Columbia River Treaty

2014/2024 Review

United States Entity Supplemental Report

Appendix C

September 2010

United States Entity

APPENDIX C
PHASE 1 SUPPLEMENTAL STUDY RESULTS
70-YEAR COMPARISONS

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C.1 INTRODUCTION

In general, the planning and operation of the Canadian Treaty projects does not recognize operations not defined in the actual Treaty or Treaty Protocol. Since the Phase 1 studies were primarily focused on looking at the two fundamental river purposes defined under the Treaty, power and flood control, the studies did not include additional operations not considered under the Treaty. By approaching the Phase 1 studies from this Treaty standpoint, both the U.S. and Canadian Entities believed they created a baseline of information for comparison and to build from for future studies and for engagement with the sovereigns and stakeholders within their respective countries. However, since the Biological Opinions (BiOp) have such a strong influence on the U.S. operations, the U.S. Entity felt it was important to look at the Phase 1 study results with the Fish operations included. The purpose of this appendix is to describe the modeling, methodology and criteria used in the U.S. Entity Phase 1 Supplemental studies that were done to assess the impacts to the U.S. system and fish operations when BiOp requirements were overlaid on the Phase 1 studies. The Phase 1 studies referred to in this appendix are:

1. Treaty continues post-2024 and Called Upon flood control is implemented (Study A);
2. Treaty is terminated in 2024 and Called Upon flood control is implemented (Study B); and
3. Treaty continues post-2024 with largely the same Treaty operations as today (Study C).

The purpose of this Appendix is to compare across Supplemental studies only. The graphs and charts in this Appendix C are entirely from the studies that include Fish operations only. For a comparison of Phase 1 studies to Supplemental studies, see Appendix B. By comparing across Supplemental studies only, the impacts of the Called Upon operations and power operations, both with and without the Treaty, on BiOp objectives can be evaluated.

C.2 STUDY HIGHLIGHTS

Across the seventy years studied the results of all the studies were compared to the C+BiOp Studies. The C+BiOp study closely represents current Treaty studies prepared with an Assured Operating Plan and Detailed Operation Plan. The C study was based on the current FCOP and did not include Called Upon flood control or U.S. effective use operations. For this set of studies, the C+BiOp study did include Fish operations at U.S. projects and the C+BiOp study included Supplemental Operating Agreements (SOA) with Canada to enhance the fishery operations within Canada and the U.S.

The B1 Studies were studies where the Treaty is terminated and the Canadian projects operated for local flood control only unless Called Upon flood control was requested. There was no consideration for Canadian power needs in this study. It was developed to evaluate the value of a Canadian power operation. Because it is not a realistic potential future operation, it is not discuss to any length in this Appendix.

The A1 studies are studies where the Treaty continues with Called Upon flood control at Canadian projects and effective use for flood control are the upper reservoir limits for operations at U.S. reservoirs. The A1 studies have a Canadian power operation developed similarly to

current Treaty studies. The Canadian power operation in the A1 studies optimizes power in both the U.S. and Canada. The B2 studies include a Canadian power operation that was developed by BC Hydro for study example purposes. The power operation in the B2 Studies was not developed with Columbia River system optimization as an objective.

C.3 UNCERTAINTIES IN POTENTIAL FUTURE CANADIAN OPERATING SCENARIOS

Under B studies, where the Treaty is terminated, it was assumed there would no longer be coordinated planning between Canada and the U.S., so Canadian operations from year to year would be highly uncertain. To address that uncertainty, two scenarios were developed by Canada to evaluate possible future Canadian operations. The power drafts developed for the studies were treated as an assured operation, although in reality there would be no assurance that the projects would be operated in this manner. It should be noted that the Study B power operations are monthly estimates of operations. The variation of the day-to-day operation may be significant, as the Canadian system will be able to fully respond to market conditions and B.C. power needs without having AOP limitations.

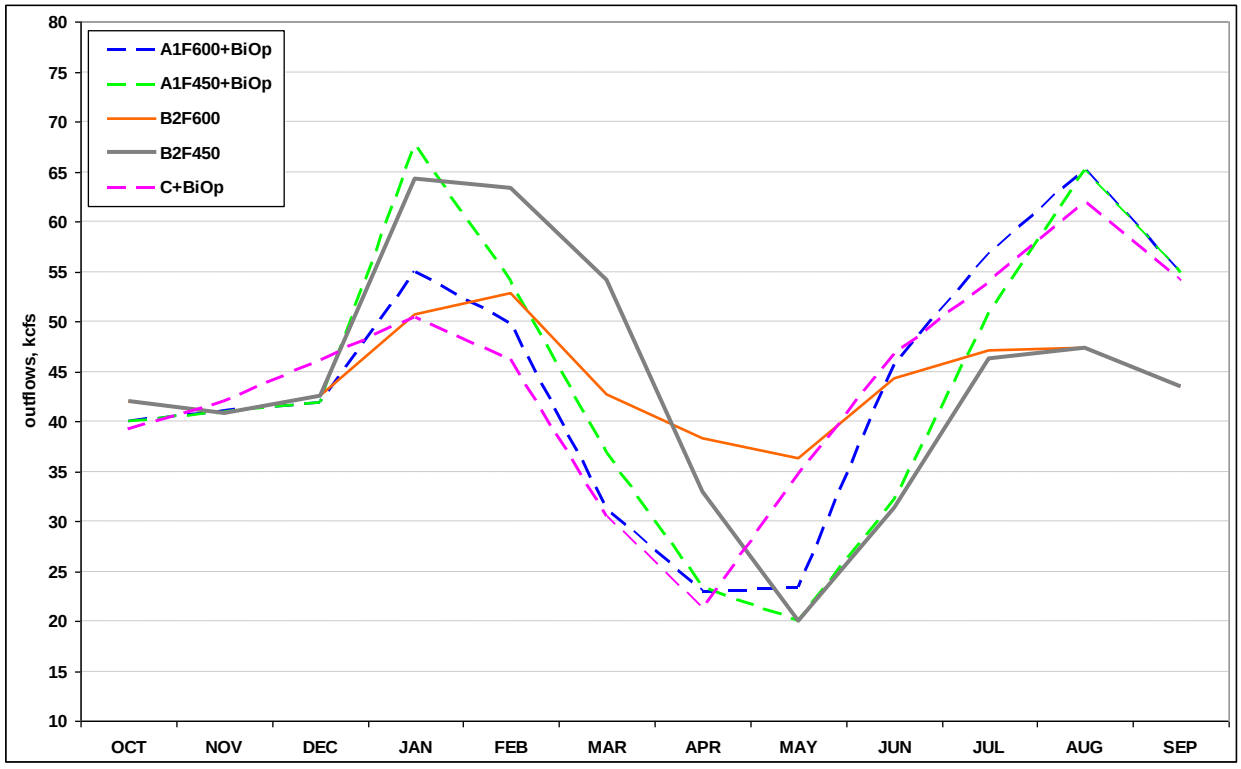
In the B2 studies, the projects were operated to a Canadian power draft, which was provided by B.C. Hydro for study example purposes only. While the scenario is not guaranteed, it does provide a possible scenario to test procedures. Based on our understanding of Canadian operations, Canada is more likely to operate for a power operation similar to the one modeled in the B2 studies as they more closely resemble current power operations.

C.4 ARROW PLUS DUNCAN OUTFLOWS

Figure C-1 shows the Arrow plus Duncan outflows in the Supplemental Studies with Fish operations. In January through April, all A1 +BiOp and B2 +BiOp studies showed more outflows than in the C+BiOp studies due to the A1 and B2 studies Canadian projects drafting deeper for Called Upon. B2 studies generally had less outflows than C studies in May through September.

Figure C-1 Arrow plus Duncan Outflows - Supplemental Studies
70-Year Averages

outflows, kcfs	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
A1F600+BiOp	40	41	42	55	50	31	23	23	46	57	65	55
A1F450+BiOp	40	41	42	68	54	37	23	20	32	51	65	55
B2F600	42	41	43	51	53	43	38	36	44	47	47	44
B2F450	42	41	43	64	63	54	33	20	31	46	47	44
C+BiOp	39	42	46	50	46	30	21	35	47	54	62	54



C.5 GENERATION SUMMARY

Generation differences help quantify possible impacts of the various scenarios developed for the 2024-25 Phase 1 studies. The accompanying tables and graphs are based on 70-year average generation both by period and as an annual average for U.S. Federal Generation, U.S. Mid-Columbia Generation, U.S. System Generation, and Canadian Generation.

Based on 70-year annual average generation, most of the Supplemental studies produced less generation in the U.S. than the C+BiOp study (generation from A1F+BiOp and B2F450+BiOp were closest to C+BiOp). B2F+BiOp studies produced the most 70-year annual average generation in Canada.

C.5.1 U.S. SYSTEM GENERATION

The following chart shows U.S. System generation including Federal and non-federal projects in the coordinated system. U.S. System generation includes generation from Federal projects, Mid-Columbia projects, plus generation from non-Federal projects whose operations are coordinated under the PNCA in the U.S. **Compared to C+BiOp:**

- Average annual U.S. generation is similar between all Supplemental studies whether Treaty continues or terminates.
- At the 600 kcfs maximum flow objective, both the Treaty scenarios (A1 and C) and the no Treaty scenarios (B2) have very similar generation shapes and amounts.
- At the 450 kcfs maximum flow objective, both the Treaty and no Treaty scenarios produce more generation during the January through April period and less generation during the May into July period than the 600 kcfs objective. This is due to a higher frequency of Called Upon years at the 450 kcfs level resulting in more generation during the drafting of projects for flood control in the winter and less generation during the spring refill.
- All of the studies produced less 70-year average generation in November and December than the Treaty continues with the FCOP (study C).
- Except for A1F600+BiOp, all studies produced more 70-year average generation in January, March, and the first half of April.
- A1F600+BiOp produced less 70-year average generation in June and July.

