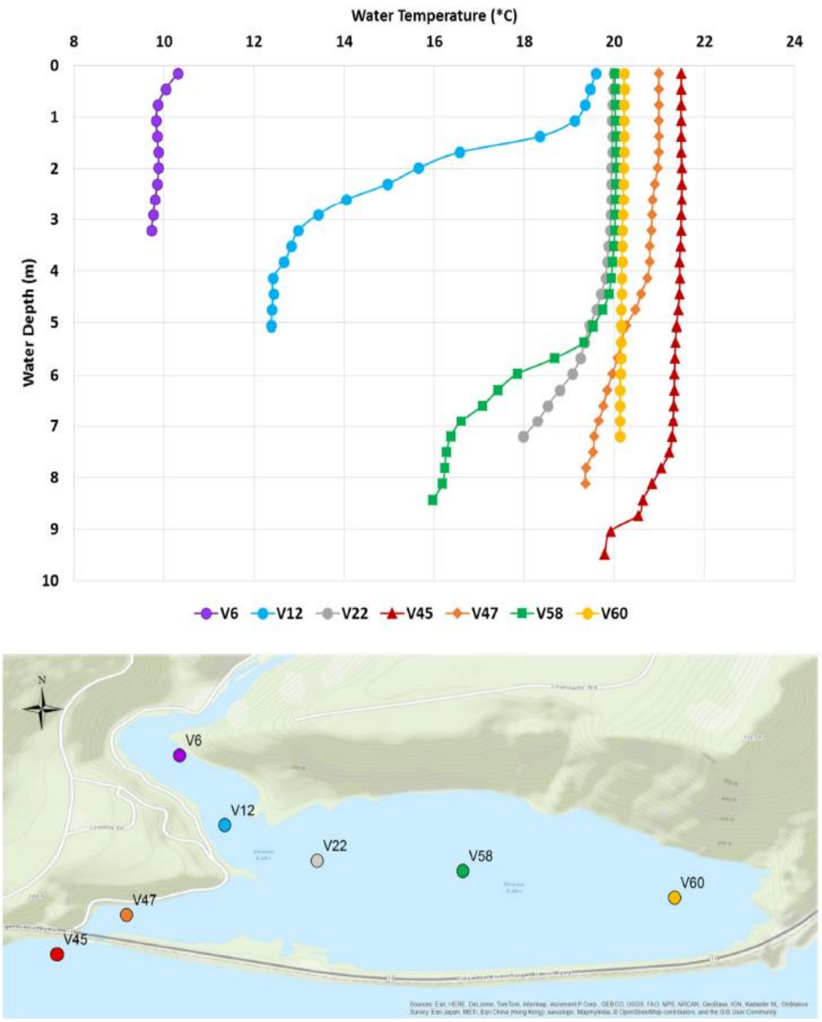
Little White Salmon (Drano Lake) Confluence

Figure 2. Measured Water Temperatures at a 1 meter depth in the Little White Salmon and Columbia River Confluence on August 17, 2016.



Little White Salmon (Drano Lake) Confluence

Figure 4. Measured Water Temperature Profile at Selected Locations at the Little White Salmon and Columbia River Confluence on August 17, 2016.



Background - Oregon Temperture Water Quality Standards

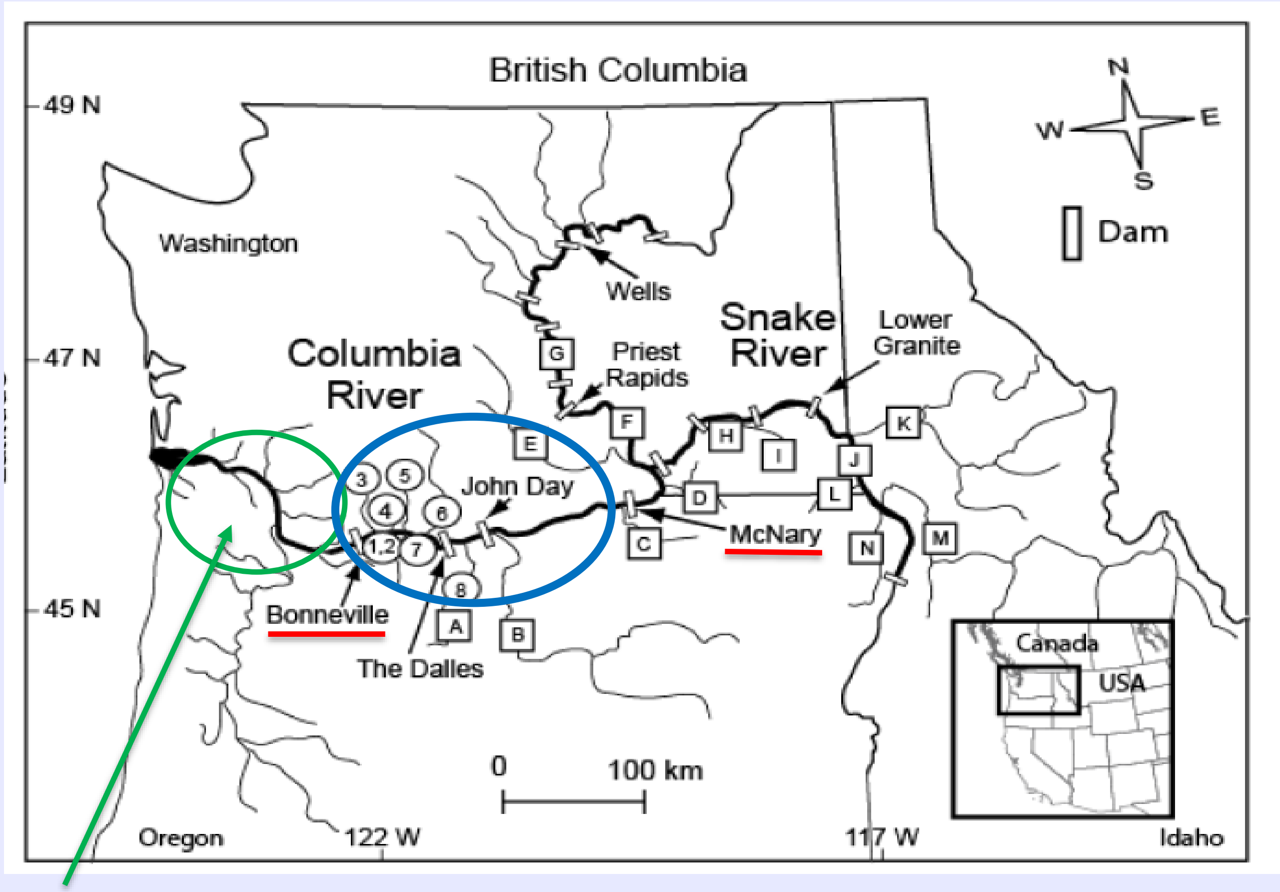
<u>Columbia & Lower Willamette River Temperature Criteria</u>

- Salmon and Trout Migration Corridor Use
- 20C numeric criteria, plus
- Cold Water Refugia (CWR) narrative criteria
  - “must have CWR that’s sufficiently distributed so as to allow salmon and steelhead migration without significant adverse effects from higher temperatures elsewhere in the water body”
  - “CWR means those portions of a water body where, or times during the diel cycle when, the water temperature is at least 2C colder than the daily maximum temperature of the adjacent well mixed flow of the water body”
- EPA approved in 2004

CWR Plan Elements

1. Characterize current spatial and temporal CWR
2. Characterize current salmon and steelhead use of CWR
3. Assess whether current CWR is sufficient to meet Oregon’s narrative criteria
4. Identity additional CWR needed to meet criteria if current CWR is insufficient
5. Identify programs and actions to protect and enhance current CWR areas
6. Identify locations and actions to restore CWR

