3.0 TECHNICAL FEASIBILITY

3.1 INTRODUCTION

To enable seasonal storage and release of water from Lake Wenatchee, an impoundment structure would need to be constructed on the lake outlet channel. The structure would span from the north shore to the south shore as indicated in Exhibits 3.5-1 and 3.5-2 and would have the ability to be manipulated to allow storage of water during the late spring and summer, allow gradual release of stored water during the late summer and early fall, and to be completely invisible to lake outflow during the non-storage season such that lake outflows can pass unimpeded.

Section 3.2 presents the definition of the term "Ordinary High Water" (OHW) used for lakes and the results of a field survey to interpret the OHW elevation on Lake Wenatchee. Section 3.3 presents some perspective on historical hydrological data collected at various gages on the Wenatchee River and the results of computer modeling of the impoundment structure and beneficial seasonal water releases from Lake Wenatchee. This study investigates the use of an air-inflatable / deflatable rubber dam to be used as an impoundment structure to control the lake level. Section 3.4 makes an assessment of the change in potential wave energy as a result of a raised lake level. Section 3.5 addresses considerations for an impoundment structure and proposes a potential layout of such a structure.

3.2 DELINEATION OF ORDINARY HIGH WATER

The purpose of this section is to present the definition of the term "Ordinary High Water" (OHW) used for lakes and the results of a field survey to interpret the OHW elevation on Lake Wenatchee.

3.2.1 Definition of Ordinary High Water

A search for the commonly used definitions of OHW was made. The OHW is generally interpreted as the line on the shore established by the fluctuations of water and indicated by physical characteristics such as a clear, natural line impressed on the bank; shelving; changes in the character of soil destruction on terrestrial vegetation, or the presence of litter and debris; or other appropriate means that consider the characteristics of the surrounding area. It is usually marked as the lowest limit of perennial vegetation.

The legal definition of OHW used by the Department of Fish and Wildlife and defined in WAC (220-110-020(57)) is:

> "*Ordinary high water line means the mark on the shores of all waters that will be found by examining the bed and banks and ascertaining where the presence and action of waters are so common and usual and so long continued in ordinary years, as to mark upon the soil or vegetation a character distinct from that of the abutting upland: Provided, That in any area where the ordinary high water line cannot be found the ordinary high water line adjoining saltwater shall be the line of mean higher high water and the ordinary high water line adjoining freshwater shall be the elevation of the mean annual flood*".

Considerable judgment is required to identify representative OHW marks. It may be difficult to identify the mark on cut or rocky banks. A biologist experienced in vegetation typing typically performs the interpretation of OHW.

3.2.2 Fieldwork Performed to Interpret OHW

On February 14, 2003 Scott Stoneman, P.E. and Bob Montgomery, P.E. of Montgomery Water Group and Tom Kahler of The Watershed Company surveyed lake level, ordinary high water (OHW) marks, and other high water marks at various locations on Lake Wenatchee. Tom is a biologist experienced in vegetation surveys. Surveyed elevations are based on the USGS benchmark located at the outlet end of the lake. The USGS benchmark is stamped "1880 T" and is 1878.47 feet NGVD 1929 datum.

The work began by a survey of the lake level near the benchmark. The lake level was 1868.69 feet at 11:00 am that day. Ordinary High Water marks were interpreted and surveyed near Lake Wenatchee State Park and at several locations on both the north and south sides of the lake. Published benchmarks at other locations adjacent to the lake were not located so the lake level was used as the benchmark for the day. It is our opinion that the interpretation of OHW is subject to more uncertainty than the use of the lake as a benchmark so our methodology should be acceptable for this level of study. We also reviewed stream gaging records from the Department of Ecology (DOE) station on Wenatchee River below Lake Wenatchee and found the river stage fluctuated between 2.62 and 2.65 feet during the time of our surveys. Since the fluctuation in the DOE stage measurements was only 0.03 feet during the time of the survey, water level fluctuations should not be a factor in the use of the Lake as a benchmark.

Table 3.2-1 presents the elevations and locations of the OHW marks interpreted and surveyed. The quality of the sites varied as some of the sites were heavily disturbed from shoreline development and were very rocky. The best sites to interpret the OHW, in our opinion, are those near the State Park. Those OHW's were interpreted and surveyed to be 1870.2 to 1870.4 feet.

Table 3.2-1. Ordinary High Water Marks Interpreted and Surveyed.

Ordinary High Water Mark Location	Elevation
300 yds South of YMCA Camp	1870.5
300 yds South of YMCA Camp	1870.4
300 yds South of YMCA Camp	1870.2
Halfway between YMCA Camp and State Park	1870.2
Near USGS BM in State Park	1870.4
Near USGS BM in State Park	1870.2
Kane Beach - 18045 North Shore Drive	1870.8
Hoyt Beach – 16181 North Shore Drive	1870.7
Aspiri Beach – 16925 North Shore Drive	1869.8
South of Aspiri Beach	1869.6
Starr Beach – 15300 South Shore Road	1870.1
Average	***1870.3***
95% Confidence (2 x Std. Dev.)	***0.7***

The average OHW mark of all the sites reviewed is El. 1870.3 feet, which is also within the range of the sites interpreted and surveyed near the State Park. The 95% confidence interval for the OHW marks is 0.7 feet. The following photographs show the site and shoreline characteristics of the OHW marks interpreted and surveyed.

Photograph 3.2-1. Approximately 300 yards south of YMCA Camp, El. 1870.5.

Photograph 3.2-2. Approximately 300 yards south of YMCA Camp, El. 1870.4.

Photograph 3.2-3. Approximately 300 yards south of YMCA Camp, El. 1870.2.

Photograph 3.2-4. Halfway between YMCA Camp and State Park, El. 1870.2.

Photograph 3.2-5. Near USGS BM at State Park, El. 1870.4 – 1870.2.

Photograph 3.2-6. Kane beach, El. 1870.8.

Photograph 3.2-7. Hoyt beach, El. 1870.7.

Photograph 3.2-8. Aspiri beach, El. 1869.8.

Photograph 3.2-9. South of Aspiri beach, El. 1869.6.

Photograph 3.2-10. Starr beach, El. 1870.1.

3.3 HYDROLOGY

3.3.1 Lake Wenatchee Historic Water Levels

This section provides statistical input to Task 2.1.D, the determination of the ordinary high water level for Lake Wenatchee. Results in this section also serve other purposes including providing general familiarity with historic lake levels, baseline data to compare historic and potential future lake levels, and information to assist development of reservoir operation scenarios for the rubber dam impoundment structure described in Section 3.5.

USGS continuous daily flow data are available for Lake Wenatchee from January 1932 through September 1958. Instantaneous annual peak lake levels are available through water year 1979. Some additional daily lake levels are available, but because there are no corresponding additional flow values, they were not used in the current study. Many graphs and data tables are organized herein on a water year basis from October 1 through September 30. For example, water year 1933 would begin on October 1, 1932 and run through September 30, 1933. Water years are the standard way of presenting hydrologic data. The USGS flow records at Lake Wenatchee provide a continuous period of record for 26 complete water years from 1933 through 1958.

As an introduction, historic daily lake levels are presented for three years having varying hydrologic conditions. Figure 3.3-1 presents daily average Lake Wenatchee levels for selected representative wet, dry, and average years. The representative years were selected on the basis of average annual outflow from the lake. Figure 3.3-1 indicates the day-to-day variability of the lake level and also shows that lake levels during dry years can occasionally be higher than during wet years for the corresponding period. An El. 1870.3 line has been added to the figure as a reference to ordinary high water (OHW) as determined by the vegetation method.

Lake Wenatchee levels as measured and published by the USGS are based on the datum of 1912. Benchmarks near Lake Wenatchee and USGS quad sheets for the vicinity of Lake Wenatchee are based on the National Geodetic Vertical Datum of 1929 (NGVD29). NGVD29 is based on mean sea level, which means that mean sea level has an elevation of 0.0 feet. Because the datum of 1912 is no longer in use, all Lake Wenatchee levels as included herein have been converted to the NGVD29 datum. To convert datum of 1912 values to NGVD29 values, subtract 1.73 feet. In equation form, the datum conversion would be:

Lake level elevations on NGVD29 = lake level elevations on datum of 1912 – 1.73 feet

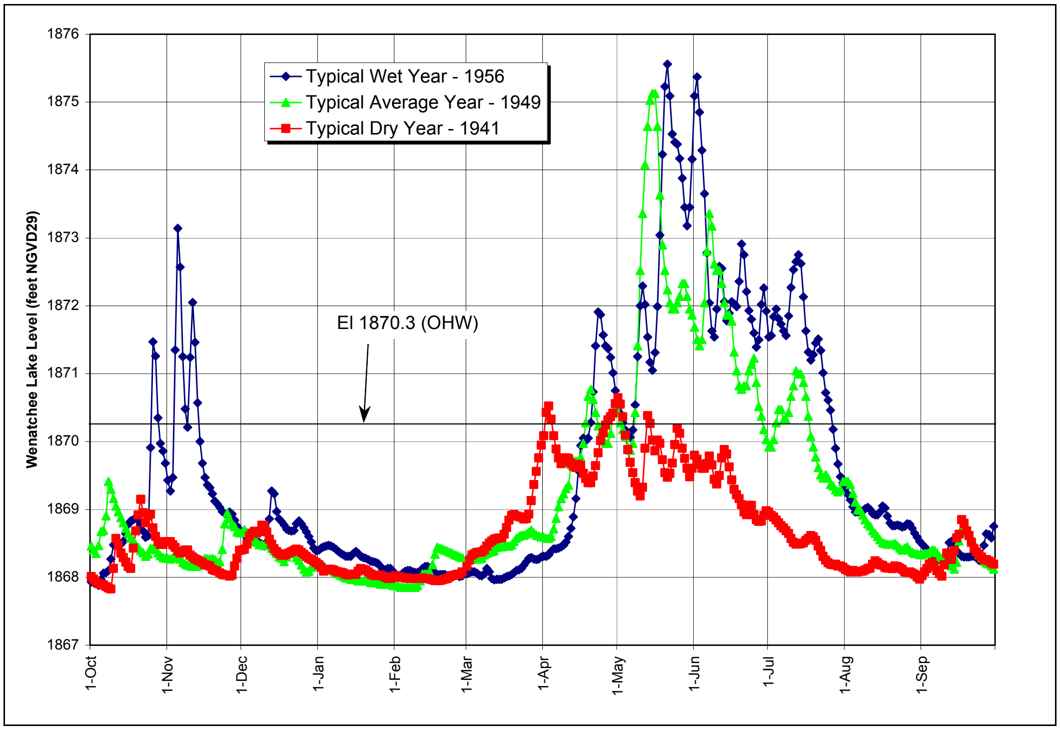


Figure 3.3-1. Representative wet, dry, and average year lake levels.

