Technical Memorandum

To: Columbia River CWR Project Team

From: John Palmer

Date: April 11, 2019

Subject: Estimated number of Steelhead and Fall Chinook using CWR in the Bonneville Reservoir Reach

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This memo describes an approach used to estimate the number of steelhead and Fall Chinook salmon within cold water refuges (CWR) in the Bonneville Reservoir Reach of the Columbia River *during the period of maximum CWR use* (mid-August to mid-September) using passage and timing information from the Columbia River DART and previous research on steelhead and Fall Chinook migration behavior in the Columbia River.

1. Steelhead

Figure 1 displays mean daily steelhead counts at Bonneville and The Dalles dams along with associated mean daily water temperatures for the 2007-2016 period. From mid-July (when river temperatures reach about 20C) to September 1 (when river temperatures begin to decline), a significant number of steelhead pass Bonneville Dam but do not pass The Dalles Dam as reflected by the difference between the red line (BON passage counts) and the green line (TDA passage counts), which results in the accumulation of steelhead in the Bonneville Reach. During this period, most of the steelhead are delaying upstream migration and holding in Bonneville Reach CWR before proceeding upstream when Columbia mainstem temperature are cooler in September and October.

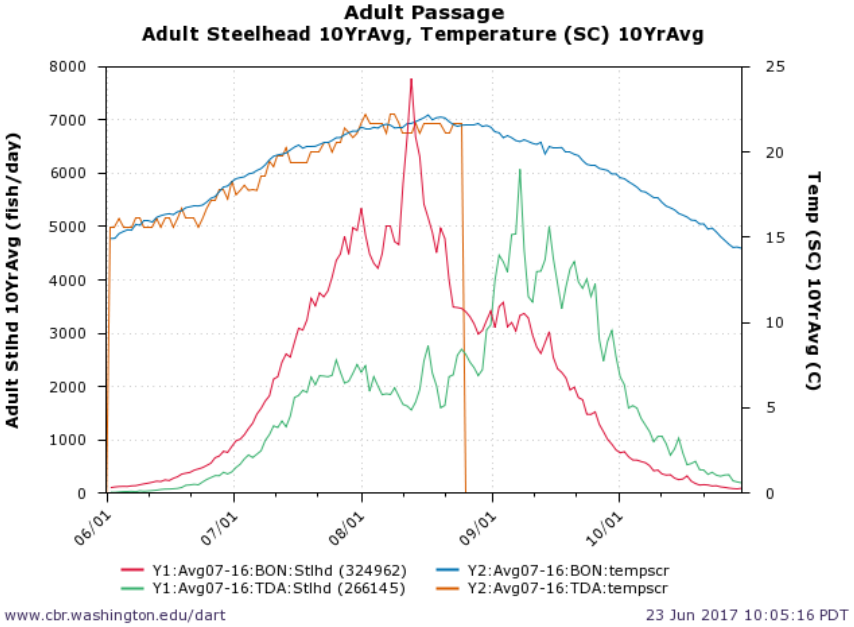

Figure 1 – Adult Steelhead Passage and Water Temperature at Bonneville Dam and The Dalles Dam (2007-2016 Average)

1.1 Number of Steelhead in Bonneville Reach CWR

Figure 2 depicts the estimated number of steelhead that are in the Bonneville Reach for each day from June through October (yellow line) and an estimate of the number of steelhead in CWR (green line) for an average year (2007-2016). The daily values used to generate each of the lines in Figure 2 are displayed in Table 1.

1.1.1 Calculations and Assumptions

Table 1 shows the daily passage of steelhead at Bonneville Dam and The Dalles Dam. A portion of the steelhead that pass Bonneville Dam is not expected to pass The Dalles Dam due to entry into natal tributaries to spawn, return to hatcheries, or harvest within the Bonneville Reach. The percentage expected to not pass The Dalles Dam is estimated to be 18% based on comparing the average annual number of steelhead passing Bonneville Dam (209,078) versus The Dalles Dam (171,235) over the June 1 – October 31 period (2007-2016). Thus, for purposes of calculating the number of accumulated steelhead in the Bonneville Reach shown in Table 1 (and displayed Figure 2), 18% of the steelhead that pass Bonneville Dam are removed from the analysis. To calculate the number of steelhead in the Bonneville Reach on each day, the net number of steelhead for each day (Bonneville steelhead passage minus 18% minus The Dalles steelhead passage) is calculated and then added to the number of steelhead in the Bonneville Reach from the previous day (see Table 1).

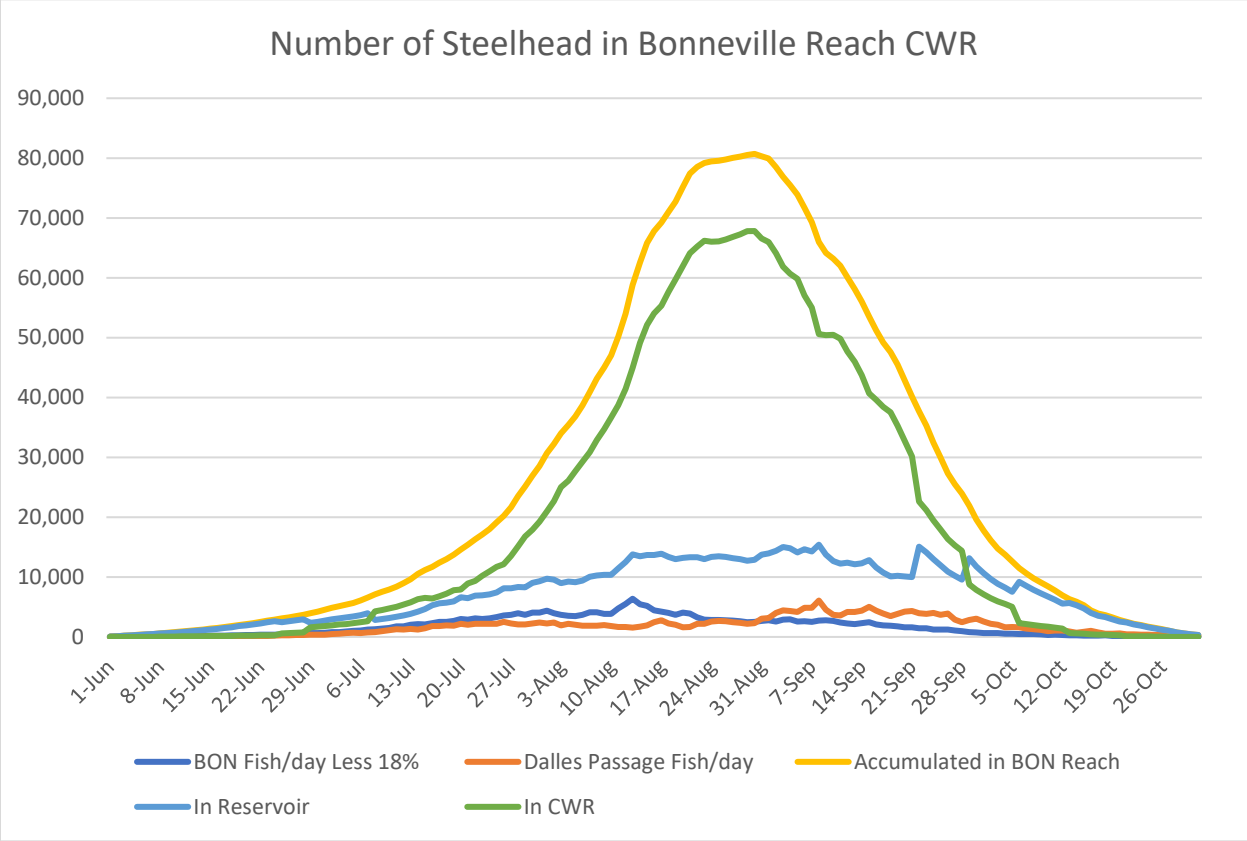

Figure 2 – Accumulation of Steelhead in the Bonneville Reach and the Number of Steelhead in CWR (2007-2016 Average)

To estimate the number of steelhead in the Bonneville Reach that are in CWR versus in the Bonneville Reservoir when temperatures exceed 20°C (as shown in Table 1 and displayed in Figure 2), the number of

steelhead passing Bonneville Dam and The Dalles Dam on a given day plus 10% of the accumulated steelhead are assumed to be in the reservoir and the rest of the steelhead in the Bonneville Reach are assumed to be in CWR. The basis for this is as follows: When temperatures exceed 20°C, studies indicate most steelhead will seek CWR or will swim quickly (i.e., not linger) in the reservoir (High et al., 2006; Keefer et al. 2004; Keefer et al. 2009; Keefer and Caudill 2017). High et al. (2006) showed that steelhead not using CWR travel at about 22 miles/day (35 km/day) and cover the 45-mile distance from Bonneville Dam to The Dalles Dam in about 2 days. Thus, assuming one day of reservoir travel for all steelhead passing the Bonneville Dam and another day of reservoir travel for all steelhead passing The Dalles Dam on a given day covers the expected total reservoir travel time that an individual steelhead is expected to have in the Bonneville Reach. Adding an additional 10% of the accumulated steelhead assumed to be in the reservoir accounts for potential additional reservoir travel time due to slower travel speeds at higher temperatures. For when temperatures are below 20°C, the percent using CWR as a function of temperature as reported in Keefer and Caudill 2017 was multiplied by the number of accumulated steelhead in the Bonneville reach. It should be noted that if the percent using CWR as a function of temperature reported in Keefer and Caudhill 2017 is used for when temperatures are above 20°C instead of the approach described above, the results are very similar to those shown in Table 1 and Figure 2.

