

Draft Technical Memorandum

Assessment of Additional Flood Control Storage at Baker River Project

Introduction

This Technical Memorandum, as prepared by Pacific International Engineering (PI Engineering), presents a preliminary assessment of whether or not potential flood reduction benefits could be realized on the lower Skagit River floodplain if additional flood control storages at Baker Lake and Lake Shannon of the Baker River Project were made available beyond the existing flood control storage of 74,000 acre-feet provided at Baker Lake.

The Baker River Project (FERC project number 2150) is owned and operated by Puget Sound Energy (PSE) and is currently involved in a FERC relicensing proceeding. This provides an opportunity for downstream floodplain communities to seek an optimum use of the storages at both lakes to benefit Skagit River flood reductions. Skagit County (County), as the local sponsor of the Skagit River Flood Reduction Project presently being studied by the U.S. Army Corps of Engineers – Seattle District (Corps), has requested that PSE conduct an analysis of their storage operation for downstream flood reduction as part of their re-licensing efforts.

During a March 18, 2003 meeting between the County and the Corps, PI Engineering was directed to perform this preliminary assessment and to recommend a study scope for work that needs to be performed in order to optimize the future flood control operation and storages at the Baker River Project.

Background

The Baker River drainage area at the Baker River streamflow gage, located at river mile (RM) 0.7 upstream from its confluence with the Skagit River, is 297 square miles, approximately 11 percent of the drainage area (2,737 square miles) at the Skagit River streamflow gage near Concrete. The annual average flow recorded at the Baker River gage is 17 percent of that recorded at the Skagit River gage near Concrete, a runoff contribution proportionately higher than any other major subbasin of the Skagit River on a unit drainage area basis.

Average annual precipitation in the Baker River basin ranges from about 70 inches at Concrete to greater than 150 inches at some of the higher elevations. The average annual runoff is approximately 120 inches from the Baker River basin and 75 inches from the Skagit River basin above the

Concrete gage. Between Concrete and Mount Vernon, the Skagit River drainage area increases by 356 square miles. The average annual runoff from this intermediate drainage area is approximately 50 inches.

Baker Lake, above the Upper Baker Dam (at RM 9.35), is about 9 miles long and covers a surface area of about 4,800 acres at normal full pool (El. 724.0). Roughly 285,000 acre-feet of water are stored in Baker Lake at normal full pool. Lake Shannon above the Lower Baker Dam (at RM 1.2) is approximately 7 miles long and covers a surface area of about 2,190 acres at normal full pool (El. 438.6). About 160,000 acre-feet of water are stored in Lake Shannon at normal full pool.

Operation for flood control storage is provided only at Baker Lake, under an agreement between the Corps and PSE. This agreement, in place since 1980, was extended in 2000 and expires in 2003. It limits the pool level of Baker Lake to El. 720.75 from November 1 to March 1 for 16,000 acre-feet of flood control storage, and to El. 707.9 under normal operation conditions from November 15 to March 1 to provide a total of 74,000 acre-feet of flood control storage.

This agreement stipulates that outflows from Baker Lake be maintained as equal to inflows until eight hours before Skagit River flow at the Concrete gage is forecasted to reach 90,000 cubic feet per second (cfs). The outflows are then dropped to 5,000 cfs at Baker Lake.

The 16,000 acre-feet of storage is intended to make up for lost valley storage from the original construction of the Baker River Project. In addition to the agreed upon total of 74,000 acre-feet, the existing FERC license states that PSE shall provide for flood control in Baker Lake up to a maximum of 26,000 additional acre-feet as may be requested by the Corps, under the condition that PSE is compensated for the reservation of flood control storage beyond the 16,000 acre-feet. Therefore, up to a total maximum of 100,000 acre-feet of flood control storage at Baker Lake would be provided, if justified and requested.

There is no formal agreement in place to limit the pool level of Lake Shannon in order to provide flood control storage operation. The Lower Baker Dam has a drainage area 38 percent larger than the area above Upper Baker Dam, and passes approximately 35 percent more water in an average year than does the Upper Baker Dam. Lake Shannon could be operated in coordination with Baker Lake to provide additional flood control protection.

Because of high runoff from the Baker River basin and the locations of Baker Lake and Lake Shannon, operation of the Baker River Project for flood control purposes has historically provided and will continue to provide a significant public benefit to the communities in the lower Skagit River valley.

Under the current FERC relicensing, PSE is required to develop a Baker River Project relicense application that is best adapted to a comprehensive plan for beneficial public uses including flood control and other purposes. The Federal Power Act requires that FERC balance hydropower and non-power resources when reviewing a relicense application and considering a new license issuance. Flood control at the Baker River Project is an important factor to be included in the FERC balancing decision, and should be optimized for both Baker Lake and Lake Shannon, and not be limited by the current flood control agreement between the Corps and PSE.