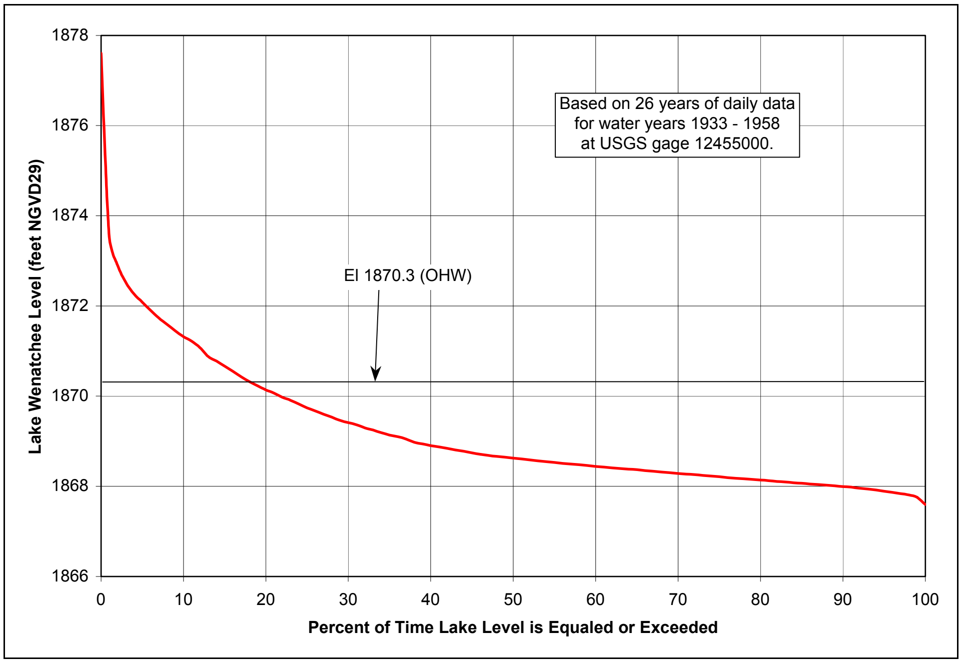


Figure 3.3-2. Lake Wenatchee level duration curve.

Figure 3.3-2 provides the Lake Wenatchee level duration curve based on daily data for the 26 years of record. The lake level duration curve indicates the percent of time that the lake level was less than or equal to the indicated level. The median lake level, which is exceeded 50% if the time, is at El. 1868.6. Figure 3.3-2 also indicates that daily water levels above El. 1871.3 occur about 10% of the time.

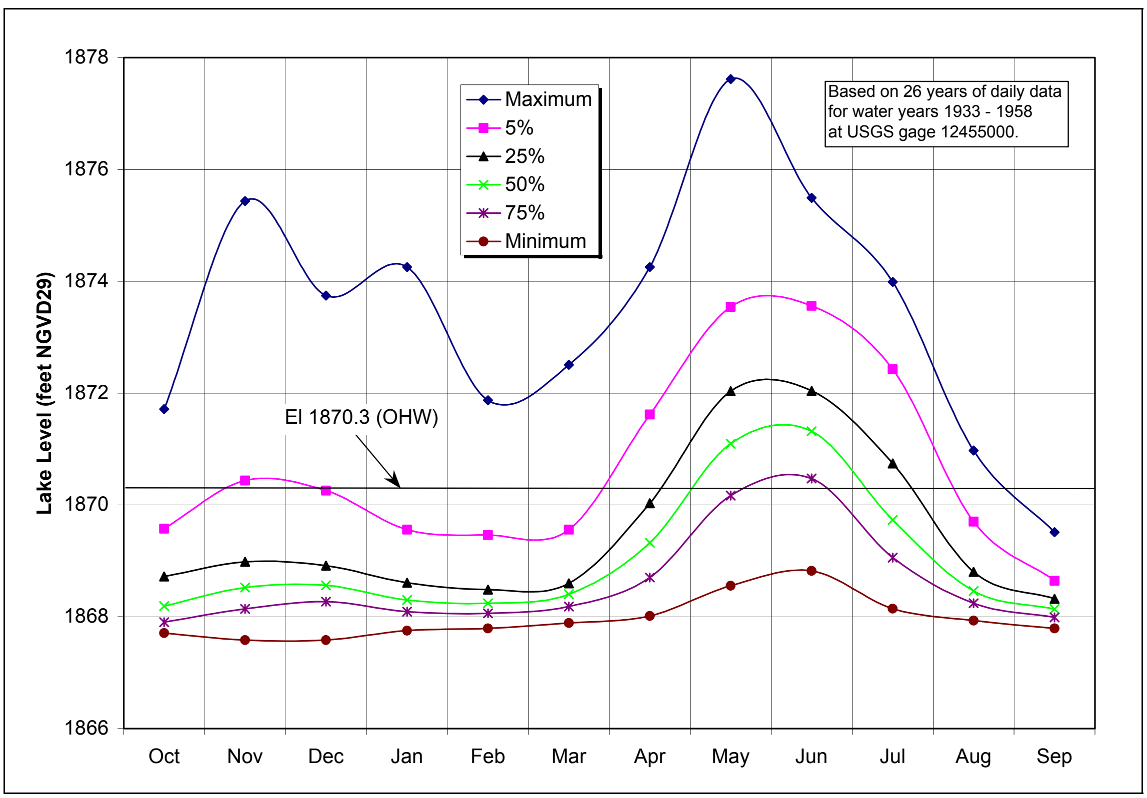


Figure 3.3-3. Lake Wenatchee monthly lake level frequency curves.

Figure 3.3-3 provides monthly lake level frequency data, based on the available daily data within each month. The information on Figure 3.3-3 includes the maximum and minimum daily lake levels recorded for each month during the 26-year period of record. The additional information is equivalent to a lake level duration curve for each month, in a manner similar to the lake level duration curve for the entire year that was presented on Figure 3.3-2.

Table 3.3-1 provides the detailed lake level frequency data by month from which the curves on Figure 3.3-3 were plotted. Daily data for the available 26-year period were used to develop the information in Table 3.3-1. The higher lake levels have typically occurred during the April through July period, but can occasionally occur in the late fall to early winter period.

Annual maximum recorded lake levels and outflows are available for a 48-year period from 1932 through 1979 at USGS gage 12455000, a much longer period than the continuous daily period of record. The complete series of annual instantaneous maximum lake levels is presented in Table 3.3-2. The data is sorted in two ways, both by chronological order and rank ordered by maximum lake level. The data in Table 3.3-2 indicates that the maximum lake level that can be expected with a frequency of about 1 in 2 years (the median high water level) would be at about El. 1873.8. The maximum water level in this period of record was at El. 1877.92 on May 29, 1948.

Table 3.3-1. Frequency data for historic Lake Wenatchee level (feet NGVD29).

% of Time Lake Level is Equaled of Exceeded	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Maximum	1871.7	1875.4	1873.7	1874.3	1871.9	1872.5	1874.3	1877.6	1875.5	1874.0	1871.0	1869.5
5	1869.6	1870.4	1870.3	1869.6	1869.5	1869.6	1871.6	1873.5	1873.6	1872.4	1869.7	1868.6
10	1869.2	1869.6	1869.5	1869.2	1869.1	1868.9	1870.9	1873.0	1872.7	1871.7	1869.4	1868.5
15	1869.0	1869.3	1869.2	1868.8	1868.9	1868.8	1870.5	1872.5	1872.5	1871.3	1869.1	1868.4
20	1868.9	1869.2	1869.1	1868.7	1868.6	1868.7	1870.2	1872.2	1872.2	1871.0	1869.0	1868.4
25	1868.7	1869.0	1868.9	1868.6	1868.5	1868.6	1870.0	1872.0	1872.0	1870.7	1868.8	1868.3
30	1868.6	1868.9	1868.8	1868.5	1868.4	1868.6	1869.8	1871.9	1871.9	1870.4	1868.7	1868.3
35	1868.5	1868.8	1868.7	1868.5	1868.4	1868.5	1869.7	1871.6	1871.7	1870.2	1868.6	1868.3
40	1868.4	1868.7	1868.7	1868.4	1868.3	1868.5	1869.5	1871.4	1871.6	1870.0	1868.6	1868.2
45	1868.3	1868.6	1868.6	1868.4	1868.3	1868.4	1869.4	1871.3	1871.4	1869.9	1868.5	1868.2
50	1868.2	1868.5	1868.6	1868.3	1868.2	1868.4	1869.3	1871.1	1871.3	1869.7	1868.5	1868.1
55	1868.1	1868.5	1868.5	1868.3	1868.2	1868.4	1869.2	1870.9	1871.2	1869.6	1868.4	1868.1
60	1868.0	1868.4	1868.5	1868.2	1868.2	1868.3	1869.1	1870.7	1871.0	1869.4	1868.4	1868.1
65	1868.0	1868.3	1868.4	1868.2	1868.1	1868.3	1868.9	1870.5	1870.8	1869.3	1868.3	1868.0
70	1867.9	1868.2	1868.3	1868.1	1868.1	1868.2	1868.8	1870.3	1870.7	1869.2	1868.3	1868.0
75	1867.9	1868.1	1868.3	1868.1	1868.1	1868.2	1868.7	1870.2	1870.5	1869.1	1868.2	1868.0
80	1867.9	1868.1	1868.2	1868.0	1868.0	1868.2	1868.6	1870.0	1870.3	1868.9	1868.2	1868.0
85	1867.8	1868.0	1868.1	1868.0	1868.0	1868.1	1868.6	1869.9	1870.1	1868.8	1868.1	1867.9
90	1867.8	1867.9	1868.0	1868.0	1868.0	1868.0	1868.5	1869.7	1869.9	1868.7	1868.1	1867.9
95	1867.8	1867.7	1867.8	1867.9	1867.8	1868.0	1868.4	1869.3	1869.7	1868.5	1868.0	1867.9
Minimum	1867.7	1867.6	1867.6	1867.8	1867.8	1867.9	1868.0	1868.6	1868.8	1868.1	1867.9	1867.8

Records at the Kane Boathouse, a stationary structure built on Lake Wenatchee in November 1938, indicate that the 48-year period from 1932 through 1979 does not contain the maximum water level events that have occurred more recently. Boathouse records show two flood levels higher than in 1948, one on November 24, 1990, and an even higher flood level on November 30, 1995. To corroborate the boathouse records, peak flow data was gathered at a gage downstream from Lake Wenatchee, USGS gage 12457000, Wenatchee River at Plain. The Wenatchee River at Plain has a 591 square mile drainage area, compared to the 273 square mile drainage area for the Wenatchee River at the outlet of Lake Wenatchee. The record for the USGS gage at Plain is unusually long, encompassing 79 years of data with only a few years missing during the period between 1911 and 2001.

Peak annual flows for the Wenatchee River at Plain are plotted chronologically on Figure 3.3-4. This figure shows that the flows on November 25, 1990 (water year 1991) and November 30, 1995 (water year 1996) were remarkably higher than the third largest flow that occurred in 1948. Most of the annual flood peaks in the record occur in the May-June period and are probably dominated by snowmelt. The maximum recent floods occurring in November are probably rain on snow events that are dominated by the rainfall component. Figure 3.3-4 confirms that the lake levels in November 1990 and November 1995 would undoubtedly have been higher than any that occurred in the period up to 1979.

Table 3.3-2. Lake Wenatchee annual instantaneous peak lake level data for USGS Gage 12455000.