Table 1 – Daily Estimate of Number of Steelhead in Bonneville Reach and in CWR (2007-2016 Average)

mm/dd	BON Passage Fish/day	BON Fish/day Less 18%	Dalles Passage Fish/day	Net in BON Reach	Accumulated in BON Reach	In Reservoir	In CWR	% in CWR	BON Temp (deg. C)
1-Jun	97	79	19	60	60	59	1	2%	14.9
2-Jun	107	87	19	68	128	125	3	2%	14.9
3-Jun	119	97	18	79	207	203	4	2%	14.9
4-Jun	127	104	26	79	286	271	14	5%	15.2
5-Jun	129	106	32	74	359	341	18	5%	15.3
6-Jun	127	104	33	72	431	410	22	5%	15.4
7-Jun	139	114	36	77	509	483	25	5%	15.4
8-Jun	143	117	30	87	596	566	30	5%	15.8
9-Jun	161	132	46	86	682	648	34	5%	15.7
10-Jun	177	145	38	107	790	711	79	10%	16.0
11-Jun	191	157	45	112	901	811	90	10%	16.0
12-Jun	207	169	51	119	1,020	918	102	10%	15.9
13-Jun	227	186	58	128	1,148	1,033	115	10%	16.2
14-Jun	220	180	71	109	1,257	1,132	126	10%	16.3
15-Jun	252	206	78	129	1,386	1,247	139	10%	16.3
16-Jun	239	196	79	117	1,503	1,353	150	10%	16.4
17-Jun	281	230	85	145	1,648	1,483	165	10%	16.3
18-Jun	310	254	91	163	1,812	1,630	181	10%	16.5
19-Jun	360	295	108	187	1,998	1,798	200	10%	16.6
20-Jun	377	309	150	159	2,157	1,941	216	10%	16.7
21-Jun	392	322	157	165	2,322	2,090	232	10%	16.8
22-Jun	433	355	168	187	2,509	2,258	251	10%	16.9
23-Jun	457	374	159	216	2,725	2,452	272	10%	16.8
24-Jun	482	395	211	184	2,909	2,618	291	10%	16.9
25-Jun	522	428	260	169	3,078	2,462	616	20%	17.1
26-Jun	565	463	294	169	3,247	2,597	649	20%	17.3
27-Jun	668	548	331	216	3,463	2,770	693	20%	17.4
28-Jun	699	573	330	243	3,706	2,965	741	20%	17.7
29-Jun	788	646	393	253	3,960	2,376	1584	40%	18.0
30-Jun	767	629	363	265	4,225	2,535	1690	40%	18.0
1-Jul	878	720	400	320	4,545	2,727	1818	40%	18.3
2-Jul	985	808	484	324	4,869	2,921	1948	40%	18.4
3-Jul	1014	831	545	286	5,155	3,093	2062	40%	18.5

4-Jul	1099	901	644	257	5,411	3,247	2165	40%	18.6
5-Jul	1214	996	719	277	5,688	3,413	2275	40%	18.7
6-Jul	1315	1,078	670	408	6,096	3,657	2438	40%	18.8
7-Jul	1486	1,218	733	486	6,581	3,949	2633	40%	18.9
8-Jul	1592	1,305	797	508	7,089	2,836	4254	60%	19.0
9-Jul	1730	1,419	991	427	7,517	3,007	4510	60%	19.3
10-Jul	1826	1,498	1100	398	7,914	3,166	4749	60%	19.5
11-Jul	2143	1,757	1264	493	8,407	3,363	5044	60%	19.8
12-Jul	2186	1,793	1233	559	8,966	3,587	5380	60%	19.8
13-Jul	2459	2,016	1354	662	9,629	3,851	5777	60%	19.9
14-Jul	2613	2,142	1248	894	10,523	4,209	6314	60%	19.9
15-Jul	2554	2,094	1447	648	11,170	4,658	6,512	58%	20.1
16-Jul	2833	2,323	1794	529	11,699	5,287	6,412	55%	20.3
17-Jul	3095	2,538	1836	702	12,401	5,614	6,787	55%	20.4
18-Jul	3061	2,510	1930	580	12,981	5,739	7,242	56%	20.2
19-Jul	3252	2,666	1894	773	13,753	5,936	7,818	57%	20.3
20-Jul	3656	2,998	2179	819	14,572	6,635	7,937	54%	20.3
21-Jul	3516	2,883	2036	847	15,419	6,461	8,958	58%	20.3
22-Jul	3759	3,082	2204	878	16,297	6,916	9,381	58%	20.4
23-Jul	3684	3,020	2198	822	17,119	6,931	10,189	60%	20.6
24-Jul	3793	3,110	2186	924	18,044	7,101	10,943	61%	20.6
25-Jul	4050	3,321	2212	1,109	19,153	7,448	11,705	61%	20.7
26-Jul	4366	3,580	2500	1,081	20,233	8,103	12,131	60%	20.8
27-Jul	4489	3,681	2271	1,410	21,643	8,116	13,527	62%	20.9
28-Jul	4818	3,951	2066	1,885	23,528	8,370	15,158	64%	21.0
29-Jul	4486	3,679	2103	1,576	25,104	8,292	16,812	67%	21.1
30-Jul	4982	4,085	2250	1,835	26,939	9,029	17,910	66%	21.2
31-Jul	4930	4,042	2415	1,627	28,566	9,314	19,252	67%	21.2
1-Aug	5345	4,383	2273	2,109	30,676	9,723	20,952	68%	21.5
2-Aug	4848	3,975	2391	1,585	32,260	9,592	22,669	70%	21.3
3-Aug	4488	3,680	1914	1,766	34,026	8,996	25,030	74%	21.3
4-Aug	4314	3,538	2186	1,352	35,378	9,262	26,117	74%	21.5
5-Aug	4221	3,461	2010	1,451	36,829	9,154	27,675	75%	21.4
6-Aug	4489	3,681	1849	1,832	38,661	9,397	29,265	76%	21.6
7-Aug	5002	4,101	1867	2,234	40,895	10,058	30,838	75%	21.6
8-Aug	5002	4,101	1853	2,249	43,144	10,268	32,876	76%	21.6
9-Aug	4719	3,870	1978	1,892	45,036	10,351	34,685	77%	21.4
10-Aug	4666	3,826	1819	2,007	47,043	10,349	36,695	78%	21.4
11-Aug	5802	4,757	1667	3,091	50,134	11,437	38,697	77%	21.4
12-Aug	6695	5,490	1636	3,853	53,987	12,525	41,463	77%	21.7
13-Aug	7781	6,380	1562	4,818	58,805	13,823	44,982	76%	21.7
14-Aug	6686	5,483	1709	3,773	62,578	13,450	49,129	79%	21.8
15-Aug	6318	5,180	1944	3,236	65,814	13,706	52,108	79%	21.9
16-Aug	5421	4,445	2485	1,959	67,774	13,708	54,066	80%	22.0
17-Aug	5167	4,237	2766	1,472	69,245	13,928	55,318	80%	22.2
18-Aug	4897	4,015	2257	1,758	71,004	13,372	57,631	81%	21.9
19-Aug	4514	3,701	2019	1,682	72,686	12,989	59,698	82%	22.0
20-Aug	4970	4,075	1606	2,470	75,156	13,197	61,959	82%	22.1
21-Aug	4781	3,920	1647	2,274	77,430	13,310	64,120	83%	22.0
22-Aug	4007	3,285	2187	1,098	78,528	13,325	65,203	83%	21.8
23-Aug	3493	2,865	2221	643	79,171	13,003	66,168	84%	21.6
24-Aug	3483	2,856	2589	268	79,439	13,389	66,050	83%	21.5
25-Aug	3467	2,843	2701	142	79,581	13,502	66,079	83%	21.6
26-Aug	3407	2,793	2608	186	79,767	13,378	66,389	83%	21.6
27-Aug	3313	2,717	2461	256	80,023	13,180	66,843	84%	21.6
28-Aug	3179	2,607	2356	251	80,274	12,990	67,284	84%	21.6
29-Aug	2988	2,450	2209	241	80,515	12,710	67,805	84%	21.7
30-Aug	3053	2,504	2317	187	80,702	12,891	67,812	84%	21.5
31-Aug	3243	2,659	3065	-406	80,296	13,754	66,542	83%	21.6
1-Sep	3419	2,804	3157	-353	79,943	13,955	65,988	83%	21.5

2-Sep	3109	2,549	3995	-1,445	78,498	14,394	64,104	82%	21.2
3-Sep	3500	2,870	4466	-1,597	76,901	15,026	61,875	80%	21.1
4-Sep	3581	2,936	4341	-1,405	75,496	14,827	60,669	80%	20.8
5-Sep	3122	2,560	4150	-1,589	73,907	14,101	59,806	81%	21.0
6-Sep	3203	2,626	4851	-2,225	71,682	14,646	57,036	80%	20.8
7-Sep	3045	2,497	4864	-2,368	69,314	14,292	55,022	79%	20.7
8-Sep	3337	2,737	6076	-3,340	65,974	15,410	50,564	77%	20.6
9-Sep	3371	2,764	4565	-1,801	64,173	13,746	50,427	79%	20.7
10-Sep	3288	2,696	3685	-989	63,184	12,700	50,484	80%	20.6
11-Sep	2968	2,434	3588	-1,155	62,030	12,225	49,805	80%	20.5
12-Sep	2744	2,250	4159	-1,910	60,120	12,421	47,699	79%	20.5
13-Sep	2623	2,151	4166	-2,015	58,105	12,127	45,977	79%	20.6
14-Sep	2825	2,317	4380	-2,063	56,042	12,301	43,741	78%	19.9
15-Sep	3030	2,485	5005	-2,520	53,521	12,842	40,680	76%	20.3
16-Sep	2544	2,086	4394	-2,308	51,214	11,602	39,612	77%	20.2
17-Sep	2336	1,916	3931	-2,015	49,199	10,766	38,433	78%	20.2
18-Sep	2266	1,858	3465	-1,606	47,593	10,082	37,510	79%	20.3
19-Sep	2165	1,775	3871	-2,096	45,497	10,195	35,301	78%	20.0
20-Sep	1938	1,589	4210	-2,621	42,876	10,086	32,789	76%	20.0
21-Sep	1990	1,632	4344	-2,712	40,164	9,992	30,171	75%	19.9
22-Sep	1795	1,472	3963	-2,491	37,673	15,069	22604	60%	19.8
23-Sep	1754	1,438	3844	-2,406	35,267	14,107	21160	60%	19.5
24-Sep	1482	1,216	4018	-2,803	32,464	12,986	19479	60%	19.3
25-Sep	1479	1,213	3691	-2,478	29,986	11,994	17992	60%	19.2
26-Sep	1526	1,252	3926	-2,674	27,312	10,925	16387	60%	19.2
27-Sep	1291	1,059	2880	-1,821	25,491	10,196	15295	60%	19.0
28-Sep	1154	946	2482	-1,536	23,955	9,582	14373	60%	19.0
29-Sep	1009	827	2856	-2,029	21,926	13,156	8770	40%	18.9
30-Sep	920	755	3051	-2,296	19,630	11,778	7852	40%	18.7
1-Oct	813	667	2563	-1,896	17,734	10,640	7093	40%	18.7
2-Oct	759	622	2183	-1,561	16,173	9,704	6469	40%	18.5
3-Oct	781	641	2035	-1,394	14,779	8,867	5912	40%	18.4
4-Oct	685	562	1598	-1,036	13,743	8,246	5497	40%	18.3
5-Oct	625	513	1645	-1,132	12,611	7,567	5044	40%	18.1
6-Oct	622	510	1598	-1,088	11,523	9,219	2305	20%	17.9
7-Oct	596	488	1403	-914	10,609	8,487	2122	20%	17.7
8-Oct	574	471	1280	-809	9,800	7,840	1960	20%	17.7
9-Oct	520	426	1159	-733	9,067	7,253	1813	20%	17.5
10-Oct	421	345	969	-624	8,443	6,754	1689	20%	17.3
11-Oct	435	357	1066	-709	7,734	6,187	1547	20%	17.3
12-Oct	363	298	1069	-771	6,963	5,570	1393	20%	17.1
13-Oct	341	279	929	-650	6,313	5,682	631	10%	16.8
14-Oct	348	285	715	-429	5,884	5,296	588	10%	16.7
15-Oct	285	233	832	-599	5,285	4,757	529	10%	16.6
16-Oct	256	210	1034	-824	4,461	4,015	446	10%	16.4
17-Oct	268	220	753	-533	3,928	3,536	393	10%	16.3
18-Oct	326	267	536	-269	3,660	3,294	366	10%	16.2
19-Oct	227	186	557	-371	3,289	2,960	329	10%	16.0
20-Oct	184	151	599	-449	2,840	2,556	284	10%	16.0
21-Oct	154	126	443	-317	2,523	2,397	126	5%	15.8
22-Oct	161	132	434	-302	2,221	2,110	111	5%	15.8
23-Oct	156	128	355	-227	1,994	1,894	100	5%	15.5
24-Oct	136	112	393	-281	1,713	1,627	86	5%	15.5
25-Oct	142	116	340	-224	1,489	1,415	74	5%	15.3
26-Oct	121	99	320	-221	1,268	1,205	63	5%	15.1
27-Oct	111	91	342	-251	1,017	997	20	2%	14.8
28-Oct	98	80	348	-268	749	734	15	2%	14.6
29-Oct	88	72	233	-161	588	576	12	2%	14.4
30-Oct	84	69	213	-144	444	436	9	2%	14.4
31-Oct	94	77	197	-120	324	318	6	2%	14.4