Approach and Assumptions

For this preliminary assessment, available historical and synthetic flood hydrographs, as well as Baker River Project operation data, were obtained from USGS, the Corps, and PSE. Selected flood hydrographs and reservoir operation data were reviewed and analyzed to determine the need for, and quantify approximately, the additional flood control storage required to maximize downstream protection at the Baker River Project during each flood event. The synthetic flood hydrographs were then adjusted to reflect the regulating effects of the quantified additional flood control storages and routed through the UNET model developed by the Corps to assess the downstream reduction in flood levels.

Three historical flood events selected for this assessment are the two November 1990 floods and the November 1995 flood. These three events are the largest floods occurring since 1981 after the current Baker Lake flood control operation of 74,000 acre-feet became effective. Each of these floods caused significant damage in the Skagit River floodplain downstream. The recurrence intervals for these three floods are estimated to be between 22 and 29 years.

Three synthetic floods provided by the Corps and selected for UNET modeling are the 10-, 25-, and 50-year events. These synthetic flood hydrographs for the Skagit River at Concrete take into consideration the 74,000 acre-foot flood control operation at Baker Lake. Additional flood control storages for these synthetic floods were estimated by a projection of the quantified additional flood control storages for the above-described three major historical events. Floods smaller than the 10-year event were not evaluated in this assessment. Floods greater than the 50-year event would involve too much projection from the historical flood events to quantify the additional flood control storage and operation requirements at the Baker River Project, therefore, they were not included in this preliminary assessment.

All flood frequency return intervals estimated and mentioned in this Technical Memorandum are based on the Corps' August 9, 2001 "Draft Hydrology Investigation Report," prepared for the Skagit River Basin.

Assumptions used to quantify the additional flood control storage requirements above the currently agreed upon 74,000 acre-foot storage at Baker Lake are as follows:

- An optimum total flood control storage could be over the total maximum of 100,000 acre-feet that PSE currently could provide, if justified and requested by the Corps. The storage would be jointly provided at both Baker Lake and Lake Shannon, not just Baker Lake only, as currently agreed upon between the Corps and PSE.
- Primary flood reduction benefits from the additional flood control storage would be realized during floods less than the 50-year event or less than the Skagit River Channel hydraulic capacity in the existing levee system downstream.
- A breakdown of the estimated flood control storage requirements between Baker Lake and Lake Shannon was not defined.
- Potential operation modifications to the current 74,000 acre-foot flood control storage were not considered.
- Optimization of the additional flood control storage operation alone, or in conjunction with the current flood control storage operation, was not considered.
- Outflows from Lake Shannon were to be reduced to a minimum flow when Skagit River flow at the Concrete gage reaches 110,000 cfs.
- A minimum outflow of 100 cfs from Lake Shannon was to be maintained.
- The rate of change of outflow from Lake Shannon was set at 5,000 cfs per hour.
- A time lag for flows from Lake Shannon to reach the Concrete gage on the Skagit River was assumed to be one hour.
- To assess flood reductions in stage and discharge, the UNET modeling for the downstream Skagit River from Sedro Woolley to Skagit Bay assumed that debris would not restrict flow at the BNSF railroad bridge and that there would be no levee failures for both with and without additional flood control storage conditions.

Additional Flood Control Storage Requirements

Figures 1, 2, and 3 show plots of hourly water surface elevations at Baker Lake and Lake Shannon, and hourly flow hydrographs for Baker River and Skagit River at gages near Concrete, for the two November 1990 floods and the November 1995 flood. As shown on these figures, outflows from Lake

Shannon were still significant, exceeding 15,000 to 20,000 cfs at the Skagit River flood peaks observed at the Concrete gages during these three major events. Based on the above assumptions, additional flood control storage requirements at the Baker River Project to store these outflows from Lake Shannon during flood peaks were estimated. The estimated additional storages ranging from 30,000 to 35,500 acre-feet are provided in Table 1. Including the current 74,000 acre-feet provided at Baker Lake, the total flood control storage requirements at the Baker River Project could range between 104,000 and 109,500 acre-feet during these three major historical floods.

Also provided in Table 1 are estimated additional flood control storage requirements between 15,400 and 59,000 acre-feet for the 10-, 25-, and 50-year synthetic floods. These estimated storages were based on similar assumptions to those used for the historical flood events. Including the current 74,000 acre-feet storage provided at Baker Lake, the total flood control storage requirements at the Baker River Project could range between 89,400 and 133,000 acre-feet for the 10- to 50-year flood events.

Figure 4 shows a comparison of Skagit River flood hydrographs for the 10-, 25-, and 50-year events between with and without additional flood control storage conditions at the Baker River Project.

