Status Report

Work to Date on the Development of the VARQ Flood Control Operation at Libby Dam and Hungry Horse Dam

January 1999

Section 3

Local Effects of the Proposed VARQ Flood Control Plan at Hungry Horse Dam, Montana

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Executive Summary

The attention of water managers in the Pacific Northwest has become increasingly focused on the impacts of reservoir operations on endangered salmon, steelhead, and resident fish species. The current flood control plans for dams such as Hungry Horse in western Montana appear "out of sync" with the changing priorities of the region. Deep reservoir drafts during the winter months coupled with minimum releases during the spring runoff period no longer appear compatible with refill goals; especially if downstream flow objectives established within the framework of the Endangered Species Act are to be successfully met. In an attempt to address this situation, the U.S. Army Corps of Engineers has developed a new flood control plan known as VARQ (pronounced "vair Q") that can provide flow regimes desirable for endangered species, maintain current flood protection, and improve the ability to refill the reservoirs. This hydrologic report evaluates the VARQ flood control plan for Hungry Horse Dam. This analysis covers Hungry Horse Reservoir and the Flathead River at Columbia Falls. Economic impacts associated with the VARQ flood control plan at Hungry Horse Dam are not addressed.

The logic behind the VARQ flood control plan is simple: If releases from Hungry Horse Dam during the spring/summer runoff period are greater than those associated with the current flood control plan during periods when flooding is not a problem, then it is not necessary to draft the reservoir as deeply to provide the same level of flood protection downstream. This allows Hungry Horse Reservoir to be more full during the winter months in years of normal or below normal snowpack, and increases the potential for refill in the summer time.

The VARQ flood control plan for Hungry Horse Dam requires up to approximately 0.4 million acre-feet less flood control storage space than the current flood control plan. In those years when a large amount of runoff is anticipated, the VARQ flood control plan targets the same minimum elevation for Hungry Horse Reservoir as the current flood control plan. There will be a general increase in the magnitude of non-damaging flows downstream of Hungry Horse Dam during the summer, but no increase in flooding. Dam operators will continue to limit reservoir releases when necessary to protect public safety. Computer simulations have shown that the VARQ flood control plan makes it easier to draft Hungry Horse Reservoir to its target flood control elevation in years of heavy runoff because draft is mostly completed by early April before snowmelt runoff seriously begins. Therefore, the likelihood of spilling water to achieve flood control target elevations is also minimized.

The VARQ flood control operation requires Hungry Horse Reservoir to draft less than the current flood control operation in years of normal and below normal runoff, creating a greater opportunity for refill. Despite this enhanced refill potential, the current minimum instream flow requirement of 3,500 cfs for the Flathead River at Columbia Falls will limit the value of VARQ in years with low winter runoff. Inflow to Hungry Horse Reservoir is often insufficient to compensate for the discharge necessary to meet the minimum flow requirement. If regulated strictly for flood control, Hungry Horse Reservoir would refill with near certainty under both the current and VARQ flood control plans.

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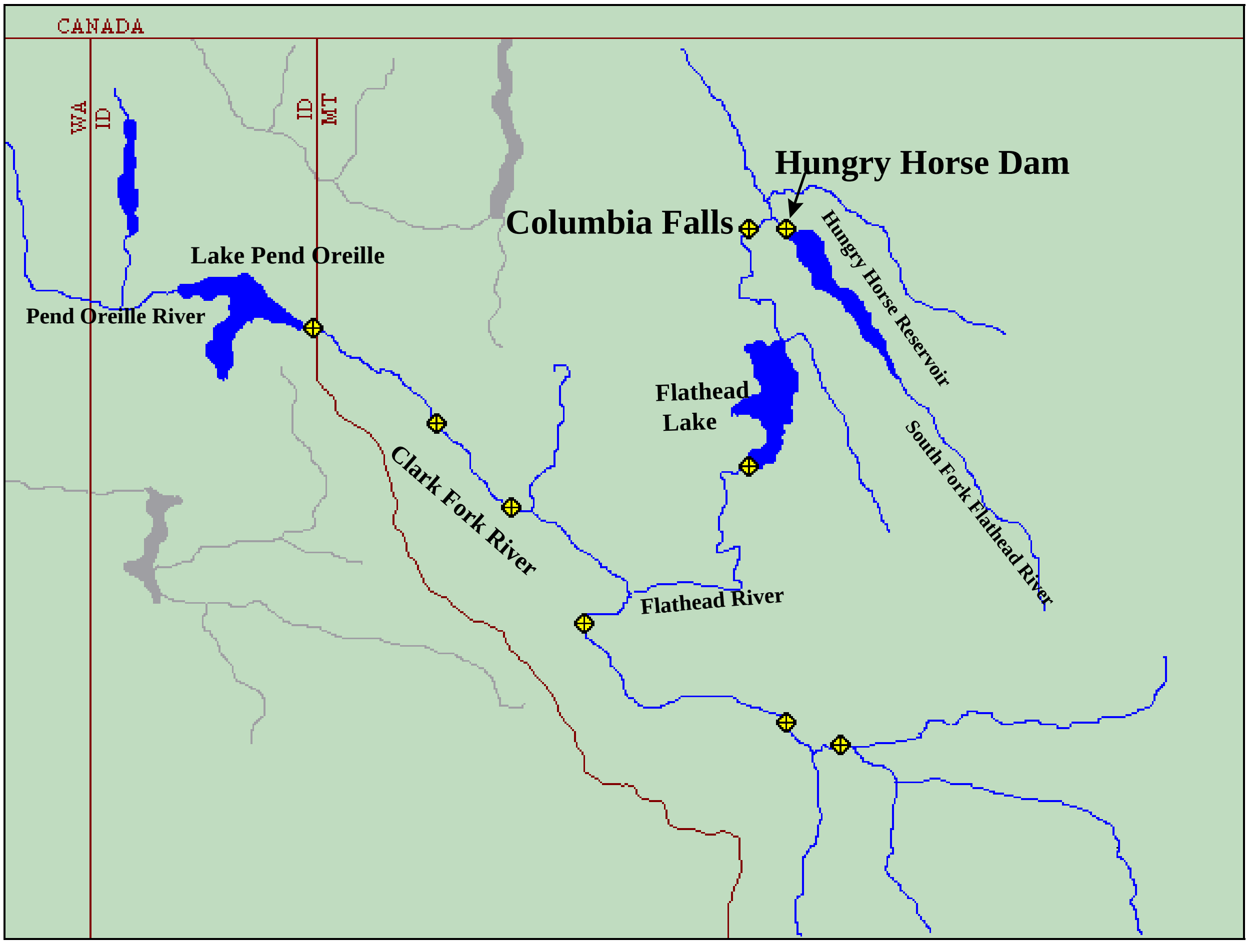

Figure 1-1 Vicinity Map of Hungry Horse Dam

1.0 Introduction

1.1 Need for Study

Hungry Horse Dam and Reservoir are located on the South Fork of the Flathead River in western Montana (Figure 1-1). The dam was completed by the U.S. Bureau of Reclamation (the Bureau) in 1953 primarily for power generation, flood control, and irrigation. Other benefits are derived from fisheries, wildlife, and recreation.[1] Hungry Horse Dam is operated for flood control under Section 7 of the Flood Control Act of 1944 by the U. S. Army Corps of Engineers (Corps) in coordination with the Bureau.[2]

[1] Project Data and Operating Limits Columbia River and Tributaries Review Study, CRT-49 (Revised), U.S. Army Corps of Engineers, North Pacific Division, Portland, July 1989, pp. 113.
[2] Review of Flood Control Columbia River Basin, Columbia River and Tributaries Study, CRT-63, U.S. Army Corps of Engineers, North Pacific Division, Portland, June 1991, pp. 49.

The current flood control plan (Standard FC) for Hungry Horse Dam was initially described in the 1952 Reservoir Regulation Manual,[3] and then modified slightly as a result of the 1991 Review of Flood Control Columbia River Basin[4]. The general philosophy of the current flood control plan is to draft the reservoir during the winter months to optimize both power and flood protection, and then refill with the minimum discharge possible. Regulation is primarily for local flood control downstream along the Flathead River. Secondary consideration is given system flood control, i.e. regulation to reduce flood stages on the Columbia River at the Dalles.[5]

The attention of water managers in the Pacific Northwest has recently become focused on reservoir impacts to endangered salmon and steelhead runs as well as declining resident fish species. In 1995 the National Marine Fisheries Service requested that the Corps of Engineers review the flood control requirements at dams within the Columbia River Basin to see if it was possible to reduce flood storage, allow higher flows downstream, and provide an enhanced opportunity for reservoir refill.[6] The Northwest Power Planning Council and the State of Montana have promoted the implementation of Integrated Rule Curves for both Libby and Hungry Horse Dams for similar reasons.[7] In an attempt to address this situation, the Corps has introduced a new flood control plan for Hungry Horse and Libby Dams known as VARQ (pronounced "vair Q") which can accommodate greater downstream releases for endangered species, maintain current flood protection, and keep the reservoirs more full during the winter in years of moderate and low snowpack.

The Northwestern Division of the U.S. Army Corps of Engineers initially developed the VARQ flood control plan in the late 1980's. It was first introduced as a possible alternative to the current flood control operation for both Libby and Hungry Horse Dams in the Columbia River System Operation Review (SOR)[8]. VARQ at Libby Reservoir was studied in the Columbia River Basin System Flood Control Review-Preliminary Analysis Report[9], and the "Kootenai River Flood Control Study Analysis of Local Impacts of the Proposed VARQ Flood Control Plan"[10]. This report is the first to target specifically the local flood control impacts of implementing the VARQ flood control plan at Hungry Horse Reservoir.

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[3] U.S. Army Corps of Engineers, Seattle District, Hungry Horse Dam Reservoir Control Manual , December 1952, pp.13-16.
[4] U.S. Army Corps of Engineers, Review of Flood Control Columbia River Basin, Columbia River and Tributaries Study, CRT-63, ,North Pacific Division, Portland, June 1991, pp. 49-56.
[5] U.S. Army Corps of Engineers, Seattle District, Hungry Horse Dam Reservoir Control Manual , December 1952, pp. 11.
[6] National Marine Fisheries Service, Endangered Species Act - Section 7 Consultation, BIOLOGICAL OPINION, Reinitiation of Consultation of 1994-1998 Operation of the Federal Columbia River Power System and Juvenile Transportation Program in 1995 and Future Years, Northwest Division, Seattle, March 2, 1995, p. 100.
[7] Marotz, Althen, Lonon, and Gustafson, Model Development to Establish Integrated Operational Rule Curves for Hungry Horse and Libby Reservoirs - Montana, Final Report, Bonneville Power Administration, Portland, January 1996, pp. 107-108.
[8] Bonneville Power Administration, Columbia River System Operation Review, Final Environmental Impact Statement, Appendix E, Flood Control, DOE/EIS 0170, November 1995, p. 4-20.
[9] U.S. Army Corps of Engineers, Columbia River Basin System Flood Control Review - Preliminary Analysis Report, North Pacific Division, Portland, February, 1997, pp. 50-69.
[10] McGrane, Patrick C. "Kootenai River Flood Control Study Analysis of Local Impacts of the Proposed VARQ Flood Control Plan", U.S. Army Corps of Engineers, Seattle District, January 8, 1998.