Source: Columbia River DART

1.1.2 Results

As shown Table 1 (and displayed in Figure 2), steelhead accumulate in the Bonneville Reach until August 30th when the maximum number of steelhead using CWR is estimated to be 67,812, for an average year. On August 31th and thereafter, more steelhead are passing The Dalles Dam versus Bonneville Dam and the number of steelhead accumulated in the Bonneville Reach and in CWR begins to decrease.

The peak CWR use period is from mid-August through early-September. From August 15 – September 10, the average number of steelhead in CWR exceeds 50,000 fish each day. During this period, between 80-85% of the steelhead in the Bonneville reach are estimated to be in CWR and 15-20% in the reservoir.

1.1.3 Field Verification

To test the above assumptions on the percentage of accumulated steelhead in the Bonneville reach that are in the reservoir versus in CWR, the location of 219 radio-tagged steelhead from the University of Idaho 2000 and 2002 research studies were analyzed. As shown in Figure 3, the number of steelhead in the Bonneville reach peaked in late August and early September and the vast percentage of steelhead were in CWR (approximately 90%) versus in the reservoir during this period.

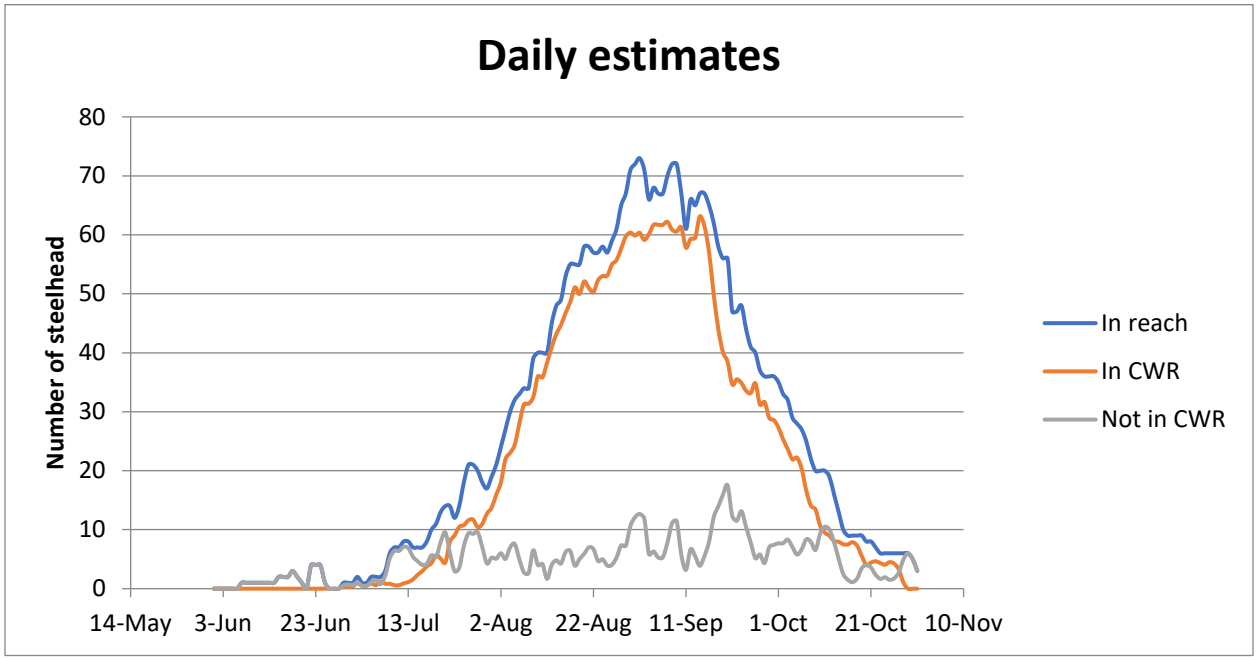

Figure 3 – Distribution of 219 Radio-Tagged Steelhead in Bonneville Reach from University of Idaho 2000 and 2002 Research Studies (Keefer 8/31/17 email)

1.2 Simplified Multi-Year Estimate of Number of Steelhead in Bonneville Reach CWR

The above approach estimates the number of steelhead in the Bonneville Reach CWR on a daily basis using daily fish passage numbers at Bonneville Dam and The Dalles Dam. An alternative simplified approach estimates the number steelhead in CWR using total steelhead passage counts at Bonneville Dam and The Dalles Dam for the critical July 15 – August 31 period, when average temperatures exceed 20C and steelhead are accumulating in the Bonneville Reach.

As shown in Table 2, during the July 15 through August 31 period, 209,078 steelhead passed Bonneville Dam on average in 2007-2016, but only 101,670 passed The Dalles Dam. As discussed above, 18% of the steelhead passing Bonneville Dam are estimated to enter tributaries, hatcheries, or are harvested in the Bonneville Reach. Thus, 171,235 (82% of the average count at Bonneville Dam) are expected to ultimately pass The Dalles Dam and would be expected to pass The Dalles Dam during the July 15-August 31 period if were not for temporary use of CWR. 171,235 (expected to pass) minus 101,670 (actually passed) approximates the number of steelhead (69,565) in the Bonneville Reach during the July 15 – August 31 period which are either temporarily in CWR or migrating in the reservoir. The number in the reservoir under this approach is estimated to be 15%, leaving 59,130 in CWR. The 15% was based on the analysis and field verification presented above for the approximate percentage of steelhead in the reservoir versus within CWR during the period of peak CWR use.

The average estimate of 59,130 steelhead in the Bonneville Reach CWR using this simplified approach is consistent with the daily analysis described above in Figure 2 and Table 1. The 59,130 number of steelhead in CWR represents the period of maximum CWR use, which is late-August – early September.

Table 2 – Estimated Number of Steelhead in CWR (2007-2016 Average)

Passed BON	Exp to Pass DAL	Passed DAL	In BON Reach	In CWR
7/15 -8/31	7/15 -8/31	7/15 -8/31	7/15 -8/31	7/15 -8/31
209,078	171,235	101,670	69,565	59,130

Source: Columbia River DART

Table 3 applies the same methodology as described above but estimates the number of steelhead in CWR for each individual year from 1999 to 2016. As shown, the number of steelhead in CWR varies in response to run size and river environment, ranging from 23,107 during a low-abundance year with below-average water temperatures (2012) to 155,492 during a high-abundance warm year (2009) with an average of 65,639 over the 1999-2016 period. In 2009 (Figure 3), temperatures reached 20°C in mid-July and climbed steeply to 23°C by early August resulting low passage at The Dalles Dam relative to passage at Bonneville Dam and high CWR use during the July 15-August 31 period. Conversely, in 2012 (Figure 4), river temperature did not reach 20°C until the 2nd week of August and exceeded 20°C for just a few weeks, resulting in high passage at The Dalles Dam relative to passage at Bonneville Dam and low CWR use during the July 15-August 31 period.