Chronological Order			Rank Ordered		
Date of Annual Maximum Level	Lake Level (feet NGVD29)		Rank	Date of Annual Maximum Level	Lake Level (feet NGVD29)
February 28, 1932	1874.41		1	May 29, 1948	1877.92
June 16, 1933	1874.84		2	December 4, 1975	1877.57
April 24, 1934	1874.35		3	November 27, 1949	1876.59
January 27, 1935	1874.46		4	June 17, 1974	1876.02
June 3, 1936	1873.82		5	June 11, 1972	1875.81
June 3, 1937	1873.62		6	June 13, 1955	1875.55
May 26, 1938	1873.86		7	May 16, 1949	1875.48
May 16, 1939	1872.89		8	May 21, 1956	1875.40
May 24, 1940	1872.73		9	June 5, 1961	1875.01
May 1, 1941	1870.79		10	June 16, 1933	1874.84
May 26, 1942	1872.66		11	May 12, 1951	1874.73
May 26, 1943	1873.80		12	May 26, 1958	1874.73
May 16, 1944	1871.43		13	June 6, 1969	1874.68
May 31, 1945	1873.18		14	June 21, 1967	1874.53
May 27, 1946	1873.82		15	November 25, 1959	1874.47
May 28, 1947	1873.36		16	January 27, 1935	1874.46
May 29, 1948	1877.92		17	February 28, 1932	1874.41
May 16, 1949	1875.48		18	April 24, 1934	1874.35
November 27, 1949	1876.59		19	June 3, 1968	1874.14
May 12, 1951	1874.73		20	June 2, 1975	1874.11
May 19, 1952	1872.46		21	June 5, 1970	1874.00
July 9, 1953	1872.37		22	May 26, 1938	1873.86
May 20, 1954	1873.86		23	May 20, 1954	1873.86
June 13, 1955	1875.55		24	June 8, 1977	1873.85
May 21, 1956	1875.40		25	May 1, 1959	1873.83
May 9, 1957	1873.74		26	June 3, 1936	1873.82
May 26, 1958	1874.73		27	May 27, 1946	1873.82
May 1, 1959	1873.83		28	May 26, 1943	1873.80
November 25, 1959	1874.47		29	May 9, 1957	1873.74
June 5, 1961	1875.01		30	June 2, 1964	1873.69
June 17, 1962	1871.94		31	June 6, 1978	1873.65
November 20, 1962	1873.01		32	June 3, 1937	1873.62
June 2, 1964	1873.69		33	June 24, 1971	1873.37
June 11, 1965	1872.76		34	May 28, 1947	1873.36
May 7, 1966	1873.18		35	May 31, 1945	1873.18
June 21, 1967	1874.53		36	May 7, 1966	1873.18
June 3, 1968	1874.14		37	November 20, 1962	1873.01
June 6, 1969	1874.68		38	May 16, 1939	1872.89
June 5, 1970	1874.00		39	June 11, 1965	1872.76
June 24, 1971	1873.37		40	May 24, 1940	1872.73
June 11, 1972	1875.81		41	May 26, 1942	1872.66
May 18, 1973	1872.36		42	May 19, 1952	1872.46
June 17, 1974	1876.02		43	July 9, 1953	1872.37
June 2, 1975	1874.11		44	May 18, 1973	1872.36
December 4, 1975	1877.57		45	June 6, 1979	1872.05
June 8, 1977	1873.85		46	June 17, 1962	1871.94
June 6, 1978	1873.65		47	May 16, 1944	1871.43
June 6, 1979	1872.05		48	May 1, 1941	1870.79

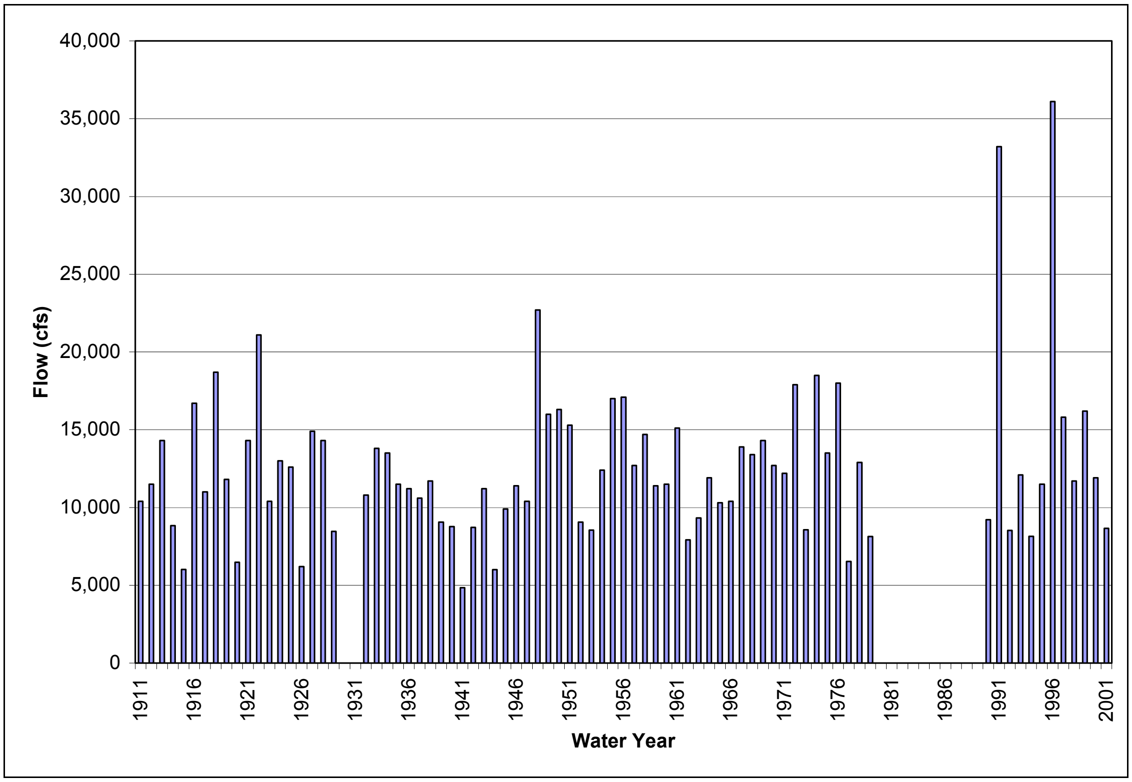


Figure 3.3-4. Peak annual flows at USGS Gage 12457000, Wenatchee River at Plain.

3.3.2 Storage Operation Model

A daily storage operation model was developed for Lake Wenatchee for Task 2.1.B. The purpose of the daily storage operation model is to determine the amount of flow that could be stored with a rubber dam impoundment structure during periods of high spring to early summer runoff for later release during the low flow periods of late summer to early fall. The model would also determine the effects of a rubber dam on lake levels and the downstream flow regime. The model would operate on a continuous record of daily data for a long-term period of years.

3.3.2.1 Historic Flow Data

Daily flow data is available on the Wenatchee River at the following USGS gages:

- USGS gage 12455000, Wenatchee River below Wenatchee Lake. Period of record is from January 1932 through September 1958. Drainage area is 273 square miles.
- USGS gage 12457000, Wenatchee River at Plain. Period of record is from October 1910 through September 1979 (monthly flows only for some periods), and October 1989 through September 2001. Drainage area is 591 square miles.
- USGS gage 12459000, Wenatchee River at Peshastin. Period of record is March 1929 through September 2001. Drainage area is 1,000 square miles, approximately.
- USGS gage 12462500, Wenatchee River at Monitor. Period of record is October 1962 through September 2001. Drainage area is 1,301 square miles.

The period of record to be used in the operation model was selected as the 26 water years 1933 through 1958, which is the period of record of full water years at gage 12455000 at Lake Wenatchee. Daily flow data at Plain and Peshastin for the common period of record with the gage below Lake Wenatchee was also included in the operation model. The gage at Monitor does not have a common period of record with the gage below Lake Wenatchee and was not included in the operation model, but the flows are only about 7% greater than the flows at Peshastin.

3.3.2.1.1 Comparison of Selected Period of Operation to Longer Term Data

It is generally desirable to use the longest period of data that is available for the operation model to ensure that the average and range of operating conditions are adequately represented. Because flow data is available on the Wenatchee River for a period much longer than water years 1933 through 1958, a comparison was made with the longer-term data.

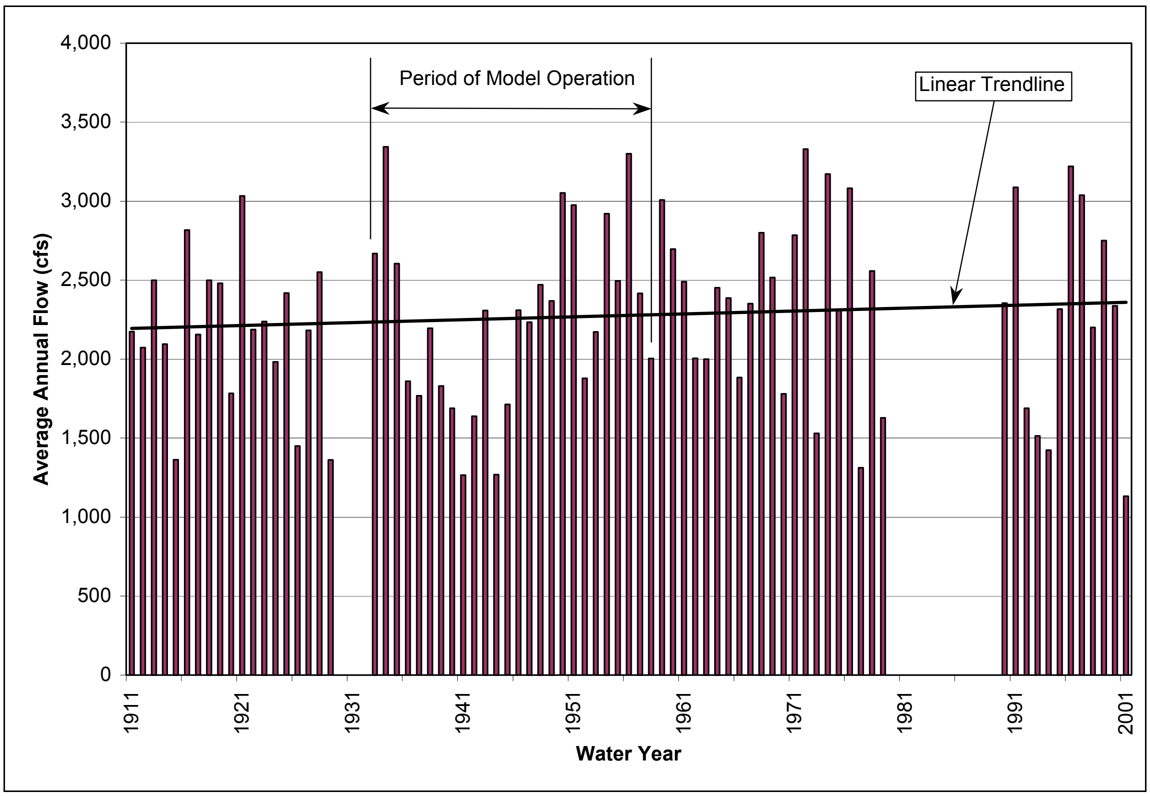


Figure 3.3-5. Annual average flow (cfs) at USGS Gage 12457000, Wenatchee River at Plain.

Figure 3.3-5 presents the annual average flow for the Wenatchee River at Plain. A linear trendline fitted to the annual flows indicates that there has not been a significant trend in the annual flows. The period of model operation from 1933 through 1958 appears to reasonably represent the average and variability of flow in the longer-term period. Only water year 2001 had a lower average flow than water year 1941and water year 1934 had the highest annual average flow on record.