1.2 Purpose of this Study

The purpose of this study is to assess the hydrologic impacts of the VARQ flood control plan on Hungry Horse Reservoir and downstream at Columbia Falls, Montana. This study compares VARQ to the current flood control operation (Standard FC). It takes a detailed look at VARQ and Standard FC from the sole perspective of flood control. No attempt is made to superimpose endangered species requirements on the basic requirements for local and system flood protection.

1.3 Flood Control Alternatives for Hungry Horse Dam

The primary flood control alternatives examined in this report are Standard FC and VARQ as shown in Table 1-1.

TABLE 1-1 PRIMARY ALTERNATIVES FOR FLOOD CONTROL PLAN AT HUNGRY HORSE DAM.

Primary Alternative	General Description as Modeled
Current Flood Control (Standard FC)	Hungry Horse Dam is regulated to meet the flood control rule curves as specified in the Review of Flood Control Columbia River Basin, Columbia River and Tributaries Study, CRT-63[11]. Hungry Horse Reservoir is drafted 0.1 maf by 31 October for winter flood control. The final flood control target elevation is achieved by 30 April. No additional power drafts. No additional ESA releases.
VARQ	Releases from Hungry Horse Dam are determined during the refill period based upon runoff forecasts and available storage, and are generally higher than Standard FC. Hungry Horse Reservoir is drafted 0.25 maf by 31 December (0.10 maf for winter flood control and 0.15 maf to prevent spill during winter drawdown). Hungry Horse Reservoir drafts to the same elevation on 30 April as Standard FC in years when 2.2 maf or greater runoff (May-Sep). No additional power drafts. No additional ESA releases.

[11] U.S. Army Corps of Engineers, Review of Flood Control Columbia River Basin, Columbia River and Tributaries Study, CRT-63, North Pacific Division, Portland, June 1991, pp. 36-49.

2.0 HYDROLOGIC ANALYSIS

2.1 Hydro-Regulations

An important element of any flood control study is the accuracy of the hydro-regulations. Hydro-regulations offer a detailed look at the impacts of both VARQ and Standard FC by simulating reservoir operation at Hungry Horse over a fixed period of record. The hydro-regulations reveal what "would have" happened if the Hungry Horse Dam had been regulated to the alternatives during those historic years. The Streamflow Synthesis and Reservoir Regulation computer model (SSARR) with it pre/post processor AUTOREG was used in this analysis. Reservoir release decisions were made on a daily basis. Limited foresight was used in the simulations to reflect the uncertainty associated with "real-time" reservoir regulation.

2.1.1 Selection of Years for Evaluation

A 50 year record (1929-1978) was used in this study. Many significant floods have occurred within this period; including those of 1954, 1964, 1974, and 1975. The rain-induced 1964 event was reviewed and used to define the upper end of the regulated frequency curves for all scenarios modeled.

2.1.2 Simulated Water Supply Forecasts

Reservoir regulators use volume runoff forecasts to determine the amount of flood control space necessary at storage reservoirs. Hydro-regulations use the volume runoff forecasts to introduce the element of forecast error into the simulations. Simulated water supply volume forecasts for the 1929-1978 period were used in development of the flood control rule curves which guide operations at Hungry Horse Dam. This study used the standard Kuehl-Moffitt Simulated Seasonal Volume Runoff Forecasts[12] to govern flood control draft.

2.1.3 Modeling Procedure

Upper rule curves which guide seasonal reservoir lowering and refill were developed for Hungry Horse based on seasonal volume runoff forecasts and the respective storage reservation diagrams (Figures 2-1 and 2-2). When comparing the storage reservation diagrams it should be

[12] Kuehl and Moffit, "Simulated Runoff Forecasts for the Period 1929-1978", prepared for the U.S. Army Corps of Engineers, North Pacific Division, Portland, July 1986.

noted that for May-September seasonal runoff forecasts of 2.2 maf or greater, VARQ and Standard FC both attempt to draft essentially the same amount of water out of Hungry Horse reservoir. One marked difference between VARQ and Standard FC is that VARQ drafts more water out of Hungry Horse sooner in the year during years of high runoff. Therefore, VARQ does not require as much water to be evacuated in April as Standard FC. Because snowmelt runoff often begins during the month of April, the early draft in VARQ decreases the likelihood of spilling water to achieve minimum flood control elevations. (See Section 3.1 for further details.) When the seasonal runoff forecast is less than 2.2 maf, a situation that occurs in roughly 7 out of 10 years, VARQ requires less flood control space than Standard FC. Table 2.1 illustrates the difference between the amount of flood storage necessary in VARQ and Standard FC.

TABLE 2.1 DIFFERENCES BETWEEN FLOOD CONTROL DRAFT TARGETS VARQ VS STANDARD FC[13]

Hungry Horse	Apr 30 FC Draft 80% of Normal Runoff (kaf)	(ft)	Apr 30 FC Draft 100% of Normal Runoff (kaf)	(ft)	Apr 30 FC Draft 120% of Normal Runoff (kaf)	(ft)	Apr 30 FC Draft 130% of Normal Runoff (kaf)	(ft)
Standard FC	**893**	**3518.8**	**1229**	**3500.9**	**1611**	**3477.5**	**1802**	**3464.6**
VARQ	**485**	**3538.6**	**836**	**3521.3**	**1475**	**3486.2**	**1793**	**3465.0**
Difference	**408 ***	**18**	**393**	**19**	**136**	**8**	**9**	**1**

* (It is often not possible to attain the complete benefit of VARQ in years of low runoff because the 3,500 cfs minimum instream flow requirement for the Flathead River at Columbia Falls requires additional water releases from Hungry Horse Dam.)

In the simulations, Hungry Horse Reservoir was drafted to its appropriate flood control elevation by releasing up to the maximum possible through the generating units. If rainfall or early runoff made it impossible to lower the reservoir using solely the generating units, spill of up to 2000 cfs was allowed. The assumption was that spill of less than 2000 cfs would not violate the Montana state water quality standard of 110% for total dissolved gases. If the flood control target elevations could still not be achieved by spilling 2000 cfs, then the target elevations were not achieved. In the Standard FC simulations, Hungry Horse passed inflow or drafted, if necessary, until system flood control concerns in the lower Columbia River required reducing discharges to 3,000 cfs or less. If the Flathead River at Columbia Falls was threatening to exceed the flood flow of 52,000 cfs, Hungry Horse discharge was set at 400 cfs. In the VARQ simulation, Hungry Horse's discharge during the system flood control period was initially determined by Figure 2-3 and subsequently modified for trapped storage and changing forecasts. In the VARQ simulations, Hungry Horse releases were also cut to 400 cfs when appropriate for local flood control.

[13] U.S. Army Corps of Engineers, North Pacific Division, Portland, "The Effects of VARQ at Libby and Hungry Horse on Columbia River System Flood Control-Draft Report", November 1997, pp. 9.

Figure 2-1 The Standard Flood Control Storage Reservation Diagram for Hungry Horse Dam.

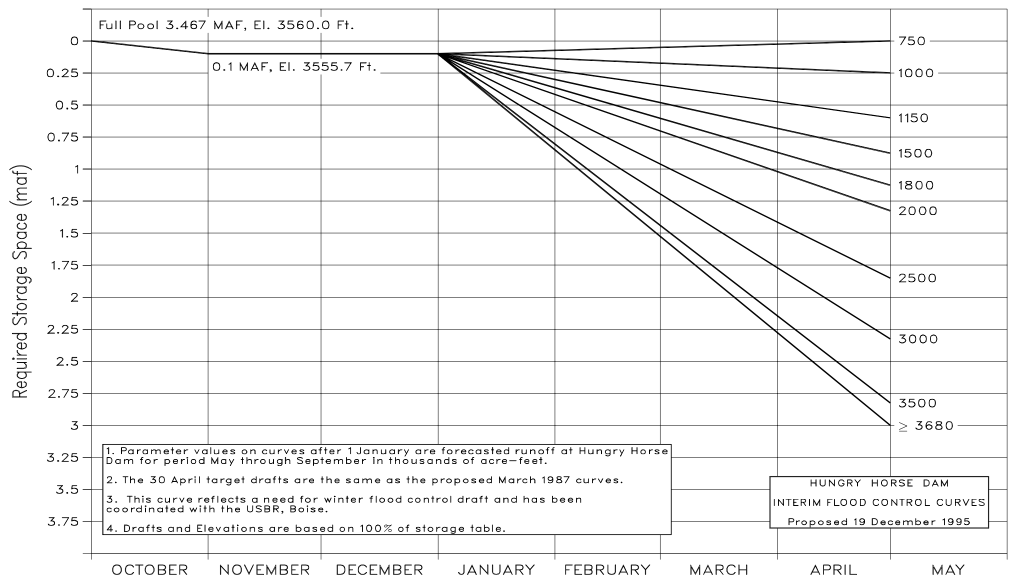


Figure 2-2 The VARQ Storage Reservation Diagram for Hungry Horse Dam

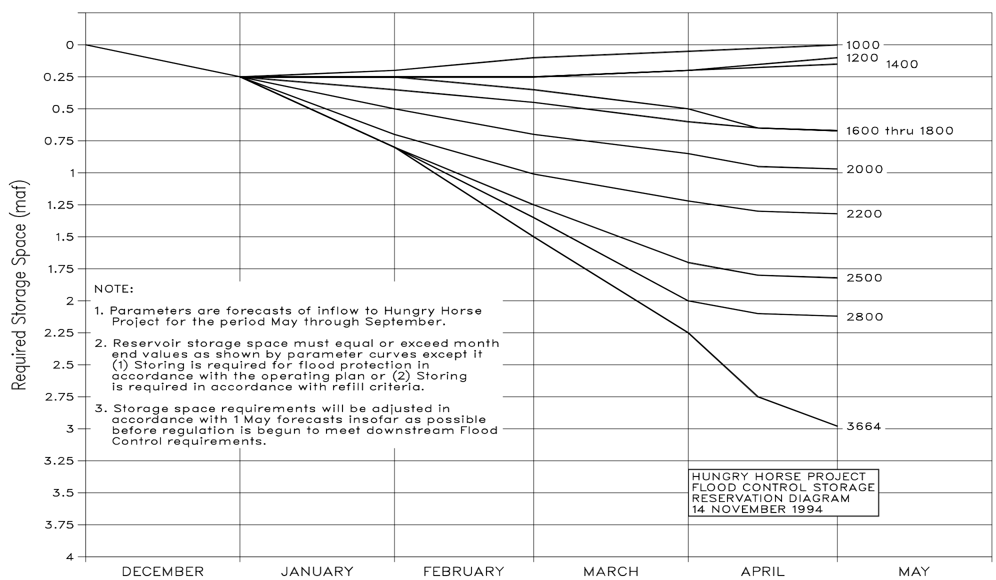
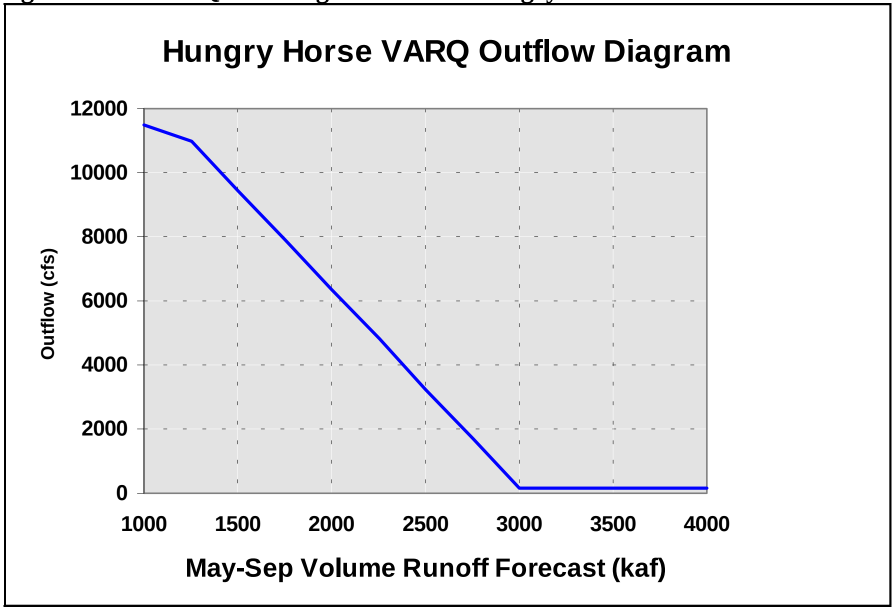


Figure 2-3 VARQ Discharge Chart for Hungry Horse Dam.