Table 3 – Estimated Number of Steelhead in CWR Each Year (1999-2016)

				Measured %	Expected		
	Ave	Passed	Passed	That Passed	to Passed		
	Temp	BON	Dalles	Dalles	Dalles	In BON Reach	In CWR
Year	July 15 -Aug 31	July 15 -Aug 31	July 15 -Aug 31	June 1-Oct 31	July 15 -Aug 31	July 15 -Aug 31	July 15 -Aug 31
2016	21.4	83,919	24,212	80%	66,868	42,656	36,258
2015	21.8	165,138	69,059	84%	137,893	68,834	58,509
2014	21.5	175,686	70,488	80%	140,923	70,435	59,869
2013	21.5	166,926	68,949	83%	138,059	69,110	58,743
2012	20.1	142,032	95,612	86%	122,797	27,185	23,107
2011	19.5	252,331	176,573	82%	207,452	30,879	26,248
2010	21.0	231,804	121,974	82%	189,445	67,471	57,350
2009	21.6	451,509	205,163	86%	388,094	182,931	155,492
2008	20.0	225,506	117,044	79%	177,048	60,004	51,004
2007	21.1	229,124	83,820	76%	173,420	89,600	76,160
2006	21.1	187,415	53,379	72%	134,561	81,182	69,005
2005	21.4	175,028	55,866	77%	135,090	79,224	67,340
2004	22.0	155,516	42,744	78%	120,905	78,161	66,437
2003	21.7	209,328	58,083	77%	160,904	102,821	87,398
2002	20.4	257,857	131,121	82%	210,238	79,117	67,250
2001	20.7	397,879	169,554	80%	319,544	149,990	127,491
2000	20.6	164,593	75,954	75%	124,114	48,160	40,936
1999	20.0	136,136	76,782	77%	104,458	27,676	23,524
Average	20.9	219,048	98,363		175,585	77,222	65,639

Source: Columbia River DART

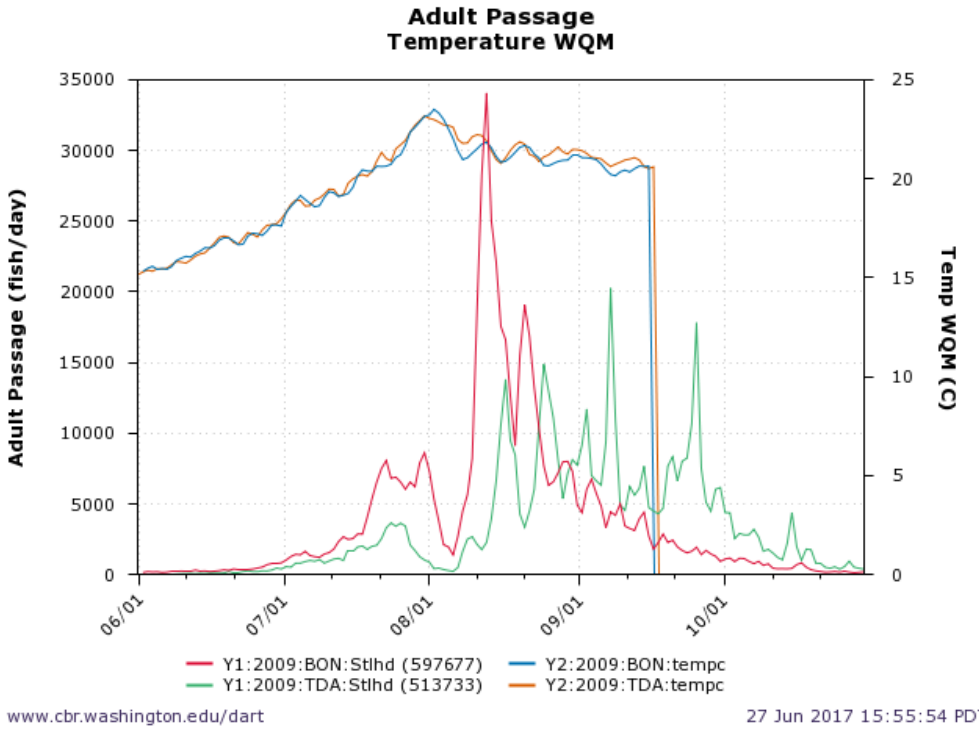

Figure 4 – Adult Steelhead Passage and Water Temperature at Bonneville Dam and The Dalles Dam During a Year with High Steelhead Returns and Above Average Temperatures (2009)

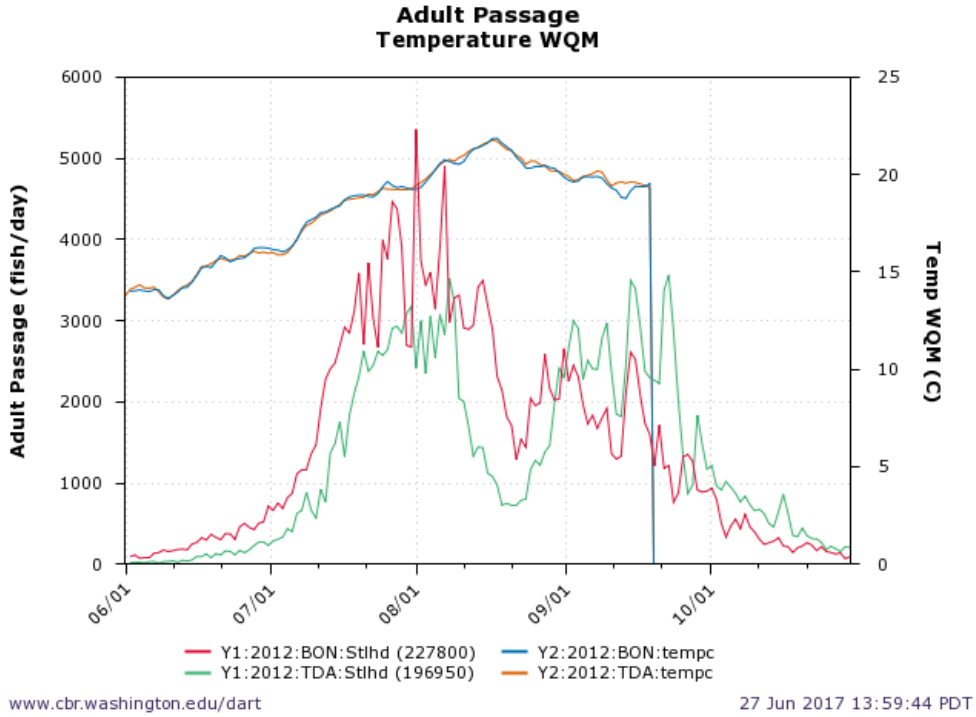

Figure 5 – Adult Steelhead Passage and Water Temperature at Bonneville Dam and The Dalles Dam During a Year with Low Steelhead Returns and Below Average Temperatures (2012)

Research studies document how the use of CWR by steelhead increases as temperature increases above 19C (Keefer et al., 2009). It's also logical that the number of steelhead in CWR is also a function of the size of the steelhead run. Thus, the number of steelhead in CWR is a function of both water temperature and the size of the run. Using data in Table 3, the following multiple linear regression (R^2=0.95) was developed to predict the number of steelhead in CWR during the period of maximum CWR use based on the average temperature and the cumulative Bonneville Dam steelhead passage for the July 15-August 31 period.

# of Steelhead in CWR = 23722.35 (Ave $T_{July\ 15\text{-}Aug\ 31}$) + 0.328729 (# $Steelhead_{July\ 15\text{-}August\ 31}$) – 503,150

1.3 Number of Steelhead in Each CWR Area

EPA has identified 23 CWR areas and associated CWR volumes between the Columbia River mouth and the Snake River confluence, eight of which are in the Bonneville Reach and are shown in Table 4. A total of 1,784,298 m^3 of CWR (greater than 2C cooler than the Columbia River) is estimated to occur in this reach. The majority (62%) occurs in Drano Lake (Little White salmon), followed by the Klickitat River (12%), Herman Creek (10%), and the White Salmon River (9%). Table 4 includes the estimated number of steelhead in each of the eight CWR areas for an average year, a high abundance year, and a low abundance year assuming steelhead are distributed proportionately to CWR volume. For example, an average of 40,507 steelhead are estimated to temporarily use Drano Lake as CWR each day during the period of maximum CWR use (mid-August through early September) during an average year, ranging from 14,260 during a low year and 95,957 during high year.

Table 4 – Estimated Number of Steelhead in Each Bonneville Pool CWR (>2C Δ CWR)

Tributary Name	Tributary Temp	Plume CWR Volume (> 2°C Δ)	Stream CWR Volume (> 2°C Δ)	Total CWR Volume (> 2°C Δ)	% of CWR in BON Reach	# Steelhead in Each CWR (1999-2016 Ave)	# Steelhead in Each CWR High Year (2009)	# Steelhead in Each CWR Low Year (2012)
	°C	m3	m3	m3				
Eagle Creek	15.1	2,100	888	2,988	0.2%	110	260	39
Rock Creek	17.4	530	1,178	1,708	0.1%	63	149	22
Herman Creek	12.0	168,000	1,698	169,698	9.5%	6,243	14,788	2,198
Wind River	14.5	60,800	44,420	105,220	5.9%	3,871	9,169	1,363
Little White Salmon River	13.3	1,097,000	4,126	1,101,126	61.7%	40,507	95,957	14,260
White Salmon River	15.7	72,000	81,529	153,529	8.6%	5,648	13,379	1,988
Hood River	15.5	28,000	0	28,000	1.6%	1,030	2,440	363
Klickitat River	16.4	73,000	149,029	222,029	12.4%	8,168	19,349	2,875
Total		1,501,430	282,868	1,784,298	100%	65,639	155,492	23,107

Studies indicate that steelhead seek cold water (8-18C) when temporarily staying in CWR, thus a better indicator of CWR volume may be the volume less than 18C (Keefer and Caudill 2017). Table 5 displays the same information as Table 4, except just for CWR less than 18C, which is estimated to be 954,176 m^3 for the Bonneville Reach. The distribution of CWR volume and steelhead is roughly the same under this scenario, with most CWR volume/steelhead in Drano Lake/Little White Salmon (56%), followed by the Klickitat River (16%), Herman Creek (10%), and the White Salmon River (10%).

Table 5 – Estimated Number of Steelhead in Each Bonneville Pool CWR (<18C Δ CWR)

Tributary Name	Tributary Temp	Plume CWR Volume (< 18°C)	Stream CWR Volume (< 18°C)	Total CWR Volume (< 18°C)	% of CWR in BON Reach	# Steelhead in Each CWR (1999-2016 Ave)	# Steelhead in Each CWR High Year (2009)	# Steelhead in Each CWR Low Year (2012)
	°C	m3	m3	m3				
Eagle Creek	15.1	610	888	1,498	0.2%	103	244	36
Rock Creek	17.4	26	1,178	1,204	0.1%	83	196	29
Herman Creek	12.0	93,958	1,698	95,656	10.0%	6,580	15,588	2,316
Wind River	14.5	20,390	44,420	64,810	6.8%	4,458	10,561	1,569
Little White Salmon River	13.3	531,524	4,126	535,650	56.1%	36,848	87,289	12,972
White Salmon River	15.7	14,000	81,529	95,529	10.0%	6,572	15,567	2,313
Hood River	15.5	7,500	0	7,500	0.8%	516	1,222	182
Klickitat River	16.4	3,300	149,029	152,329	16.0%	10,479	24,823	3,689
Total		671,308	282,868	954,176	100%	65,639	155,492	23,107

1.3.1 Comparison to Field Studies

In 2000, of 243 radio-tagged steelhead documented in Bonneville Reach CWR, 144 (59%) were detected in the Little White Salmon River/Drano Lake, 33 (14%) were detected in Herman Creek/Cove, 30 (12%) were detected in the White Salmon River, 20 (8%) were detected in the Wind River, 15 (6%) were detected in the Klickitat River, 1 was detected in Eagle Creek, and none were detected in the Hood River (Keefer and Caudill 2017). These data affirm most steelhead CWR use is in the Little White Salmon River/Drano Lake and the estimated proportion of CWR use aligns with the proportion of CWR volume available in each of the eight refuges; except the field data indicates a slightly higher amount of CWR use of Herman Creek and the White Salmon River and a lesser amount of CWR use of the Klickitat River than what is predicted based on CWR volume as shown in Tables 4 and 5. One reason for lesser CWR of the Klickitat River than predicted based on CWR volume is that the Klickitat River delta is shallow at the confluence with the Columbia River and that may impede access up the Klickitat River.