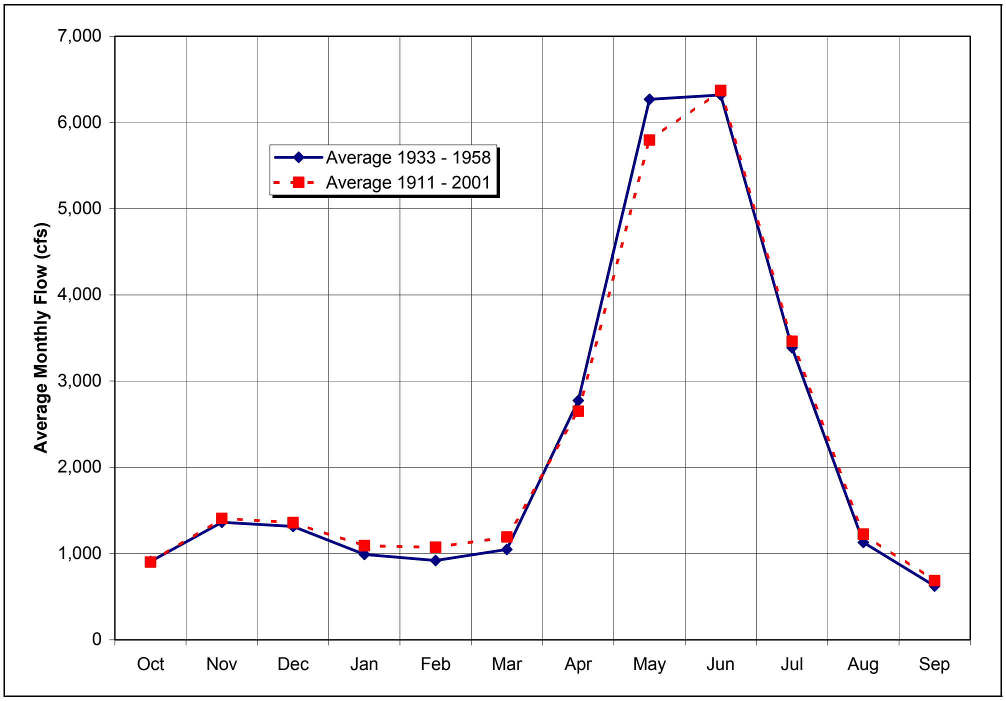


Figure 3.3-6. Monthly average flow (cfs) at USGS Gage 12457000, Wenatchee River at Plain.

Figure 3.3-6 presents the average monthly flows for the Wenatchee River at Plain for both the period of model operation, 1933 through 1958, as well as the average monthly flows for the entire period of record. The results on Figure 3.3-6 indicate that there is no significant difference between the two periods. From these comparisons it is concluded that water years 1933 through 1958 are an adequate period to represent the average and range of operating conditions for the rubber dam.

3.3.2.1.2 Historic Flow Data Summaries

This section provides a summary of historic flow data at the three USGS gages on the Wenatchee River that are included in the model, which are at Lake Wenatchee, at Plain, and at Peshastin. The data summaries are based on daily flow data for the common period of record of water years 1933 through 1958. The data in the tables provides the baseline historic conditions to which the potential future conditions with the rubber dam can be compared.

The following data summaries are of two types for each gauging station, monthly flow data and monthly flow frequency data. The flow frequency data essentially presents a daily flow duration curve for each month at each gauging station.

Table 3.3-3. Historic flow (cfs) at USGS Gage 12455000, Wenatchee River below Lake Wenatchee.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1933	402	2,128	1,149	620	461	529	1,054	1,873	4,508	3,659	1,255	572	1,520
1934	1,565	1,821	2,237	1,549	1,185	2,113	4,715	3,312	2,444	1,117	506	287	1,906
1935	475	1,656	717	1,528	1,209	741	925	3,061	3,983	2,181	655	428	1,462
1936	241	198	197	222	186	369	1,986	4,467	3,783	1,014	398	289	1,115
1937	204	147	317	222	200	303	766	2,803	4,901	2,057	440	289	1,056
1938	318	812	737	605	331	424	1,844	3,803	3,908	1,500	367	260	1,245
1939	260	355	588	887	367	537	1,813	3,381	2,545	1,732	496	251	1,105
1940	343	711	970	384	415	818	1,948	3,385	2,356	759	335	265	1,060
1941	516	400	532	298	262	804	1,907	1,840	1,338	588	323	457	773
1942	1,087	759	1,036	358	300	363	1,535	2,291	2,274	1,291	432	230	1,000
1943	171	321	464	466	364	461	2,355	2,919	4,208	3,502	932	356	1,380
1944	256	288	695	274	273	482	1,095	2,332	2,128	702	293	355	766
1945	337	392	613	926	776	453	689	3,076	2,813	1,241	391	312	1,003
1946	515	566	347	360	295	418	1,349	4,935	3,995	2,344	684	309	1,349
1947	408	359	875	657	844	1,194	2,173	4,102	2,970	1,540	550	312	1,335
1948	1,045	947	634	459	419	395	1,039	3,834	5,773	1,807	747	442	1,464
1949	665	487	480	265	336	540	1,709	4,807	3,811	2,082	731	468	1,371
1950	606	1,936	1,383	651	438	812	971	2,913	5,806	4,171	1,303	464	1,793
1951	1,124	1,350	1,608	902	1,598	599	1,926	4,162	3,733	2,004	597	346	1,661
1952	837	784	400	274	309	334	1,631	3,378	2,924	1,674	557	259	1,117
1953	184	153	168	1,077	1,376	614	1,220	3,191	3,225	2,975	944	385	1,292
1954	506	891	1,057	697	504	533	1,108	3,827	4,218	4,556	1,971	887	1,739
1955	618	1,457	779	425	494	324	647	2,043	5,137	3,338	1,218	470	1,414
1956	965	2,020	725	435	298	318	1,848	5,125	5,066	3,584	911	495	1,822
1957	924	876	1,717	507	390	564	1,319	4,788	3,211	1,185	500	312	1,365
1958	253	384	439	357	515	628	1,237	5,017	3,236	955	424	342	1,152
Average	570	854	802	593	544	603	1,570	3,487	3,627	2,060	691	379	1,318

Table 3.3-4. Historic flow (cfs) Frequency at USGS Gage 12455000, Wenatchee River below Lake Wenatchee.

% of Time Flow is Equaled of Exceeded	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Maximum	3,990	9,350	6,800	7,550	4,200	5,060	7,550	13,000	9,440	7,160	3,020	1,490
5	1,560	2,490	2,290	1,540	1,440	1,540	3,860	6,510	6,540	4,950	1,690	676
10	1,180	1,580	1,490	1,180	1,040	952	2,990	5,730	5,390	3,970	1,330	584
15	1,020	1,310	1,180	852	874	786	2,560	5,080	5,040	3,460	1,080	507
20	868	1,130	1,050	718	672	691	2,260	4,690	4,630	3,110	962	470
25	744	989	928	648	550	639	2,040	4,420	4,430	2,840	820	438
30	641	916	830	580	479	608	1,800	4,180	4,250	2,480	736	419
35	564	829	755	537	460	572	1,650	3,900	3,990	2,250	676	396
40	498	736	698	500	436	532	1,530	3,640	3,800	2,040	604	373
45	420	657	648	462	408	511	1,410	3,420	3,600	1,890	567	350
50	362	579	608	426	390	491	1,300	3,180	3,470	1,720	533	333
55	304	525	577	401	362	467	1,190	2,970	3,280	1,560	506	314
60	264	460	539	376	344	442	1,060	2,760	3,080	1,400	473	302
65	247	403	486	349	329	414	938	2,610	2,920	1,290	445	289
70	232	364	449	324	314	386	825	2,390	2,750	1,130	410	274
75	222	335	408	309	295	359	727	2,190	2,530	1,030	391	261
80	208	306	359	287	281	344	672	2,060	2,330	916	370	252
85	197	268	328	272	270	319	609	1,880	2,170	817	338	242
90	183	206	281	247	243	287	545	1,710	1,910	699	314	231
95	170	155	194	220	194	268	493	1,310	1,640	584	289	217
Minimum	143	100	100	160	175	215	273	604	838	338	235	175

Table 3.3-5. Historic flow (cfs) at USGS Gage 12457000, Wenatchee River at Plain.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1933	651	3,156	1,962	1233	680	656	2,043	4,319	8,038	6,086	2,123	988	2,668
1934	2,527	3,066	3,720	2,537	1,994	3,719	8,162	6,516	4,434	1,953	918	538	3,344
1935	785	2,716	1269	2,399	2,162	1433	1920	5,941	7,007	3,749	1168	716	2,604
1936	470	401	392	426	387	688	3,279	7,480	5,986	1,625	651	471	1,859
1937	344	236	571	352	332	595	1395	4,628	8,075	3,315	819	521	1,768
1938	544	1340	1240	1059	630	838	3,272	6,838	6,899	2,494	692	452	2,196
1939	462	635	1011	1421	659	946	3,055	5,632	4,129	2,671	827	424	1,830
1940	465	857	1446	643	676	1328	3,260	5,521	3,847	1258	523	400	1,689
1941	807	617	828	499	444	1313	3,240	3,174	2,236	886	456	671	1,266
1942	1,528	1243	1,654	631	519	635	2,614	3,972	3,817	2,029	644	313	1,638
1943	251	526	765	805	635	800	3,857	5,064	7,276	5,627	1435	582	2,307
1944	458	502	1093	476	491	826	1,823	3,876	3,461	1154	468	557	1,268
1945	562	636	905	1625	1292	766	1231	5,344	4,956	2,060	643	506	1,713
1946	786	1080	611	619	486	746	2,309	8,640	6,893	3,759	1120	542	2,310
1947	663	599	1348	1010	1272	1,945	3,835	7,266	5,033	2,389	878	504	2,233
1948	1,600	1529	1064	715	668	643	1,744	6,615	10,080	3,000	1235	712	2,470
1949	1072	832	798	469	575	869	3,154	8,736	6,570	3,307	1174	756	2,369
1950	966	2,869	2,149	1090	760	1325	1779	5,413	10,330	6,968	2,071	798	3,052
1951	1,678	2,113	2,544	1531	2,805	1192	3,719	8,119	6,943	3,426	1036	627	2,975
1952	1296	1223	713	525	573	656	2,781	5,956	4,906	2,535	870	427	1,877
1953	300	271	296	1,532	2,064	1071	2,057	5,656	5,798	4,891	1472	645	2,172
1954	810	1301	1,593	1054	817	901	1,995	6,868	7,549	7,540	3,045	1383	2,920
1955	1026	2,232	1308	768	852	628	1196	3,945	9,442	5,733	1,974	791	2,495
1956	1593	3,316	1379	800	584	636	3,654	9,771	9,198	6,094	1618	825	3,301
1957	1462	1424	2,801	888	687	998	2,566	8,855	5,769	2,006	851	527	2,415
1958	480	689	750	636	889	1089	2,214	8,843	5,621	1535	687	533	2,003
Average	907	1,362	1,316	990	921	1,048	2,775	6,269	6,319	3,388	1,131	623	2,259

Table 3.3-6. Historic flow (cfs) Frequency at USGS Gage 12457000, Wenatchee River at Plain.