In the simulations, Hungry Horse Reservoir was filled to elevation 3535 feet (25 feet from normal full pool) with releases guided by Figure 2-3. The final refill was guided by filling transition curves (FTCs). FTCs are computer algorithms that objectively attempt to refill based on forecasted inflow and current reservoir elevation. The FTCs act to limit the amount of foresight used in the hydro-regulations. No attempt was made in the simulations to meet endangered species flow targets in the lower Columbia River with additional releases from Hungry Horse Dam.

2.2 Statistical Analysis

Frequency curves were constructed for Hungry Horse Reservoir and the Flathead River at Columbia Falls to illustrate the differences between the two flood control plans. Procedures for graphing regulated frequency curves are explained in the U.S. Army Corps Of Engineer's Engineering Memorandum Hydrologic Frequency Analysis, EM 1110-2-1415[14].

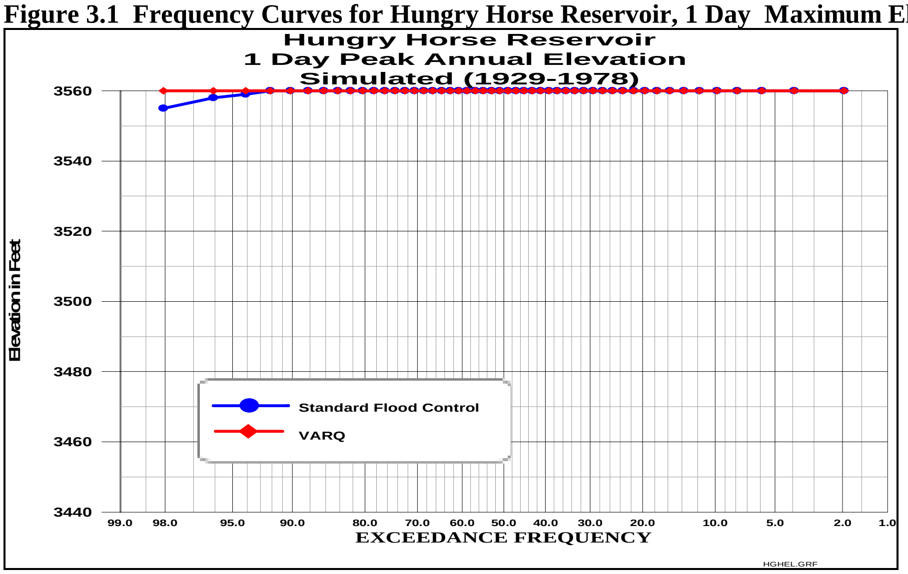
[14] U.S. Army Corps of Engineers, Hydrologic Frequency Analysis, EM 1110-2-1415, 5 March 1993, pp. 6.1-6.4.

3.0 Results

3.1 VARQ Effects at Hungry Horse Dam

The VARQ and Standard FC simulations reflected operations for the sole purpose of flood control. Power drafts at Hungry Horse Reservoir have historically supplemented flood control drafts, often resulting in more flood control space being available at the beginning of the spring runoff period, and sometimes resulting in reservoir refill shortfalls later in the summer. With the release of the National Marine Fisheries Services' 1995 Biological Opinion for salmon, which requires that federal dam projects be at, or near flood control elevations at the beginning of the spring runoff season[15], supplemental power drafts have been limited to that which will allow refilling to the April 30 flood control elevation with a 75% level of confidence. The VARQ flood control operation drafts Hungry Horse Reservoir up to 0.4 million acre-feet (maf) less than the Standard FC operation, creating a greater opportunity for refill. Despite this enhanced refill potential, the current minimum instream flow requirement of 3,500 cfs for the Flathead River at Columbia Falls will limit the value of VARQ in years with low winter runoff. Inflow to Hungry Horse Reservoir is insufficient to compensate for the discharge necessary to meet the minimum flow requirement during dry winters. VARQ and Standard FC would result in refill of Hungry Horse Reservoir in almost every year if no additional power or endangered species releases are required. Figure 3-1 compares the peak daily elevation reached during the summer refill period (June/July) for both Standard FC and VARQ.

Figure 3.1 Frequency Curves for Hungry Horse Reservoir, 1 Day Maximum Elevation (June-July).



Despite the fact that both Standard FC and VARQ target essentially the same minimum flood control elevations on April 30 in years with a May-September seasonal runoff forecast of greater

[15] National Marine Fisheries Service, Endangered Species Act - Section 7 Consultation, BIOLOGICAL OPINION, Reinitiation of Consultation of 1994-1998 Operation of the Federal Columbia River Power System and Juvenile Transportation Program in 1995 and Future Years, Northwest Division, Seattle, March 2, 1995, p. 95.

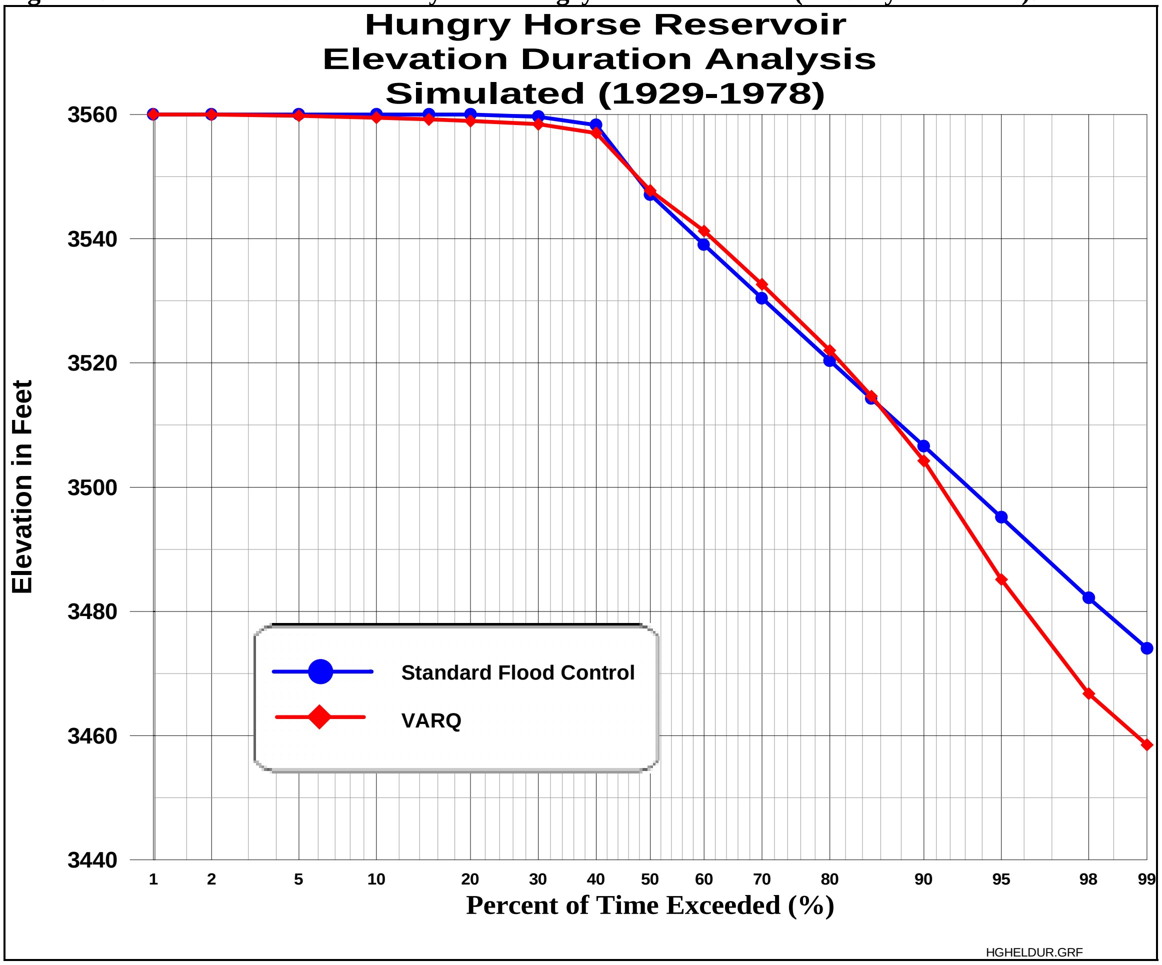
than 2.2 maf, the VARQ flood control plan resulted in deeper drafts of Hungry Horse Reservoir in years of large runoff during the simulations. This can be attributed to the lower elevation target specified by the VARQ storage reservation diagram on December 31, combined with the higher draft rate required by VARQ in January, February, and March. Table 3.1 reflects the differences between the minimum draft points *achieved* in the simulations as related to the seasonal volume forecast. Since significant snowmelt runoff often begins during April, it may often be difficult to achieve the April 30 target minimum elevation with Standard FC without spilling water or predrafting the reservoir in the big runoff years. In years with less than 2.2 maf forecasted, VARQ and Standard FC both met their target minimum flood control elevations in the simulations, and Standard FC generally drafted 10-20 feet more than VARQ, as would be expected.