The University of Idaho radio-tagged data for 2000 and 2001 was analyzed on two specific days to see what CWR sites were used on those specific days. Table 6 shows the distribution of steelhead in the Bonneville Reservoir reach for August 7 and August 31. August 7 was chosen to reflect the early phase on accumulation of steelhead in the Bonneville reservoir reach. August 31 was chosen to reflect the time of peak accumulation of steelhead in the Bonneville reservoir reach and maximum amount of CWR use (see Figures 2 and 3). These data confirm the Little White Salmon/Drano Lake and Herman Creek/Cove as the highest used CWR sites. These data also suggest Herman Creek/Cove is used in higher proportion earlier in the season and steelhead tend to accumulate in Little White Salmon/Drano Lake as the season progresses.

Table 6 – Distribution of Radio-Tagged Steelhead in the Bonneville Reach on Two Specific Days (Combined 2000/2001 Data Set) (Keefer 9/11/2017 email)

	August 7	August 31
Below Bonneville Dam	1 (2.9%)	0 (0%)
Bonneville Reservoir	3 (8.8%)	9 (12.5%)
Herman Creek	8 (23.5%)	6 (8.3%)
Wind River	1 (2.9%)	1 (1.4%)
Little White Salmon/Drano Lake	12 (35.3%)	40 (55.6%)
White Salmon	3 (8.8%)	4 (5.6%)
Klickitat River	4 (11.8%)	4 (5.6%)
Unknown CWR	0 (0%)	4 (5.6%)
The Dalles Dam Tailrace/Fishway	2 (5.9%)	4 (5.6%)
Total	34 Steelhead	72 Steelhead

1.4 Steelhead Density in CWR

The fish density within CWR in the Bonneville Reach can be calculated by dividing the number of steelhead estimated to be in CWR by the volume of CWR. Table 7 presents the fish density for the different scenarios presented in Tables 4 and 5. For example, considering just CWR less than 18C, for an average year, the fish density in each of the CWR areas in the Bonneville Reach is estimated to be 172 steelhead per 2,500 m^3 (size of an Olympic swimming pool), ranging from 407 per Olympic pool in a high year and 61 per Olympic pool in a low year.

Table 7 – Estimated Steelhead Density in CWR

	CWR Volume (> 2°C Δ)			CWR Volume (< 18°C)		
	Average	High	Low	Average	High	Low
	1999-2016	2009	2012	1999 -2016	2009	2012
# fish/m3	0.0368	0.0871	0.0130	0.0688	0.1630	0.0242
# fish/2500 m3	92	218	32	172	407	61

1.5 Historical Analysis of Bonneville Reservoir Reach Steelhead CWR Use

Since The Dalles Dam was built in 1957, the comparison of steelhead passage at the Bonneville Dam versus The Dalles Dam is available since 1957. As shown in Figure 1 and in this memo, passage data from the last decade shows there is a significant delay in passage over the The Dalles Dam and accumulation of steelhead in the Bonneville Reservoir Reach during the period of summer maximum temperatures. Interestingly, as shown in Figure 6, there is not a significant delay over the The Dalles Dam in the decade after the The Dalles Dam was built (1957-1966). Limited temperature data collected in this decade depicted in Figure 6 also shows summer peak temperatures were lower compared current day temperatures. These data suggest steelhead use of CWR sites in the Bonneville Reach was less historically than what we observe today and that steelhead are using CWR more today in response to increased summer temperatures of the Columbia River.

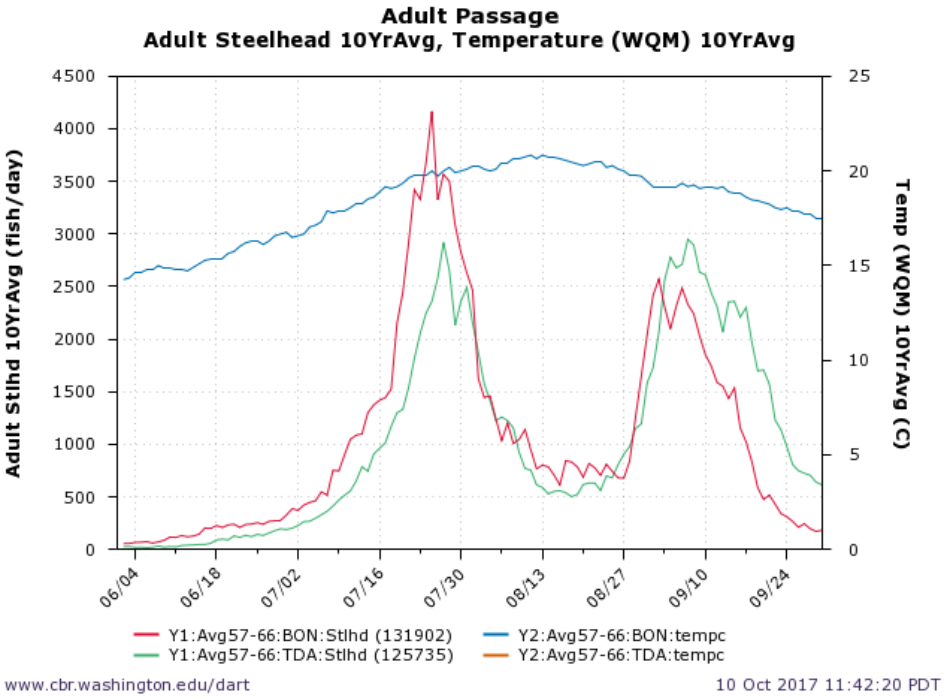

Figure 6 – Adult Steelhead Passage and Water Temperature at Bonneville Dam and The Dalles Dam (1957-1966 Average)

2. Fall Chinook Salmon

Figure 7 shows the average daily passage of Fall Chinook at Bonneville Dam and The Dalles Dam for the 2008-2017 period. Unlike summer steelhead as discussed above, there is not a pronounced delay in Fall Chinook passage between Bonneville Dam and The Dalles Dam. Rather, there is a small delay in August and early September and very little delay in late September and October. The small delay in August and early September is likely associated with CWR use, but the duration of Fall Chinook CWR use is less than steelhead CWR use (Goniea et al. 2006 and Keefer et al. 2009)

The delay of Fall Chinook passage between Bonneville Dam and The Dalles Dam is best illustrated in a year such as in 2017 that had relatively warm temperatures in August and early September as shown in Figure 8. In 2017, temperatures were about 22°C in August and early September and there were two spikes of Fall Chinook passing Bonneville Dam but no corresponding spikes in passage at The Dalles Dam. Presumably, many of the Fall Chinook passing Bonneville Dam in August and early September of 2017 passed The Dalles Dam later in September and likely used CWR in the Bonneville reach to temporarily escape the warm mainstem river temperatures.

Figure 9 shows the average passage rate (travel speed) of Fall Chinook between Bonneville Dam and The John Day Dam is reduced by about half when temperatures rise above 21°C (Goniea et al., 2006). It should be noted that this study includes delays that may occur while passing the Dalles Dam, which likely effects the average passage rate shown in this figure. Keefer et al. (2004) documented a Fall Chinook average passage rate of about 65 km/day (40 miles/day) through the Bonneville Reservoir, which was heavily weighted with Fall Chinook migrating when temperatures were below 21°C. Thus, Fall Chinook not using CWR can travel through 45-mile Bonneville Reservoir reach in a little more than a day. Keefer et al. (2009) noted that the typical resident time in CWR for Fall Chinook was 3-5 days for Fall Chinook

using CWR (up to 40% based on Goniea et al., 2006), which likely explains the decrease in the average passage rate when temperature exceed 21°C.

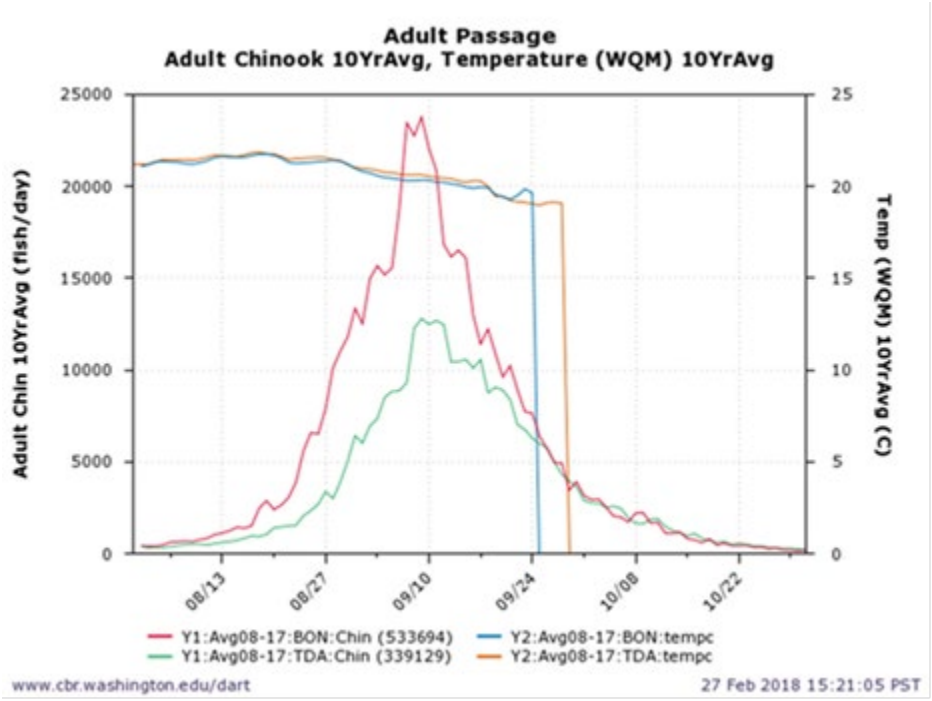

Figure 7 – Adult Fall Chinook Passage and Water Temperature at Bonneville Dam and The Dalles Dam (2008-2017 Average)