Skagit River Flood Reductions at Concrete

Table 2 shows potential reductions of the Skagit River flood stage and peak flow, as well as recurrence interval at the Concrete gage for the two November 1990, the November 1995, and the 10-, 25-, and 50-year floods if the estimated additional flood control storage during each of these events was provided at the Baker River Project. The flood stage reductions range from 1.21 to 1.57 feet on the Skagit River at the Concrete gage. The peak flow reductions are approximately 10 to 13 percent of the Skagit River flood peaks. The three major historical floods with recurrence intervals ranging from 22 to 29 years, would become 13- to 17-year medium flood events. The 10-, 25-, and 50-year synthetic events would be reduced to approximately 6-, 15-, and 30-year events, respectively.

Skagit River Flood Reductions from Sedro Woolley to Mt. Vernon

Hydrographs of the 10-, 25-, and 50-year synthetic floods for the current Baker Lake storage operation conditions, as well as conditions with the estimated additional flood control storages at the Baker River Project, were routed by use of the Corps-developed UNET model through the downstream Skagit River assuming no debris blocking at BNSF railroad bridge and no levee failure. Routing results were compared between conditions with and without the additional flood control storages. Figure 5 shows a comparison of Skagit River flood hydrographs at the Mount Vernon gage for the 10-, 25-, and 50-year events between with and without additional flood control storage conditions at the Baker River Project. Figures 6 and 7 show comparisons of

the Skagit River flood peak flow and maximum stage profiles between these two conditions for the three modeled flood events.

Table 3 provides potential reductions of the Skagit River flood peak flows and stages at selected locations. Flood stage reductions range from 0.55 to 1.05 feet on the main stem of the Skagit River between Sedro Woolley and Mount Vernon. Peak flow reductions are higher in Sedro Woolley (ranging from 8 to 11 percent) than in Mount Vernon (ranging from 5 to 7 percent) as flood peaks attenuated when moving downstream of Sedro Woolley through the Nookachamps Creek flood plain. Table 4 shows potential reductions of overbank flows in Sedro Woolley and Mount Vernon.

Conclusions and Recommendations

It is concluded from the above assessment that an additional flood control storage at the Baker River Project, above the currently provided 74,000 acre-foot storage at Baker Lake, could provide significant additional flood reduction benefits on the Skagit River floodplain below Concrete. The additional storage requirement was estimated to be 35,500 acre-feet in order to maximize downstream flood reductions for the three major events occurring in 1990 and 1995. With this additional storage provided, the downstream flood peaks during those events could have been within the channel hydraulic capacity of the existing levee system. This additional flood control storage requirement would increase to approximately 59,000 acre-feet to achieve the maximum flood reduction during a 50-year event. A breakdown of the estimated storage requirements between Baker Lake and Lake Shannon was not determined in this assessment. Optimization of the additional storage needs in conjunction with the current 74,000 acre-foot storage operation was not evaluated in this assessment. A more detailed study is required to determine an optimum use of the Baker River Project storages for flood control operation, including use of available surcharge storages.

It is therefore recommended that a detailed evaluation of the Baker River Project flood control operation be performed. A scope of the detailed evaluation is recommended as follows:

- Optimize the total flood control storage including the current 74,000 acre-foot and additional storage at the Baker River Project.
- Determine the optimum relationship of flood control storage between Baker Lake and Lake Shannon.
- Optimize the flood control storage operation and the drawdown-refill rule curve at each lake.
- Perform hydrologic study and hydrodynamic flood routing modeling of major historical floods and synthetic floods for this detailed evaluation.

- Estimate hydropower generation impacts based on the new flood control operation rule curves.
- Perform economic analysis for a study area including all downstream flood damage areas in order to maximize net benefits.
- Perform detailed topographic mapping and surveying for the area between Concrete and Sedro Woolley, as required for flood damage reduction analysis and for a better flood routing analysis.
- Perform an environmental analysis to assess potential impact and mitigation due to implementation of a future optimum flood control operation at the Baker River Project.

Table 1 Flood Control (FC) Storage Requirements at Baker River Project

Flood	Current FC Storage at Baker Lake (Ac-Ft)	Estimated Additional FC Storage at Baker Lake and Lake Shannon (Ac-Ft)	Total FC Storage at Baker River Project (Ac-Ft)
<i>Historical Events</i>			
Nov. 8 to Nov. 15, 1990	74,000	33,182	107,182
Nov. 21 to Nov. 28, 1990	74,000	29,953	103,953
Nov. 26 to Dec. 3, 1995	74,000	35,457	109,457
<i>Synthetic Events</i>			
10-year	74,000	15,400	89,400
25-year	74,000	24,600	98,600
50-year	74,000	59,000	133,000