TABLE 3.1 SEASONAL RUNOFF FORECAST VERSUS SIMULATED MINIMUM FLOOD CONTROL ELEVATIONS

YEAR	Standard FC APRIL MIN	VARQ FC APRIL MIN	VARQ higher by:	1April(May-Sep)FCST
1972	3454	3442	-12	2745
1974	3473	3454	-19	2637
1959	3472	3457	-15	2594
1967	3465	3453	-12	2584
1950	3479	3459	-20	2556
1947	3480	3462	-18	2527
1956	3483	3463	-20	2514
1965	3476	3465	-11	2493
1971	3478	3470	-8	2438
1934	3491	3493	2	2407
1969	3490	3487	-3	2289
1951	3490	3487	-3	2284
1932	3495	3495	0	2225
1976	3491	3495	4	2210
1952	3495	3498	3	2193
1970	3486	3484	-2	2188
1954	3491	3493	2	2165
1962	3502	3501	-1	2157
1975	3495	3501	6	2101
1943	3506	3509	3	2089
1960	3497	3508	11	2082
1948	3495	3506	11	2077
1978	3494	3498	4	2023
1964	3497	3504	7	2018
1946	3506	3516	10	2006
1933	3503	3515	12	2002
1936	3511	3520	9	1955
1958	3503	3513	10	1946
1957	3506	3519	13	1945
1949	3507	3523	16	1897
1939	3511	3524	13	1892
1961	3506	3515	9	1884
1968	3508	3524	16	1870
1938	3513	3525	12	1863
1963	3511	3530	19	1798
1953	3517	3530	13	1767
1935	3515	3530	15	1694
1937	3516	3530	14	1672
1930	3522	3532	10	1657
1940	3517	3530	13	1652
1966	3517	3530	13	1647
1955	3521	3537	16	1542
1931	3522	3540	18	1526
1929	3523	3543	20	1496
1945	3525	3542	17	1450
1973	3526	3546	20	1405
1942	3531	3547	16	1293
1977	3533	3550	17	1228
1944	3535	3549	14	1185
1941	3536	3546	10	1123

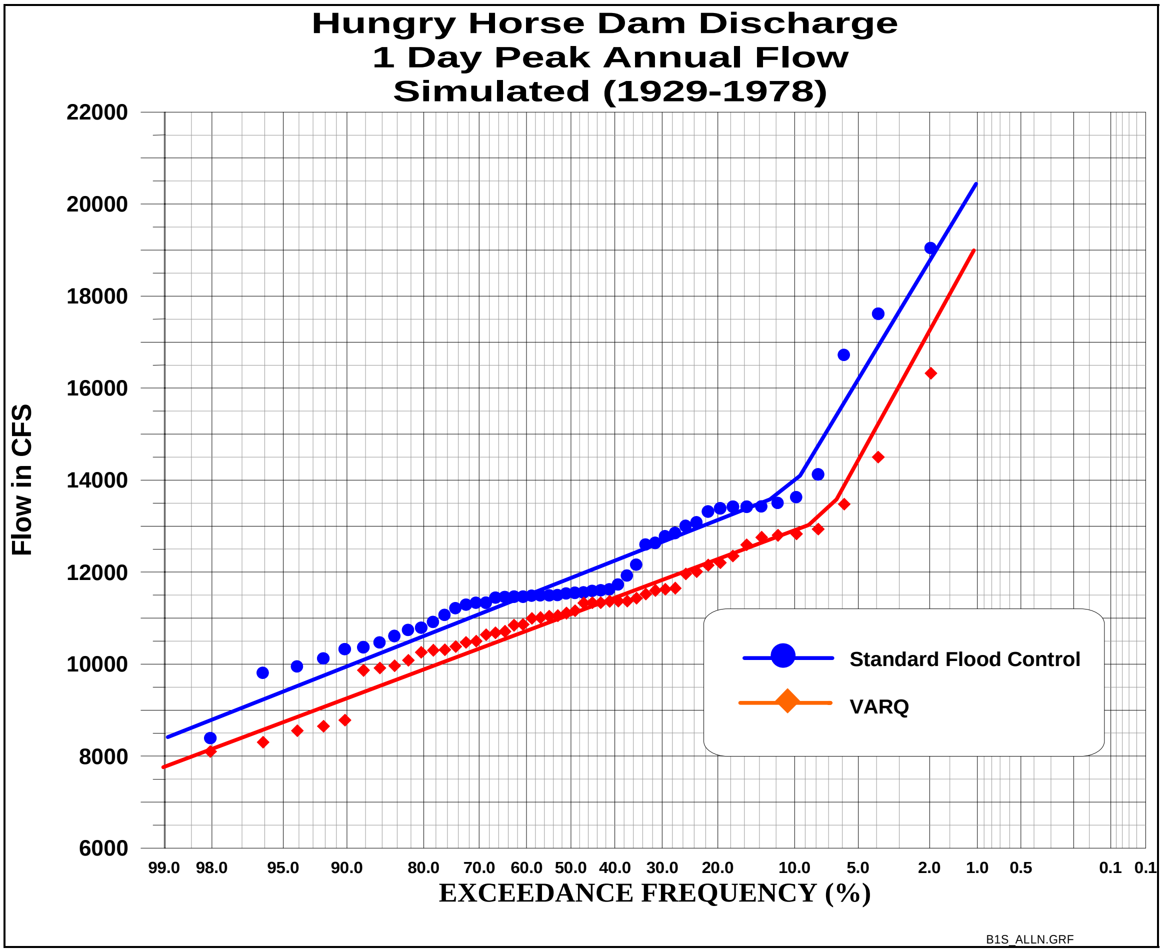
A duration analysis was conducted to evaluate the effect of VARQ on Hungry Horse over time. The results are shown in Figure 3.2.

Figure 3.2 Elevation - Duration Analysis at Hungry Horse Reservoir (January-December).



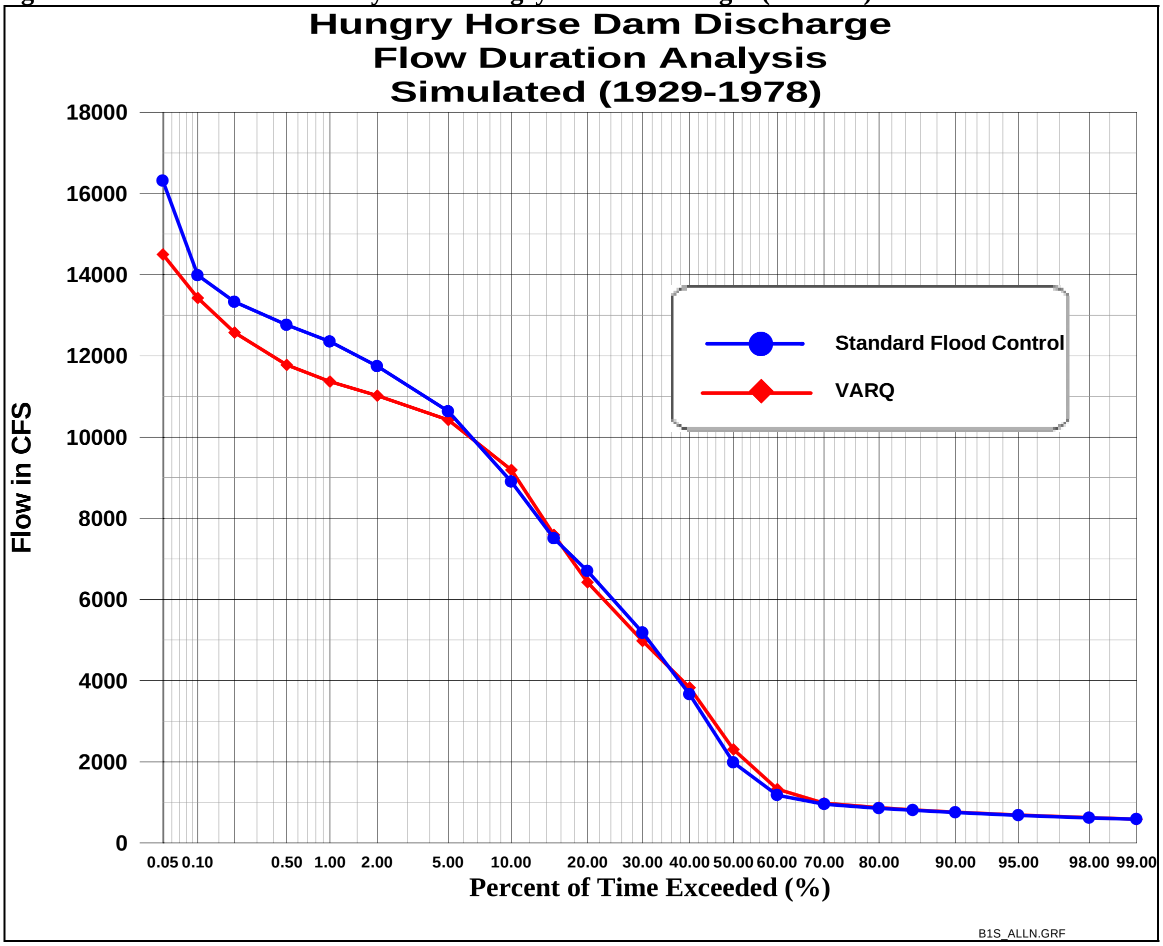
In the simulations, Hungry Horse Reservoir was drafted to its appropriate flood control elevation by releasing up to the maximum possible through the generating units. This involves less efficient use of the turbines, but also prevents the total dissolved gas problems associated with using the spillway. If rainfall or early runoff made it impossible to lower the reservoir using solely the generating units, spill of up to 2,000 cfs was allowed. The assumption was that spill of less than 2,000 cfs would not violate the Montana state water quality standard of 110% for total dissolved gases. Frequency curves for Hungry Horse discharges were developed for both Standard FC and VARQ (Figure 3.3).

Figure 3.3 Frequency Curves for Hungry Horse Dam Discharges, 1 Day Maximum Flow (Jan-Dec).



During the simulations, the majority of discharges greater than power house capacity were associated with drafting to flood control elevation targets in the spring time. In both the Standard FC and VARQ simulations, there were few spill events resulting from prematurely filling the reservoir to elevation 3560 feet and then spilling. These spill events were generally not in years of unusually high seasonal runoff, but in years of relatively low runoff when an large rain event occurred with the reservoir near full. It is believed that in "real life" additional stoplogs would be added to the spillway crest allowing for pool elevations in excess of elevation 3560 feet in the event of premature refill, and therefore the actual incidence of "fill and spill" would be minimized. Flow-duration curves for Hungry Horse discharges are displayed in Figure 3.4.

Figure 3.4 Flow - Duration Analysis for Hungry Horse Discharges (Jan-Dec).



3.2 VARQ Effects on the Flathead River at Columbia Falls, Montana

Hungry Horse Dam is operated under Section 7 of the Flood Control Act of 1944 by the U. S. Army Corps of Engineers for flood control, in coordination with the Bureau of Reclamation. The reservoir provides flood regulation which locally benefits the flood plain from Columbia Falls to Flathead Lake, and downstream along the Clark Fork and Pend Oreille Rivers. In addition to the local flood control objective, Hungry Horse Reservoir provides approximately 5% of the total flood storage in the Columbia River basin and is an important element in system flood control. [16]

[16] U.S. Army Corps of Engineers, Review of Flood Control Columbia River Basin, Columbia River and Tributaries Study, CRT-63, North Pacific Division, Portland, June 1991, pp. 49.

The flood stage for the Flathead River valley as measured at the Columbia Falls gage is elevation 14.0 feet (2978.67 msl).[17] This flood stage corresponds to a flow of 52,000 cfs, the U.S. Army Corps of Engineers' "zero damage" level for the Flathead River at Columbia Falls.[18]

Changing the flood control operation at Hungry Horse Dam will not increase the probability of exceeding the flood stage for the Flathead River at Columbia Falls. Because Hungry Horse Reservoir can be up to 0.4 maf more full during the winter in years of normal and below normal snowpack, regulated releases from Hungry Horse are usually greater during the refill period. While flows in the Flathead River are generally higher under VARQ as compared to Standard FC in years of normal and below normal runoff, the resulting stages are well below flood stage. This is reflected in Figure 3.5, the frequency curves for the Flathead River at Columbia Falls. A summary of the flow for a give exceedance frequency is presented in Table 3.2.