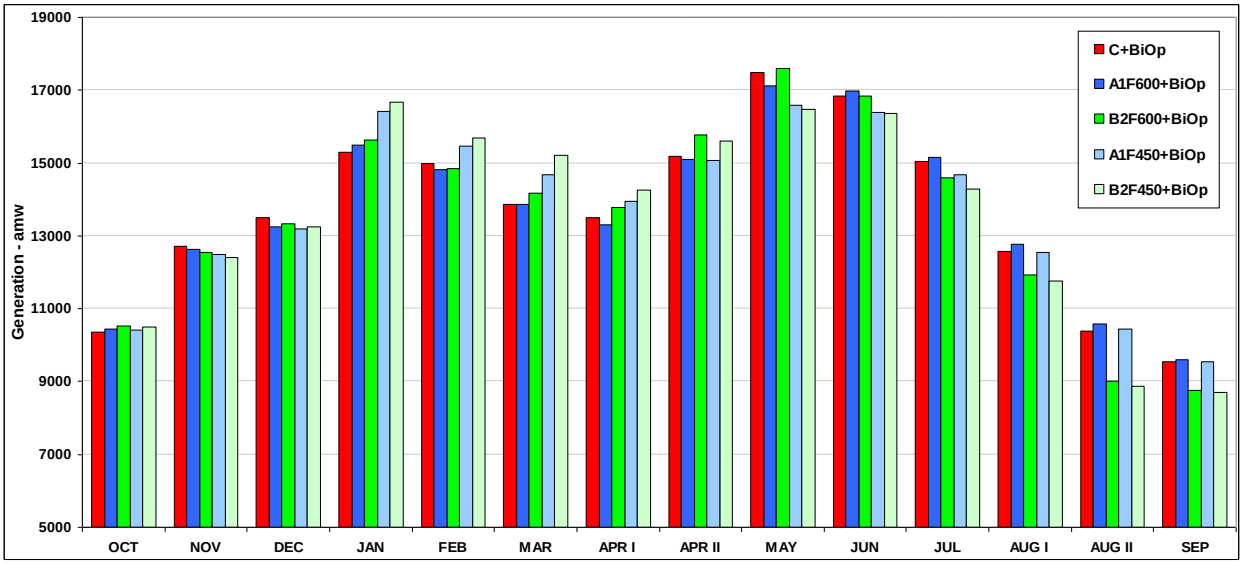
The C+BiOp Study where the Treaty continues and there is no Called Upon operation in Canada or effective use in the U.S. had the highest Annual Average generation. The C+BiOp Study is used to compare to the other studies as it is a nearer representation to current Treaty study procedures.

Figure C-2 U.S. System Generation - Supplemental Studies
70-Year Averages

aMW	OCT	NOV	DEC	JAN	FEB	MAR	APR I	APR II	MAY	JUN	JUL	AUG I	AUG II	SEP	ANN AV
C+BiOp	10363	12727	13511	15283	14989	13854	13499	15179	17494	16846	15036	12578	10385	9538	13781
A1F600+BiOp	10437	12635	13247	15480	14825	13858	13315	15098	17133	16979	15156	12767	10594	9606	13764
B2F600+BiOp	10522	12549	13325	15639	14843	14177	13792	15769	17611	16840	14606	11940	9012	8770	13670
A1F450+BiOp	10426	12504	13195	16415	15462	14690	13944	15075	16579	16382	14667	12555	10443	9543	13813
B2F450+BiOp	10506	12409	13256	16675	15681	15219	14262	15611	16464	16367	14297	11752	8875	8707	13724

Diff = C+BiOp minus study **red means C+BiOp produced more generation than the study being compared to** 70 year studies - Average Differences

aMW	OCT	NOV	DEC	JAN	FEB	MAR	APR I	APR II	MAY	JUN	JUL	AUG I	AUG II	SEP	ANN AV
A1F600+BiOp	-74	93	264	-196	164	-4	184	81	362	-133	-120	-189	-210	-67	17
B2F600+BiOp	-159	178	186	-356	146	-323	-293	-590	-117	6	431	638	1373	768	111
A1F450+BiOp	-63	224	316	-1132	-473	-835	-445	104	915	464	369	24	-59	-4	-33
B2F450+BiOp	-143	318	255	-1392	-691	-1365	-763	-432	1030	479	740	827	1510	831	57



C.5.2 FEDERAL GENERATION

The following chart shows the Federal generation in all the studies prepared with Fish operations. U.S. Federal generation includes generation from the following projects: Libby, Hungry Horse, Albeni Falls, Grand Coulee, Chief Joseph, Dworshak, Lower Granite, Little Goose, Lower Monumental, Ice Harbor, McNary, John Day, The Dalles, and Bonneville.
Compared to C+BiOp:

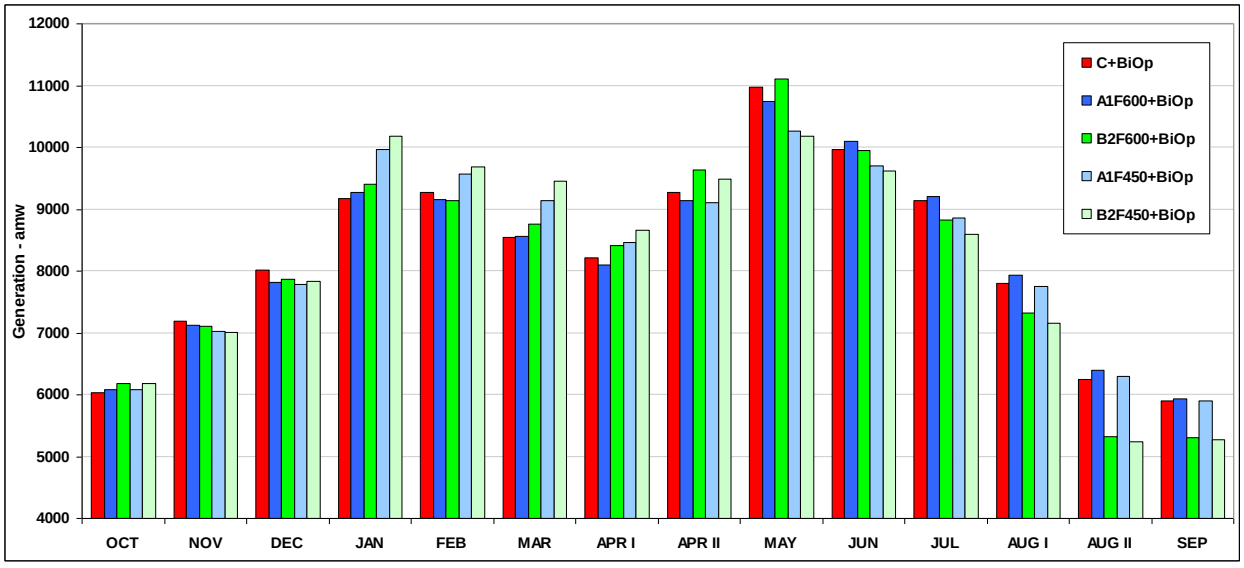
- All Supplemental studies produced less 70-year average annual Federal generation, except A1F450+BiOp.
- All of the studies produced less 70-year average generation in November and December.
- Except for A1F600+BiOp, all studies produced more 70-year average generation in January, March, and the first half of April.
- A1F600+BiOp produced more 70-year average generation in June through October.

Figure C-3 U.S. Federal Generation - Supplemental Studies
70-Year Averages

aMW	OCT	NOV	DEC	JAN	FEB	MAR	APR I	APR II	MAY	JUN	JUL	AUG I	AUG II	SEP	ANN AV
C+BiOp	6035	7194	8023	9177	9270	8547	8210	9268	10969	9960	9138	7795	6244	5894	8325
A1F600+BiOp	6086	7125	7821	9280	9149	8557	8095	9139	10742	10093	9213	7933	6401	5934	8311
B2F600+BiOp	6182	7114	7870	9408	9142	8754	8416	9636	11104	9952	8820	7316	5324	5300	8244
A1F450+BiOp	6083	7027	7786	9975	9570	9135	8463	9101	10258	9696	8855	7754	6293	5901	8335
B2F450+BiOp	6176	7002	7832	10181	9694	9447	8660	9494	10175	9627	8592	7153	5234	5269	8264

Diff = C+BiOp minus study **red means C+BiOp produced more generation than the study being compared to** 70 year studies - Average Differences

aMW	OCT	NOV	DEC	JAN	FEB	MAR	APR I	APR II	MAY	JUN	JUL	AUG I	AUG II	SEP	ANN AV
A1F600+BiOp	-50	68	203	-102	121	-10	115	129	228	-133	-75	-138	-157	-40	14
B2F600+BiOp	-147	79	153	-230	128	-207	-206	-368	-134	8	318	479	920	594	81
A1F450+BiOp	-48	167	237	-798	-300	-588	-253	166	711	264	283	42	-48	-7	-10
B2F450+BiOp	-141	192	192	-1004	-424	-900	-450	-226	794	333	546	643	1010	625	61



C.5.3 MID-C GENERATION

The power generation in the Mid-Columbia projects demonstrates the same trend in the magnitude of changes to generation as the reminder of the U.S. system. Mid-Columbia generation includes generation from the following projects on the middle reach of the Columbia River: Wells, Chelan, Rocky Reach, Rock Island, Wanapum, and Priest Rapids. **Compared to C+BiOp:**

- A1F450+BiOp studies produced slightly more 70-year average annual Mid-Columbia generation.
- All of the studies produced less 70-year average generation in November and December.
- A1F450+BiOp and B2F450+BiOp produced more 70-year average generation in January, February, March, and the first half of April.