Fish use of CWR studied in Columbia River from Bonneville Dam to McNary Dam (University of Idaho)

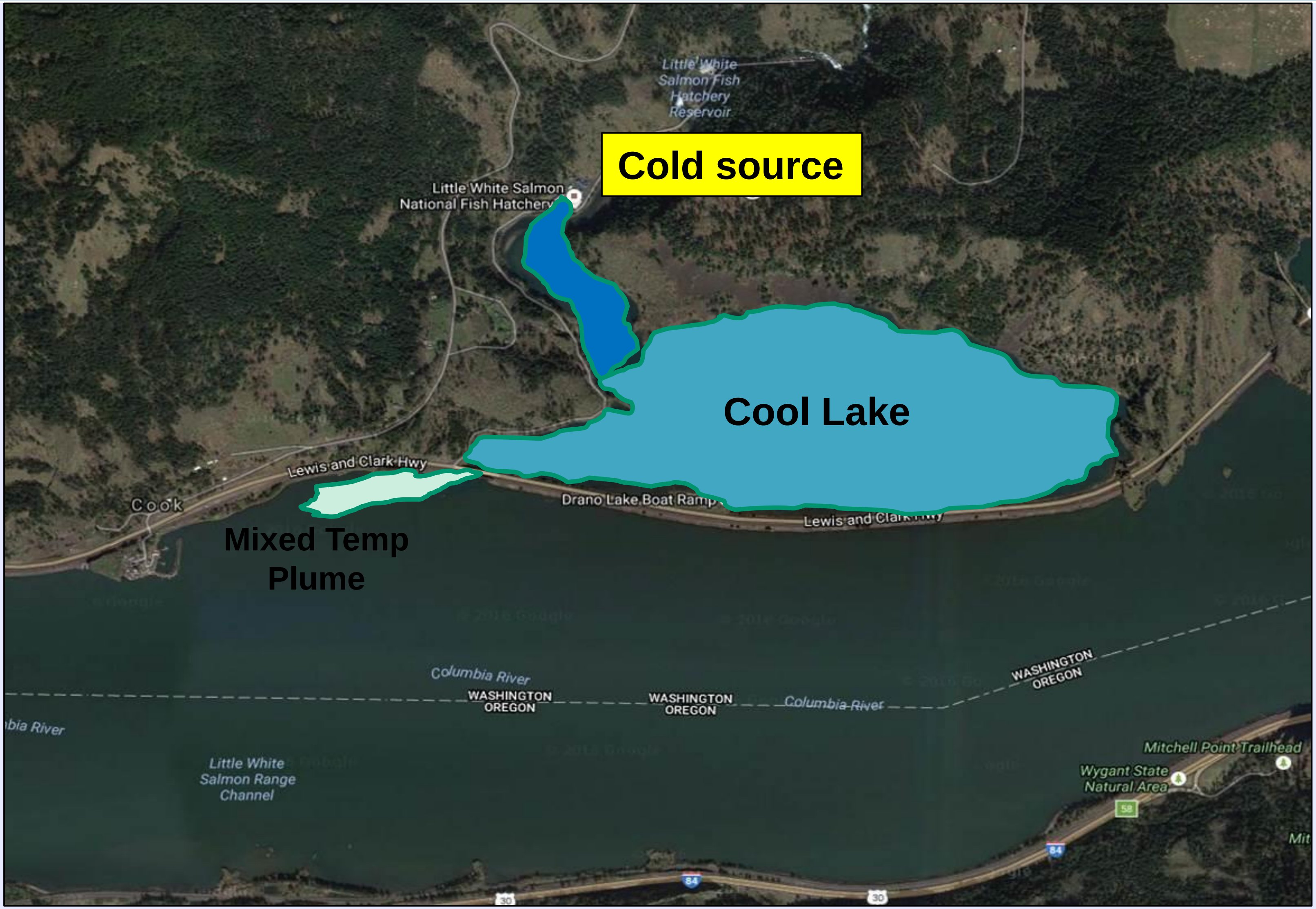


Little CWR research below Bonneville Dam

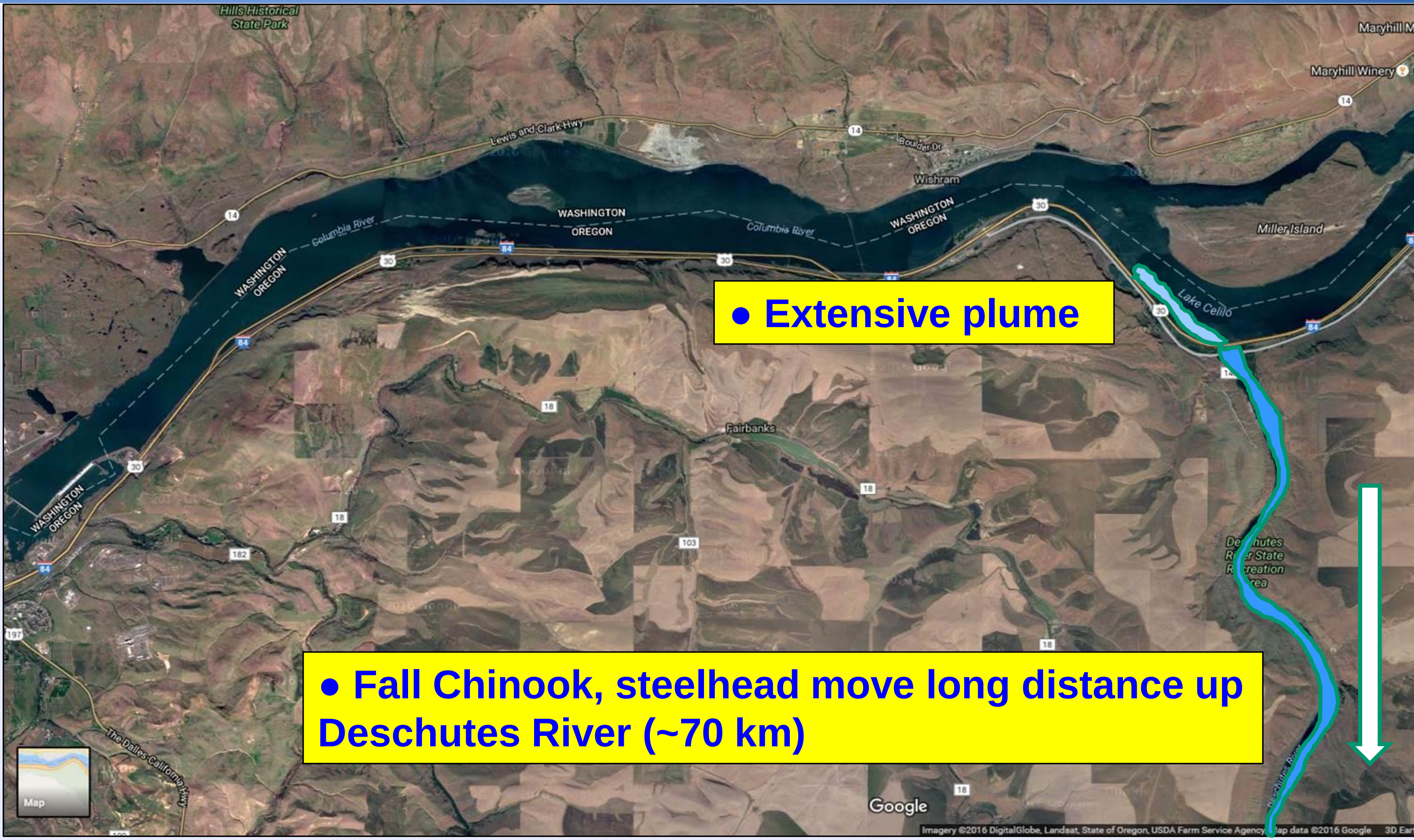
Source - Keefer et. al. 2011

1. **Eagle Creek**
2. **Herman Creek**
3. **Wind River**
4. **Little White Salmon**
5. **White Salmon River**
6. **Klickitat River**
7. **Hood River**
8. **Deschutes River**