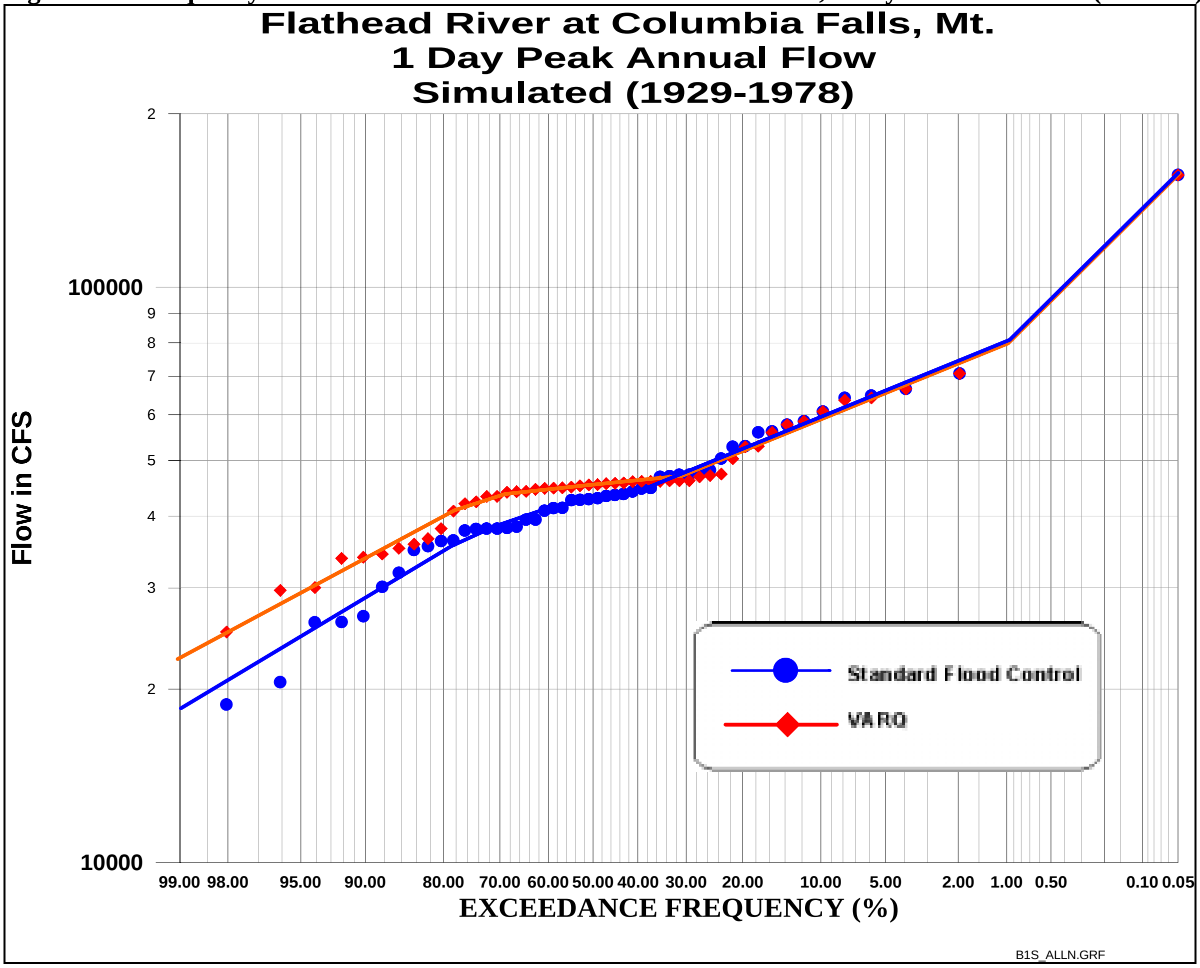
Since there are no flood impacts at Columbia Falls related to the VARQ flood control operation at Hungry Horse Dam, further study of the flood impacts downstream at Flathead Lake, the Clark Fork River, Lake Pend Oreille, and the lower Pend Oreille River does not appear warranted.

TABLE 3.2 PEAK 1-DAY DISCHARGE FREQUENCY ANALYSIS FOR FLATHEAD RIVER AT COLUMBIA FALLS.

Exceedance Frequency (%)	Standard Flood Control (cfs)	VARQ (cfs)	Difference (cfs)
.2	120,000	120,000	0
.5	95,000	95,000	0
1	80,000	80,000	0
2	74,000	74,000	0
5	66.000	66.000	0
10	59,000	59,000	0
20	52,000	52,000	0
30	47,000	47,000	0
40	45,000	46,000	1,000
50	43,000	45,000	2,000
70	38,000	44,000	6,000
90	29,000	34,000	5,000
99	19,000	23,000	4,000

[17] Nickless, Ray, National Weather Service, Missoula, Mt., in letter to Tom Murphy, U.S. Army Corps of Engineers, January 22, 1998.
[18] U.S. Army Corps of Engineers, Columbia River Basin System Flood Control Review - Preliminary Analysis Report, North Pacific Division, Portland, February, 1997, pp. 82.

Figure 3.5 Frequency Curves for the Flathead River at Columbia Falls, 1 Day Maximum Flow (Jan-Dec).



4.0 Summary and Conclusions

The VARQ flood control plan for Hungry Horse Dam will not impact the ability to control floods on the Flathead River at Columbia Falls, Montana. There will be no increase in the likelihood of flow in excess of 52,000 cfs, or river stages in excess of 14.0 feet, the "zero damage" levels used by the Corps of Engineers. Since there are no flood impacts at Columbia Falls related to the VARQ flood control operation at Hungry Horse Dam, further study of the flood impacts downstream at Flathead Lake, the Clark Fork River, Lake Pend Oreille, and the lower Pend Oreille River does not appear warranted.

VARQ and Standard FC would both result in refill of Hungry Horse Reservoir in almost every year if no additional power or endangered species releases are superimposed. The VARQ flood control operation drafts up to 0.4 maf less than the Standard FC operation. This additional water could be used to provide greater releases for fishery enhancement, or to further increase the potential for reservoir refill.

VARQ can minimize the likelihood of spilling water from Hungry Horse Dam by requiring earlier reservoir draft than the current flood control operation. In the simulations, the majority of discharges greater than power house capacity at Hungry Horse were associated with drafting to flood control elevation targets in the spring time. Few spill events resulted from prematurely filling the reservoir to elevation 3560 feet. It is believed that in "real life" additional stoplogs would be added to the spillway crest allowing for pool elevations in excess of elevation 3560 feet in the event of premature refill, and therefore the actual incidence of "fill and spill" would be minimized.

5.0 References

Bonneville Power Administration, Columbia River System Operation Review Final Environmental Impact Statement Appendix E Flood Control, November 1995.

Kuehl and Moffit, "Simulated Runoff Forecasts for the Period 1929-1978", prepared for the U.S. Army Corps of Engineers, North Pacific Division, Portland, July 1986.

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APPENDIX - Statistical Output from Computer Simulations[19].

A-1 Hungry Horse Elevation - Standard FC

HIGHEST MEAN VALUE FOR DURATION, ELEV,FT

YEAR	1	3	7	15	30	60	90	120	183
1929	3560.	3560.	3560.	3560.	3560.	3558.	0.	0.	0.
1930	3560.	3560.	3560.	3560.	3559.	3555.	0.	0.	0.
1931	3560.	3560.	3560.	3560.	3560.	3559.	0.	0.	0.
1932	3560.	3560.	3560.	3560.	3560.	3555.	0.	0.	0.
1933	3560.	3560.	3560.	3560.	3560.	3554.	0.	0.	0.
1934	3560.	3560.	3560.	3560.	3560.	3560.	0.	0.	0.
1935	3560.	3560.	3560.	3560.	3560.	3558.	0.	0.	0.
1936	3560.	3560.	3560.	3560.	3560.	3560.	0.	0.	0.
1937	3560.	3560.	3560.	3560.	3560.	3558.	0.	0.	0.
1938	3560.	3560.	3560.	3560.	3560.	3556.	0.	0.	0.
1939	3560.	3560.	3560.	3560.	3560.	3560.	0.	0.	0.
1940	3560.	3560.	3560.	3560.	3560.	3558.	0.	0.	0.
1941	3560.	3560.	3560.	3560.	3560.	3560.	0.	0.	0.
1942	3560.	3560.	3560.	3560.	3560.	3559.	0.	0.	0.
1943	3560.	3560.	3560.	3560.	3560.	3553.	0.	0.	0.
1944	3560.	3560.	3560.	3560.	3560.	3560.	0.	0.	0.
1945	3560.	3560.	3560.	3560.	3560.	3560.	0.	0.	0.
1946	3560.	3560.	3560.	3560.	3560.	3559.	0.	0.	0.
1947	3560.	3560.	3560.	3560.	3560.	3555.	0.	0.	0.
1948	3560.	3560.	3560.	3560.	3560.	3558.	0.	0.	0.
1949	3560.	3560.	3560.	3560.	3560.	3559.	0.	0.	0.
1950	3560.	3560.	3560.	3560.	3560.	3547.	0.	0.	0.
1951	3560.	3560.	3560.	3560.	3560.	3556.	0.	0.	0.
1952	3560.	3560.	3560.	3560.	3559.	3553.	0.	0.	0.
1953	3560.	3560.	3560.	3560.	3560.	3558.	0.	0.	0.
1954	3560.	3560.	3560.	3560.	3560.	3553.	0.	0.	0.
1955	3560.	3560.	3560.	3560.	3560.	3557.	0.	0.	0.
1956	3560.	3560.	3560.	3560.	3560.	3556.	0.	0.	0.
1957	3560.	3560.	3560.	3560.	3560.	3560.	0.	0.	0.
1958	3560.	3560.	3560.	3560.	3560.	3559.	0.	0.	0.
1959	3560.	3560.	3560.	3560.	3560.	3549.	0.	0.	0.
1960	3560.	3560.	3560.	3560.	3560.	3552.	0.	0.	0.
1961	3560.	3560.	3560.	3560.	3560.	3559.	0.	0.	0.
1962	3560.	3560.	3560.	3560.	3560.	3554.	0.	0.	0.
1963	3560.	3560.	3560.	3560.	3560.	3553.	0.	0.	0.
1964	3560.	3560.	3560.	3560.	3560.	3556.	0.	0.	0.
1965	3560.	3560.	3560.	3560.	3560.	3548.	0.	0.	0.
1966	3560.	3560.	3560.	3560.	3560.	3559.	0.	0.	0.
1967	3560.	3560.	3560.	3560.	3560.	3550.	0.	0.	0.
1968	3560.	3560.	3560.	3560.	3560.	3555.	0.	0.	0.
1969	3560.	3560.	3560.	3560.	3558.	3550.	0.	0.	0.
1970	3560.	3560.	3560.	3560.	3560.	3553.	0.	0.	0.
1971	3560.	3560.	3560.	3560.	3560.	3557.	0.	0.	0.
1972	3560.	3560.	3560.	3560.	3559.	3548.	0.	0.	0.
1973	3560.	3560.	3560.	3560.	3560.	3559.	0.	0.	0.
1974	3560.	3560.	3560.	3560.	3559.	3541.	0.	0.	0.
1975	3560.	3560.	3560.	3560.	3560.	3552.	0.	0.	0.
1976	3560.	3560.	3560.	3560.	3560.	3557.	0.	0.	0.
1977	3560.	3560.	3560.	3560.	3560.	3560.	0.	0.	0.
1978	3560.	3560.	3560.	3560.	3560.	3553.	0.	0.	0.