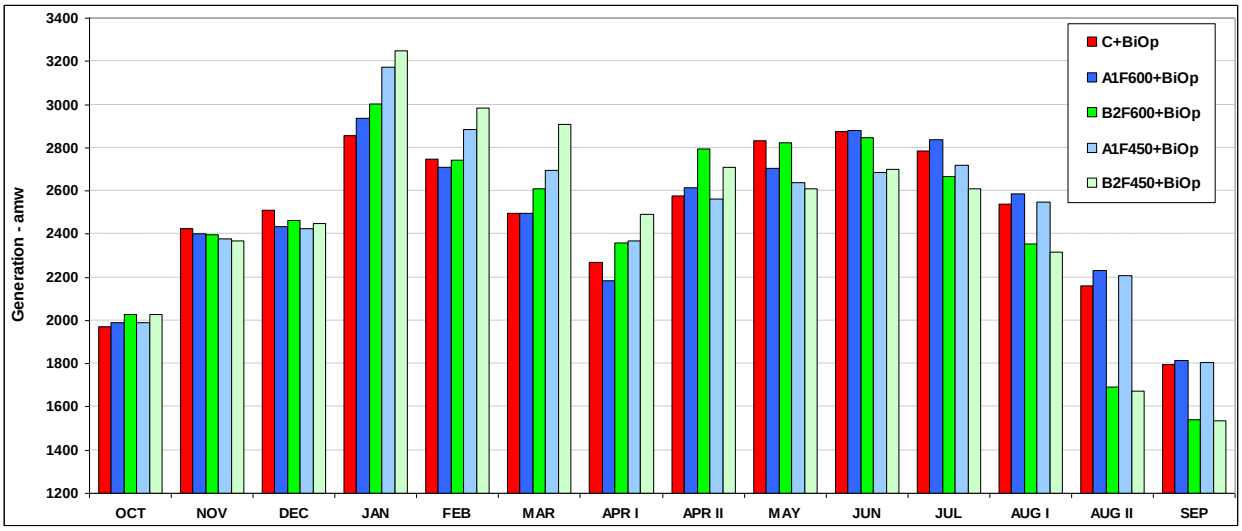
Figure C-4 Mid-Columbia Generation - Supplemental Studies
70-Year Averages

aMW	OCT	NOV	DEC	JAN	FEB	MAR	APR I	APR II	MAY	JUN	JUL	AUG I	AUG II	SEP	ANN AV
C+BiOp	1970	2425	2512	2856	2747	2496	2271	2579	2833	2873	2784	2539	2162	1798	2505
A1F600+BiOp	1992	2403	2436	2934	2711	2494	2183	2615	2706	2882	2839	2587	2232	1817	2501
B2F600+BiOp	2030	2398	2463	3001	2744	2611	2359	2792	2822	2848	2668	2354	1690	1542	2475
A1F450+BiOp	1991	2379	2425	3174	2885	2696	2368	2564	2640	2687	2719	2549	2210	1807	2519
B2F450+BiOp	2028	2369	2451	3247	2982	2910	2493	2711	2612	2699	2612	2318	1672	1535	2501

Mid-Columbia Generation from Wells, Chelan, Rocky Reach, Rock Island, Wanapum, and Priest Rapids

Diff = C+BiOp minus study **red means C+BiOp produced more generation than the study being compared to** 70 year studies - Average Differences

aMW	OCT	NOV	DEC	JAN	FEB	MAR	APR I	APR II	MAY	JUN	JUL	AUG I	AUG II	SEP	ANN AV
A1F600+BiOp	-22	22	76	-78	36	2	88	-36	127	-8	-54	-48	-70	-19	4
B2F600+BiOp	-61	27	50	-145	3	-115	-89	-213	11	26	116	185	472	256	29
A1F450+BiOp	-21	46	87	-318	-138	-200	-98	15	192	186	65	-10	-48	-9	-15
B2F450+BiOp	-58	57	61	-392	-235	-414	-222	-132	221	175	173	221	491	263	4



C.5.4 CANADIAN GENERATION

Canadian generation includes generation from the following Columbia Basin projects in Canada: Mica, Revelstoke, Arrow, Corra Linn, Upper Bonnington, Lower Bonnington, South Slocan, Canal Plant, Brilliant, Seven Mile, and Waneta. **Compared to C+BiOp:**

- B2F+BiOp studies produced more 70-year average annual Canadian generation.

A1F+BiOp and B2F+BiOp studies produced similar generation, generating more than C+BiOp in November through February and less than C+BiOp in the first half of April through August 15. The Canadian projects had the highest Annual Average generation in the B2 studies, which were designed to have a Canadian power operation. The Canadian generation was shaped into the fall and winter months with less generation in the spring and summer than the shape of power generation in current Treaty studies like the C Study.

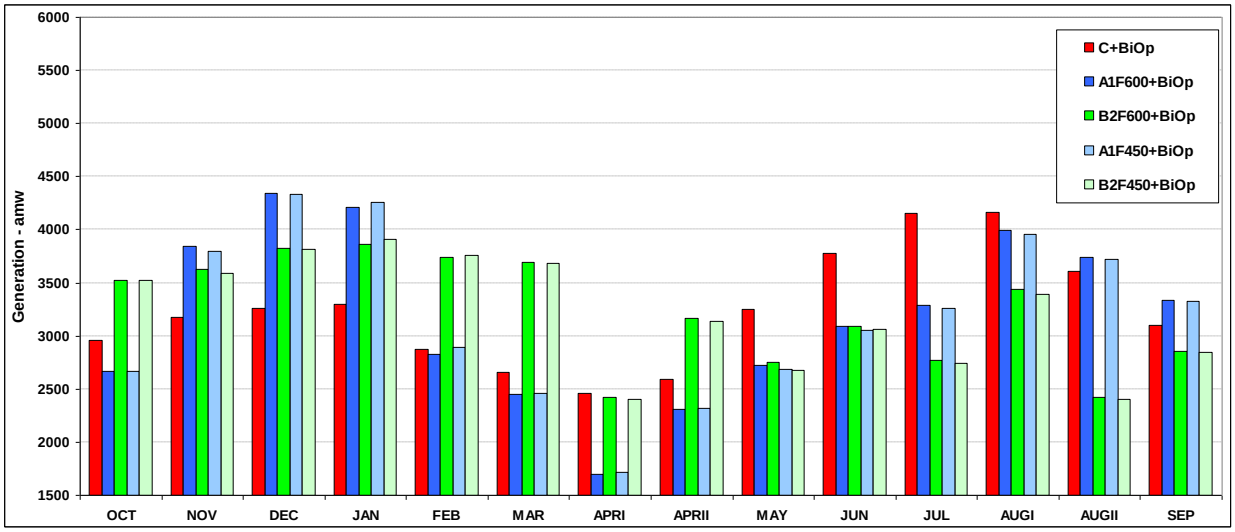
Figure C-5 Canadian Generation - Supplemental Studies
70-Year Averages

aMW	OCT	NOV	DEC	JAN	FEB	MAR	APRI	APRII	MAY	JUN	JUL	AUGI	AUGII	SEP	ANN AV
C+BiOp	2956	3172	3257	3297	2870	2661	2458	2597	3248	3778	4151	4167	3606	3098	3245
A1F600+BiOp	2671	3841	4345	4216	2832	2455	1693	2307	2725	3095	3291	3995	3740	3340	3228
B2F600+BiOp	3522	3629	3826	3861	3743	3695	2420	3167	2749	3095	2771	3435	2424	2856	3286
A1F450+BiOp	2671	3801	4336	4260	2890	2458	1717	2320	2688	3049	3257	3953	3724	3331	3221
B2F450+BiOp	3522	3588	3815	3906	3759	3680	2404	3142	2678	3062	2743	3392	2401	2846	3269

***Canadian Generation includes: Mica+Revelstoke+Arrow+Corra Linn+U. Bonnington+ L. Bonnington+South Slocan+Canal+Brilliant+Seven Mile+Waneta*

Diff = C+BiOp minus study red means C+BiOp produced more generation than the study being compared to

aMW	OCT	NOV	DEC	JAN	FEB	MAR	APRI	APRII	MAY	JUN	JUL	AUGI	AUGII	SEP	ANN AV
A1F600+BiOp	285	-669	-1088	-919	38	205	765	290	522	682	860	172	-134	-242	17
B2F600+BiOp	-566	-456	-568	-564	-872	-1035	38	-570	499	683	1380	732	1182	243	-41
A1F450+BiOp	285	-629	-1079	-963	-20	203	742	277	560	729	894	214	-118	-232	25
B2F450+BiOp	-566	-416	-557	-609	-889	-1019	54	-546	570	716	1408	775	1205	252	-24



C.6 RESERVOIR OPERATION SUMMARIES

The following series of graphs and charts begin with Arrow plus Duncan outflow in all the studies prepared with the Biological Opinion operations included. The Arrow and Duncan outflow is followed by reservoir elevations at U.S. reservoirs in each of the studies. Because these results are the average of all seventy years being studied, the impact of reservoirs operating