Little White Salmon / Drano Lake CWR



Deschutes River CWR



- **Extensive plume**
- **Fall Chinook, steelhead move long distance up Deschutes River (~70 km)**

Fish Passage Timing at Bonneville Dam

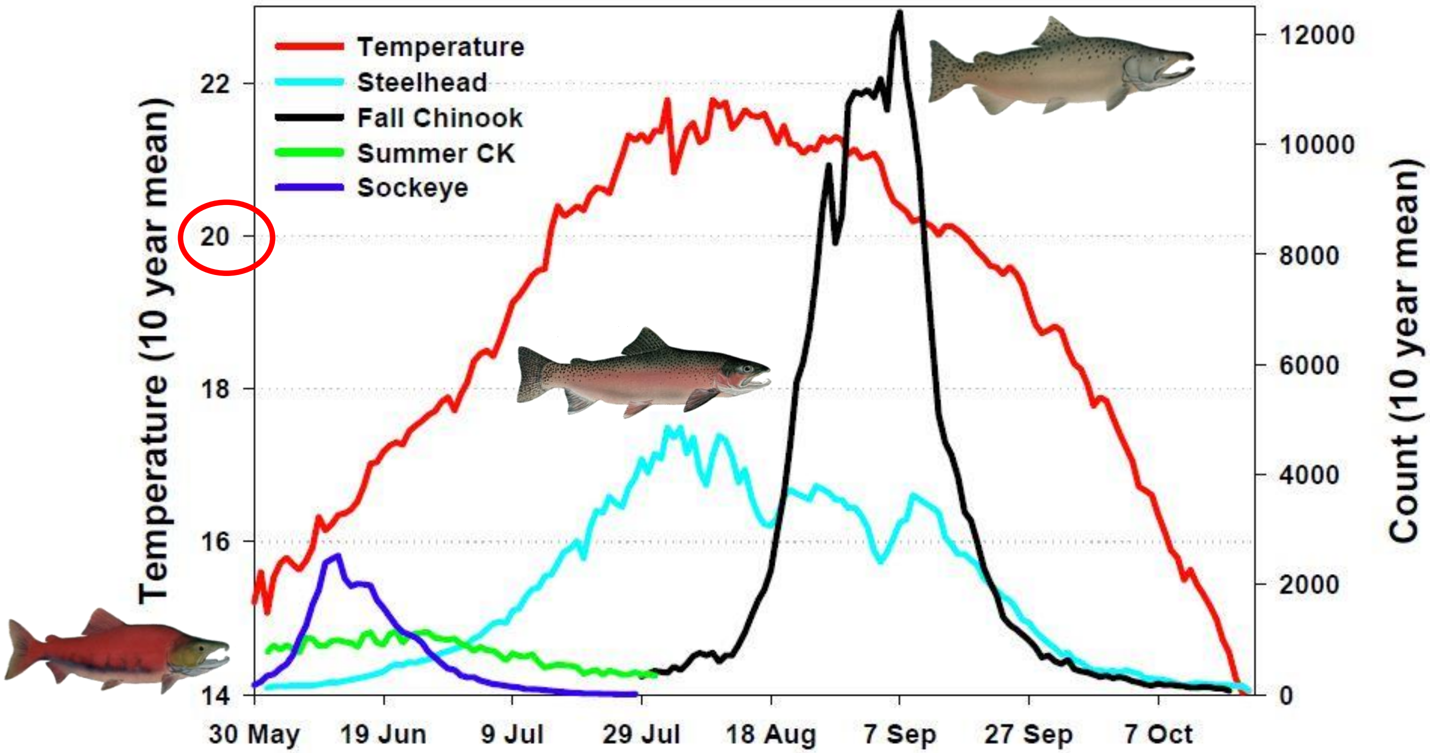
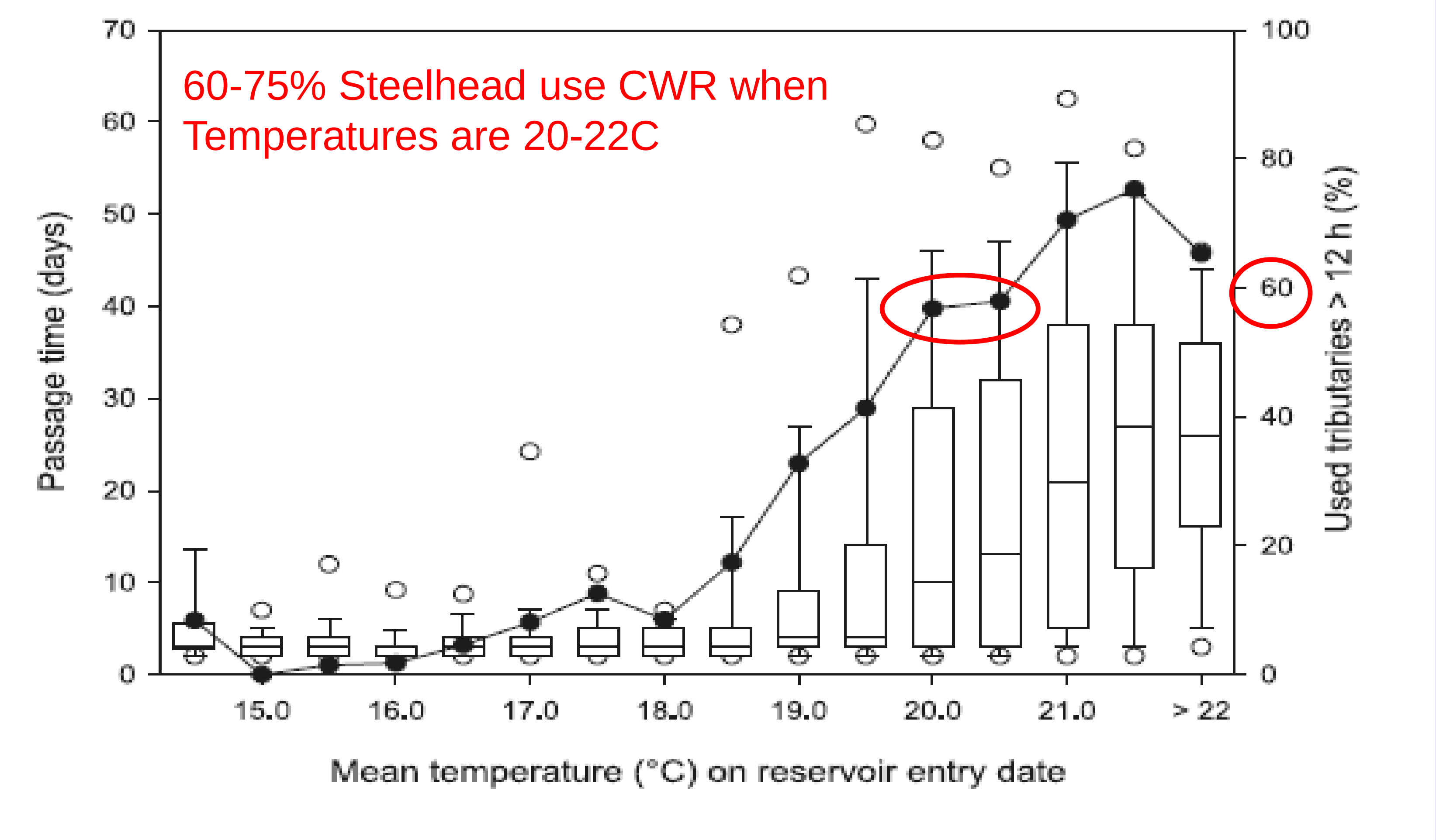


Figure 2. Ten-year (1996-2005) mean lower Columbia River water temperature (°C) and mean run size and timing of adult summer Chinook salmon, fall Chinook salmon, sockeye salmon, and summer steelhead at Bonneville Dam. Thermal refugia use by many adult populations has been associated with water temperatures greater than 19-20 °C.