Table 2 Potential Skagit River Flood Reductions at Concrete Gage

Flood	With Current FC Storage at Baker Lake			With Additional FC Storage at Baker Lake and Lake Shannon			Reductions		
	Max. Stage El. (ft)	Peak Flow (cfs)	Return Interval (year)	Max. Stage El. (ft)	Peak Flow (cfs)	Return Interval (year)	Max. Stage El. (ft)	Peak Flow (cfs)	Return Interval (year)
<i>Historical Events</i>									
Nov 8 to Nov 15, 1990	167.84*	149,000	25	166.62*	134,000	14	1.22	15,000	11
Nov 21 to Nov 28, 1990	167.61*	146,000	22	166.25*	129,900	13	1.36	16,100	9
Nov 26 to Dec 3, 1995	168.56*	159,000	29	166.99*	138,500	17	1.57	20,500	12
<i>Synthetic Events</i>									
10-year	165.72	123,804	10	164.49	110,804	6	1.23	13,000**	4
25-year	167.94	150,168	25	166.73	135,168	15	1.21	15,000**	10
50-year	170.43	185,392	50	168.88	162,392	30	1.55	23,000**	20

* Estimate based on projection of synthetic flood events, until further historical flood event data becomes available

** Estimate based on projection of historical flood events

Note: All stages are based on NGVD29. Concrete Gage datum is 130 ft above NGVD29.

Table 3 Downstream Skagit River Flood Reductions

Location	River Mile (RM)	Flood	With Current FC Storage at Baker Lake		With Additional FC Storage at Baker Lake and Lake Shannon		Reductions	
			Max. Stage (ft)	Peak Flow (cfs)	Max. Stage (ft)	Peak Flow (cfs)	Max. Stage (ft)	Peak Flow (cfs)
Downstream SR-9 Bridge	22.27	10-year	40.55	133,526	39.70	122,864	0.85	10,662
		25-year	41.85	159,682	41.27	145,155	0.58	14,527
		50-year	42.94	197,498	42.39	174,889	0.55	22,609
Mount Vernon Gage (Downstream Riverside Bridge)	17.05	10-year	37.35	124,704	36.30	115,917	1.05	8,787
		25-year	38.86	139,141	38.18	132,472	0.68	6,669
		50-year	40.09	153,592	39.47	145,872	0.62	7,720
North Fork	8.85	10-year	21.94	60,589	21.24	57,086	0.70	3,503
		25-year	23.11	66,209	22.61	63,616	0.50	2,593
		50-year	23.53	68,877	23.34	67,774	0.19	1,103
South Fork	8.75	10-year	21.32	64,048	20.65	58,885	0.67	5,163
		25-year	22.45	72,609	21.97	68,853	0.48	3,756
		50-year	22.85	76,014	22.67	74,478	0.18	1,536

Note: All stages are based on NGVD29

Table 4 Overbank Flow Reductions on Skagit River

Location	River Mile (RM)	Flood	With Current	With Additional	Reductions
			FC Storage at Baker Lake	FC Storage at Baker Lake and Lake Shannon	
			Peak Overflow (cfs)	Peak Overflow (cfs)	Peak Overflow (cfs)
Sedro Woolley	20.90 to 22.20	10-year	391	0	391
		25-year	15,982	7,220	8,762
		50-year	42,730	26,535	16,195
Mount Vernon	11.70 to 15.00	10-year	0	0	0
		25-year	353	0	353
		50-year	7,646	3,686	3,960