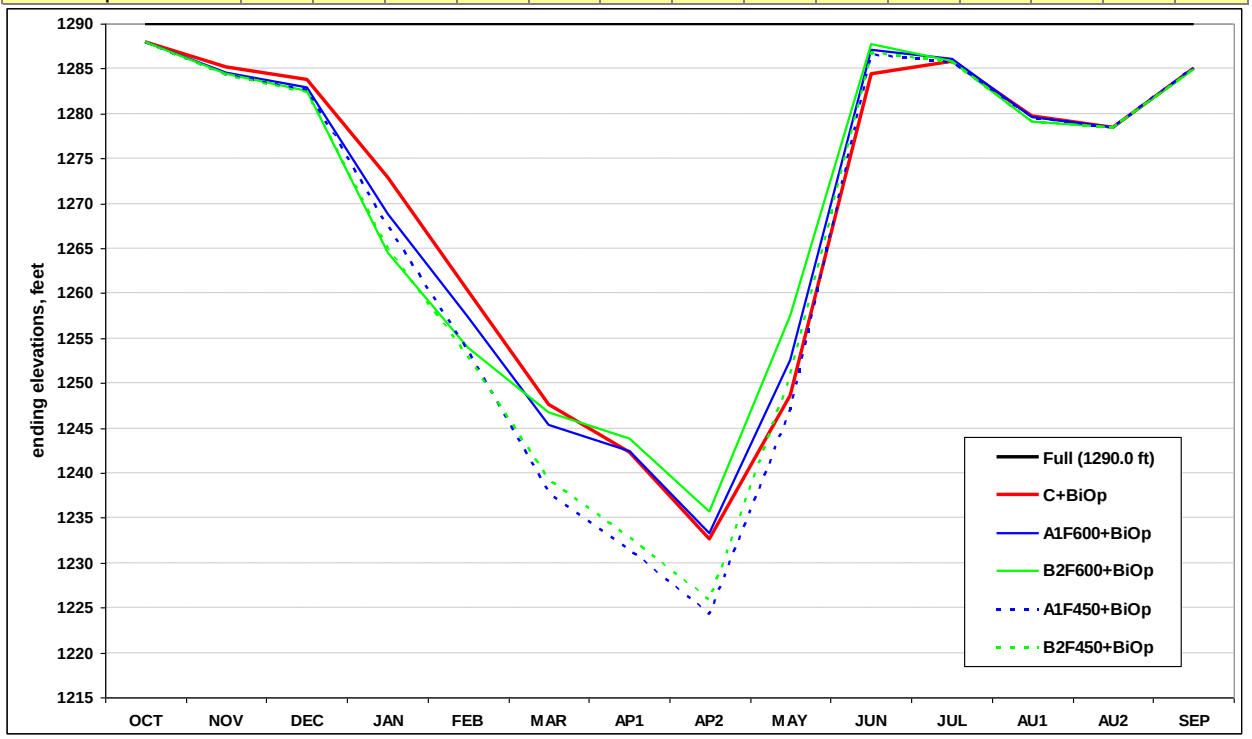
to Called Upon flood control in Canada, or effective use for upper reservoir limits in the U.S. is somewhat hidden. The comparison of data in only those Called Upon years are explored in Appendix D.

C.6.1 GRAND COULEE

In all the Supplemental studies, Grand Coulee's reservoir elevation was similar throughout the year. The reservoir drafted for power through December, then operated up to the April 10 flood control elevation and refill by late June, or early July. The reservoir drafted through August for flow augmentation for fish and refilled in September. The studies prepared with a maximum flow objective at The Dalles of 450 kcfs drafted Grand Coulee more deeply on a 70-year average because there are more years that operated for effective use as the upper draft limit and draft Grand Coulee toward empty by the end of April. The 450 kcfs studies had 52 years that may draft Grand Coulee toward empty by the end of April and the 600 kcfs studies had only 21 years that may draft Grand Coulee toward empty by the end of April if forecasts required this operation.

Figure C-6 Grand Coulee Elevations, feet - Supplemental Studies
70-Year Averages

end of period elevations, ft	OCT	NOV	DEC	JAN	FEB	MAR	AP1	AP2	MAY	JUN	JUL	AU1	AU2	SEP
Full (1290.0 ft)	1290	1290	1290	1290	1290	1290	1290	1290	1290	1290	1290	1290	1290	1290
C+BiOp	1288	1285	1284	1273	1260	1248	1242	1233	1249	1284	1286	1280	1279	1285
A1F600+BiOp	1288	1285	1283	1269	1257	1245	1242	1233	1253	1287	1286	1280	1278	1285
B2F600+BiOp	1288	1284	1283	1265	1254	1247	1244	1236	1258	1288	1286	1279	1278	1285
A1F450+BiOp	1288	1284	1283	1267	1254	1238	1231	1224	1247	1287	1286	1280	1278	1285
B2F450+BiOp	1288	1284	1282	1265	1253	1239	1233	1226	1251	1287	1286	1279	1278	1285

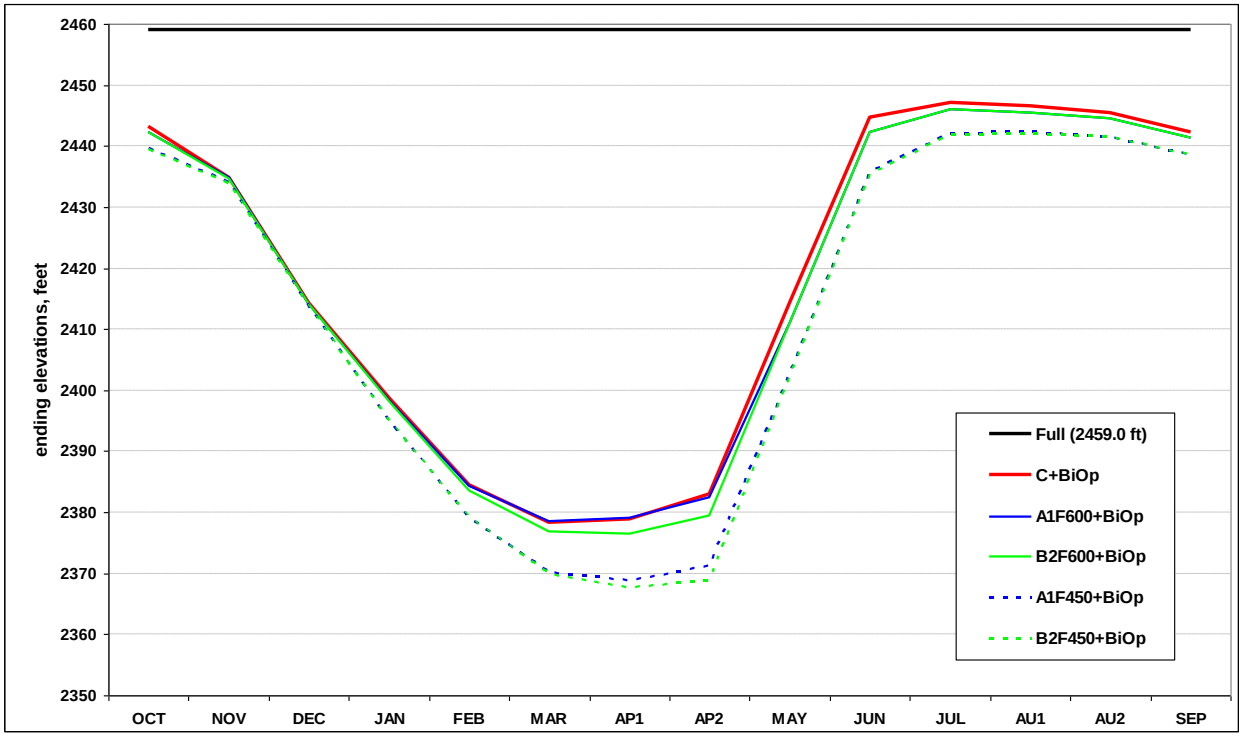


C.6.2 LIBBY DAM

In the Supplemental studies, Libby operated to variable end of December flood control and then to VarQ flood control from January through April. During the refill period it released flow for white sturgeon and bull trout needs. In years when Called Upon was triggered, Libby operated for effective use as the upper draft limit and drafted more deeply than the VarQ flood control elevation. The studies where the maximum flow at The Dalles was 450 kcfs showed Libby drafting more deeply by the end of April than the 600 kcfs studies. That is because there were more years that operated to effective use in the 450 kcfs studies. While attempting to refill by June 30, Libby released flow augmentation water for salmon species then drafted the reservoir to elevation 2439 by the end of August. On average over 70-years, Libby did not refill.

Figure C-7 Libby Elevations, feet - Supplemental Studies
70-Year Averages

end of period elevations, ft	OCT	NOV	DEC	JAN	FEB	MAR	AP1	AP2	MAY	JUN	JUL	AU1	AU2	SEP
Full (2459.0 ft)	2459	2459	2459	2459	2459	2459	2459	2459	2459	2459	2459	2459	2459	2459
C+BiOp	2443	2435	2414	2399	2384	2378	2379	2383	2415	2445	2447	2447	2446	2442
A1F600+BiOp	2442	2435	2414	2398	2384	2379	2379	2382	2411	2442	2446	2446	2445	2441
B2F600+BiOp	2442	2435	2414	2398	2383	2377	2376	2379	2411	2442	2446	2446	2445	2441
A1F450+BiOp	2440	2434	2414	2395	2379	2370	2369	2371	2403	2436	2442	2442	2442	2439
B2F450+BiOp	2439	2434	2414	2395	2379	2370	2368	2369	2402	2435	2442	2442	2441	2438



C.6.3 HUNGRY HORSE DAM

In the Supplemental studies, Hungry Horse operated to VarQ flood control from January through April and met minimum flow at Columbia Falls. During the refill period it met flow at Columbia Falls for bull trout while trying to refill the reservoir. In years when Called Upon was triggered, Hungry Horse operated for effective use as the upper draft limit and drafted more deeply than the VarQ flood control elevation. After refilling by the end of June, Hungry Horse drafted 20 feet in July and August for flow augmentation in the lower Columbia River. The studies where the maximum flow at The Dalles was 450 kcfs show Hungry Horse drafted more deeply by the end of April than the 600 kcfs studies. That is because there were more years that operated to effective use in the 450 kcfs studies. On average over 70-years, Hungry Horse did not refill. The C+BiOp Study showed Hungry Horse to have the highest reservoir elevations; this is because the C+BiOp study does not have an effective use operation at Hungry Horse. Ending elevations were the same between the 600 kcfs studies and the similar between the 450 kcfs studies. All scenarios were similar to the C study ending elevations except were deeper in January through the second half of April.