(Keefer et al. 2011)

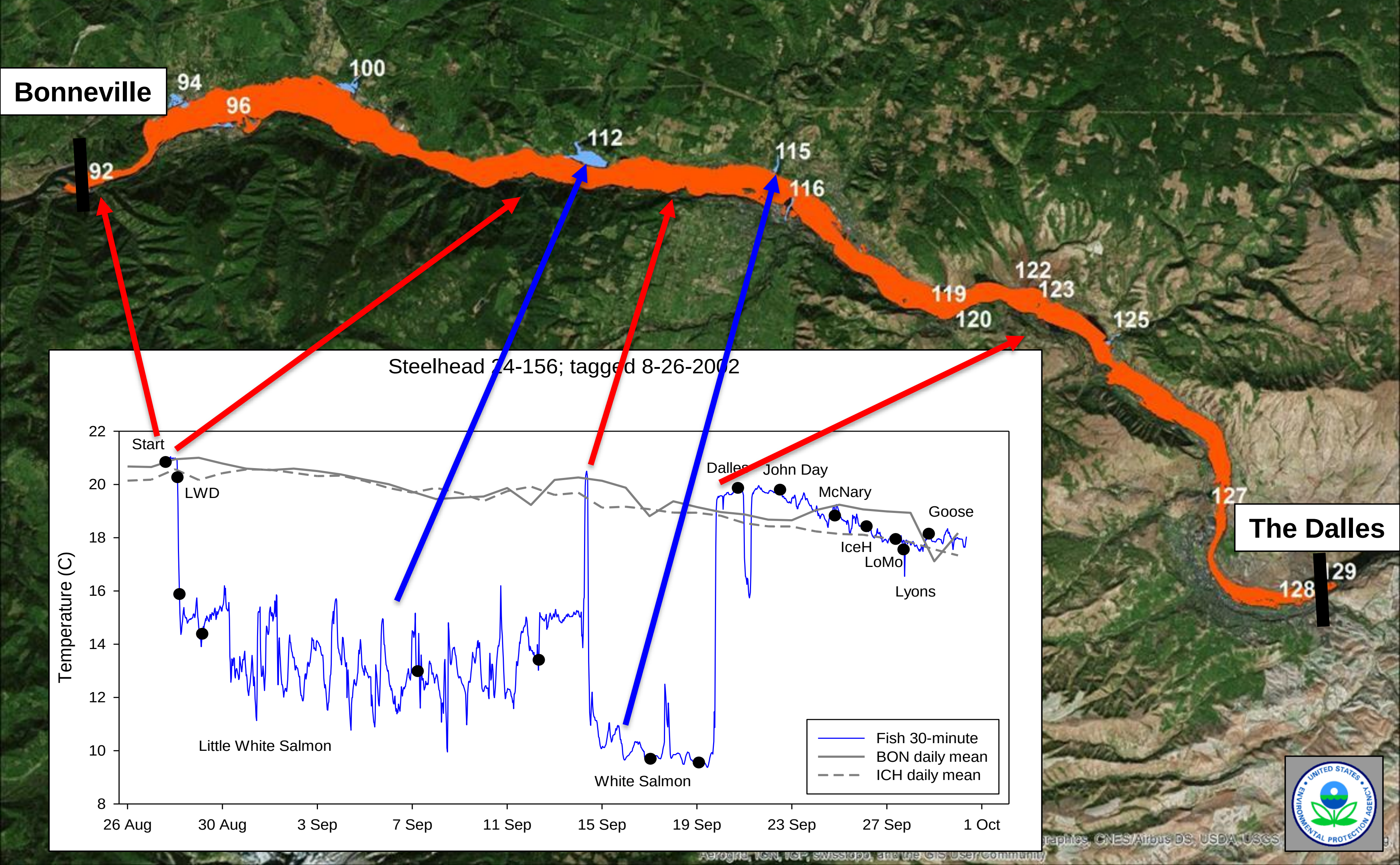
Steelhead use of CWR
(between Bonneville Dam and the Dalles Dam)



Source - Keefer et al. 2009

Steelhead use of CWR

Columbia River between Bonneville Dam and The Dalles Dam



Steelhead holding in CWR Tributaries between Bonneville Dam and John Day Dam

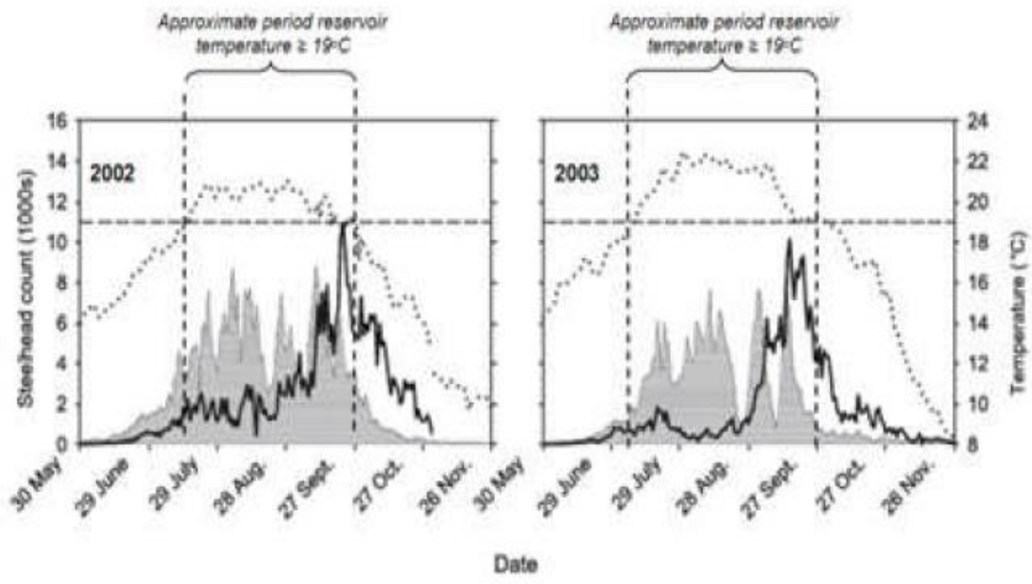


Figure 4. Number of steelhead counted at Bonneville Dam (shaded area) and at John Day (solid black line) for 2002-2003. The vertical dashed lines bound the time periods when an increased use of thermal refuges is observed. The horizontal dashed line at 66.2˚F (19 ˚C) line is a threshold temperature where use of thermal refuges rapidly increases. The dotted lines are the average daily Columbia River water temperature at the Bonneville Dam. *Sources*: Graph modified from Keefer et al 2009, (2002 and 2003 years excerpted); Columbia River temperatures from DART (water quality monitoring site in Bonneville Dam forebay; *www.cbr.washington.edu/dart/river.html*).