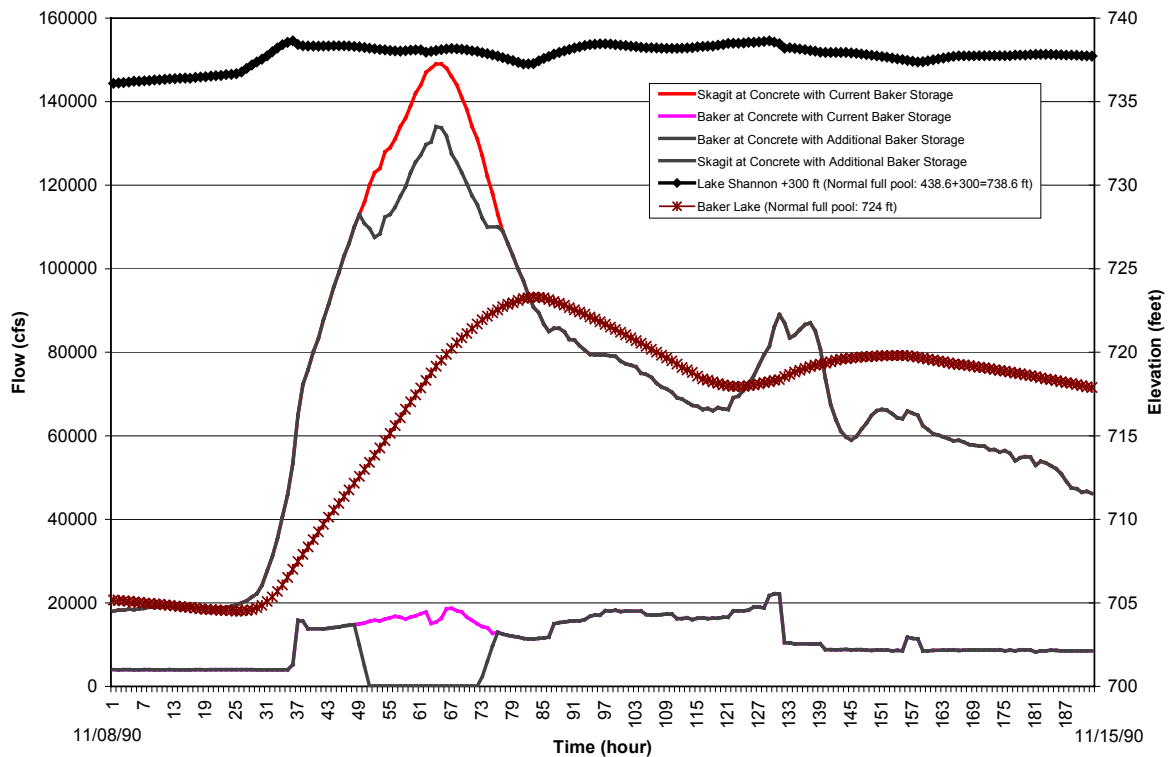


Figure 1 Hydrographs for November 8 to November 15, 1990 Flood

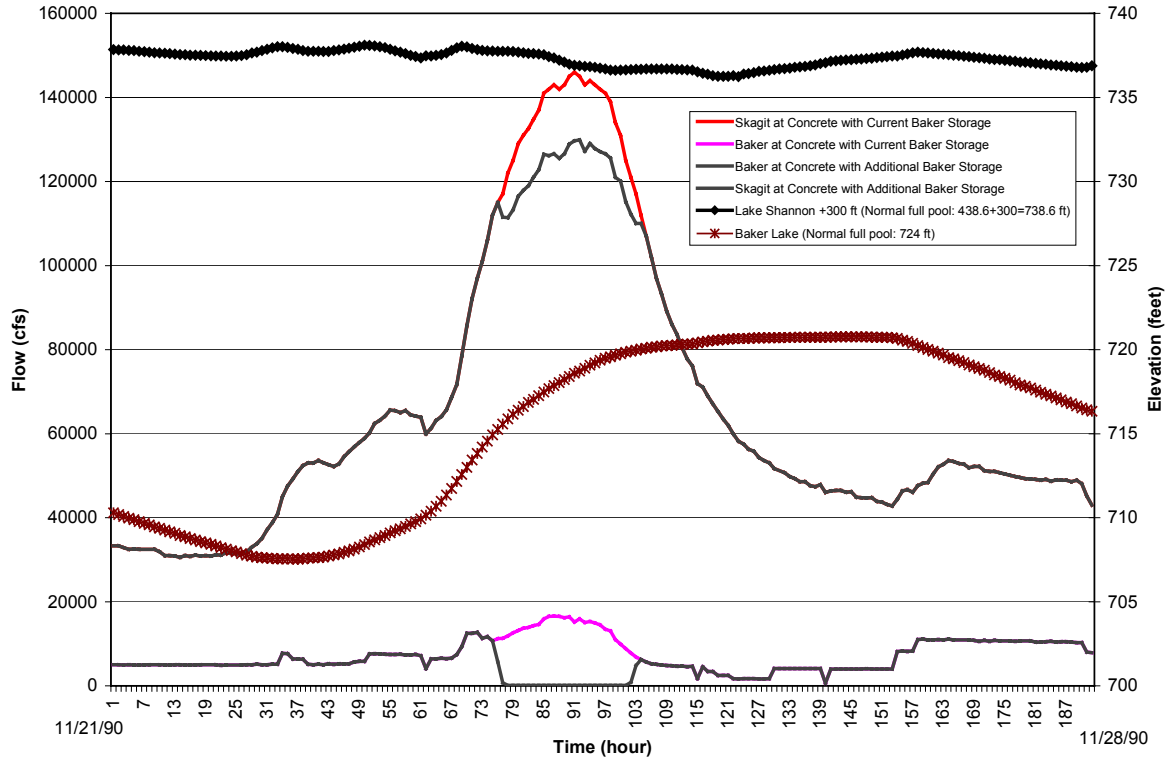


Figure 2 Hydrographs for November 