Figure C-8 Hungry Horse Elevations, feet - Supplemental Studies
70-Year Averages

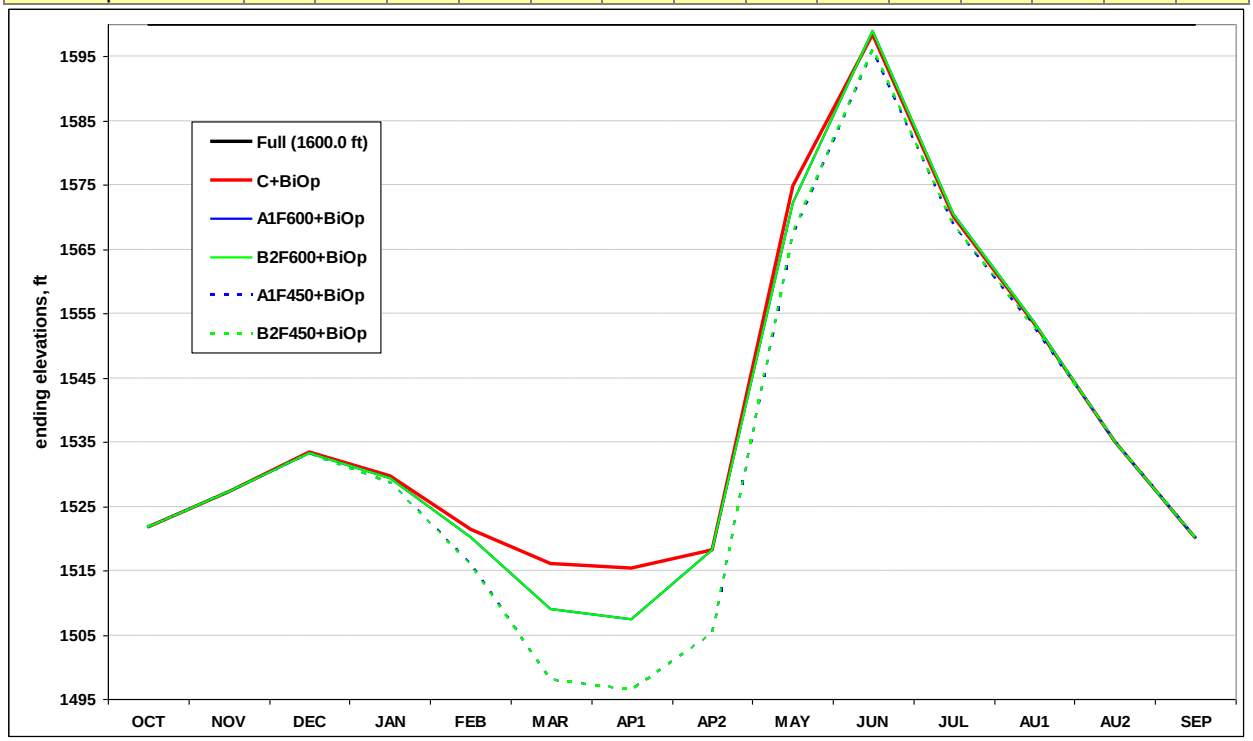
end of period elevations, ft	OCT	NOV	DEC	JAN	FEB	MAR	AP1	AP2	MAY	JUN	JUL	AU1	AU2	SEP
Full (3560.0 ft)	3560	3560	3560	3560	3560	3560	3560	3560	3560	3560	3560	3560	3560	3560
C+BiOp	3546	3545	3541	3529	3518	3507	3506	3511	3536	3557	3554	3553	3551	3548
A1F600+BiOp	3546	3545	3541	3528	3517	3506	3504	3506	3535	3557	3554	3553	3551	3547
B2F600+BiOp	3546	3545	3541	3528	3517	3506	3504	3506	3535	3557	3554	3553	3551	3547
A1F450+BiOp	3545	3544	3540	3527	3513	3495	3490	3487	3526	3554	3552	3551	3550	3547
B2F450+BiOp	3545	3544	3540	3527	3513	3496	3490	3487	3526	3554	3552	3551	3550	3547

C.6.4 DWORSHAK DAM

Under Fish operations, Dworshak filled from October through December. From January through April it operated up to flood control. During May and June the reservoir refilled while releasing flow augmentation water. From July through September, the reservoir drafted 80 feet from full for flow augmentation. In years where Called Upon was triggered, the reservoir operated for effective use as upper limits and drafted more deeply than its normal flood control operation. As with other reservoirs, the C+BiOp study with no Called Upon operation showed Dworshak reservoir elevation the highest by the end of April and the studies where 450 kcfs was the maximum flow at The Dalles as the lowest. Because the 450 kcfs studies had the most years where the reservoir operated for effective use, the reservoir did not refill, on average, by June 30 in the 450 kcfs studies.

Figure C-9 Dworshak Elevations, feet - Supplemental Studies
70-Year Averages

end of period elevations, ft	OCT	NOV	DEC	JAN	FEB	MAR	AP1	AP2	MAY	JUN	JUL	AU1	AU2	SEP
Full (1600.0 ft)	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600
C+BiOp	1522	1527	1533	1530	1521	1516	1515	1518	1575	1598	1570	1553	1535	1520
A1F600+BiOp	1522	1527	1533	1529	1520	1509	1507	1518	1572	1599	1570	1554	1535	1520
B2F600+BiOp	1522	1527	1533	1529	1520	1509	1507	1518	1572	1599	1570	1554	1535	1520
A1F450+BiOp	1522	1527	1533	1529	1516	1498	1496	1505	1567	1596	1569	1553	1535	1520
B2F450+BiOp	1522	1527	1533	1529	1516	1498	1496	1505	1568	1596	1569	1553	1535	1520

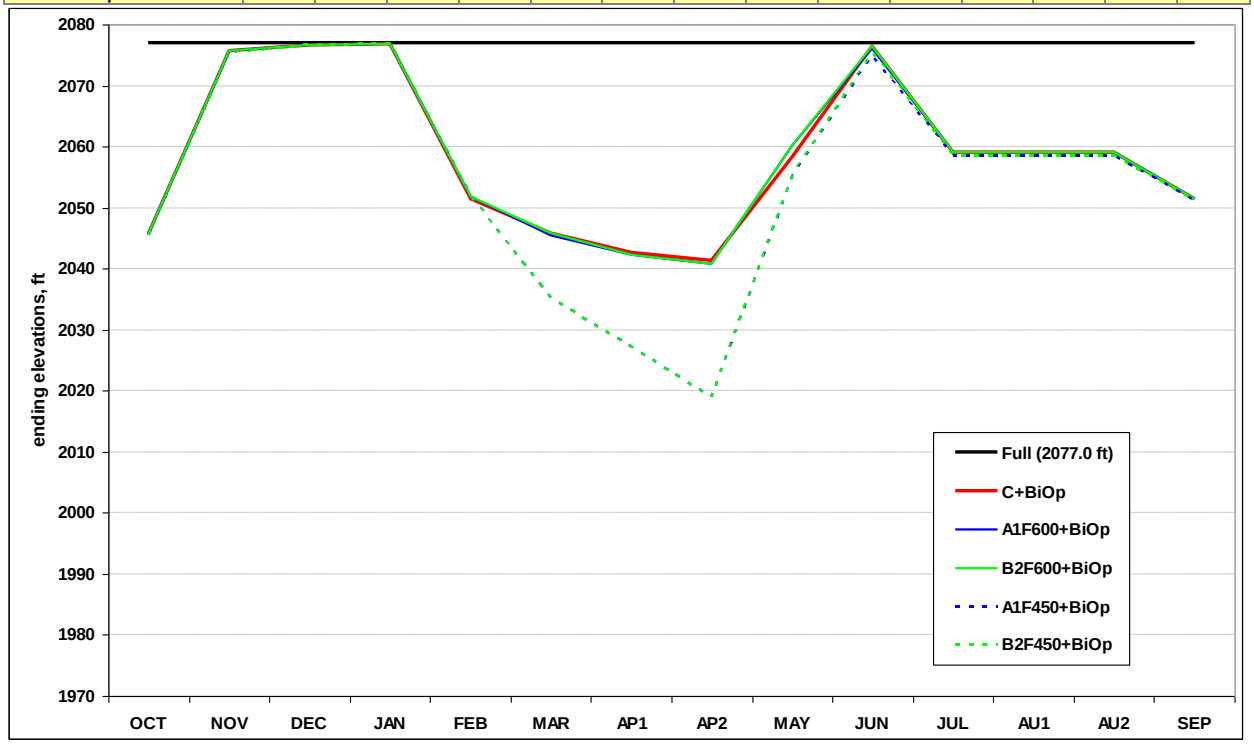


C.6.5 BROWNLEE DAM

In power studies Brownlee was generally operated to a fixed operation and did not vary to meet loads or flow augmentation. In years where Called Upon was triggered Brownlee drafted toward empty by the end of April. Since there were more years where Called Upon was triggered in the studies where 450 kcfs was the maximum flow at The Dalles, Brownlee was drafted more deeply, on average, in those studies.