Source - Cramer Fish Sciences, 2011

- **Approximately 80,000 Steelhead in CWR tributaries on any given day in August**
- Based on following rough estimate:
- BON July 15 – Aug 31 = Approx. 5,000 Steelhead/day = 225,000
- 225,000 x .76 (10 year avg. % expected to pass JDA) = 171,000
- JDA July 15 – Aug 31 = Approx. 2,000 Steelhead/day = 90,000
- 171,000 – 90,000 = 81,000 of Steelhead using CWR between BON- JDA

Steelhead population use of specific CWR areas in the Columbia River

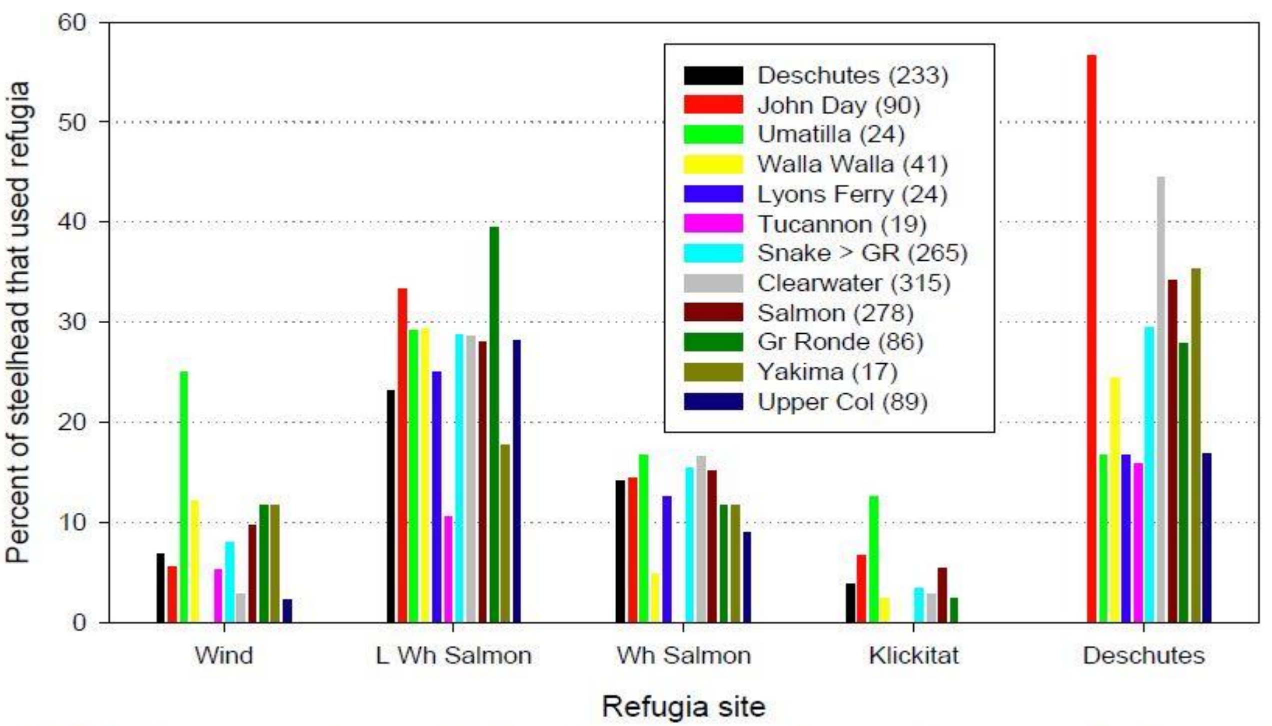


Figure 7. Population-specific use of selected cool-water refugia tributaries in the Bonneville-John Day reach by radio-tagged summer steelhead in 1996-1997 and 2000. Bar colors represent upriver populations, with sample sizes in parentheses. Steelhead additionally used Herman and Eagle creeks, but these small sites were inconsistently monitored in these study years. A small number of steelhead temporarily used the Hood River (not shown).

Source - Keefer et al. 2011

Chinook use of CWR

- CWR use associated with 21C temperature
- 20-40% use CWR with 21-22C
- Migration rate cut in half
- Plume use as well (not fully counted as CWR use – so above statistics don't account for this)
- Fall Chinook likely use CWR more than Summer Chinook

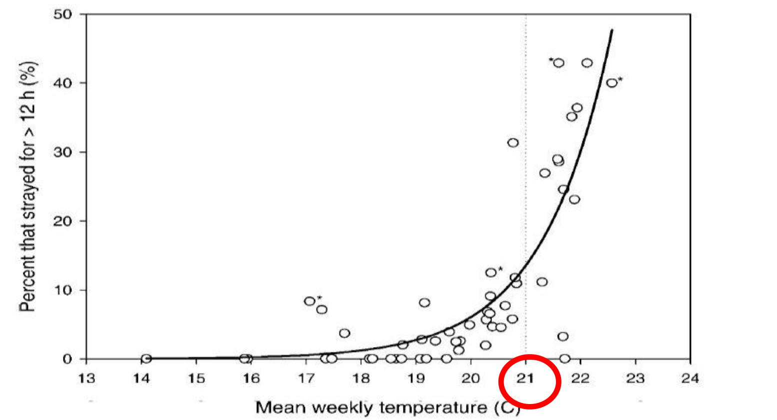


FIGURE 6.—Relationship between the percent of fall Chinook salmon that used (>12 h) coolwater tributaries and mean weekly water temperatures at Bonneville Dam. Circles represent 52 weekly bins (mean = 41 fish/bin; range = 4–122 fish/bin). The curve is the exponential regression line that best fits the data ($r^2 = 0.80$; $P < 0.0001$; percent $= 6.558^{-7}e^{0.802 \times \text{temperature}}$). Asterisks indicate data points with fewer than 10 fish.