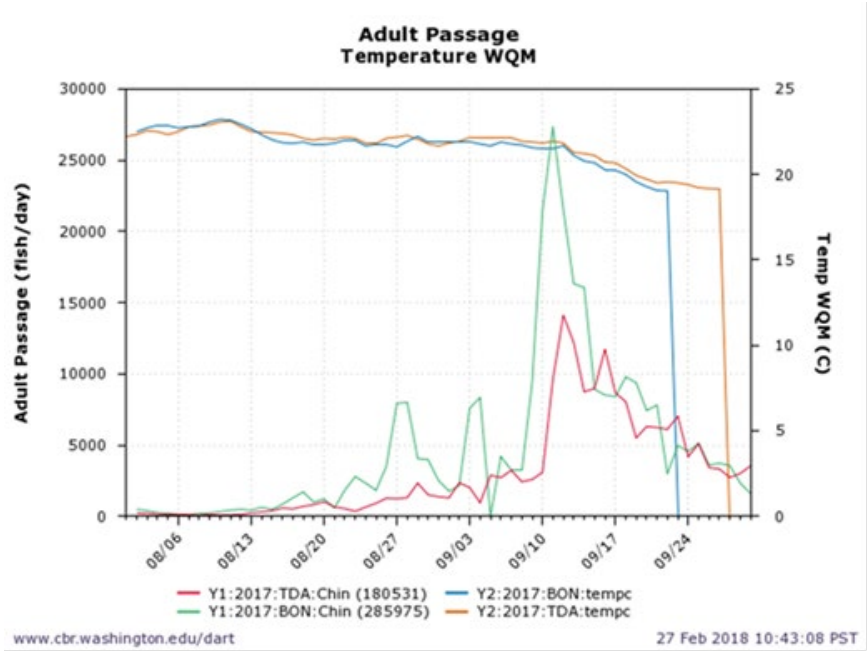

Figure 7 – Adult Fall Chinook Passage and Water Temperature at Bonneville Dam and The Dalles Dam (2017)

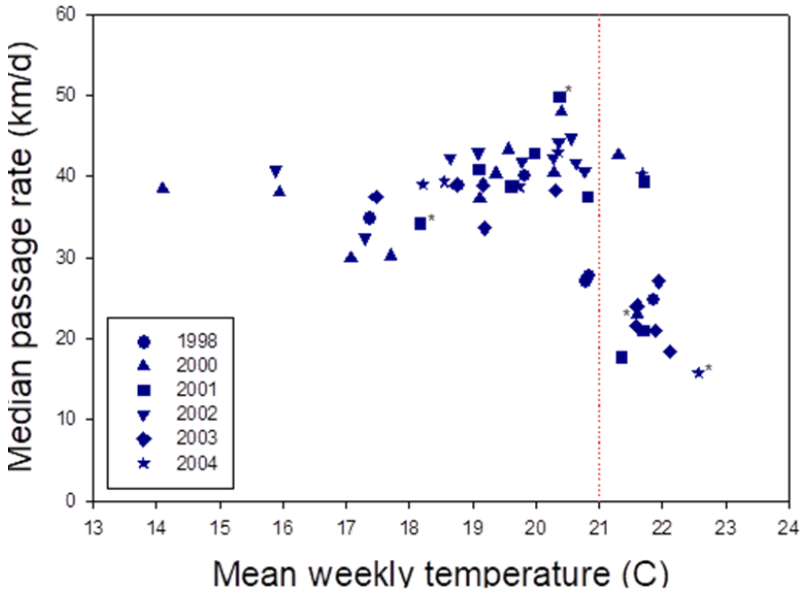

Figure 9 – Adult Fall Chinook Passage Rate between Bonneville Dam and The John Day Dam (Goniea et al., 2004)

2.1 Number of Fall Chinook Salmon in Bonneville Reach CWR

Figure 10 depicts the estimated number of Fall Chinook that are in the Bonneville Reach for each day from August through October (yellow line) and an estimate of the number of Fall Chinook in CWR for each day (green line) for an average year (2008-2017). The daily values used to generate each of the lines in Figure 10 are displayed in Table 8.

2.1.1 Calculations and Assumptions

Table 8 shows the daily passage of Fall Chinook at Bonneville Dam and The Dalles Dam. A portion of the Fall Chinook that pass Bonneville Dam are not expected to pass The Dalles Dam due to entry into natal tributaries to spawn, return to hatcheries, or harvest within the Bonneville Reach. The percentage expected to not pass The Dalles Dam is estimated to be 36% based on comparing the average annual number of Fall Chinook passing Bonneville Dam (533,695) versus The Dalles Dam (339,129) over the August 1 – October 31 period (2008-2017). Thus, for purposes of calculating the accumulation of Fall Chinook in the Bonneville Reach in Table 8 (and displayed in Figure 10), 36% of the Fall Chinook that pass Bonneville Dam are removed from the analysis. To calculate the number of Fall Chinook in the Bonneville Reach on each day, the net number of Fall Chinook for each day (Bonneville Fall Chinook passage minus 36% minus The Dalles Fall Chinook passage) is calculated and then added to the number of Fall Chinook in the Bonneville Reach from the previous day (see Table 8).

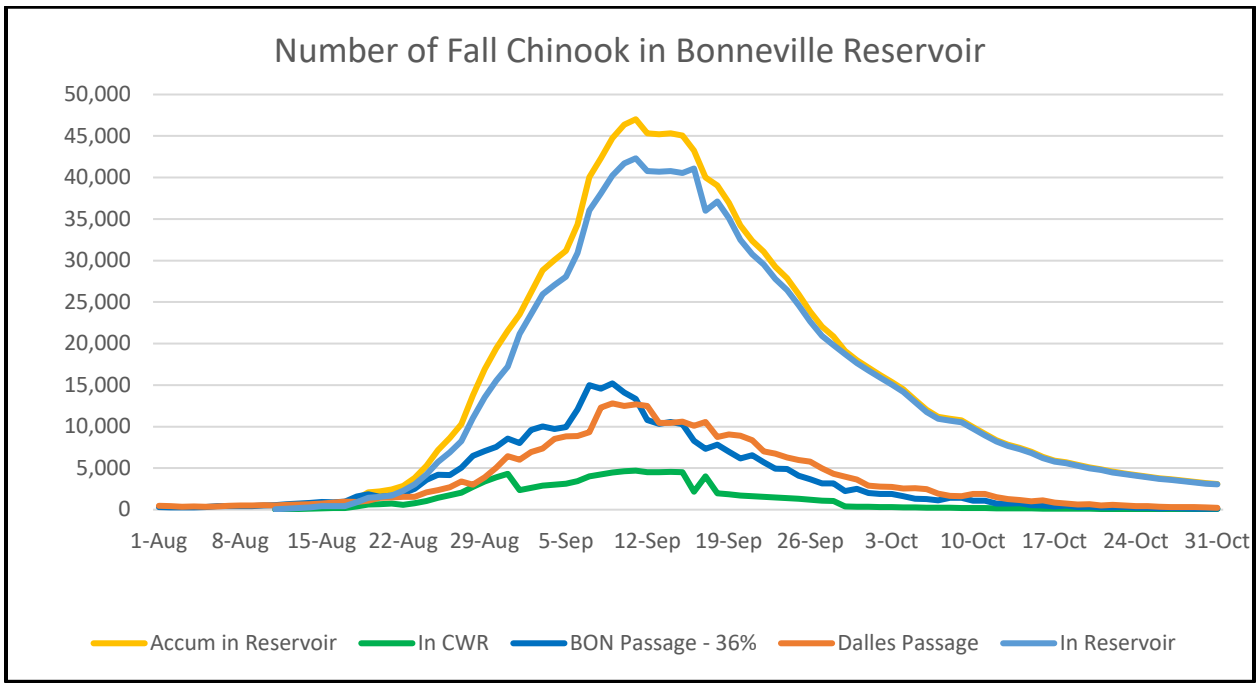

Figure 10 – Accumulation of Fall Chinook in the Bonneville Reach and the Number of Fall Chinook in CWR (2008-2017 Average)

Table 8 – Daily Estimate of Number of Fall Chinook in Bonneville Reach and in CWR (2008-2017 Average)

mm/dd	BON Passage Fish/day	BON Fish/Day Less 36%	Dalles Passage Fish/day	Net In BON Reach	Accumulated in BON Reach	In Res	In CWR	% in CWR	Temp @ BON
1-Aug	494	316	481	0					21.1
2-Aug	450	288	410	0					21.1
3-Aug	434	278	332	0					21.2
4-Aug	436	279	372	0					21.3
5-Aug	493	315	341	0					21.4
6-Aug	640	409	392	0					21.3
7-Aug	658	421	452	0					21.3
8-Aug	698	447	513	0					21.2
9-Aug	664	425	523	0					21.2
10-Aug	780	499	532	0					21.3
11-Aug	854	546	492	55	55	44	11	20%	21.4
12-Aug	1057	676	569	107	162	113	49	30%	21.6
13-Aug	1134	726	625	100	262	184	79	30%	21.6
14-Aug	1264	809	676	133	396	277	119	30%	21.6
15-Aug	1451	929	733	195	591	414	177	30%	21.6
16-Aug	1393	892	856	35	627	439	188	30%	21.6
17-Aug	1540	986	980	5	632	443	190	30%	21.7
18-Aug	2479	1586	940	646	1278	895	384	30%	21.7
19-Aug	2896	1853	1065	789	2067	1447	620	30%	21.7
20-Aug	2410	1543	1420	123	2190	1533	657	30%	21.7
21-Aug	2654	1699	1472	227	2417	1692	725	30%	21.5
22-Aug	3076	1969	1528	441	2858	2286	572	20%	21.3
23-Aug	3912	2504	1559	945	3802	3042	760	20%	21.2