21 to November 28, 1990 Flood

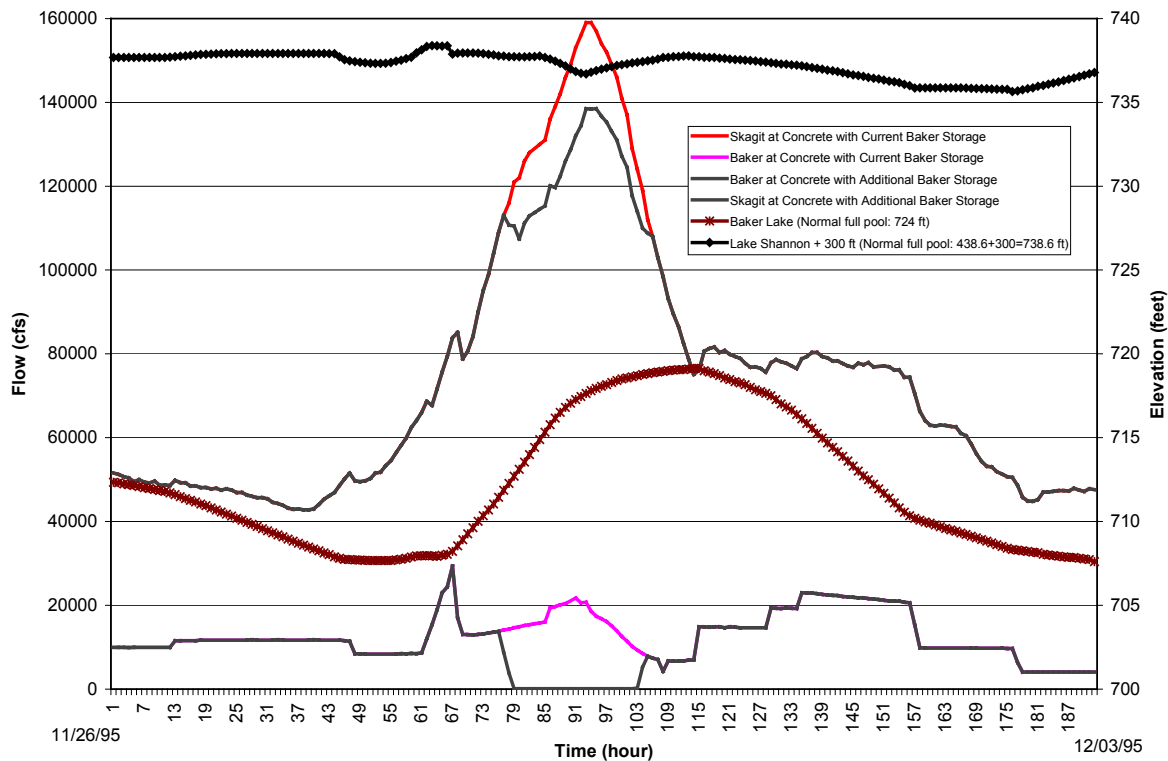


Figure 3 Hydrographs for November 26 to December 3, 1995 Flood

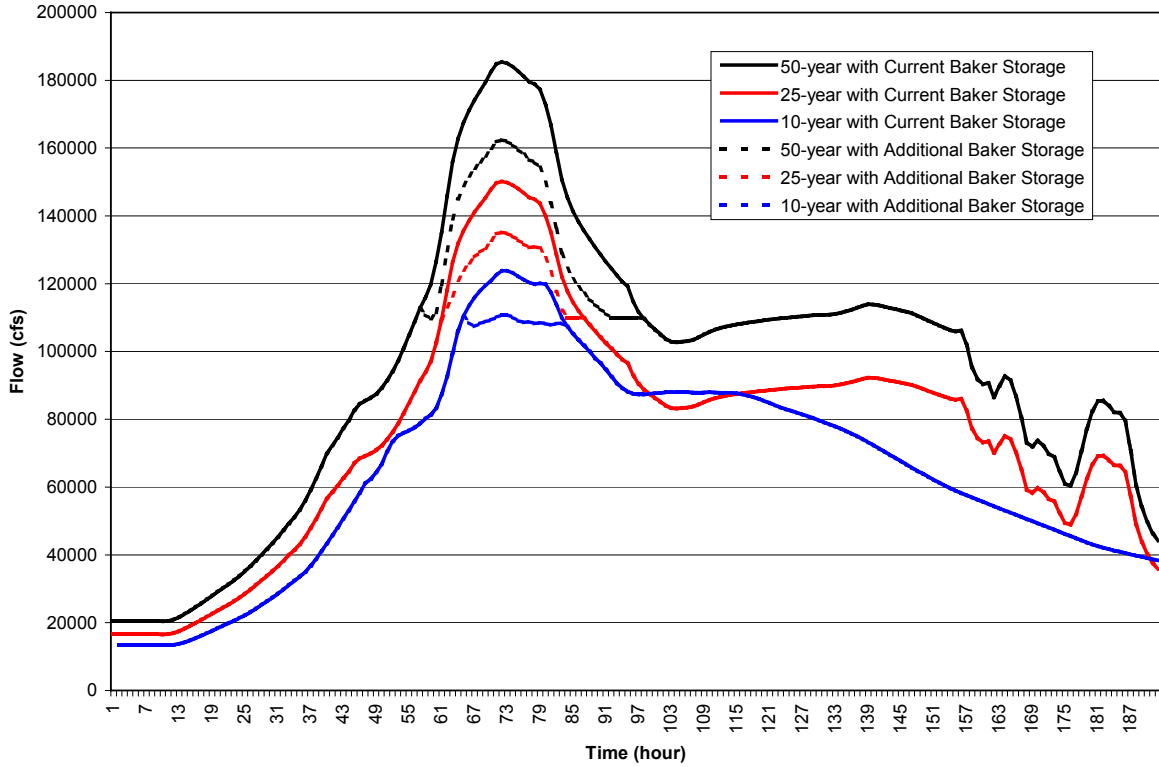