414 GONIEA ET AL.

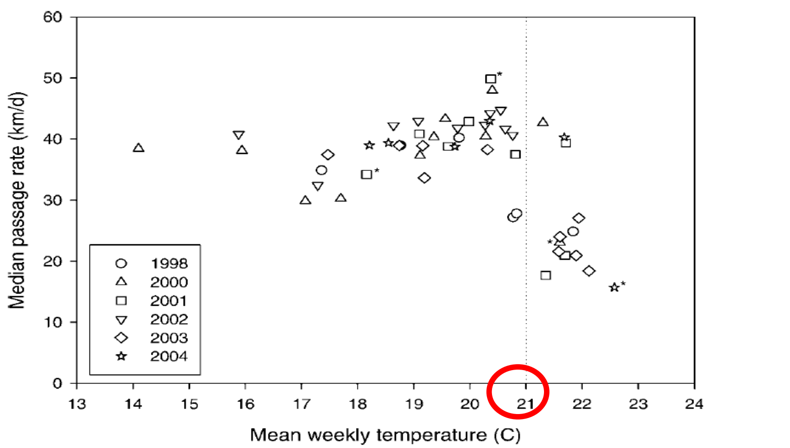
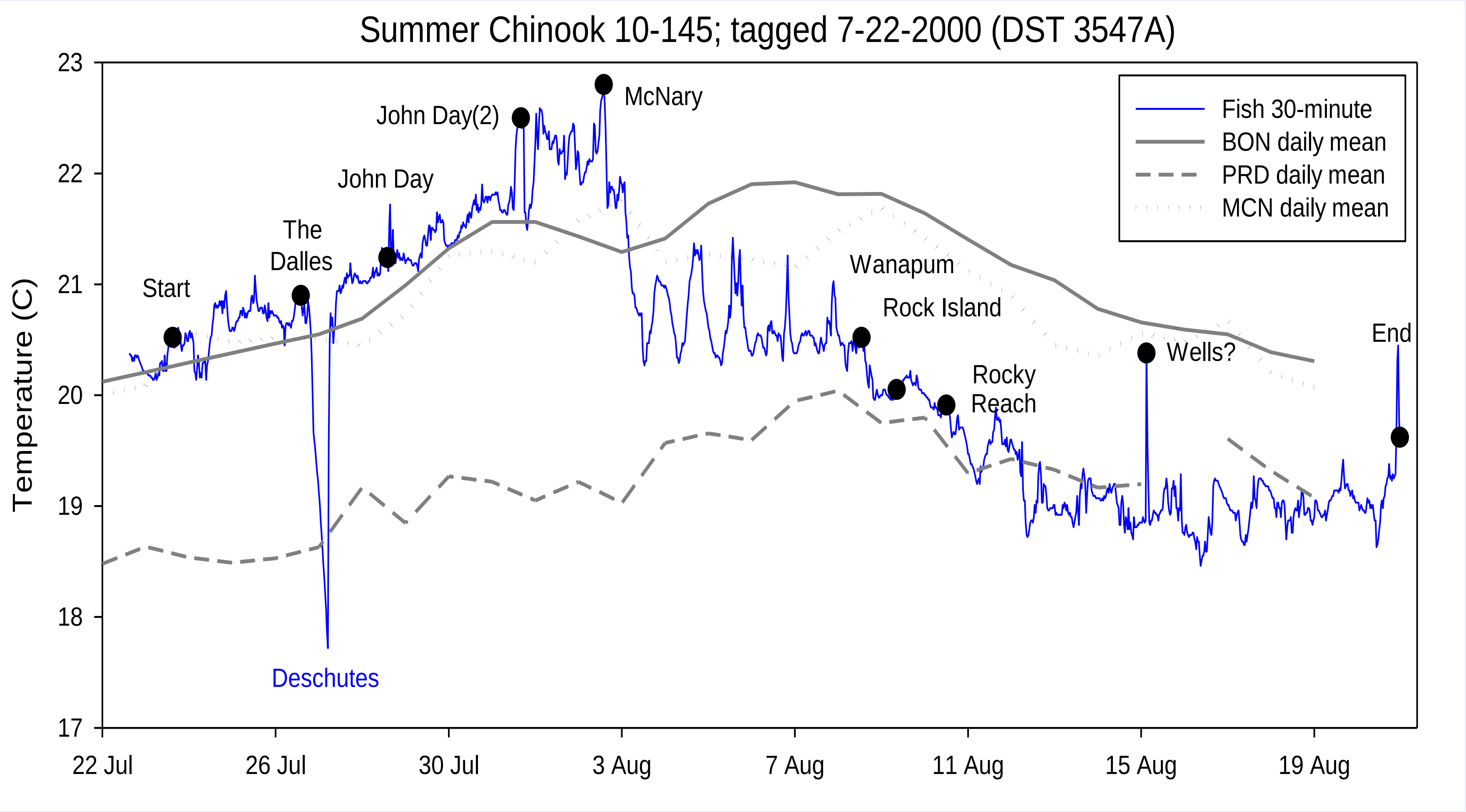


FIGURE 5.—Relationship between median fall Chinook salmon migration rates (Bonneville Dam to John Day Dam) and mean weekly water temperatures at Bonneville Dam. Symbols represent 52 weekly bins (mean = 41 fish/bin; range = 4–122 fish/bin). Asterisks indicate data points with fewer than 10 fish.

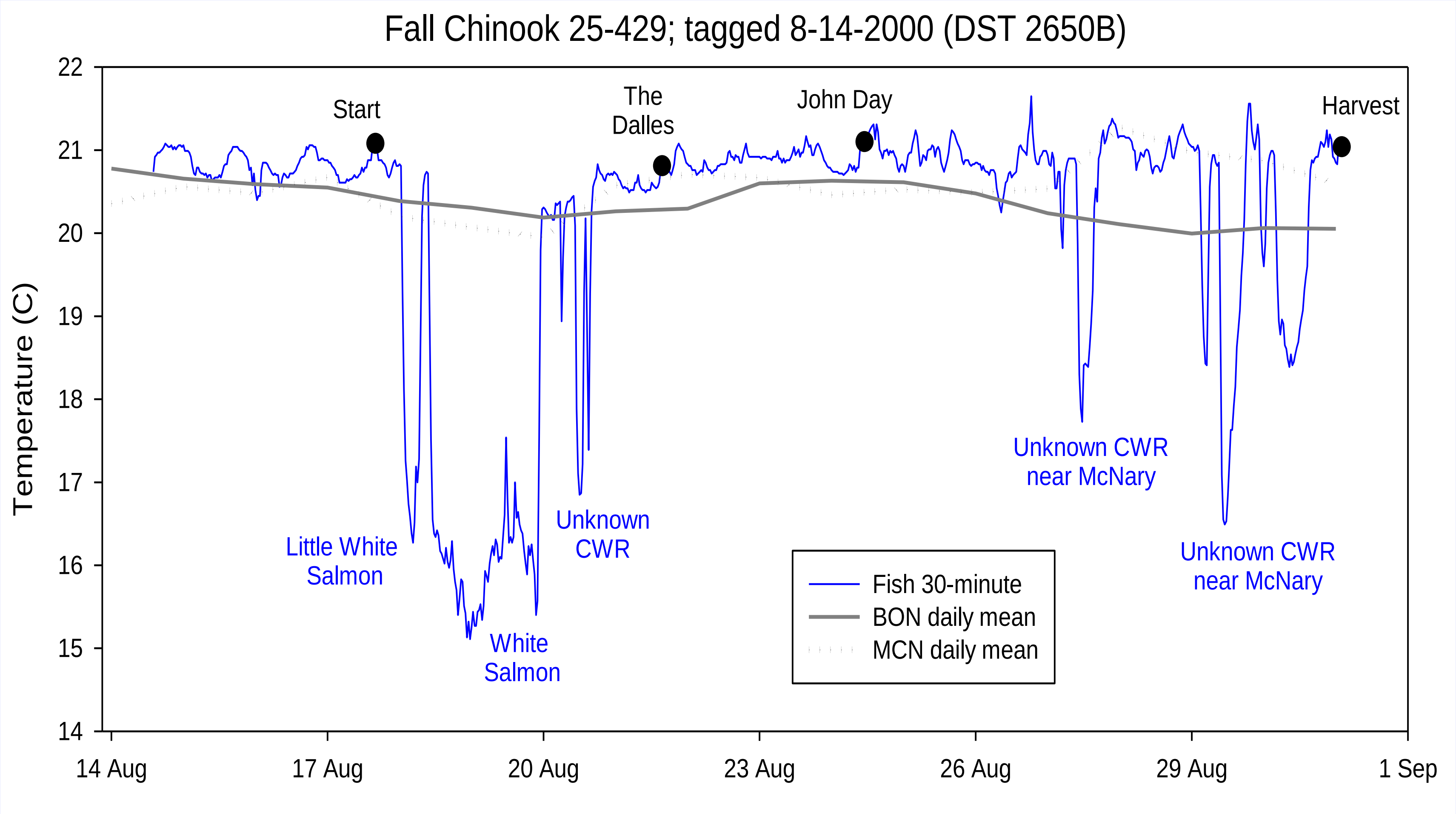
Sources - Goniea et. al. 2006; Keefer et. al., 2011

Summer Chinook CWR use example

(U of I data)



Fall Chinook use of CWR example
(U of I data)



Sockeye use of CWR

- Appears to be minimal CWR use
- Most sockeye typically migrate before peak temperatures
- Delay in migration would result in exposure to higher temperatures
- 2015 - early warm temperatures during peak migration resulting very high mortality

Most of the nearly 500,000 Sockeye died prior to spawning in 2015 due high temperatures