% of Time Flow is Equaled of Exceeded	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Maximum	5,840	13,600	9,880	10,100	8,720	7,710	13,200	21,900	16,800	12,200	4,740	2,560
5	2,330	3,960	3,580	2,450	2,390	2,650	6,480	11,800	11,500	8,110	2,680	1,100
10	1,820	2,640	2,390	1,900	1,770	1,670	5,230	10,100	9,420	6,680	2,080	941
15	1,550	2,140	1,900	1,430	1,410	1,340	4,540	9,020	8,750	5,720	1,780	838
20	1,350	1,840	1,660	1,230	1,110	1,210	4,030	8,490	8,140	5,070	1,560	772
25	1,180	1,610	1,510	1,120	950	1,120	3,640	7,940	7,790	4,720	1,360	726
30	1,030	1,440	1,390	1,010	800	1,080	3,210	7,410	7,490	4,100	1,230	690
35	908	1,320	1,290	930	748	1,010	2,920	6,970	7,120	3,660	1,120	652
40	800	1,160	1,190	868	724	938	2,740	6,590	6,790	3,280	1,040	622
45	698	1,050	1,100	813	689	893	2,500	6,190	6,430	3,040	960	590
50	615	978	1,040	740	658	842	2,310	5,840	6,150	2,760	914	561
55	520	873	970	684	634	789	2,140	5,430	5,810	2,530	853	542
60	481	761	898	635	607	743	1,920	5,070	5,430	2,310	818	517
65	446	691	813	590	583	694	1,710	4,720	5,020	2,070	755	490
70	419	642	757	560	563	667	1,490	4,430	4,660	1,850	695	462
75	390	575	701	540	544	648	1,340	4,000	4,270	1,670	644	441
80	365	508	625	514	508	628	1,250	3,670	3,970	1,480	600	420
85	340	468	568	484	457	598	1,120	3,420	3,630	1,330	547	400
90	320	386	474	450	420	559	1,010	3,000	3,240	1,170	496	370
95	271	271	379	390	370	507	875	2,520	2,740	928	452	344
Minimum	226	186	196	283	300	385	495	1,240	1,350	512	358	262

Table 3.3-7. Historic flow (cfs) at USGS Gage 12459000, Wenatchee River at Peshastin.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1933	867	4,459	2,710	1680	962	971	2,898	5,920	11,710	8,584	2,817	1254	3,744
1934	3,640	4,546	5,648	3,696	3,043	5,172	11,250	8,911	6,079	2,644	1119	683	4,706
1935	1086	3,897	1888	3,505	3,131	2095	2780	8,208	9,941	4,945	1447	854	3,644
1936	612	525	497	550	486	1018	4,693	11,090	8,934	2,257	790	588	2,677
1937	475	339	728	493	476	839	1923	6,602	11,440	4,481	1071	637	2,463
1938	720	1778	1697	1445	872	1293	4,696	9,777	10,070	3,345	816	522	3,091
1939	622	845	1310	1841	901	1372	4,234	7,447	5,516	3,481	981	495	2,429
1940	611	1151	2037	883	923	1855	4,385	7,773	5,214	1586	660	543	2,307
1941	1045	778	1072	643	618	1867	4,334	4,414	3,191	1164	587	953	1,725
1942	2,089	1761	2,308	887	705	880	3,661	5,770	5,499	2,801	789	426	2,305
1943	336	782	1122	1190	972	1239	5,501	6,854	10,070	7,572	1835	689	3,186
1944	627	647	1444	616	651	1126	2,518	5,677	5,062	1576	577	767	1,778
1945	780	846	1293	2125	1855	1090	1712	7,403	6,808	2,667	785	682	2,339
1946	1044	1452	820	849	657	1113	3,418	12,110	9,592	4,993	1394	683	3,191
1947	930	849	1863	1457	1823	2,884	5,250	10,140	7,097	3,265	1125	733	3,125
1948	2,306	2288	1576	1050	979	972	2,441	9,433	14,750	4,234	1639	933	3,554
1949	1507	1161	1175	689	989	1450	4,572	12,410	9,379	4,560	1533	1046	3,385
1950	1455	4,001	2,965	1495	1121	1843	2539	7,448	14,650	9,491	2,687	1017	4,237
1951	2,255	2,893	3,563	2194	3,943	1862	5,379	11,250	9,754	4,651	1356	802	4,154
1952	1848	1765	1081	809	830	948	3,978	8,314	6,723	3,367	1081	615	2,621
1953	463	384	421	2,076	2,917	1588	2,883	7,955	8,183	6,888	1967	802	3,045
1954	979	1558	2,043	1371	1143	1325	2,728	9,400	10,230	10,350	4,003	1746	3,927
1955	1329	2,889	1732	1019	1140	880	1706	5,305	13,320	7,695	2,420	942	3,368
1956	2034	4,511	2107	1213	906	1001	5,719	13,800	13,030	8,358	2149	1105	4,676
1957	1901	1853	3,794	1199	932	1474	3,348	12,430	7,723	2,577	1069	699	3,267
1958	655	903	992	873	1330	1593	3,009	12,390	7,734	2019	808	653	2,755
Average	1,239	1,879	1,842	1,379	1,319	1,529	3,906	8,778	8,912	4,598	1,443	803	3,142

Table 3.3-8. Historic flow (cfs) Frequency at USGS Gage 12459000, Wenatchee River at Peshastin.

% of Time Flow is Equaled of Exceeded	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Maximum	7,700	18,300	15,700	14,200	11,900	10,200	18,400	30,900	23,800	17,200	6,220	3,350
5	3,120	5,290	5,100	3,520	3,560	3,800	9,260	16,800	16,400	11,400	3,480	1,450
10	2,520	3,600	3,360	2,570	2,620	2,440	7,520	14,300	13,400	9,470	2,760	1,210
15	2,100	3,000	2,640	2,020	2,020	2,000	6,360	12,900	12,400	7,830	2,330	1,070
20	1,830	2,500	2,340	1,700	1,590	1,770	5,550	12,000	11,700	6,830	1,990	998
25	1,620	2,210	2,140	1,510	1,380	1,690	5,010	11,300	11,200	6,260	1,780	942
30	1,370	1,990	1,960	1,400	1,200	1,620	4,450	10,500	10,600	5,540	1,560	892
35	1,210	1,770	1,780	1,300	1,070	1,500	4,040	9,780	10,000	4,910	1,430	840
40	1,070	1,590	1,660	1,230	1,010	1,420	3,710	9,260	9,520	4,450	1,310	798
45	958	1,450	1,560	1,110	977	1,330	3,490	8,660	9,010	4,080	1,220	750
50	822	1,300	1,450	1,030	940	1,240	3,240	8,020	8,550	3,740	1,110	718
55	712	1,160	1,350	976	900	1,160	3,050	7,520	8,000	3,380	1,050	686
60	646	1,010	1,240	911	878	1,070	2,720	6,990	7,500	3,050	998	660
65	598	932	1,110	850	840	1,030	2,470	6,530	7,030	2,780	918	634
70	569	862	1,040	794	798	990	2,160	6,030	6,520	2,480	855	608
75	542	770	942	750	755	945	1,960	5,420	5,960	2,240	777	582
80	520	686	876	712	686	911	1,800	5,010	5,430	1,960	724	536
85	486	598	775	640	624	865	1,630	4,610	4,980	1,740	672	503
90	454	520	630	604	590	797	1,510	4,150	4,400	1,480	604	481
95	395	390	486	520	460	705	1,270	3,460	3,820	1,200	576	435
Minimum	276	270	270	400	430	525	757	1,660	1,940	636	460	347

3.3.2.1.3 Rating Curves

Rating curves provide a graphical presentation of the relationship between flow rate and water level at a given location. The rating curve for outflow from Lake Wenatchee under historic conditions (no rubber dam or rubber dam fully down) as used in the operation model is presented on Figure 3.3-7.

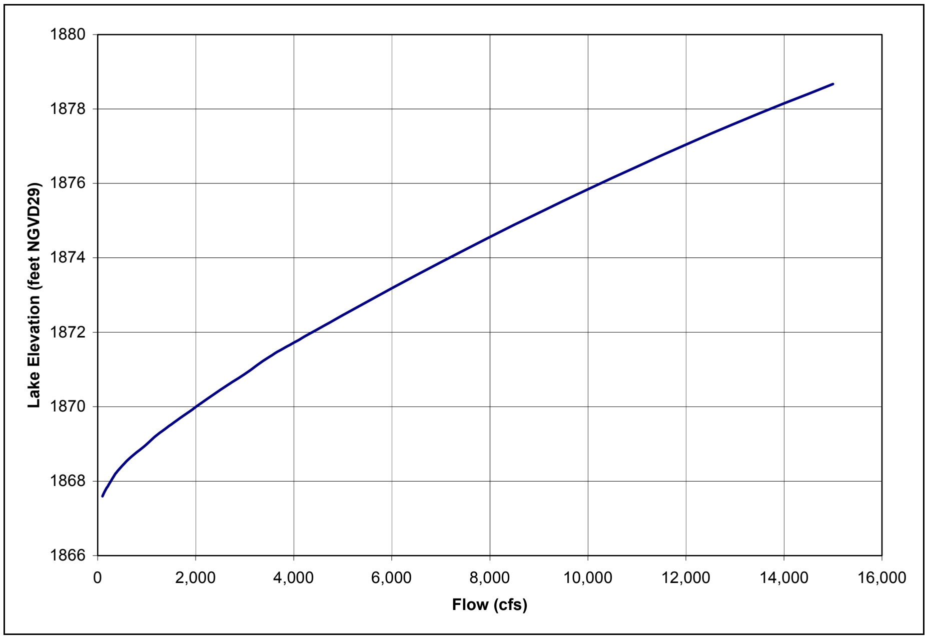


Figure 3.3-7. Lake Wenatchee outflow rating curve.

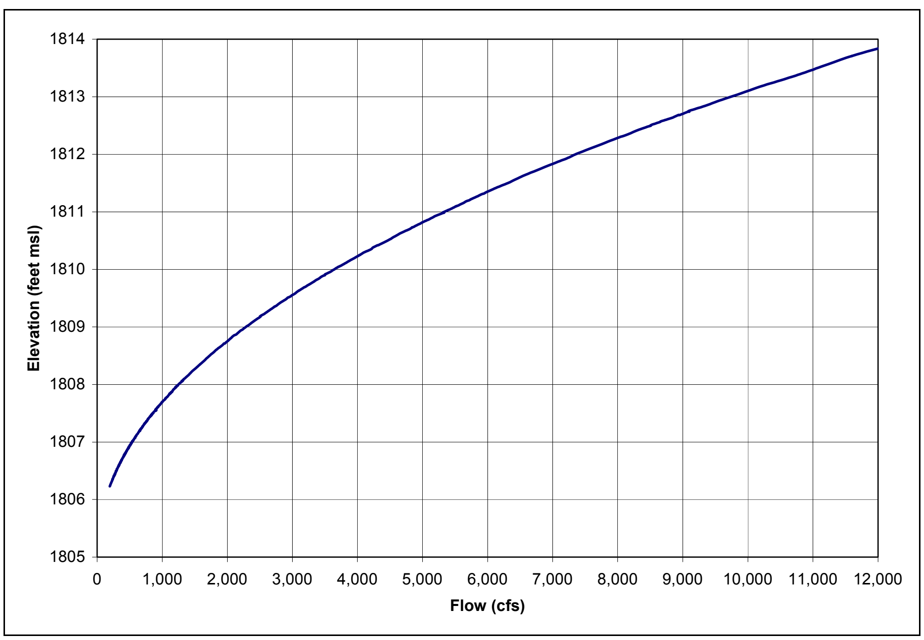


Figure 3.3-8. Rating curve for USGS Gage 12457000, Wenatchee River at Plain.

The downstream variation of water level with flow is a consideration for fishery issues and could have some impact on future operation of the rubber dam. To provide an indication of how water levels vary with flow rates at downstream locations, a rating curve for the Wenatchee River at Plain is provided on Figure 3.3-8. In a similar manner, the rating curve for the Wenatchee River at Peshastin is provided on Figure 3.3-9.