[19] U.S. Army Corps of Engineers, STATS Statistical Analysis of Time Series Data, Hydrologic Engineering Center, Davis, Ca., May 1987.

A-2 Hungry Horse Elevation - VARQ

HIGHEST MEAN VALUE FOR DURATION, ELEV,FT

YEAR	1	3	7	15	30	60	90	120	183
1929	3560.	3560.	3560.	3560.	3560.	3559.	0.	0.	0.
1930	3560.	3560.	3560.	3560.	3560.	3558.	0.	0.	0.
1931	3560.	3560.	3560.	3560.	3560.	3559.	0.	0.	0.
1932	3560.	3560.	3560.	3560.	3559.	3551.	0.	0.	0.
1933	3560.	3560.	3560.	3560.	3560.	3554.	0.	0.	0.
1934	3560.	3560.	3560.	3560.	3560.	3556.	0.	0.	0.
1935	3560.	3560.	3560.	3560.	3560.	3558.	0.	0.	0.
1936	3560.	3560.	3560.	3560.	3560.	3559.	0.	0.	0.
1937	3560.	3560.	3560.	3560.	3560.	3556.	0.	0.	0.
1938	3560.	3560.	3560.	3560.	3560.	3556.	0.	0.	0.
1939	3560.	3560.	3560.	3560.	3560.	3558.	0.	0.	0.
1940	3559.	3559.	3558.	3558.	3558.	3554.	0.	0.	0.
1941	3560.	3560.	3560.	3560.	3560.	3560.	0.	0.	0.
1942	3560.	3560.	3560.	3560.	3560.	3559.	0.	0.	0.
1943	3560.	3560.	3560.	3560.	3560.	3555.	0.	0.	0.
1944	3560.	3560.	3560.	3560.	3560.	3560.	0.	0.	0.
1945	3560.	3560.	3560.	3560.	3560.	3558.	0.	0.	0.
1946	3560.	3560.	3560.	3560.	3560.	3556.	0.	0.	0.
1947	3560.	3560.	3560.	3560.	3558.	3549.	0.	0.	0.
1948	3560.	3560.	3560.	3560.	3560.	3557.	0.	0.	0.
1949	3560.	3560.	3560.	3560.	3560.	3558.	0.	0.	0.
1950	3560.	3560.	3560.	3560.	3558.	3542.	0.	0.	0.
1951	3560.	3560.	3560.	3560.	3557.	3547.	0.	0.	0.
1952	3560.	3560.	3560.	3560.	3560.	3558.	0.	0.	0.
1953	3560.	3560.	3560.	3560.	3560.	3557.	0.	0.	0.
1954	3560.	3560.	3560.	3560.	3559.	3553.	0.	0.	0.
1955	3560.	3560.	3560.	3560.	3560.	3556.	0.	0.	0.
1956	3560.	3560.	3560.	3560.	3559.	3551.	0.	0.	0.
1957	3560.	3560.	3560.	3560.	3560.	3559.	0.	0.	0.
1958	3560.	3560.	3560.	3560.	3560.	3556.	0.	0.	0.
1959	3560.	3560.	3560.	3560.	3559.	3544.	0.	0.	0.
1960	3560.	3560.	3560.	3560.	3560.	3553.	0.	0.	0.
1961	3560.	3560.	3560.	3560.	3560.	3556.	0.	0.	0.
1962	3560.	3560.	3560.	3560.	3559.	3551.	0.	0.	0.
1963	3560.	3560.	3560.	3560.	3559.	3553.	0.	0.	0.
1964	3560.	3560.	3560.	3560.	3559.	3550.	0.	0.	0.
1965	3558.	3558.	3558.	3557.	3554.	3539.	0.	0.	0.
1966	3560.	3560.	3560.	3560.	3560.	3559.	0.	0.	0.
1967	3560.	3560.	3560.	3560.	3559.	3544.	0.	0.	0.
1968	3560.	3560.	3560.	3560.	3559.	3552.	0.	0.	0.
1969	3560.	3560.	3560.	3559.	3557.	3550.	0.	0.	0.
1970	3555.	3555.	3555.	3554.	3553.	3542.	0.	0.	0.
1971	3560.	3560.	3560.	3560.	3560.	3552.	0.	0.	0.
1972	3560.	3560.	3560.	3560.	3558.	3544.	0.	0.	0.
1973	3560.	3560.	3560.	3560.	3560.	3560.	0.	0.	0.
1974	3560.	3560.	3560.	3560.	3558.	3536.	0.	0.	0.
1975	3560.	3560.	3560.	3560.	3559.	3548.	0.	0.	0.
1976	3560.	3560.	3560.	3560.	3560.	3554.	0.	0.	0.
1977	3560.	3560.	3560.	3560.	3560.	3560.	0.	0.	0.
1978	3560.	3560.	3560.	3560.	3559.	3550.	0.	0.	0.

A-3 Hungry Horse Discharge - Standard FC

HIGHEST MEAN VALUE FOR DURATION, FLOW,CFS

YEAR	1	3	7	15	30	60	90	120	183
1929	10364.	10023.	8500.	7074.	6104.	5041.	4617.	4479.	4243.
1930	10786.	10519.	10439.	10404.	10391.	7746.	6556.	6122.	4454.
1931	10608.	9443.	8352.	7752.	7436.	5368.	4862.	5019.	3933.
1932	11554.	11544.	11524.	11487.	11427.	9850.	8827.	8106.	6074.
1933	16720.	16512.	15989.	14209.	11731.	8225.	8394.	7963.	7330.
1934	13497.	13488.	13469.	13426.	13354.	10219.	9780.	9646.	7738.
1935	11210.	10501.	9981.	9036.	8410.	6310.	5937.	5938.	5229.
1936	11486.	11481.	11480.	11476.	10815.	8630.	7452.	6586.	5520.
1937	10320.	9619.	7934.	7197.	5281.	5121.	4924.	4743.	3911.
1938	11491.	11490.	11486.	10230.	9178.	7471.	6692.	6468.	5078.
1939	11464.	11459.	11457.	11035.	9549.	7980.	7065.	6742.	5666.
1940	11585.	10943.	10266.	9805.	8404.	7573.	6106.	5679.	3947.
1941	8386.	7484.	6712.	4472.	4425.	4232.	3649.	3346.	2646.
1942	11721.	11710.	11702.	10088.	7494.	5199.	5244.	4659.	4426.
1943	11487.	11478.	11461.	11443.	11436.	10228.	8922.	8235.	7063.
1944	12157.	11927.	11723.	10508.	7804.	4102.	4235.	3604.	3032.
1945	14120.	13053.	11380.	9551.	8718.	6324.	5106.	4916.	4578.
1946	11546.	11538.	11521.	11486.	11346.	8521.	7665.	7161.	5870.
1947	11329.	11318.	11296.	11251.	11185.	10215.	9756.	9467.	7016.
1948	11620.	11513.	11491.	11445.	11039.	9290.	8079.	7390.	6639.
1949	11595.	11585.	11566.	11531.	11483.	9249.	7475.	6686.	5167.
1950	13075.	12594.	12409.	11319.	11234.	10222.	9513.	8929.	7208.
1951	11438.	11426.	11406.	11374.	10948.	9358.	8835.	8378.	6366.
1952	11462.	11451.	11427.	11387.	9814.	8229.	7474.	6812.	5422.
1953	13619.	12762.	11833.	10759.	9863.	6910.	6363.	6110.	5957.
1954	12998.	12665.	11391.	11064.	9999.	8411.	8232.	7490.	7202.
1955	11062.	10920.	10199.	9365.	8352.	6295.	5919.	5994.	5228.
1956	11327.	11315.	11291.	11239.	10724.	9439.	8967.	8804.	6932.
1957	10119.	10119.	9833.	9465.	7647.	6975.	6328.	5934.	5364.
1958	10910.	10644.	10249.	9052.	7715.	7646.	6703.	6222.	5078.
1959	13314.	13300.	13277.	13231.	13130.	10815.	10421.	10018.	7968.
1960	11479.	11472.	11459.	11446.	11406.	9577.	8577.	8261.	6483.
1961	12630.	11829.	10533.	9561.	9096.	8350.	7747.	7120.	6382.
1962	13383.	13377.	13370.	13369.	12655.	10308.	8866.	8266.	6429.
1963	9801.	9356.	8687.	8151.	8002.	6948.	6556.	6540.	5197.
1964	12771.	12317.	11802.	11514.	10931.	8330.	7317.	7062.	6437.
1965	11288.	11275.	11249.	11191.	11102.	10427.	10112.	9829.	7643.
1966	10736.	10427.	9702.	9135.	8506.	6821.	6224.	5904.	5318.
1967	13421.	13386.	12832.	12407.	11226.	9485.	9634.	8937.	6764.
1968	9944.	9573.	8125.	7687.	7464.	6894.	6681.	6521.	5087.
1969	11917.	11717.	11503.	11316.	11280.	8978.	9262.	8839.	6466.
1970	11528.	11517.	11495.	11453.	11365.	9654.	8719.	7766.	5769.
1971	13418.	13405.	13377.	13322.	13223.	10280.	10540.	9703.	7731.
1972	13417.	13405.	13384.	13338.	13255.	13042.	11989.	10564.	7578.
1973	12590.	11067.	9627.	8097.	6213.	4606.	4249.	4365.	3865.
1974	17615.	16546.	13942.	13041.	12992.	11183.	10451.	10592.	8434.
1975	19040.	18357.	16141.	13352.	9381.	6951.	6970.	6487.	6074.
1976	11451.	11440.	11417.	11386.	11342.	9340.	8551.	8153.	6308.
1977	12848.	12515.	11616.	8810.	8601.	4923.	4176.	4002.	3181.
1978	10464.	10457.	10444.	10430.	10388.	9286.	8490.	8190.	6089.