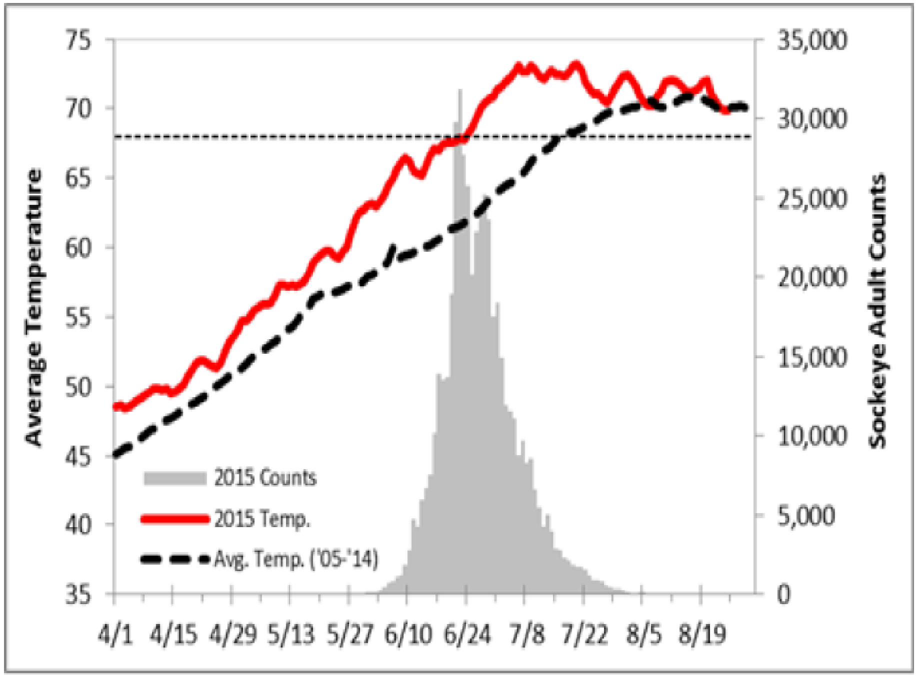
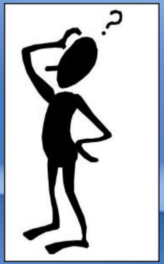


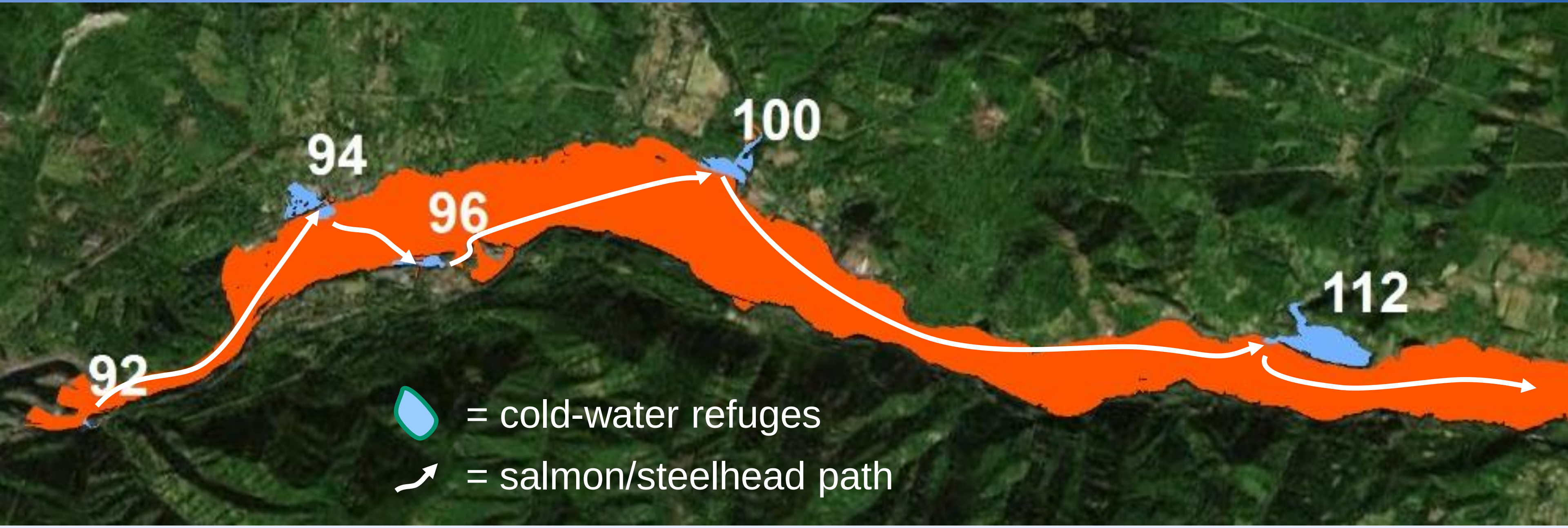
Figure 6. Water temperature at Bonneville Dam in 2015 compared to the average for the past 10 years, and the adult sockeye dam counts at Bonneville Dam in 2015.

Is The Current CWR Sufficient?



- What do we know?
  - High migrations temperatures (above 19/20C) associated with mortality and reduced egg viability
  - T&E salmon populations experience about 10% mortality (excluding harvest) between Bonneville Dam and McNary Dam (temperature exposure likely a contributing factor)
  - Presume use of CWR reduces thermal exposure and risk
- Key questions
  - If more CWR available, would mortality rates decrease?
  - If so, what's the quantitative relationship?
  - What is the CWR abundance vs mortality relationship at recovered/harvestable populations levels of salmon and steelheed (e.g., 8 million vs 2 million fish)
  - What Columbia River mainstem temperatures do we apply?
    - Current temperatures (cool, average, warm years)
    - Future projected temperatures due to climate change
    - 20C (numeric criteria)

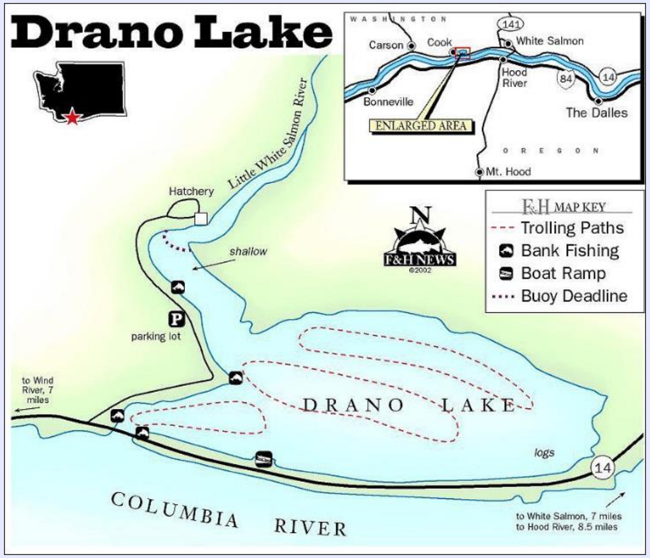
HexSim Model – EPA Corvallis Lab



- Track individual fish over time
  - Accumulated thermal exposure as fish migrate
  - Net effect on survival, egg viability
  - Differential exposure to other risks (harvest, predation, disease)
- Allows comparison of travel paths, spacing, size, quality of cold-water refuges

How does the availability and use of cold-water matter to salmon and steelhead?