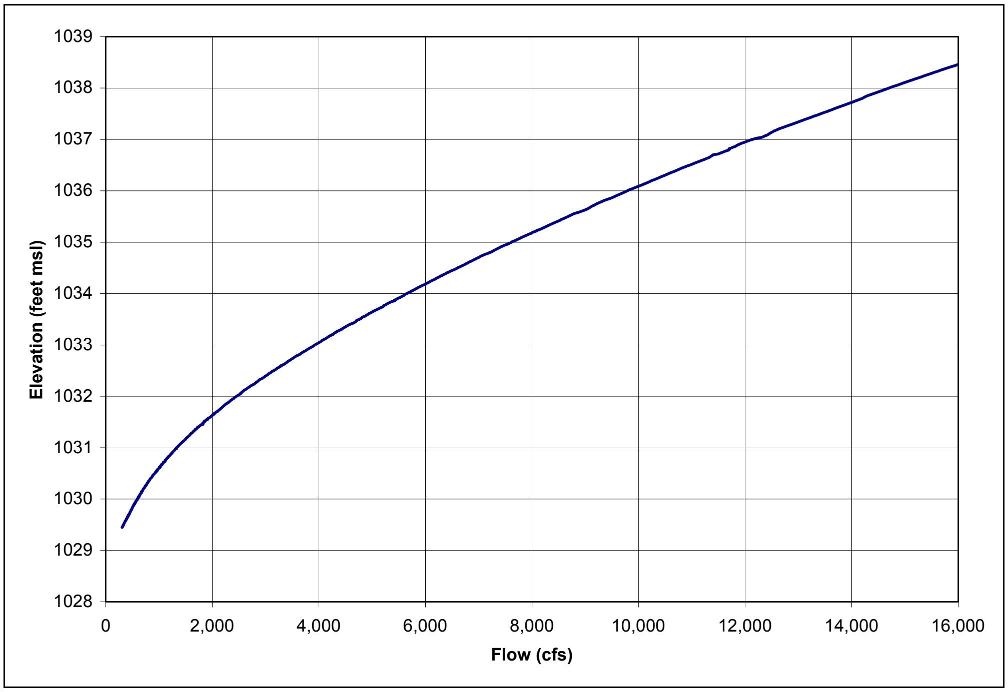


Figure 3.3-9. Rating curve for USGS Gage 12459000, Wenatchee River at Peshastin.

3.3.2.2 Operation Model Description

This section provides a general description of the storage operation model input and output. A basic input to any storage operation model is the inflow to the lake or reservoir. For Lake Wenatchee, the available flow data is lake outflow, not the required lake inflow. Lake inflow was developed by a process called reverse routing. The basic storage equation for the lake can be written as:

lake inflow – lake outflow = change in lake storage

Lake inflow can be calculated by rearranging the terms as follows:

lake inflow = change in lake storage + lake outflow

The lake outflow and lake levels are known. The lake storage was determined from an elevation-area-capacity curve. Using available maps, the lake area (at El. 1868) and the area at the next highest contour (El. 1880) were measured. A linear interpolation was assumed between the two measured areas to develop the area-elevation-capacity data. The lake inflow calculation was performed on a daily basis for the 26-year period of operation. The elevation-area-storage table as used in the storage operation model is presented in Table 3.3-9.

Table 3.3-9. Lake Wenatchee elevation-area-storage.

Elevation (feet NGVD29)	Area (acres)	Storage Capacity (acre-feet)
1867.6	2,416	0
1868	2,440	978
1869	2,500	3,448
1870	2,560	5,978
1871	2,619	8,568
1872	2,679	11,217
1873	2,739	13,926
1874	2,799	16,695
1875	2,858	19,515
1876	2,918	22,403
1877	2,978	25,351
1878	3,038	28,359
1879	3,097	31,426
1880	3,157	34,553

The Lake Wenatchee storage capacity was set to zero at El. 1867.6, the minimum historic elevation. The important thing about the elevation-capacity table is that it covers the entire potential range of lake elevations that could occur in the operation model, and not the assumed zero point of storage.

The following items summarize operation model input:

- Calculated daily lake inflows and historic daily flow data at Plain and Peshastin
- Historic daily lake levels and outflows to be used for comparison to potential operations with the rubber dam
- Elevation-storage capacity table for the lake
- Elevation-outflow table for uncontrolled discharge
- Instream flow requirements at Peshastin and Plain
- Operating criteria for the rubber dam

Operation model output included the following tables:

- Monthly average Lake Wenatchee elevations
- Lake Wenatchee elevation frequency data by month similar to the data presented in Table 3.3-1
- Lake Wenatchee storage
- Monthly average flows and flow frequency data for the lake outflow and flows at Plain and Peshastin that are similar to the data presented in Tables 3.3-3 through 3.3-7.
- Change in lake elevation, storage, and outflow in comparison to historic data

- Number of days in each month when instream flow requirements are not met at Plain and Peshastin

3.3.2.3 Operation Model Verification

The operation model was initially run with the calculated lake inflows and without any rubber dam to determine whether the model adequately simulates the existing conditions. A summary of the resulting simulated lake level frequency data is presented in Table 3.3-10. By comparison to Table 3.3-1, it can be seen that there is essentially no difference between the simulated and historic lake levels, except for a few tenths of a foot on the maximum day of some months.

Table 3.3-10. Simulated Lake Wenatchee level (feet NGVD29) frequency data – Historic Operation.

% of Time Lake Level is Equaled of Exceeded	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Maximum	1871.8	1875.8	1873.7	1874.6	1872.1	1872.7	1874.3	1877.7	1875.6	1874.1	1871.0	1869.6
5	1869.6	1870.4	1870.3	1869.6	1869.5	1869.6	1871.6	1873.6	1873.6	1872.4	1869.7	1868.7
10	1869.2	1869.6	1869.5	1869.2	1869.0	1868.9	1870.9	1873.1	1872.8	1871.7	1869.4	1868.5
15	1869.0	1869.3	1869.2	1868.8	1868.9	1868.8	1870.5	1872.6	1872.5	1871.3	1869.1	1868.4
20	1868.9	1869.1	1869.1	1868.7	1868.6	1868.7	1870.2	1872.3	1872.2	1871.0	1869.0	1868.4
25	1868.7	1869.0	1868.9	1868.6	1868.5	1868.6	1870.0	1872.1	1872.0	1870.7	1868.8	1868.3
30	1868.6	1868.9	1868.8	1868.5	1868.4	1868.6	1869.8	1871.9	1871.9	1870.4	1868.7	1868.3
35	1868.5	1868.8	1868.7	1868.5	1868.3	1868.5	1869.7	1871.7	1871.7	1870.2	1868.6	1868.3
40	1868.4	1868.7	1868.7	1868.4	1868.3	1868.5	1869.6	1871.4	1871.5	1870.0	1868.6	1868.2
45	1868.3	1868.6	1868.6	1868.4	1868.3	1868.4	1869.5	1871.2	1871.4	1869.9	1868.5	1868.2
50	1868.2	1868.5	1868.6	1868.3	1868.2	1868.4	1869.3	1871.1	1871.3	1869.7	1868.5	1868.1
55	1868.1	1868.4	1868.5	1868.3	1868.2	1868.4	1869.2	1870.9	1871.2	1869.6	1868.4	1868.1
60	1868.0	1868.3	1868.5	1868.2	1868.2	1868.3	1869.1	1870.7	1871.0	1869.4	1868.4	1868.1
65	1868.0	1868.3	1868.4	1868.2	1868.1	1868.3	1868.9	1870.5	1870.8	1869.3	1868.3	1868.0
70	1867.9	1868.2	1868.3	1868.1	1868.1	1868.2	1868.8	1870.3	1870.6	1869.2	1868.3	1868.0
75	1867.9	1868.1	1868.3	1868.1	1868.1	1868.2	1868.7	1870.2	1870.5	1869.0	1868.2	1868.0
80	1867.9	1868.1	1868.2	1868.0	1868.0	1868.2	1868.6	1870.0	1870.3	1868.9	1868.2	1868.0
85	1867.8	1868.0	1868.1	1868.0	1868.0	1868.1	1868.6	1869.9	1870.2	1868.8	1868.1	1867.9
90	1867.8	1867.9	1868.0	1868.0	1867.9	1868.0	1868.5	1869.7	1869.9	1868.7	1868.1	1867.9
95	1867.8	1867.7	1867.8	1867.9	1867.8	1868.0	1868.4	1869.3	1869.6	1868.5	1868.0	1867.9
Minimum	1867.7	1867.6	1867.6	1867.8	1867.8	1867.9	1868.0	1868.5	1868.8	1868.2	1867.9	1867.8

Table 3.3-11 presents the simulated flow frequency for the lake outflows, which can be compared to the historic flow frequency of lake outflows as presented in Table 3.3-4. The agreement between historic and simulated flow frequency is mostly within about 1%, again with the exception of the maximum flows of record.

Table 3.3-11. Simulated flow (cfs) frequency at USGS Gage 12455000, Wenatchee River below Lake Wenatchee – Historic Operation.

% of Time Flow is Equaled of Exceeded	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Maximum	4,145	9,986	6,706	8,026	4,551	5,282	7,578	13,205	9,690	7,304	3,079	1,603
5	1,615	2,474	2,278	1,545	1,426	1,534	3,808	6,605	6,596	4,967	1,669	701
10	1,203	1,592	1,468	1,141	1,033	953	2,974	5,821	5,431	3,940	1,321	585
15	1,009	1,294	1,204	854	873	774	2,541	5,147	5,007	3,431	1,090	510
20	863	1,130	1,048	721	657	691	2,268	4,729	4,690	3,136	958	469
25	736	1,000	920	647	540	644	2,040	4,463	4,380	2,817	814	438
30	633	919	833	575	479	607	1,790	4,182	4,200	2,459	735	413
35	553	824	754	533	455	572	1,653	3,915	3,973	2,234	678	394
40	493	729	695	498	431	533	1,527	3,618	3,760	2,025	608	372
45	423	652	647	465	409	510	1,425	3,384	3,589	1,885	567	348
50	362	581	598	427	386	489	1,297	3,181	3,459	1,716	537	332
55	298	524	571	399	361	471	1,177	2,971	3,295	1,563	506	314
60	266	456	539	374	345	443	1,061	2,757	3,090	1,392	473	303
65	249	403	485	348	329	414	926	2,555	2,900	1,291	446	288
70	232	365	444	323	312	382	820	2,356	2,718	1,144	412	275
75	218	334	400	309	295	358	719	2,179	2,524	1,031	387	262
80	207	304	358	287	281	341	660	2,050	2,312	903	369	252
85	195	267	325	269	270	318	600	1,882	2,175	807	338	240
90	181	208	282	248	238	286	537	1,700	1,894	698	310	230
95	168	153	193	221	194	267	493	1,294	1,632	582	288	215
Minimum	144	102	101	160	174	215	271	592	821	340	233	175

The overall agreement between simulated and historic data is better than expected. No simulation model should be expected to exactly reproduce historic results. The operation model is considered to be verified and should provide acceptably accurate results for the purposes for which it was intended.

3.3.2.4 Operating Criteria

Operating criteria are intended to provide guidelines and objectives for beneficial use of the rubber dam. For example, one of the alternative operations would collect water to storage during periods of high flows in the late spring or early summer and have an objective of releasing the stored water at the rate of about 100 cfs in excess of historic releases for about 60 days in the late summer to early fall time period. From the objective for this alternative operation, the implied storage capability of the rubber dam would be about 12,000 acre-feet.

Operating criteria also provide restrictions on the storage operation of the rubber dam. The most obvious restriction would be the maximum pool level to be controlled by the rubber dam. The rubber dam would be lowered to limit pool levels above the maximum operating level to the extent possible. Other restrictions would include the period of the year when the rubber dam could be raised, and the desired rate of release of the stored water. Another restriction that was included in the storage operation model was that the rubber dam would not be used to add water to storage on days on which instream flow requirements would not be met at Plain and Peshastin. The instream flow requirements at Plain and Peshastin are presented in Table 3.3-12 on a half-month basis.

Table 3.3-12. Instream flows (cfs) for the Wenatchee River (Ref: WAC 173-545-030, last update 6/9/88)

Month	Day	USGS Gage 12457000 Wenatchee River at Plain	USGS Gage 12459000 Wenatchee R. at Peshastin
Jan	1	550	700
	15	550	700
Feb	1	550	700
	15	550	700
Mar	1	550	750
	15	700	940
Apr	1	910	1,300
	15	1,150	1,750
May	1	1,500	2,200
	15	2,000	2,800
June	1	2,500	3,500
	15	2,000	2,600
July	1	1,500	1,900
	15	1,200	1,400
Aug	1	880	1,000
	15	700	840
Sep	1	660	820
	15	620	780
Oct	1	580	750
	15	520	700
Nov	1	550	750
	15	550	750
Dec	1	550	750
	15	550	750

The instream flow requirements provide a substantial restriction on the ability to collect water to storage in some years. The number of days in each month of each year when instream flows were not historically met at Plain and Peshastin are presented in Table 3.3-13 and Table 3.3-14, respectively.