Figure 4 Synthetic Flood Hydrographs – Skagit River at Concrete Gage

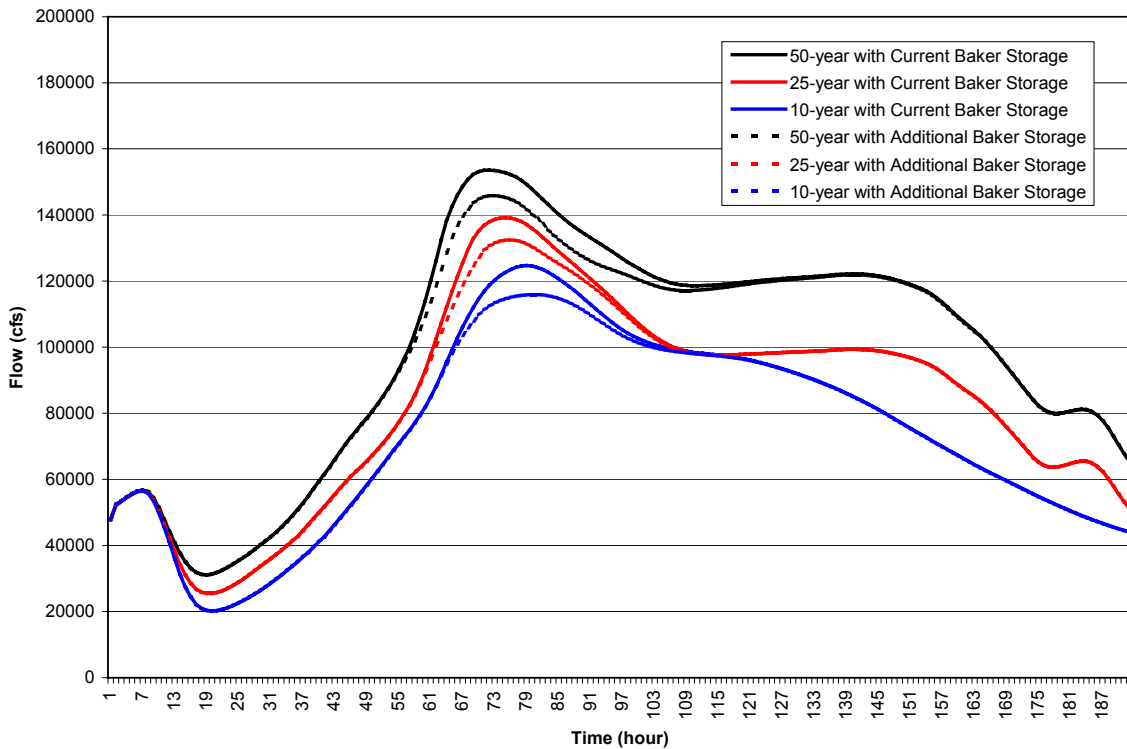


Figure 5 Synthetic Flood Hydrographs – Skagit River at Mount Vernon Gage