24-Aug	5596	3581	2083	1498	5301	4240	1060	20%	21.3
25-Aug	6593	4220	2350	1870	7170	5736	1434	20%	21.3
26-Aug	6524	4176	2705	1471	8641	6913	1728	20%	21.4
27-Aug	7904	5059	3388	1670	10311	8249	2062	20%	21.4
28-Aug	10126	6481	3020	3461	13772	11018	2754	20%	21.4
29-Aug	11028	7058	3911	3147	16919	13535	3384	20%	21.4
30-Aug	11810	7558	5046	2512	19430	15544	3886	20%	21.2
31-Aug	13358	8549	6433	2116	21546	17237	4309	20%	21.0
1-Sep	12527	8017	6035	1982	23528	21175	2353	10%	20.8
2-Sep	14979	9587	6959	2628	26156	23540	2616	10%	20.7
3-Sep	15672	10030	7350	2680	28836	25952	2884	10%	20.6
4-Sep	15193	9723	8513	1211	30046	27042	3005	10%	20.5
5-Sep	15552	9953	8835	1118	31164	28048	3116	10%	20.4
6-Sep	18858	12069	8881	3188	34352	30917	3435	10%	20.4
7-Sep	23452	15009	9321	5688	40040	36036	4004	10%	20.3
8-Sep	22750	14560	12279	2281	42321	38089	4232	10%	20.3
9-Sep	23766	15210	12801	2409	44730	40257	4473	10%	20.3
10-Sep	22049	14112	12483	1629	46359	41723	4636	10%	20.3
11-Sep	20872	13358	12696	662	47020	42318	4702	10%	20.2
12-Sep	16848	10782	12480	-1697	45323	40791	4532	10%	20.2
13-Sep	16163	10344	10451	-106	45217	40695	4522	10%	20.1
14-Sep	16524	10576	10463	112	45329	40796	4533	10%	20.1
15-Sep	16094	10300	10585	-285	45045	40540	4504	10%	20.0
16-Sep	12983	8309	10103	-1794	43251	41088	2163	5%	19.9
17-Sep	11424	7311	10569	-3258	39993	35994	3999	10%	20.0
18-Sep	12233	7829	8771	-941	39052	37099	1953	5%	19.9
19-Sep	10898	6975	9060	-2085	36967	35119	1848	5%	19.5
20-Sep	9627	6161	8917	-2756	34212	32501	1711	5%	19.4
21-Sep	10238	6552	8384	-1832	32379	30760	1619	5%	19.3
22-Sep	8928	5714	7030	-1317	31063	29510	1553	5%	19.5
23-Sep	7743	4956	6764	-1808	29254	27792	1463	5%	19.9
24-Sep	7652	4897	6300	-1403	27852	26459	1393	5%	19.7
25-Sep	6372	4078	5992	-1914	25938	24641	1297	5%	
26-Sep	5740	3674	5770	-2096	23841	22649	1192	5%	
27-Sep	4962	3176	4977	-1801	22040	20938	1102	5%	
28-Sep	4947	3166	4335	-1169	20871	19828	1044	5%	
29-Sep	3483	2229	3978	-1749	19123	18740	382	2%	
30-Sep	3926	2513	3637	-1124	17999	17639	360	2%	
1-Oct	3168	2027	2909	-881	17118	16776	342	2%	
2-Oct	2957	1892	2778	-886	16232	15907	325	2%	
3-Oct	2978	1906	2743	-837	15395	15087	308	2%	
4-Oct	2544	1628	2530	-901	14493	14204	290	2%	
5-Oct	2056	1316	2597	-1281	13212	12948	264	2%	
6-Oct	2008	1285	2482	-1197	12015	11775	240	2%	
7-Oct	1738	1112	1950	-837	11178	10954	224	2%	
8-Oct	2224	1423	1664	-240	10938	10719	219	2%	
9-Oct	2242	1435	1630	-195	10743	10528	215	2%	
10-Oct	1688	1080	1888	-808	9935	9736	199	2%	
11-Oct	1719	1100	1911	-810	9124	8942	182	2%	
12-Oct	1158	741	1494	-753	8372	8204	167	2%	
13-Oct	1158	741	1286	-545	7827	7671	157	2%	
14-Oct	1183	757	1143	-386	7441	7292	149	2%	
15-Oct	832	533	993	-461	6981	6841	140	2%	
16-Oct	760	486	1112	-625	6355	6228	127	2%	
17-Oct	620	397	836	-439	5916	5798	118	2%	
18-Oct	811	519	729	-209	5707	5593	114	2%	

19-Oct	482	308	618	-310	5397	5289	108	2%	
20-Oct	578	370	675	-305	5092	4990	102	2%	
21-Oct	455	291	509	-218	4874	4777	97	2%	
22-Oct	448	286	587	-301	4574	4482	91	2%	
23-Oct	472	302	511	-209	4365	4277	87	2%	
24-Oct	365	233	430	-197	4168	4085	83	2%	
25-Oct	381	244	430	-186	3982	3902	80	2%	
26-Oct	274	175	368	-193	3789	3713	76	2%	
27-Oct	329	211	324	-113	3676	3603	74	2%	
28-Oct	219	140	298	-158	3519	3448	70	2%	
29-Oct	211	135	306	-171	3347	3280	67	2%	
30-Oct	177	113	263	-149	3198	3134	64	2%	
31-Oct	203	130	222	-92	3106	3044	62	2%	

Source: Columbia River DART

Notes: 1) Not feasible to calculate accumulated Fall Chinook from Aug. 1 to Aug. 10 with the method and assumptions; 2) Bonneville Forebay temperatures not available after September 24.

Many of the "accumulated" Fall Chinook in the Bonneville Reservoir shown in Figure 10 are due to the increasing number of Fall Chinook migrating through the reach and not using CWR. To estimate the number of accumulated Fall Chinook in the Bonneville Reach that are in CWR versus in the Bonneville Reservoir, it is estimated that the percent in CWR is a function of the temperature as reported in Goniea et al. (2006):

% Fall Chinook in CWR	Columbia River Temperature
40%	>22C
30%	21.5 – 22.9C
20%	21.0 – 21.4C
10%	20.0 – 20.9C
5%	19.0 – 19.9C
2%	<19C

2.1.2 *Results*

As shown in Figure 10 (and Table 8), the number of Fall Chinook using CWR in the Bonneville Reservoir reach is estimated to be approximately 5,000 during the last week of August and the first two weeks of September for an average year (2008-2017). Unlike steelhead, the majority of Fall Chinook that are in the Bonneville Reservoir are estimated to be migrating in the reservoir. After mid-September, the number Fall Chinook passing Bonneville Dam begins to decrease, the accumulated number of Fall Chinook in the reach begins to decrease, and temperatures are 20°C and declining resulting in fewer Fall Chinook in CWR after mid-September in an average year.

On warmer years, when temperatures remain above 21°C into early September, which is the peak of the Fall Chinook run passing Bonneville Dam, it would be expected that a higher number of Fall Chinook would be in CWR within the Bonneville Reach. Also, this analysis excluded 36% of the Fall Chinook passing Bonneville Dam as explained above. Many of those Fall Chinook are likely harvested by fishing in CWR. Thus, this analysis is likely to underestimate the number of Fall Chinook in Bonneville Reach CWR.

2.1.3 Field Verification

To test the above assumptions on the percentage of Fall Chinook in the Bonneville reach that are in the reservoir versus in CWR, the location of 49 radio-tagged Fall Chinook from the University of Idaho 2000 and 2002 research studies were analyzed. As shown in Figure 11, the percentage of Fall Chinook in the CWR was highest in in mid-August (about 44% averaged over the August 12-27th period), then dropped to 25% then 10% in late August and early September. After the first week of September nearly all the Fall Chinook were migrating in the reservoir and were not in CWR.

The results shown in Figure 11 generally comport to the percentages and pattern of Fall Chinook in CWR depicted in Figure 10 above, although the 44% of the Fall Chinook using CWR in August is slightly higher than the assumptions used in Table 8 and Figure 10. Also, Fall Chinook use of CWR in Figure 11 drops off more rapid than in Figure 10, which is likely because early September temperatures in 2000 and 2002 were below average. The results in Figure 11 should, however, be viewed with caution due to the low number of Fall Chinook on each day.

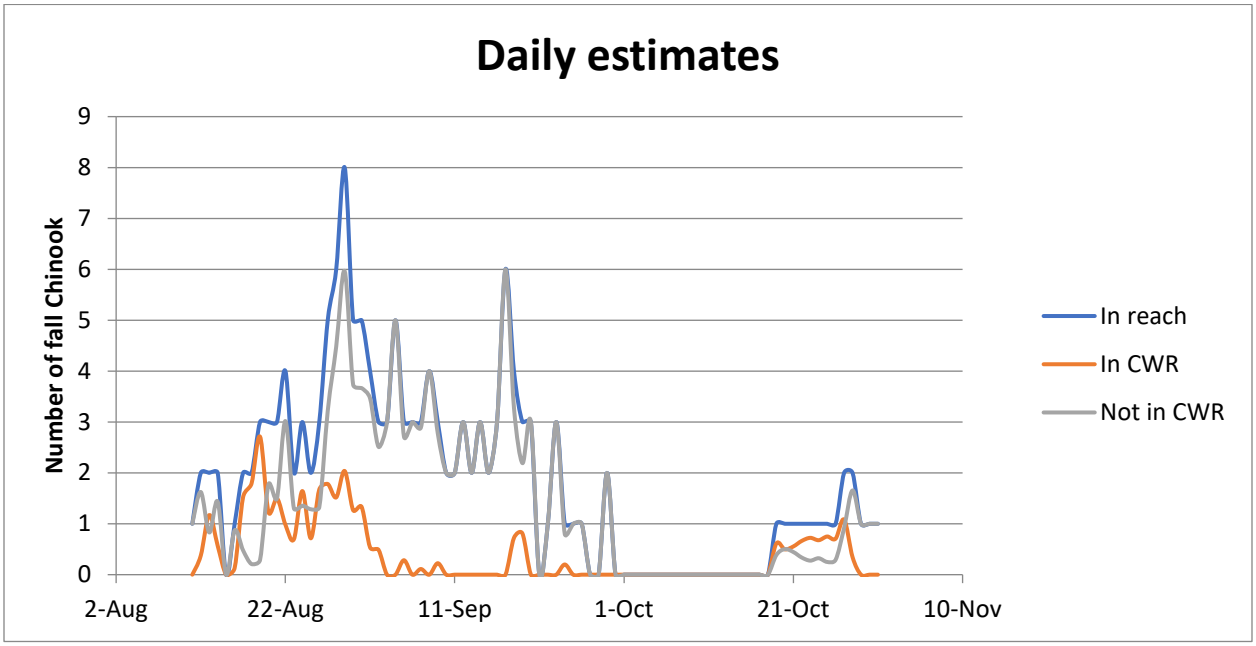

Figure 11 – Distribution of 49 Radio-Tagged Fall Chinook in Bonneville Reach from University of Idaho 2000 and 2002 Research Studies (Keefer 6/22/17 email)

2.2 Number of Fall Chinook Salmon in Bonneville Reach CWR in 2013

Using the same methodology as described in Section 2.1 above, the number of Fall Chinook Salmon in CWR is estimated for 2013 and is shown in Figure 12 and Table 9. 2013 was selected because it represents a relatively warm Columbia River temperature year for August and September and represents a relatively large Fall Chinook run. And therefore, represents conditions that would be expected to result in the highest number of Fall Chinook using CWR.