Table 3.3-13. Number of days with flow less than instream flow requirement at USGS Gage 12457000, Wenatchee River at Plain – Historic Operation.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1933	14	0	0	0	0	13	2	0	0	0	0	0	29
1934	0	0	0	0	0	0	0	0	0	0	0	29	29
1935	20	0	0	0	0	0	0	0	0	0	0	11	31
1936	31	30	31	31	29	17	11	0	0	7	31	26	244
1937	31	30	17	31	28	24	0	0	0	0	11	26	198
1938	24	0	0	0	5	0	2	0	0	1	26	30	88
1939	25	10	1	0	1	21	0	0	0	0	16	30	104
1940	22	3	0	4	0	0	0	0	0	22	31	30	112
1941	11	14	0	29	28	0	0	0	15	31	31	15	174
1942	0	0	0	1	18	21	0	0	0	5	27	30	102
1943	30	18	10	6	1	10	0	0	0	0	0	22	97
1944	30	25	6	30	23	8	0	0	0	26	31	18	197
1945	18	8	4	1	0	1	14	0	0	7	30	27	110
1946	24	0	15	14	25	6	0	0	0	0	0	23	107
1947	22	12	0	0	0	0	0	0	0	0	15	29	78
1948	1	0	0	1	4	12	14	0	0	0	0	9	41
1949	0	0	0	27	15	0	0	0	0	0	0	8	50
1950	4	0	0	0	0	0	0	0	0	0	0	5	9
1951	2	0	0	0	0	0	0	0	0	0	1	21	24
1952	0	0	0	23	12	19	0	0	0	0	12	30	96
1953	31	30	31	8	0	0	3	0	0	0	0	16	119
1954	0	0	0	0	0	0	2	0	0	0	0	0	2
1955	0	0	0	0	0	17	9	3	0	0	0	9	38
1956	5	0	0	0	4	14	3	0	0	0	0	0	26
1957	0	0	0	8	4	0	0	0	0	1	8	29	50
1958	29	4	0	9	0	0	0	0	0	9	29	23	103
Average	14	7	4	9	8	7	2	0	1	4	12	19	87

Table 3.3-14. Number of days with flow less than instream flow requirement at USGS Gage 12459000, Wenatchee River at Peshastin – Historic Operation.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1933	14	0	0	0	0	2	2	0	0	0	0	0	18
1934	0	0	0	0	0	0	0	0	0	0	0	27	27
1935	20	0	0	0	0	0	0	0	0	0	0	13	33
1936	30	30	31	31	27	3	10	0	0	6	25	27	220
1937	31	30	19	31	28	22	0	0	0	0	5	28	194
1938	25	0	0	0	0	0	0	0	0	0	24	30	79
1939	26	10	1	0	0	20	0	0	0	0	16	30	103
1940	23	3	0	1	0	0	0	0	0	21	31	30	109
1941	11	16	0	28	27	0	0	0	13	28	31	10	164
1942	0	0	0	0	12	18	0	0	0	3	25	30	88
1943	30	18	7	0	0	9	0	0	0	0	0	25	89
1944	28	27	7	29	22	9	1	0	0	24	31	15	193
1945	15	10	1	0	0	0	18	0	0	2	29	25	100
1946	24	0	14	0	25	0	0	0	0	0	0	22	85
1947	21	8	0	0	0	0	0	0	0	0	10	26	65
1948	1	0	0	0	0	7	11	0	0	0	0	4	23
1949	0	0	0	19	11	0	0	0	0	0	0	2	32
1950	2	0	0	0	0	0	0	0	0	0	0	3	5
1951	0	0	0	0	0	0	0	0	0	0	0	19	19
1952	0	0	0	0	0	18	0	0	0	0	12	30	60
1953	31	30	31	8	0	0	4	0	0	0	0	15	119
1954	0	0	0	0	0	0	2	0	0	0	0	0	2
1955	0	0	0	0	0	15	14	4	0	0	0	10	43
1956	4	0	0	0	0	9	0	0	0	0	0	0	13
1957	0	0	0	6	2	0	0	0	0	0	6	30	44
1958	28	5	0	0	0	0	0	0	0	7	28	23	91
Average	14	7	4	6	6	5	2	0	1	4	11	18	78

Table 3.3-15 presents the number of days during which instream flows were not met at either Plain or Peshastin, which is the restriction on number of days during which water cannot be diverted to storage as included in the model. The range of number of days in a year not meeting instream flow requirements is large, varying from 2 days to 245 days in a year. The year 1941 is of particular note because storage would be restricted from about mid-June until mid-September. In other years, there would be no restrictions on collections to storage during the period when the rubber dam might be in use.

Table 3.3-15. Number of days with flow less than instream flow requirement at the Peshastin or Plain USGS Gages – Historic Operation.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1933	14	0	0	0	0	13	2	0	0	0	0	0	29
1934	0	0	0	0	0	0	0	0	0	0	0	29	29
1935	20	0	0	0	0	0	0	0	0	0	0	13	33
1936	31	30	31	31	29	17	11	0	0	7	31	27	245
1937	31	30	19	31	28	24	0	0	0	0	11	28	202
1938	25	0	0	0	5	0	2	0	0	1	26	30	89
1939	26	10	1	0	1	21	0	0	0	0	17	30	106
1940	23	3	0	4	0	0	0	0	0	22	31	30	113
1941	11	16	0	29	28	0	0	0	15	31	31	15	176
1942	0	0	0	1	18	21	0	0	0	5	27	30	102
1943	30	18	10	6	1	10	0	0	0	0	0	25	100
1944	30	27	7	30	23	9	1	0	0	26	31	18	202
1945	19	10	4	1	0	1	18	0	0	7	30	27	117
1946	24	0	15	14	25	6	0	0	0	0	0	23	107
1947	22	12	0	0	0	0	0	0	0	0	15	29	78
1948	1	0	0	1	4	12	14	0	0	0	0	10	42
1949	0	0	0	27	15	0	0	0	0	0	0	8	50
1950	4	0	0	0	0	0	0	0	0	0	0	5	9
1951	2	0	0	0	0	0	0	0	0	0	1	22	25
1952	0	0	0	23	12	22	0	0	0	0	12	30	99
1953	31	30	31	8	0	0	4	0	0	0	0	17	121
1954	0	0	0	0	0	0	2	0	0	0	0	0	2
1955	0	0	0	0	0	17	15	4	0	0	0	10	46
1956	5	0	0	0	4	14	3	0	0	0	0	0	26
1957	0	0	0	8	4	0	0	0	0	1	8	30	51
1958	29	5	0	9	0	0	0	0	0	9	29	23	104
Average	15	7	5	9	8	7	3	0	1	4	12	20	89

The storage that could potentially be impounded by the rubber dam is much smaller than the volume that would be required to meet all downstream instream flow requirements during the summer months. To provide background information on the historic deficiency of flows in relation to current instream flow requirements, Table 3.3-16 presents the storage volume (acre-feet) that would be required to meet requirements at Plain, or at Plain and Peshastin for the indicated periods. In a few years, no storage would be required as instream flows were met on every day of the season. More typically though, the storage required to meet downstream instream flows would be greatly in excess of any storage volume that is under consideration for the rubber dam.

Table 3.3-16. Storage (acre-feet) necessary to be impounded by the rubber dam to meet instream flow requirements at Plain or at Plain and Peshastin

	Meet Instream Flows at Plain Only		Meet Instream Flows at Plain and Peshastin	
Calendar Year	June 1 - Oct. 15 Storage (acre-feet)	June 1 - Oct 31 Storage (acre-feet)	June 1 - Oct. 15 Storage (acre-feet)	June 1 - Oct 31 Storage (acre-feet)
1933	0	0	0	0
1934	11,256	12,305	14,065	15,995
1935	4,465	6,436	6,325	9,094
1936	28,552	34,346	33,132	40,499
1937	16,518	17,863	19,583	21,362
1938	22,217	24,510	29,726	33,037
1939	21,098	22,949	29,472	32,261
1940	44,325	44,372	47,562	47,609
1941	62,122	62,122	66,184	66,184
1942	39,346	47,901	45,170	56,914
1943	8,390	9,780	11,802	13,609
1944	42,244	44,049	45,685	48,081
1945	25,002	28,235	25,769	29,022
1946	13,678	15,957	15,604	18,353
1947	10,467	10,467	10,491	10,491
1948	543	543	563	563
1949	1,501	1,501	1,501	1,501
1950	357	357	357	357
1951	2,809	2,809	3,221	3,221
1952	22,017	29,845	22,667	31,640
1953	2,561	2,561	3,667	3,667
1954	0	0	0	0
1955	2,475	2,475	4,395	4,395
1956	0	0	0	0
1957	12,883	16,086	13,668	17,401
1958 (1)	15,477		20,138	
Minimum	0	0	0	0
Maximum	62,122	62,122	66,184	66,184
Average	15,781	17,499	18,106	20,210

Note (1): Values represent June 1 through September 30, 1958.

The amount of water that is potentially storable by the rubber dam is substantial in most years under a given set of rules for collection to storage. This paragraph describes the criteria used by the operation model to determine the amount of water that could be stored by the rubber dam. As used in the operation model, the daily amount of water that was potentially storable was the minimum of the following three values:

1. Daily amount of historic flow at Plain in excess of instream flow requirements at Plain.

2. Daily amount of historic flow at Peshastin in excess of instream flow requirements at Peshastin.

3. 50% of the Lake Wenatchee daily inflow up to 3,000 cfs, plus 25% of the Lake Wenatchee daily inflow greater than 3,000 cfs.

The amount of Lake Wenatchee inflow that would be potentially available for storage under the rules presented above is presented in Table 3.3-17. Of course collections to storage by the rubber dam would only be desired only at limited times of the year. During most of the year, the rubber dam would be either fully down or would be operating in the augmentation (release) mode. Flow augmentation is used herein to denote flow released in excess of the historic flow on the corresponding day.

Table 3.3-17. Lake Wenatchee inflow (acre-feet) potentially available for storage with rubber dam.