Figure C-10 Brownlee Elevations, feet - Supplemental Studies
70-Year Averages

end of period elevations, ft	OCT	NOV	DEC	JAN	FEB	MAR	AP1	AP2	MAY	JUN	JUL	AU1	AU2	SEP
Full (2077.0 ft)	2077	2077	2077	2077	2077	2077	2077	2077	2077	2077	2077	2077	2077	2077
C+BiOp	2046	2076	2077	2077	2051	2046	2043	2041	2058	2077	2059	2059	2059	2052
A1F600+BiOp	2046	2076	2077	2077	2052	2045	2042	2041	2060	2076	2059	2059	2059	2052
B2F600+BiOp	2046	2076	2077	2077	2052	2046	2042	2041	2060	2076	2059	2059	2059	2052
A1F450+BiOp	2046	2075	2077	2077	2052	2035	2027	2019	2055	2075	2059	2059	2059	2051
B2F450+BiOp	2046	2075	2077	2077	2052	2035	2027	2019	2055	2075	2059	2059	2059	2051



C.7 FLOW OBJECTIVES

The next series of figures show how often instream flow objectives for Biological Opinions were met in the studies that included the BiOp. Also shown is a chart of flow at each location for each study for each period there is a flow objective.

C.7.1 LOWER GRANITE

Figure C-11 shows the number of years the BiOp flow objectives were met at Lower Granite. This is a function of outflow from Dworshak and Brownlee reservoirs. The flow objective in spring varies with the magnitude of the expected seasonal runoff volume and the information shown demonstrates how often each varying objective was met, month by month, and on a seasonal average basis. The C+BiOp Study is being used as a basis to compare because it is a Treaty continues study with no Called upon or effective use operations and is a good measure of how studies are prepared today. Generally the current C+BiOp Study with the Treaty met flow objectives more often in the spring than the operations with Called upon and effective use, but less often in the summer flow augmentation period. There was quite a bit of similarity in the study results at Lower Granite because there is minimal influence on the lower Snake River by the Canadian operation. The 450 kcfs study met flow objectives in a few less years less than in the C+BiOp study because Dworshak and Brownlee drafted deeper for effective use resulting in less water available in the spring. The 600 kcfs study showed very similar results to the C+BiOp, with flow objectives met 1 year less.

Figure C-11 Lower Granite Flow Objectives - Supplemental Studies
70-Year Averages
Number of Target Years Met

	(85-100 kcfs)	(85-100 kcfs)	(85-100 kcfs)	(85-100 kcfs)	(85-100 kcfs)	(50-55 kcfs)	(50-55 kcfs)	(50-55 kcfs)
	Apr1-15	Apr16-30	May	June	Apr16-Jun 30	July	August	Jul1-Aug31
C+BiOp	23	30	45	49	48	32	0	9
A1F600+BiOp	23	29	45	49	47	32	0	10
B2F600+BiOp	23	29	45	49	47	32	0	10
A1F450+BiOp	25	29	42	48	46	32	0	9
B2F450+BiOp	25	29	42	48	46	32	0	9

Diff = C+BiOp minus study red means C+BiOp met the objective more often than the study being compared to

C - A1F600	0	1	0	0	1	0	0	-1
C - B2F600	0	1	0	0	1	0	0	-1
C - A1F450	-2	1	3	1	2	0	0	0
C - B2F450	-2	1	3	1	2	0	0	0

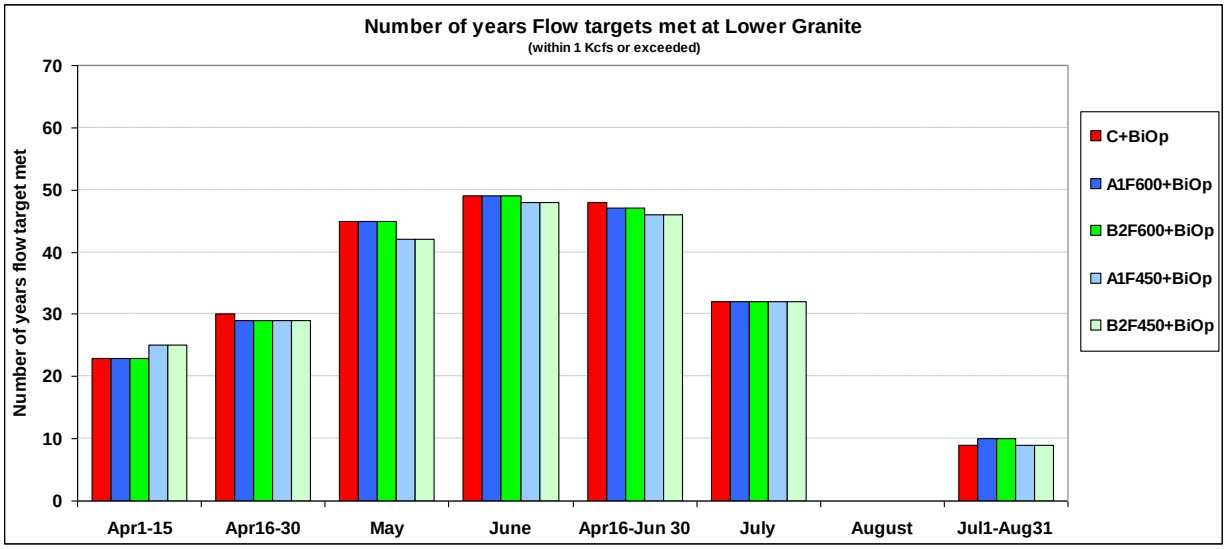


Figure C-12 shows the average flow at Lower Granite for all the studies as well as the flow at Lower Granite in high, medium, and low runoff volume years. Average flow differences at Lower Granite were small, usually less than 5 kcfs, and were the result of flood control differences at Brownlee and Dworshak.

Figure C-12 Lower Granite Average Flows (kcfs) - Supplemental Studies
70-Year Averages

C+BiOp	Apr1-15	Apr16-30	May	June	Apr16-Jun 30	July	August	Jul1-Aug31
70 yr avg	75	90	109	102	103	52	29	40
Avg. of less than 72 MAF years (8)	42	55	70	53	60	34	23	28
Avg. of 72-100 MAF years (21)	69	87	107	93	98	48	28	38
Avg. of 100-120 MAF years (26)	97	106	123	128	121	65	32	49
Avg. of greater than 120 MAF years (15)	99	130	159	169	157	70	35	52

A1F600+BiOp	Apr1-15	Apr16-30	May	June	Apr16-Jun 30	July	August	Jul1-Aug31
70 yr avg	75	86	109	102	102	52	29	40
Avg. of less than 72 MAF years (8)	41	51	71	54	60	34	23	29
Avg. of 72-100 MAF years (21)	71	80	106	94	96	48	28	38
Avg. of 100-120 MAF years (26)	96	105	125	125	121	65	32	49
Avg. of greater than 120 MAF years (15)	100	131	159	168	157	70	35	52

B2F600+BiOp	Apr1-15	Apr16-30	May	June	Apr16-Jun 30	July	August	Jul1-Aug31
70 yr avg	75	86	109	102	102	52	29	40
Avg. of less than 72 MAF years (8)	41	51	71	54	60	34	23	29
Avg. of 72-100 MAF years (21)	71	80	106	94	96	48	28	38
Avg. of 100-120 MAF years (26)	96	105	125	125	121	65	32	49
Avg. of greater than 120 MAF years (15)	100	131	159	169	157	70	35	52

A1F450+BiOp	Apr1-15	Apr16-30	May	June	Apr16-Jun 30	July	August	Jul1-Aug31
70 yr avg	76	89	106	101	101	51	28	40
Avg. of less than 72 MAF years (8)	41	51	71	54	60	34	23	29
Avg. of 72-100 MAF years (21)	73	84	102	92	94	47	27	37
Avg. of 100-120 MAF years (26)	97	107	120	125	119	65	32	48
Avg. of greater than 120 MAF years (15)	100	131	158	168	157	70	35	52

B2F450+BiOp	Apr1-15	Apr16-30	May	June	Apr16-Jun 30	July	August	Jul1-Aug31
70 yr avg	76	89	106	101	100	52	28	40
Avg. of less than 72 MAF years (8)	41	51	71	54	60	34	23	29
Avg. of 72-100 MAF years (21)	73	84	102	92	94	47	27	37
Avg. of 100-120 MAF years (26)	97	107	119	125	119	65	32	48
Avg. of greater than 120 MAF years (15)	100	131	158	168	157	70	35	52

runoff volumes are Apr-Aug at The Dalles

C.7.2 PRIEST RAPIDS

Figure C-13 shows how often of the 70-years being studied, the spring flow objectives at Priest Rapids were met. This is a fixed objective that is the same every year. The B2+BiOp scenarios included a Canadian power operation and the B2F600+BiOp performed better than the A1+BiOp studies that were Treaty continues studies with Called Upon flood control in Canada and effective use operations at U.S. projects.