As shown in Figure 12 and Table 9, 20,000 to 40,000 Fall Chinook are estimated to have been in Bonneville Reach CWR in 2013 in the latter part of August through mid-September. This is four to eight times the estimated number of Fall Chinook (5,000) in CWR in an average year (2006-2017) as shown in

Section 2.1. Late August and early September temperatures were consistently around 22°C in 2013, and as documented by Goniea et al. (2006), are temperatures at which a significant number of Fall Chinook seek CWR. In 2013, 953,222 Adult Fall Chinook passed Bonneville Dam, which is about twice the 10 year (2007-2016) annual average of 504,148 (Fish Passage Center Annual Reports).

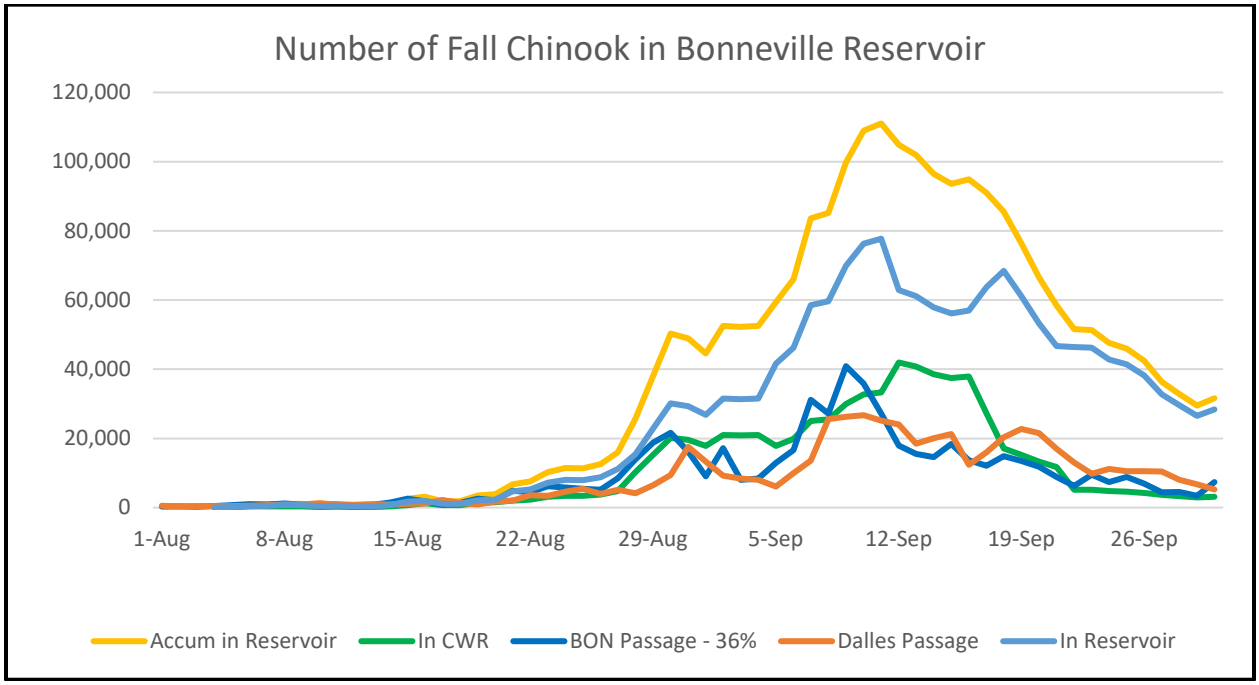

Figure 12 – Accumulation of Fall Chinook in the Bonneville Reach and the Number of Fall Chinook in CWR (2013)

Table 9 – Daily Estimate of Number of Fall Chinook in Bonneville Reach and in CWR (2013)

mm/dd	BON Passage Fish/day	BON Fish/Day Less 36%	Dalles Passage Fish/day	Net In BON Reach	Accumulated in BON Reach	In Res	In CWR	% in CWR	Temp @ BON
1-Aug	456	292	486	-194					21.1
2-Aug	556	356	317	39					21.0
3-Aug	461	295	463	-168					21.0
4-Aug	648	415	402	13	13	10	3	20%	21.3
5-Aug	1062	680	447	233	245	172	74	30%	21.6
6-Aug	1623	1039	532	507	752	451	301	40%	22.0
7-Aug	1441	922	742	180	932	559	373	40%	22.2
8-Aug	1774	1135	938	197	1130	791	339	30%	21.9
9-Aug	1310	838	908	-70	1060	742	318	30%	21.8
10-Aug	1345	861	1249	-388	672	470	202	30%	21.8
11-Aug	1464	937	823	114	786	550	236	30%	21.7
12-Aug	1102	705	848	-143	643	450	193	30%	21.8
13-Aug	1250	800	961	-161	482	338	145	30%	21.8
14-Aug	2222	1422	891	531	1013	709	304	30%	21.8
15-Aug	4009	2566	1048	1518	2531	1772	759	30%	21.9
16-Aug	2816	1802	1204	598	3129	1878	1252	40%	22.0
17-Aug	1326	849	2196	-1347	1782	1069	713	40%	22.1
18-Aug	2130	1363	1353	10	1792	1075	717	40%	22.1
19-Aug	4060	2598	906	1692	3484	2091	1394	40%	22.1
20-Aug	3255	2083	1742	341	3826	2295	1530	40%	22.0

21-Aug	7650	4896	2028	2868	6694	4686	2008	30%	21.9
22-Aug	6857	4388	3552	836	7530	5271	2259	30%	21.9
23-Aug	9622	6158	3426	2732	10262	7184	3079	30%	21.9
24-Aug	9038	5784	4609	1175	11438	8006	3431	30%	21.9
25-Aug	8431	5396	5451	-55	11382	7968	3415	30%	21.9
26-Aug	8023	5135	3966	1169	12551	8786	3765	30%	21.8
27-Aug	13312	8520	5136	3384	15935	11154	4780	30%	21.7
28-Aug	21720	13901	4159	9742	25677	15406	10271	40%	22.0
29-Aug	29308	18757	6449	12308	37985	22791	15194	40%	22.1
30-Aug	33819	21644	9366	12278	50263	30158	20105	40%	22.2
31-Aug	25199	16127	17511	-1384	48879	29328	19552	40%	22.3
1-Sep	14086	9015	13289	-4274	44605	26763	17842	40%	22.4
2-Sep	26807	17156	9223	7933	52539	31523	21016	40%	22.3
3-Sep	12593	8060	8383	-323	52215	31329	20886	40%	22.1
4-Sep	13045	8349	8031	318	52533	31520	21013	40%	22.0
5-Sep	20216	12938	6074	6864	59397	41578	17819	30%	21.8
6-Sep	25956	16612	9954	6658	66055	46239	19817	30%	21.5
7-Sep	48710	31174	13612	17562	83618	58532	25085	30%	21.3
8-Sep	42445	27165	25628	1537	85154	59608	25546	30%	21.5
9-Sep	63870	40877	26225	14652	99806	69864	29942	30%	21.7
10-Sep	56044	35868	26710	9158	108964	76275	32689	30%	21.9
11-Sep	42506	27204	25140	2064	111028	77720	33308	30%	21.9
12-Sep	27964	17897	24071	-6174	104854	62912	41942	40%	22.2
13-Sep	24175	15472	18441	-2969	101885	61131	40754	40%	22.3
14-Sep	22755	14563	20037	-5474	96411	57847	38565	40%	22.2
15-Sep	28761	18407	21239	-2832	93579	56148	37432	40%	22.3
16-Sep	21370	13677	12402	1275	94854	56912	37942	40%	22.0
17-Sep	18896	12093	15951	-3858	90997	63698	27299	30%	21.7
18-Sep	23268	14892	20357	-5465	85531	68425	17106	20%	21.3
19-Sep	21118	13516	22700	-9184	76347	61077	15269	20%	
20-Sep	18390	11770	21544	-9774	66572	53258	13314	20%	
21-Sep	13789	8825	16993	-8168	58404	46723	11681	20%	
22-Sep	9725	6224	13030	-6806	51598	46438	5160	10%	
23-Sep	14803	9474	9735	-261	51337	46203	5134	10%	
24-Sep	11596	7421	11150	-3729	47609	42848	4761	10%	
25-Sep	13906	8900	10534	-1634	45974	41377	4597	10%	
26-Sep	10857	6948	10501	-3553	42422	38180	4242	10%	
27-Sep	6901	4417	10474	-6057	36365	32728	3636	10%	
28-Sep	7041	4506	8055	-3549	32816	29534	3282	10%	
29-Sep	5286	3383	6760	-3377	29439	26495	2944	10%	
30-Sep	11556	7396	5269	2127	31566	28409	3157	10%	

Source: Columbia River DART

Notes: 1) Started calculation of accumulated Fall Chinook on Aug. 4 to avoid a negative initial count; 2) Bonneville Forebay temperatures not available after September 18; 3) the % in CWR after September 18 is based on estimated temperatures through September.

As report in Goniea et al. (2006), Fall Chinook appear to use the larger CWR tributaries in the Bonneville Reach, including the Little White Salmon (Drano Lake), White Salmon, Klickitat rivers. Herman Creek/Cove is also likely used by Fall Chinook salmon.

3. Summary

Peak use of Bonneville Reservoir CWR by steelhead occurs mid-August through early September and peak use by Fall Chinook occurs in late August through mid-September. During an average year (river temperatures and run size), approximately 65,000 steelhead and 5,000 Fall Chinook are in Bonneville Reservoir CWR. During years with warm August-September Columbia River temperatures and high run size, as many as 155,000 steelhead and 40,000 Fall Chinook are predicated to be in Bonneville Reservoir CWR during the period of peak CWR use, although these peak numbers for steelhead and Fall Chinook may not occur in the same years.

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