Complicating Factors



Steelhead that used CWR had less survival to natal streams than those that don't due to a higher harvest rate (Keefer, et. al. 2009)

Human use of CWR (Oneonta Creek) on a hot Portland day

Protect & Enhance - Wind River

- ✓ Documented CWR use
- ✓ Currently 2-4C colder than Columbia River
- ✓ TMDL: potential to cool the river by 3-4C
- ✓ Federal land protection (USFS)
- ✓ Targeted restoration

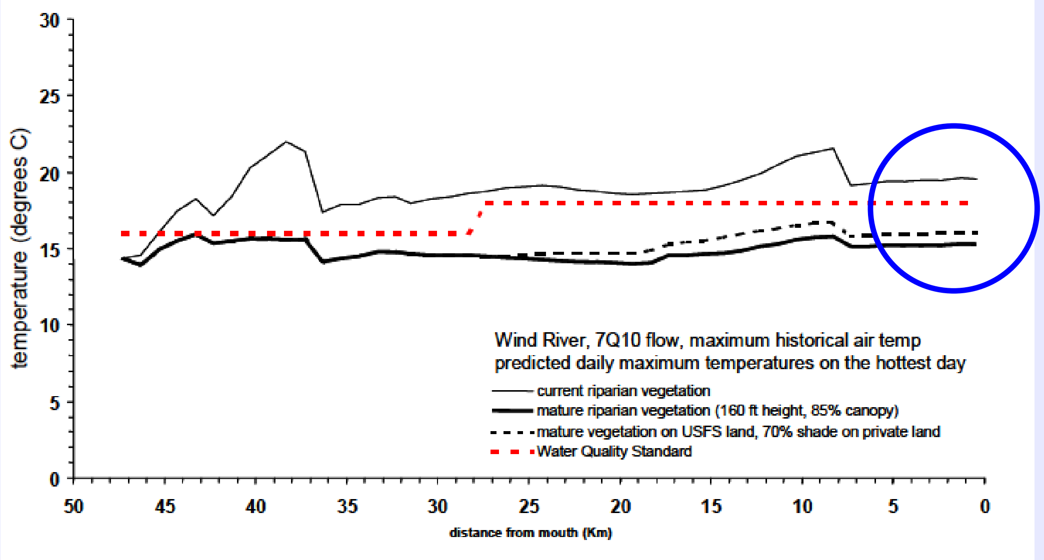
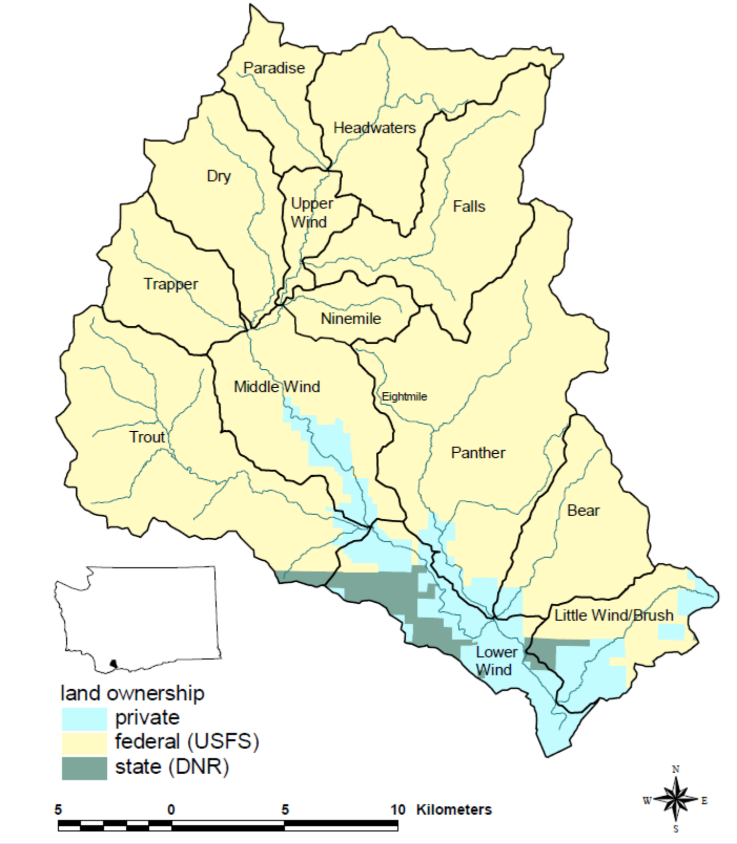
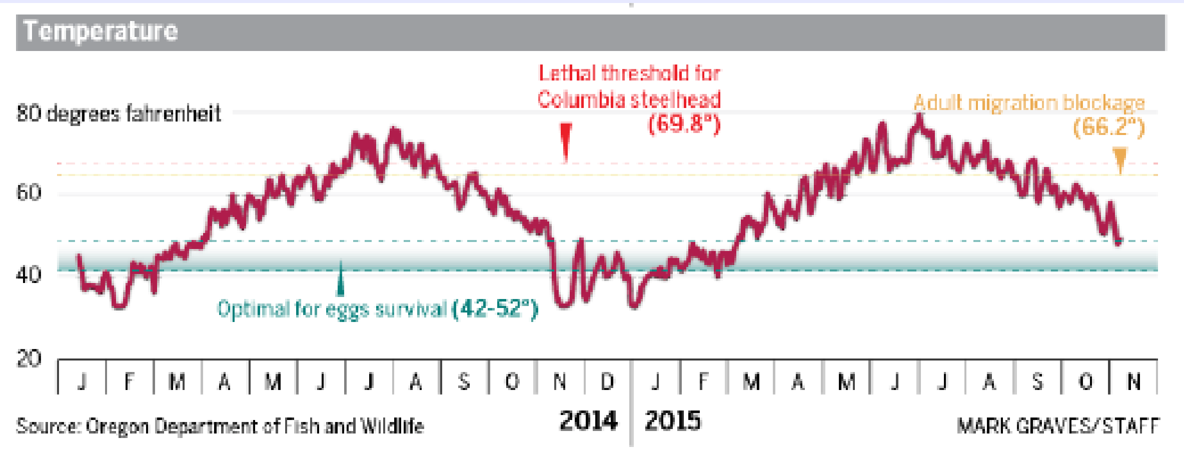
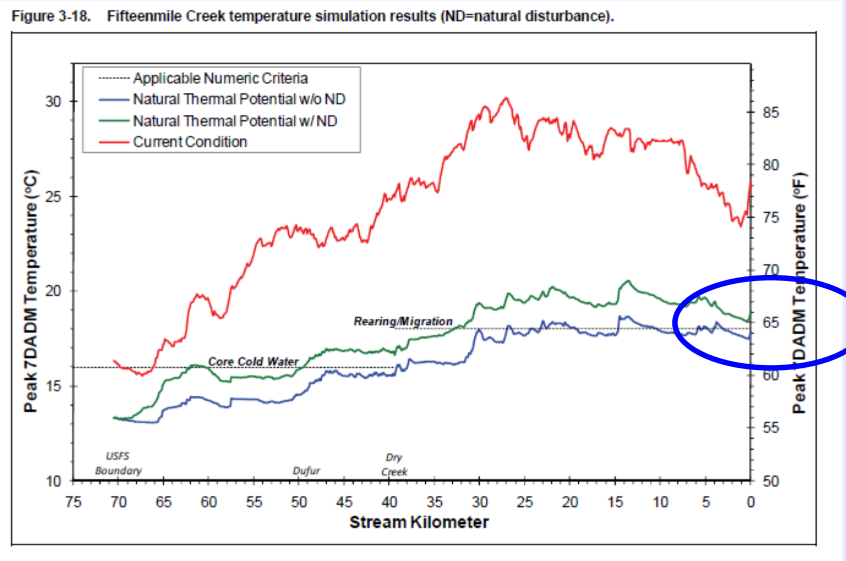


Figure 17. Predicted daily maximum temperature in Wind River under critical conditions for the TMDL.



Potential Restore - Fifteenmile Creek





Potential CWR