Figure C-13 Priest Rapids Flow Objectives - Supplemental Studies
70-Year Averages
Number of Target Years Met

	(135 kcfs)	(135 kcfs)	(135 kcfs)	(135 kcfs)	(135 kcfs)
	Apr1-15	Apr16-30	May	June	Apr1-Jun 30
C+BiOp	37	36	60	59	58
A1F600+BiOp	33	37	58	61	58
B2F600+BiOp	41	46	60	60	61
A1F450+BiOp	45	36	52	55	53
B2F450+BiOp	47	47	50	54	56

Diff = C+BiOp minus study
Red means C+BiOp met the objective more often than the study being compared to

C - A1F600	4	-1	2	-2	0
C - B2F600	-4	-10	0	-1	-3
C - A1F450	-8	0	8	4	5
C - B2F450	-10	-11	10	5	2

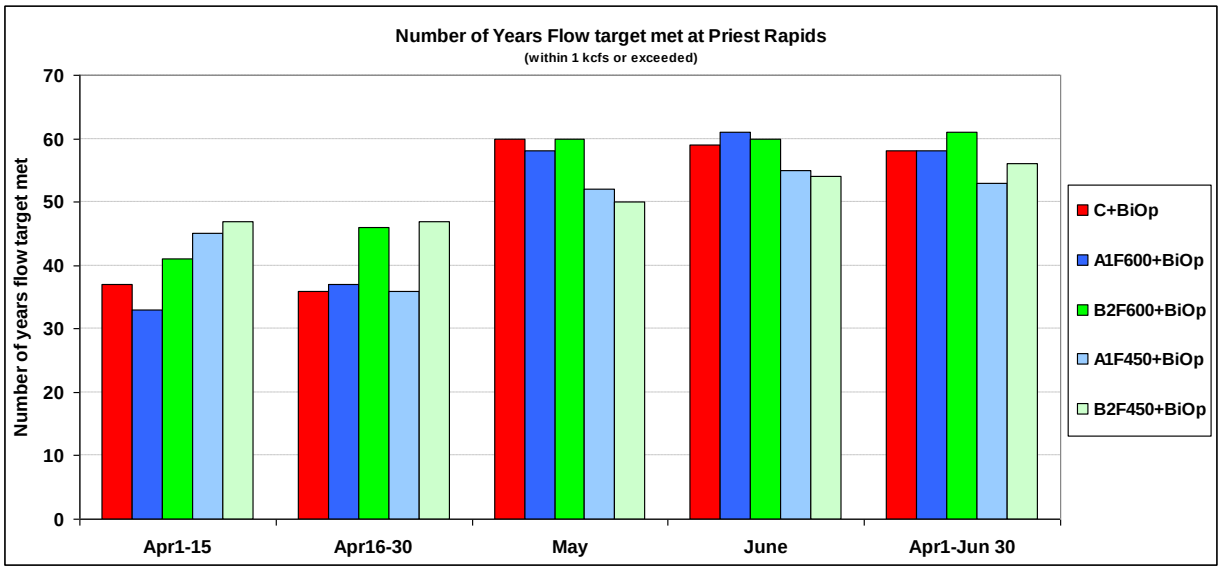


Figure C-14 shows the average flow at Priest Rapids for all the studies as well as the flow at Priest Rapids in high, medium, and low runoff volume years. As expected, the high runoff volume years met the flow objective more often and exceeded the objective more often. This demonstrates how the C+BiOp Study where the Treaty continues and there are no Called Upon or effective use operations, compared across the season to the B2+BiOp study.

Figure C-14 Priest Rapids Average Flows (kcfs) - Supplemental Studies
70-Year Averages

C+BiOp	Apr1-15	Apr16-30	May	June	Apr16-Jun 30
70 yr avg	95	140	171	187	171
Avg. of less than 72 MAF years (8)	65	108	113	126	117
Avg. of 72-100 MAF years (21)	91	137	162	172	161
Avg. of 100-120 MAF years (26)	109	153	198	214	196
Avg. of greater than 120 MAF years (15)	134	183	250	302	257

A1F600+BiOp	Apr1-15	Apr16-30	May	June	Apr16-Jun 30
70 yr avg	92	141	158	186	166
Avg. of less than 72 MAF years (8)	64	102	115	125	116
Avg. of 72-100 MAF years (21)	84	136	154	181	161
Avg. of 100-120 MAF years (26)	109	166	172	207	185
Avg. of greater than 120 MAF years (15)	138	172	220	279	234

B2F600+BiOp	Apr1-15	Apr16-30	May	June	Apr16-Jun 30
70 yr avg	105	158	167	190	174
Avg. of less than 72 MAF years (8)	66	117	124	104	115
Avg. of 72-100 MAF years (21)	97	159	168	192	176
Avg. of 100-120 MAF years (26)	128	175	179	214	192
Avg. of greater than 120 MAF years (15)	152	183	211	284	234

A1F450+BiOp	Apr1-15	Apr16-30	May	June	Apr16-Jun 30
70 yr avg	101	139	152	165	154
Avg. of less than 72 MAF years (8)	63	101	112	122	114
Avg. of 72-100 MAF years (21)	101	133	148	151	146
Avg. of 100-120 MAF years (26)	116	164	166	180	171
Avg. of greater than 120 MAF years (15)	139	165	212	275	228

B2F450+BiOp	Apr1-15	Apr16-30	May	June	Apr16-Jun 30
70 yr avg	110	150	149	168	157
Avg. of less than 72 MAF years (8)	66	118	124	103	114
Avg. of 72-100 MAF years (21)	108	147	146	164	153
Avg. of 100-120 MAF years (26)	129	166	153	187	169
Avg. of greater than 120 MAF years (15)	151	182	208	271	228

runoff volumes are Apr-Aug at The Dalles

C.7.3 McNary

McNary has varying flow objectives during the April through June period based on the water supply forecast. The flow objective in July and August is always 200 kcfs. This chart shows how often the system met the varying flow objectives. The B2+BiOp Studies included a Canadian power operation, but the studies where the maximum flow at The Dalles was 450 kcfs did not perform as well as other studies. This is because the U.S. Projects operated for effective use in the years where Called Upon was triggered and drafted deeply during the drawdown period and released less flow in the refill period.

Figure C-15 McNary Flow Objectives - Supplemental Studies
70-Year Averages
Number of Target Years Met

	(220-260 kcfs)	(220-260 kcfs)	(220-260 kcfs)	(220-260 kcfs)	(200 kcfs)	(200 kcfs)	(200 kcfs)
	Apr16-30	May	June	Apr16-Jun30	July	August	Jul1-Aug31
C+BiOp	29	51	48	54	37	3	19
A1F600+BiOp	29	45	54	52	38	3	23
B2F600+BiOp	38	53	53	55	34	3	19
A1F450+BiOp	25	41	46	44	32	3	20
B2F450+BiOp	34	38	45	46	31	3	18

Diff = C+BiOp minus study red means C+BiOp met the objective more often than the study being compared to

C - A1F600	0	6	-6	2	-1	0	-4
C - B2F600	-9	-2	-5	-1	3	0	0
C - A1F450	4	10	2	10	5	0	-1
C - B2F450	-5	13	3	8	6	0	1

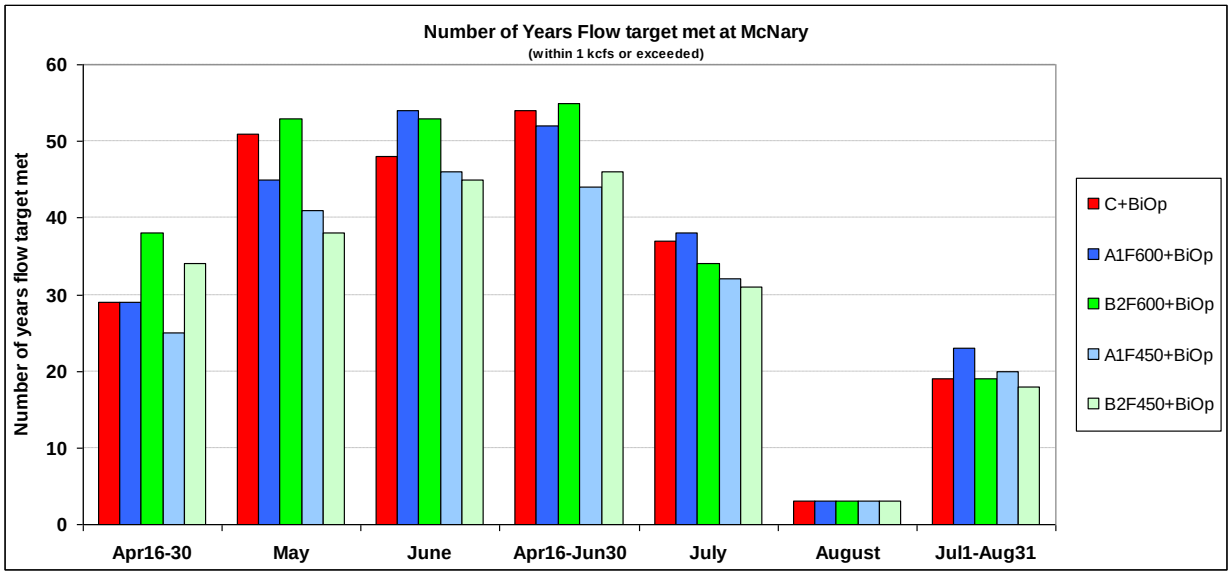


Figure C-16 shows the flow at McNary each month during the flow augmentation period. The B2+BiOp Studies, which included a Canadian power draft, performed rather well during the April through June period as Arrow also operated for Called Upon flood control when needed. In the July period the B2+BiOp Studies did not perform as well as in the spring as upstream reservoirs were refilling. The A1+BiOp Study, which was the study where the Treaty continues with Called Upon and effective use, had slightly higher flow in July and August than the B2+BiOp studies.