A-4 Hungry Horse Discharge - VARQ

HIGHEST MEAN VALUE FOR DURATION, FLOW,CFS

YEAR	1	3	7	15	30	60	90	120	183
1929	11650.	11650.	11492.	10850.	9360.	7588.	6267.	5272.	3853.
1930	10082.	10081.	10074.	9325.	8870.	5859.	5574.	4564.	4003.
1931	10500.	10500.	10500.	9772.	9262.	6279.	5138.	4175.	3519.
1932	10993.	10980.	10956.	10923.	10799.	8841.	7312.	6860.	5955.
1933	16325.	16325.	15571.	13737.	12031.	10236.	9305.	7979.	6735.
1934	12800.	11073.	11068.	11023.	10893.	9949.	8640.	8608.	7455.
1935	8300.	8300.	8300.	8300.	7687.	7248.	6396.	5518.	4647.
1936	10384.	10383.	10376.	10349.	9669.	8782.	7502.	6561.	5028.
1937	8100.	8100.	8029.	7800.	7700.	5673.	4918.	4320.	3723.
1938	10258.	10251.	9887.	8900.	7717.	7539.	6103.	4980.	4938.
1939	10299.	10297.	10287.	10238.	9565.	8120.	6822.	5832.	5366.
1940	9963.	8454.	8200.	8200.	7565.	7290.	6450.	4983.	4204.
1941	11010.	9390.	8093.	7029.	6443.	4379.	3195.	2516.	2167.
1942	13477.	12021.	12018.	12016.	10518.	8469.	7326.	5845.	4027.
1943	14497.	14497.	13628.	12540.	10858.	9082.	7905.	7328.	6460.
1944	10710.	10253.	9550.	8653.	7676.	6301.	4772.	3760.	2636.
1945	9863.	9861.	9853.	9836.	9803.	8587.	7422.	6093.	4234.
1946	10474.	10458.	10419.	10346.	8383.	7670.	7105.	6104.	5486.
1947	12351.	10830.	10417.	10302.	10192.	9964.	9444.	9251.	7691.
1948	10845.	10842.	10833.	10814.	10544.	9324.	8331.	7695.	6037.
1949	10311.	10305.	10282.	10172.	8612.	7935.	7465.	6265.	4830.
1950	11369.	11350.	11320.	11262.	11161.	9719.	9864.	8727.	7162.
1951	11336.	11138.	11105.	11034.	9269.	8050.	7770.	7795.	6726.
1952	12151.	11460.	10235.	9073.	7378.	6041.	5725.	5795.	4997.
1953	11107.	10646.	10069.	9643.	8599.	8185.	7885.	6699.	5607.
1954	12829.	12829.	12342.	11869.	9871.	7575.	7890.	7067.	6915.
1955	9915.	9897.	9867.	9804.	9360.	8710.	7873.	7273.	5084.
1956	11601.	11216.	11049.	10675.	10263.	9480.	8954.	8940.	7211.
1957	8553.	8082.	7578.	7091.	6845.	6090.	5818.	5758.	4735.
1958	11522.	11513.	11494.	10948.	8819.	7232.	7073.	6128.	4990.
1959	11328.	11300.	11243.	11143.	10690.	10368.	10174.	9828.	8281.
1960	10681.	10668.	10648.	10343.	8789.	7464.	6901.	6350.	5841.
1961	10640.	10638.	10636.	10623.	10557.	9280.	8040.	7363.	5841.
1962	10864.	10861.	10851.	10826.	10711.	8203.	7900.	6817.	6314.
1963	8649.	7683.	7400.	7400.	7172.	6314.	5303.	4671.	4737.
1964	11961.	11956.	11944.	11580.	9949.	9567.	8350.	7684.	6127.
1965	11159.	11093.	11082.	11056.	10474.	10218.	9962.	9205.	8212.
1966	11051.	10744.	10019.	9286.	8349.	7409.	6487.	5987.	4906.
1967	11333.	11282.	11138.	11026.	10820.	10002.	9437.	8606.	7117.
1968	8783.	7500.	7500.	7500.	7500.	6722.	5375.	5283.	4943.
1969	11040.	11011.	10955.	10846.	10650.	9394.	8307.	7456.	6054.
1970	11626.	11616.	11596.	11555.	11474.	11062.	9271.	8312.	6432.
1971	11364.	11351.	11324.	11273.	11126.	10776.	10239.	9171.	7388.
1972	11366.	11358.	11338.	11300.	11218.	11038.	10843.	10250.	7873.
1973	12590.	11900.	10593.	10129.	9923.	7848.	5795.	4519.	3263.
1974	12202.	11618.	11404.	11228.	10999.	10624.	10369.	10157.	8678.
1975	12936.	12936.	11240.	9000.	7689.	6247.	6191.	6039.	5769.
1976	11431.	11121.	11011.	10871.	8598.	7236.	6988.	6828.	6263.
1977	12009.	12008.	12006.	10460.	7097.	6387.	4809.	3847.	2779.
1978	12755.	10778.	9238.	9058.	8761.	7939.	7179.	6632.	5769.

A-5 Flathead River at Columbia Falls Flow - Standard FC

HIGHEST MEAN VALUE FOR DURATION, FLOW,CFS

YEAR	1	3	7	15	30	60	90	120	183
1929	47093.	44623.	36628.	29533.	28358.	22508.	18726.	15571.	11922.
1930	31849.	30840.	29906.	28643.	25498.	20959.	18131.	15149.	11830.
1931	38005.	33429.	29025.	24973.	21061.	17123.	14957.	12648.	10177.
1932	55887.	49170.	39878.	38697.	31630.	29256.	26414.	23109.	18130.
1933	64154.	62637.	56859.	51213.	46899.	36586.	31818.	26130.	19738.
1934	39400.	38781.	37885.	35304.	32910.	29582.	26226.	22501.	19308.
1935	43477.	40506.	34844.	32230.	31086.	26731.	23009.	19248.	15196.
1936	40827.	38478.	35819.	31334.	30497.	27084.	22231.	18506.	14053.
1937	30108.	28358.	26093.	24033.	22727.	21324.	18086.	14857.	11599.
1938	47637.	45494.	41032.	36735.	29178.	27039.	23914.	20021.	15475.
1939	46870.	38629.	33260.	30625.	27360.	23397.	21171.	18629.	14414.
1940	26113.	24321.	21706.	20985.	18927.	17131.	14835.	13003.	10198.
1941	18803.	17000.	15525.	13977.	12741.	11812.	10002.	8578.	7262.
1942	36251.	34711.	30764.	25703.	24062.	21148.	19998.	17005.	12720.
1943	42597.	39900.	37689.	32976.	28709.	25804.	26544.	23892.	18480.
1944	20554.	19428.	18494.	16773.	15946.	13420.	12510.	10592.	7750.
1945	41308.	39635.	37260.	31254.	27756.	23417.	19204.	16023.	12202.
1946	43280.	38953.	34163.	32908.	29246.	27065.	24443.	21479.	16489.
1947	47103.	44672.	41853.	39667.	32958.	28447.	24896.	22170.	18044.
1948	60758.	54724.	51822.	45923.	41155.	32024.	27294.	22890.	17492.
1949	38325.	38100.	36523.	29554.	27930.	25054.	21261.	17888.	13602.
1950	48064.	46103.	41438.	39181.	37012.	33194.	28546.	25033.	19830.
1951	42665.	40571.	37078.	33405.	29343.	27100.	25060.	22904.	18705.
1952	38007.	35115.	30165.	26052.	25653.	23240.	21145.	18280.	14637.
1953	56079.	52503.	47420.	44024.	37793.	30641.	26923.	22173.	17225.
1954	66565.	62135.	54632.	47003.	42287.	38875.	32285.	27404.	20995.
1955	44621.	42540.	39286.	38259.	33096.	27406.	23159.	19630.	14752.
1956	58434.	55720.	50970.	47646.	40777.	30728.	26434.	22973.	18267.
1957	46784.	45705.	40101.	35308.	33070.	28841.	22879.	19269.	15011.
1958	38097.	35694.	34800.	32391.	29031.	22733.	19188.	16656.	13092.
1959	50299.	47230.	42194.	37944.	36358.	30052.	27871.	25208.	20312.
1960	41252.	37704.	32508.	29003.	24362.	21261.	20912.	19435.	15645.
1961	52894.	50630.	46280.	44736.	40305.	30784.	25369.	21691.	16856.
1962	37684.	35587.	33348.	29760.	26578.	24624.	22740.	19587.	15416.
1963	26751.	25921.	24908.	23699.	22029.	19622.	17947.	16003.	13271.
1964	156575.	102661.	74021.	56848.	46219.	36475.	29763.	25305.	18714.
1965	44687.	42108.							
1966	44100.	41992.	39028.	35936.	31093.	25171.	21840.	19230.	14753.
1967	52742.	49215.	41528.	39463.	36706.	31991.	25442.	22307.	18247.
1968	34900.	32669.	28298.	27124.	24863.	21699.	18757.	16352.	13763.
1969	37936.	35575.	30881.	27529.	25278.	24382.	21467.	18440.	15527.
1970	39379.	38927.	35770.	32290.	31036.	26473.	22241.	19155.	15121.
1971	43631.	42025.	37592.	36031.	34504.	31267.	28088.	24872.	20586.
1972	57633.	54310.	49042.	46095.	40386.	31247.	27145.	25157.	20993.
1973	36143.	35310.	29664.	24831.	23939.	19995.	16519.	13850.	10974.
1974	64723.	63367.	60774.	53857.	43233.	35260.	32366.	28408.	22985.
1975	70729.	57701.	46801.	41801.	38830.	33887.	27119.	22549.	17462.
1976	42948.	40008.	36441.	31094.	27203.	24828.	23227.	20933.	16708.
1977	26158.	25231.	22907.	18137.	15274.	13410.	12245.	10326.	7899.
1978	35437.	34303.	31802.	25791.	23154.	21566.	20492.	19179.	15367.

A-6 Flathead River at Columbia Falls Flow - VARQ

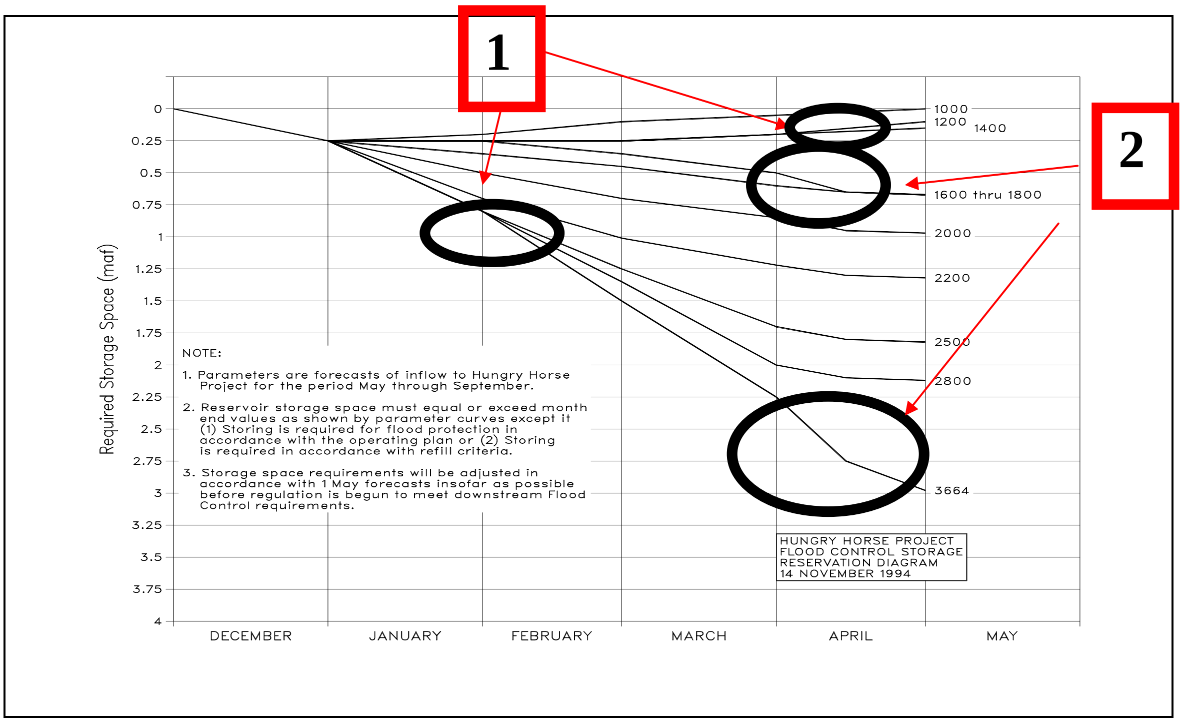
HIGHEST MEAN VALUE FOR DURATION, FLOW,CFS