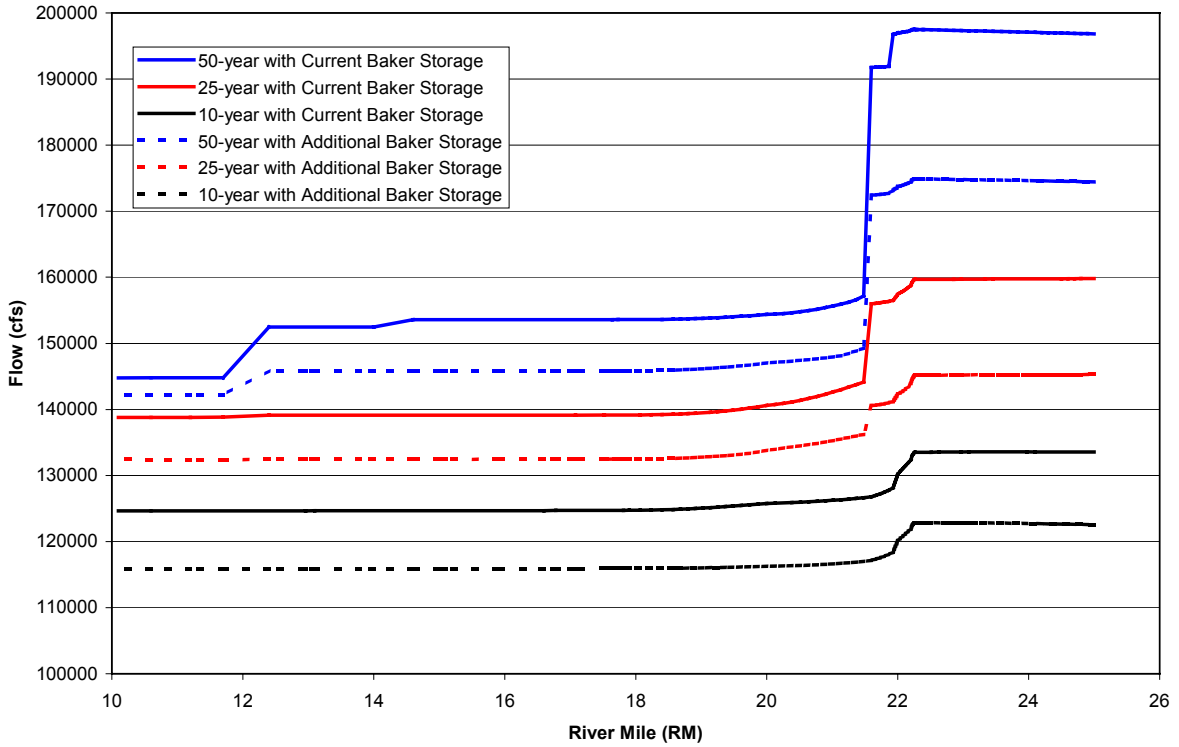


Figure 6 Peak Flood Flow Profiles on Skagit River

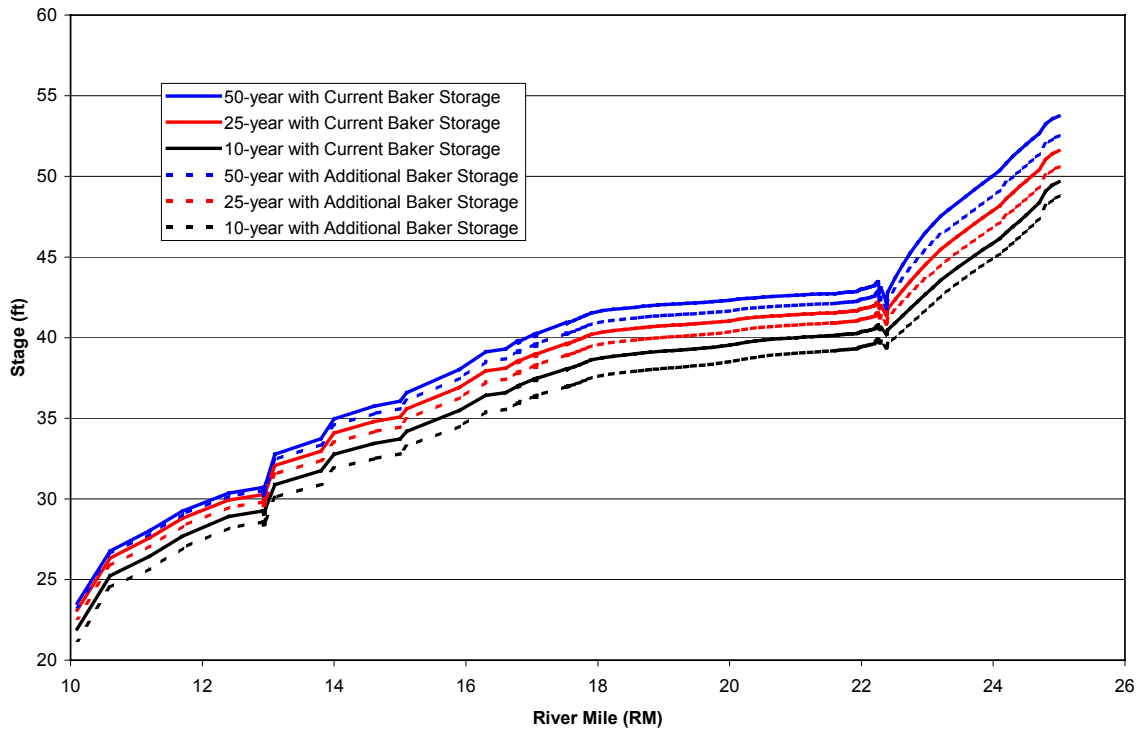


Figure 7 Maximum Flood Stage Profiles on Skagit River