Figure C-16 McNary Average Flows (kcfs) - Supplemental Studies
70-Year Averages

C+BiOp	Apr16-30	May	June	Apr16-Jun30	July	August	Jul1-Aug31	September
70 yr avg	234	282	294	288	207	142	175	98
Avg. of less than 72 MAF years (8)	163	183	179	181	148	118	133	95
Avg. of 72-100 MAF years (21)	228	272	270	271	191	134	163	93
Avg. of 100-120 MAF years (26)	265	324	349	336	248	161	204	106
Avg. of greater than 120 MAF years (15)	318	415	487	450	284	177	230	104

A1F600+BiOp	Apr16-30	May	June	Apr16-Jun30	July	August	Jul1-Aug31	September
70 yr avg	232	270	294	281	212	145	179	99
Avg. of less than 72 MAF years (8)	154	186	178	182	150	116	133	91
Avg. of 72-100 MAF years (21)	220	263	280	271	197	138	168	95
Avg. of 100-120 MAF years (26)	277	299	339	319	256	165	210	106
Avg. of greater than 120 MAF years (15)	309	385	463	424	276	179	228	105

B2F600+BiOp	Apr16-30	May	June	Apr16-Jun30	July	August	Jul1-Aug31	September
70 yr avg	248	279	297	288	203	127	165	88
Avg. of less than 72 MAF years (8)	170	195	157	176	123	94	109	74
Avg. of 72-100 MAF years (21)	243	277	291	284	186	118	152	84
Avg. of 100-120 MAF years (26)	285	307	346	326	257	149	203	99
Avg. of greater than 120 MAF years (15)	319	376	469	422	286	170	228	100

A1F450+BiOp	Apr16-30	May	June	Apr16-Jun30	July	August	Jul1-Aug31	September
70 yr avg	231	260	271	266	203	143	173	98
Avg. of less than 72 MAF years (8)	153	183	176	179	149	116	132	91
Avg. of 72-100 MAF years (21)	222	253	248	250	185	135	160	95
Avg. of 100-120 MAF years (26)	276	289	312	300	244	163	204	106
Avg. of greater than 120 MAF years (15)	302	376	460	417	273	179	226	105

B2F450+BiOp	Apr16-30	May	June	Apr16-Jun30	July	August	Jul1-Aug31	September
70 yr avg	243	257	274	266	199	125	162	87
Avg. of less than 72 MAF years (8)	170	194	156	176	122	94	108	73
Avg. of 72-100 MAF years (21)	236	250	260	255	180	116	148	84
Avg. of 100-120 MAF years (26)	279	275	319	297	251	147	199	99
Avg. of greater than 120 MAF years (15)	319	372	455	413	285	170	228	100

runoff volumes are Apr-Aug at The Dalles

C.7.4 BONNEVILLE DAM

At Bonneville Dam the winter fish operation is to enhance spawning for chum salmon downstream of the dam. The goal is to set a flow in November when the chum begins to spawn and have that flow steadily increase through March when they emerge. The minimum flow objective of 125 kcfs was met most often in the early periods of the operation in the C+BiOp Studies, which are Treaty studies without Called Upon or effective use operations. The B2+BiOp power studies met the objective most often during the January through March period because the Canadian reservoirs were often drafting for Called Upon flood control and the U.S. reservoirs were drafting deeply for effective use operations. As compared to the C+BiOp study, all other Supplemental studies met the November and December flow objectives in fewer years.

Figure C-17 Bonneville Flow Objectives - Supplemental Studies
70-Year Averages
Number of Target Years Met

	(125 kcfs)	(125 kcfs)	(125 kcfs)	(125 kcfs)	(125 kcfs)	(125 kcfs)	(125 kcfs)
	Nov	December	January	February	March	Oct1-Mar31	Nov1-Mar31
C+BiOp	37	59	55	54	55	56	60
A1F600+BiOp	32	57	54	53	55	56	59
B2F600+BiOp	37	50	62	55	56	58	58
A1F450+BiOp	32	53	56	56	54	57	59
B2F450+BiOp	35	51	62	57	57	59	59

Diff = C+BiOp minus study	red means C+BiOp met the objective more often than the study being compared to						
C - A1F600	5	2	1	1	0	0	1
C - B2F600	0	9	-7	-1	-1	-2	2
C - A1F450	5	6	-1	-2	1	-1	1
C - B2F450	2	8	-7	-3	-2	-3	1

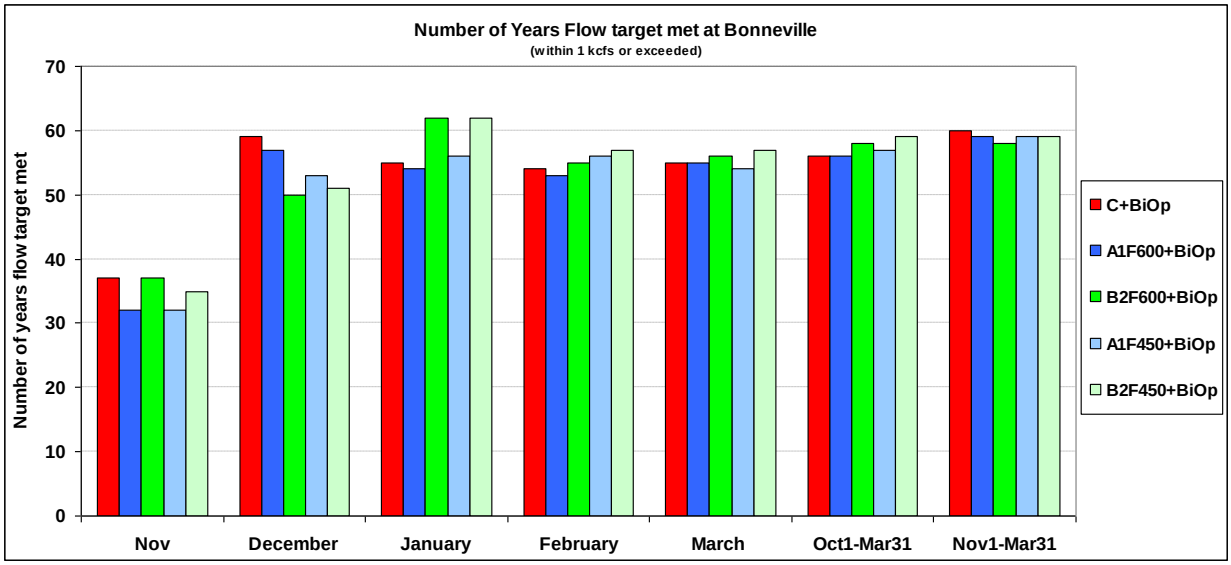


Figure C-18 shows the flow at Bonneville Dam during the chum spawning period. Most of the studies had increasing monthly flow on a 70-year average from October through February. Often the 70-year average flow in March was less than the February average flow, except in the B2F450+BiOp Study.

Figure C-18 Bonneville Average Flows (kcfs) - Supplemental Studies
70-Year Averages

C+BiOp	Sept	Oct	Nov	December	January	February	March	Oct1 - Mar31	Nov1 - Mar31
70 yr avg	105	111	134	152	177	189	181	157	166
Avg. of less than 72 MAF years (8)	100	103	125	128	131	125	130	124	128
Avg. of 72-100 MAF years (21)	99	110	131	147	163	175	168	149	157
Avg. of 100-120 MAF years (26)	114	115	141	171	206	229	209	178	191
Avg. of greater than 120 MAF years (15)	112	116	140	167	247	265	268	200	217

A1F600+BiOp	Sept	Oct	Nov	December	January	February	March	Oct1 - Mar31	Nov1 - Mar31
70 yr avg	105	112	133	148	186	191	182	158	168
Avg. of less than 72 MAF years (8)	96	105	125	126	128	124	132	123	127
Avg. of 72-100 MAF years (21)	102	111	131	144	166	171	167	148	156
Avg. of 100-120 MAF years (26)	114	115	140	166	223	237	209	181	195
Avg. of greater than 120 MAF years (15)	113	116	138	162	284	285	277	209	229

B2F600+BiOp	Sept	Oct	Nov	December	January	February	March	Oct1 - Mar31	Nov1 - Mar31
70 yr avg	94	113	133	149	186	193	188	160	170
Avg. of less than 72 MAF years (8)	79	110	119	123	136	126	134	125	128
Avg. of 72-100 MAF years (21)	90	113	131	145	175	172	176	152	160
Avg. of 100-120 MAF years (26)	106	116	141	168	211	239	214	181	194
Avg. of greater than 120 MAF years (15)	108	115	141	168	267	292	283	210	230

A1F450+BioP	Sept	Oct	Nov	December	January	February	March	Oct1 - Mar31	Nov1 - Mar31
70 yr avg	105	112	132	148	202	201	196	165	175
Avg. of less than 72 MAF years (8)	96	105	125	126	137	124	131	125	129
Avg. of 72-100 MAF years (21)	101	111	130	143	182	190	184	156	165
Avg. of 100-120 MAF years (26)	114	115	138	165	246	241	232	189	204
Avg. of greater than 120 MAF years (15)	113	116	137	162	294	288	282	212	232

B2F450+BiOp	Sept	Oct	Nov	December	January	February	March	Oct1 - Mar31	Nov1 - Mar31
70 yr avg	94	113	131	149	201	208	211	168	180
Avg. of less than 72 MAF years (8)	78	110	119	122	140	126	133	125	128
Avg. of 72-100 MAF years (21)	90	113	130	144	191	197	203	163	173
Avg. of 100-120 MAF years (26)	106	115	139	167	233	252	250	192	208
Avg. of greater than 120 MAF years (15)	108	114	140	168	276	292	293	213	233

runoff volumes are Apr-Aug at The Dalles