YEAR	1	3	7	15	30	60	90	120	183
1929	45593.	43881.	39481.	35397.	34268.	25881.	20689.	16712.	11876.
1930	34338.	32886.	29897.	28514.	25513.	21731.	18853.	15856.	11538.
1931	45523.	40968.	36387.	29862.	26963.	20690.	16499.	13473.	9593.
1932	55887.	49170.	41634.	40616.	34675.	30359.	26482.	23028.	17500.
1933	63585.	62085.	57079.	54090.	49965.	38533.	32931.	26469.	19446.
1934	42318.	40808.	37688.	36849.	34698.	31287.	26398.	22040.	19157.
1935	46077.	44650.	40455.	39062.	36178.	29273.	24313.	20039.	14848.
1936	45261.	43131.	41571.	36711.	34517.	28741.	23212.	18957.	13896.
1937	36527.	35558.	31819.	29428.	27527.	23630.	19163.	15622.	11518.
1938	47276.	46518.	46053.	43993.	35393.	29517.	25124.	20608.	14908.
1939	45654.	40845.	39919.	34775.	32948.	25927.	21981.	18989.	13916.
1940	33913.	32121.	29269.	28580.	24282.	19425.	16303.	13881.	10067.
1941	25139.	23220.	21314.	19045.	17463.	13834.	11228.	9375.	7012.
1942	44676.	42647.	39640.	34781.	30393.	25501.	21951.	18312.	13009.
1943	44490.	42010.	38684.	36001.	33276.	29873.	26949.	23885.	17952.
1944	29682.	28564.	27630.	22637.	21063.	16943.	13168.	10689.	7794.
1945	40778.	39552.	36796.	32870.	30104.	26135.	21678.	17450.	12360.
1946	45880.	43086.	40105.	37183.	34404.	30201.	25331.	21927.	16094.
1947	47028.	44086.	42432.	38728.	33186.	27886.	23849.	20764.	17429.
1948	60758.	54724.	51822.	49124.	42930.	34186.	27963.	23260.	17494.
1949	45925.	45700.	44123.	37154.	34877.	27731.	22326.	18533.	13692.
1950	45146.	43932.	40062.	36739.	35140.	32373.	26800.	23633.	19307.
1951	43265.	41929.	39532.	35996.	32483.	28454.	24739.	22229.	18028.
1952	38007.	35115.	32928.	30951.	27611.	24220.	21031.	17901.	13916.
1953	46072.	44913.	43688.	43025.	38852.	32437.	28435.	23039.	16989.
1954	66565.	62135.	54702.	46718.	40105.	38414.	32490.	27259.	20838.
1955	46015.	45773.	43554.	40074.	36217.	30082.	25042.	20997.	15066.
1956	58434.	55720.	50970.	48338.	40111.	28937.	24775.	21393.	17433.
1957	46783.	45916.	42987.	39962.	36883.	30644.	23814.	19719.	14645.
1958	44076.	41674.	40780.	38371.	34676.	26002.	20185.	17272.	12816.
1959	50299.	47230.	43338.	40410.	36357.	29490.	25945.	23431.	19457.
1960	44752.	41204.	36008.	34906.	28616.	23988.	21027.	19101.	14808.
1961	52894.	50630.	47437.	45804.	41393.	32140.	26288.	22182.	16595.
1962	35141.	32269.	31948.	31103.	29690.	26030.	23158.	19636.	14776.
1963	33751.	32921.	31908.	30232.	28034.	22916.	19514.	16663.	12849.
1964	156575.	102661.	73674.	58266.	46889.	37523.	30393.	25641.	18732.
1965	44687.	40027.	35323.	33640.	31878.	29980.	25588.	21284.	17996.
1966	44882.	44337.	42579.	38648.	32814.	27816.	22819.	19942.	14680.
1967	52742.	49251.	41925.	40022.	37166.	30275.	24291.	20719.	17581.
1968	42000.	39769.	35398.	34224.	31963.	25716.	20435.	16700.	13296.
1969	35730.	35284.	32375.	28950.	28358.	23161.	20525.	17210.	14895.
1970	44124.	40715.	37640.	36024.	33433.	28521.	23476.	20149.	15289.
1971	45950.	44361.	39489.	37421.	32933.	30536.	26957.	23573.	20035.
1972	57633.	54310.	49321.	46482.	41080.	31093.	26401.	24071.	20059.
1973	45943.	45110.	39457.	33854.	31633.	24627.	18819.	15174.	10785.
1974	64180.	62387.	57940.	51312.	41798.	34141.	30674.	26703.	22178.
1975	70729.	59026.	48504.	42912.	39990.	34296.	27951.	22768.	17320.
1976	44006.	41435.	39638.	35046.	31436.	25768.	22999.	20526.	16083.
1977	30013.	28603.	26621.	24319.	19507.	17088.	13167.	10890.	8177.
1978	43237.	42103.	39602.	33569.	29204.	25569.	21712.	18308.	14488.

A-7 Possible Modifications to the VARQ Storage Reservation Diagrams.

The hydro-regulations for this study were done using the VARQ storage reservation diagram (SRD) displayed earlier in the text as Figure 2.2. Figure A-7.1 points out several areas where the original VARQ storage reservation diagram could be modified to make it easier to use, and improve its performance with regard to spill. The modifications discussed would have little or no flood control impact. Any modification to the original SRD would be done by the Hydrologic Engineering Branch of Northwestern Division of the U.S. Army Corps of Engineers.

Figure A-7.1 Original VARQ Storage Reservation Diagram with Possible Modifications.



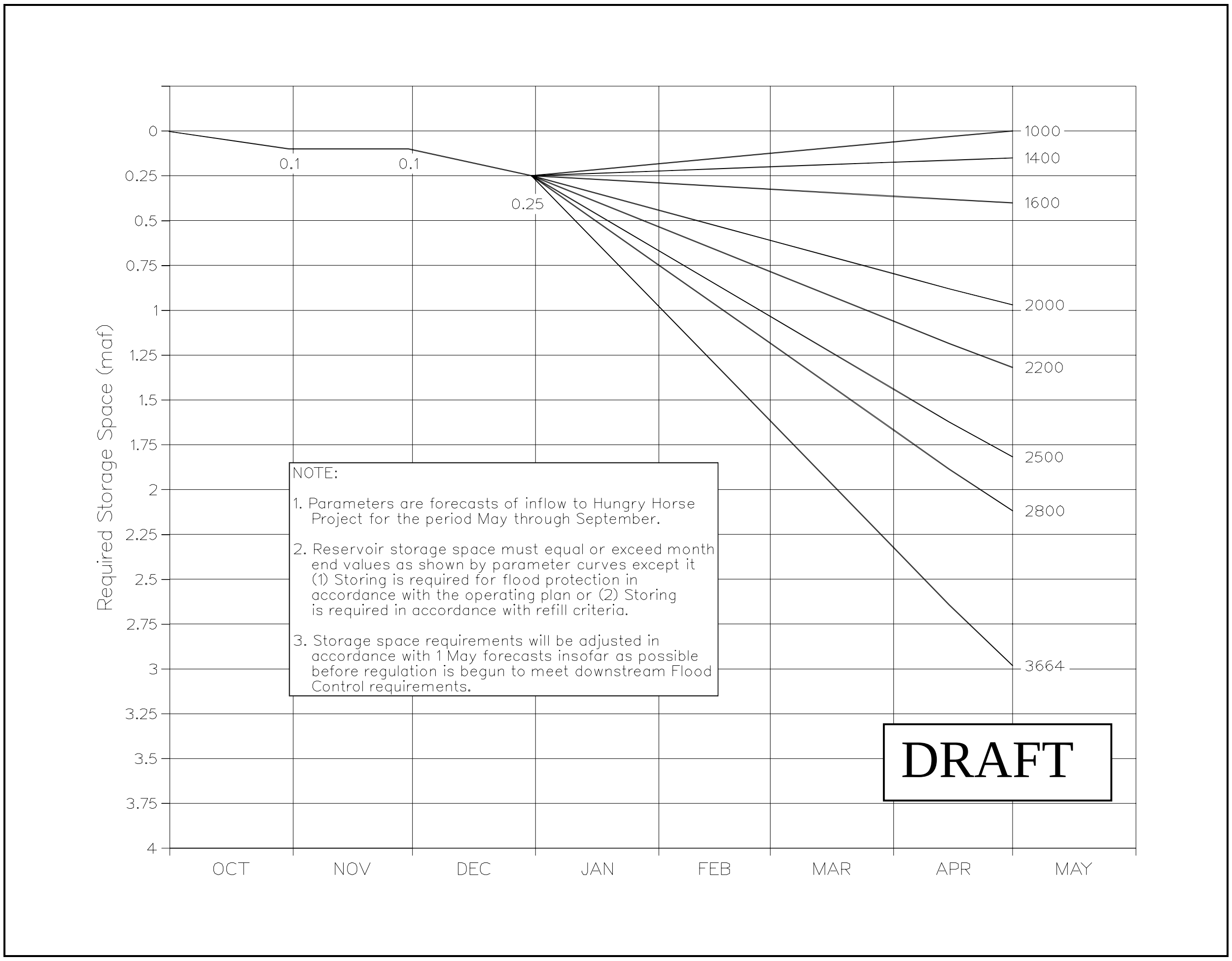
1. Drawdown could be linear from the January 1 until the final flood control elevation is achieved. This would eliminate unnecessary complexity. There would be no converging and diverging of drawdown curves.

2. Increases in the drawdown rates in April could be eliminated to prevent unnecessary spill, especially in years with a forecasted runoff volume of 3.664 maf.

3. The minimum elevation could be achieved earlier in April (instead of May 1) to further minimize spill.

An alternative storage reservation diagram was created at the request of the U.S. Bureau of Reclamation.[20] That SRD is displayed in Figure A-7.2, and satisfies the desire for a simple, linear flood control plan. It would not produce the same benefits associated with minimizing spill during some high runoff years as does the original VARQ storage reservation diagram, Figure 2-2.

Figure A-7.2 Alternative VARQ Storage Reservation Diagram Modified for the Bureau of Reclamation.



[20] Personal conversation with Harry Taylor, USBR, Boise, March 25, 1998.

Another possible alternative to the original VARQ storage reservation diagram is the composite SRD displayed in Figure A-7.3 that combines the best features of Figure 2-2, and Figure A-7.2. The composite SRD would draft to the same minimum elevations as both Figures 2-2 and A-7.2, but achieve the minimum elevation earlier in years of greater than 2200 kaf and less than 3664 kaf (May-Sep) runoff. Drawdown curves do not merge or diverge.

Figure A-7.3 Composite VARQ Storage Reservation Diagram for Hungry Horse Dam.