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1933	7,727	53,650	32,966	18,875	6,903	2,660	29,226	56,557	111,261	97,999	36,762	15,727	470,313
1934	46,965	47,149	63,593	46,647	32,620	65,699	113,231	93,164	66,284	29,076	8,065	4	612,497
1935	8,568	47,986	21,705	40,705	30,950	22,736	28,174	89,732	102,294	63,554	18,086	5,195	479,685
1936	0	0	0	0	0	4,585	53,642	116,177	95,103	17,447	0	674	287,628
1937	0	0	4,560	0	0	1,031	18,467	84,286	118,335	56,226	4,063	258	287,227
1938	4,623	24,878	21,908	17,706	4,457	11,610	51,954	101,326	101,331	40,668	805	0	381,267
1939	1,617	5,301	17,187	26,967	5,988	11,884	55,610	95,104	73,681	50,515	4,898	0	348,752
1940	2,128	16,960	29,582	5,188	7,118	25,945	58,152	94,988	63,512	4,919	0	0	308,492
1941	12,035	4,820	14,162	42	0	26,496	57,528	54,032	10,592	0	0	5,489	185,195
1942	33,535	23,003	30,966	4,951	254	2,261	45,911	66,975	66,604	27,671	444	0	302,576
1943	22	4,161	10,232	11,340	4,705	8,501	65,799	82,076	107,564	93,997	25,424	666	414,486
1944	0	674	16,683	12	839	12,505	31,415	71,081	58,372	1,984	0	4,450	198,015
1945	2,845	5,391	15,073	27,103	21,599	7,953	11,004	90,760	76,895	29,371	30	1,085	289,109
1946	11,000	15,568	4,967	4,083	228	6,994	37,550	121,994	100,920	69,906	16,845	708	390,764
1947	8,390	3,458	24,801	16,620	23,240	37,631	65,239	109,067	82,493	44,142	7,344	6	422,431
1948	31,792	27,879	19,057	8,796	6,931	2,674	24,003	97,055	128,565	52,116	21,480	4,764	425,111
1949	20,012	12,252	12,002	327	5,215	13,898	51,909	117,492	97,460	62,892	17,478	6,812	417,750
1950	17,259	51,219	38,614	19,058	10,597	25,169	29,373	83,553	132,505	105,524	38,401	8,304	559,576
1951	33,997	41,029	47,251	26,133	41,181	18,128	59,139	107,490	100,409	58,223	13,307	1,918	548,205
1952	26,355	22,527	8,920	323	1,603	4,097	48,056	93,255	81,320	45,219	7,525	0	339,201
1953	0	0	0	32,921	34,746	19,119	32,429	90,840	89,137	82,971	26,846	2,811	411,819
1954	12,668	26,746	32,168	20,830	12,192	13,793	32,266	100,657	108,041	114,437	58,701	25,284	557,785
1955	18,104	44,735	22,388	10,983	12,087	2,846	7,486	60,423	120,476	92,114	35,452	9,672	436,767
1956	27,680	52,456	21,905	11,642	2,049	2,896	51,972	124,561	118,254	94,895	26,893	10,071	545,275
1957	26,583	25,758	50,900	11,235	6,387	16,144	41,619	120,311	83,020	31,588	5,451	0	418,996
1958	2,933	5,621	11,285	5,534	12,477	17,362	37,873	124,311	87,171	13,926	214	930	319,638
Average	13,725	21,662	22,034	14,155	10,937	14,793	43,809	94,126	91,600	53,130	14,404	4,032	398,406
Maximum	46,965	53,650	63,593	46,647	41,181	65,699	113,231	124,561	132,505	114,437	58,701	25,284	612,497
Minimum	0	0	0	0	0	1,031	7,486	54,032	10,592	0	0	0	185,195

Additional rubber dam operating criteria include the following:

- The rubber dam was operated so that it achieves the maximum controlled pool level in all years. In designated dry years, storage would begin up to one month earlier than during normal or wet years. In practice, this operation could be keyed to snowpack in the mountains.
- Storage and release seasons would be designated and would be the same in most years, with the exception being the designated dry years. The rubber dam would not be operated to augment flows in the storage season. During the release season, lake storage would not increase beyond that which would have occurred under natural conditions.
- When the rubber dam is fully down, the historic rating curve would control lake outflows.

- The rubber dam would not control lake levels above the designated maximum level. At times high inflows would cause natural lake levels to rise above the designated maximum normal pool level for the rubber dam. During these high flow periods, the rubber dam would be fully down and the historic rating curve would control lake outflows.
- During the storage season, if downstream instream flow requirements were not being met, outflow at the rubber dam would equal inflow, which would result in a constant lake level.

3.3.3 Operating SCENARIOS

This section describes the potential operating scenarios for the water storage project and also describes specific alternatives that were analyzed using the hydrologic model of Lake Wenatchee.

3.3.3.1 Selection of Storage Levels

Two storage levels were selected for analysis. The first and lowest storage level is the OHW elevation, defined in Section 3.2 as 1870.3. The OHW level was selected at the outset of the project as it is the level below which the State owns the bed of the lake except those second class shorelands purchased by certain property owners. At the February 26, 2003 Project Team meeting the MWH team presented its estimate of the OHW elevation (1870.3 ft) and the potential water storage available at that elevation (6,700 acre-feet). MWH was asked at that meeting to analyze a storage level higher than OHW so that costs and benefits of two different storage levels could be compared.

Additional storage provided in Lake Wenatchee would likely be used to supplement instream flow in the Wenatchee River downstream and may also be used to offset future, increased water demands in the Wenatchee River Watershed. Analyses of water needs for instream flow was performed by comparing historic streamflow in the Wenatchee River to instream flows set by the Instream Resources Protection Program (IRPP) and WAC 173-545. The analyses found the volume of additional storage needed to augment streamflow to meet IRPP flows at the Wenatchee River at Plain gaging station ranged from 0 to 62,122 acre-feet and averaged 17,499 acre-feet for the period of June 1 to October 31 as indicated in Table 3.3-16. The additional volume of water needed to meet future municipal and domestic water demands is much less, estimated to be 7.3 cfs peak and 1868 acre-feet annually.

To meet those water needs, storage levels in Lake Wenatchee would need to be increased substantially. A comparison of lake levels to potential storage is listed in Table 3.3-18. A description of what the various lake levels correspond to is also contained in Table 3.3-18. The first three lake levels listed in Table 3.3-18 could satisfy most to all instream flow needs. The fourth and fifth lake levels indicated in the table represent peak lake levels that occur in most years and are lower in elevation than the first three levels. Although those levels would not satisfy most instream flow needs they would provide additional storage that would be useful to augment instream flow or offset future water needs.

Table 3.3-18. Comparison of lake levels to potential storage.

Description of Lake Level	Storage Elevation (ft-msl)	Storage Volume (acre-ft)
Maintain In-Stream Flow (all 29 of 29 recorded years)	1888.1	62,100
Maintain In-Stream Flow (all but the worst 2 of 29 years)	1882.4	42,200
Maintain In-Stream Flow (all but the worst 5 of 29 years)	1876.9	25,000
Mean Annual Spring Peak Lake Elevation	1873.9	16,400
90% Exceedance[1] Annual Spring Peak Lake Elevation	1872.4	12,300
Ordinary High Water	1870.3	6,700

[1] This is the Spring high water level that has been exceeded nine out of ten years of our 47 years of record

The elevations contained in Table 3.3-18 were preliminarily reviewed for their potential effect on shoreline property owners and structures. It was our opinion that the storage levels above 1872.4 ft have a high potential for impacts to shoreline property owners. As an example, a photograph of the Kane Boathouse that is annotated with various lake levels is shown in Figure3.3-10. The lake levels required to provide a reliable instream flow benefit would submerge most or all of the Kane Boathouse. Even the mean annual spring lake level of 1873.9 ft would keep two feet of water over the boathouse deck. It is our opinion that the next to the lowest lake level shown in Table 3.3-18 is a reasonable lake level to further analyze with the hydrologic model. This level was presented at the April 30, 2003 project team meeting as the consultants second, higher level recommended for further study.

Figure 3.3-10. Illustration of Water Levels at Kane Boathouse

3.3.3.2 Operation Model Alternatives

This section describes the specific alternatives that were considered. The impoundment structure operating objectives, guidelines, and restrictions are described in the following items.

- Alternative 1 – The maximum lake level controlled by the rubber dam would be at El. 1872.4. The normal collection season for storage behind the rubber dam would be from July 1 through August 22. Augmentation flows would be ramped up at a rate of 10 cfs per day from August 23 through August 31. Lake outflows would be augmented by 100 cfs in excess of historic outflows from September 1 until storage behind the rubber dam was exhausted.
- Alternative 2 – The maximum lake level controlled by the rubber dam would be at El. 1872.4. The normal collection season for storage behind the rubber dam would be from July 1 through August 22. Augmentation flows would be ramped up at a rate of 20 cfs per day from August 23 through August 31. Lake outflows would be augmented by 200 cfs in excess of historic outflows from September 1 until storage behind the rubber dam was exhausted.
- Alternative 3 – The maximum lake level controlled by the rubber dam would be at El. 1872.4. The normal collection season for storage behind the rubber dam would be from June 1 through June 30. Pulse flows would be released daily at the rate of 100 cfs for 4 hours from July 1 through August 15. Lake outflows would be augmented by 100 cfs in excess of historic outflows from August 16 until storage behind the rubber dam was exhausted.
- Alternative 4 – The maximum lake level controlled by the rubber dam would be at El. 1870.3. The normal collection season for storage behind the rubber dam would be from July 1 through August 22. Augmentation flows would be ramped up at a rate of 5 cfs per day from August 23 through August 31. Lake outflows would be augmented by 50 cfs in excess of historic outflows from September 1 until storage behind the rubber dam was exhausted.
- Alternative 5 – The maximum lake level controlled by the rubber dam would be at El. 1870.3. The normal collection season for storage behind the rubber dam would be from July 1 through August 22. Augmentation flows would be ramped up at a rate of 10 cfs per day from August 23 through August 31. Lake outflows would be augmented by 100 cfs in excess of historic outflows from September 1 until storage behind the rubber dam was exhausted.

For Alternatives 1, 2, and 3, which all have a maximum pool level controlled by the rubber dam at El. 1872.4, the designated dry years are 1940, 1941, and 1944. During these designated dry years, storage begins on June 1, which is necessary to achieve a stored water level at El. 1872.4 during the driest year of 1941.

For Alternatives 4 and 5, which both have a maximum normal pool level controlled by the rubber dam at El. 1870.3, the designated dry years are 1941 and 1944. During these designated dry years, storage begins on June 15. Storage can begin later in the dry years for Alternatives 4 and 5 because there is less water collected into storage with the rubber dam.

The maximum pool level controlled by the rubber dam at El. 1872.4 was based on a storage of about 12,000 acre-feet above the historic minimum level of the lake. The maximum lake level controlled by the rubber dam at El. 1870.3 is based on the ordinary high water level as determined from the vegetation line.

3.3.3.3 Operation Model Results

The operation model produced a great deal of output that is also evaluated in other sections of this report. This section provides summary results for each alternative in graphical and tabular form. The results are presented in comparison to the historic condition as a reference. The following types of summary results are provided for each alternative:

- Daily Lake Wenatchee water levels plots for an average water year, 1949, and a dry water year, 1941.
- Daily Lake Wenatchee outflow plots for an average water year, 1949, and a dry water year, 1941. These plots are provided for both the entire year, as well as an additional plot that is focused on the primary augmentation season.
- A tabulation of Lake Wenatchee elevation frequency in comparison to the historic condition for the entire 26-year period of simulation based on daily levels. This table is developed by a simple subtraction of corresponding values in the historic elevation frequency table from Alternative elevation frequency table. Positive values indicate higher lake levels for the alternatives in comparison to the historic condition.
- A tabulation of Lake Wenatchee outflow frequency in comparison to the historic condition for the entire 26-year period of simulation based on daily outflows. In the same manner as the elevation frequency difference table, this table is developed by a subtraction of corresponding values in the historic outflow frequency table from Alternative outflow frequency table. Positive values indicate flow augmentation.
- Daily flow plots at the USGS gage at Plain for an average water year, 1949, and a dry water year, 1941.

Results have been grouped in the following sections into three categories, which are Lake Wenatchee elevations, Lake Wenatchee outflows, and flow at the USGS gage at Plain.

3.3.3.3.1 Lake Wenatchee Elevation Results

Results show that the maximum storage in excess of historic conditions attained on any day for any of the five alternatives was 11,425 acre-feet, which was achieved by Alternatives 1 and 2 on August 22, 1944. As shown on Figure 3.3-11, during a normal year such as 1949 for Alternative 1, the maximum lake storage on any day impounded with the rubber dam would be 10,199 acre-feet in excess of the historic storage on August 22, which corresponds to a lake level 3.93 feet higher than for historic conditions. In comparison to Alternative 1, Alternative 2 shows a more rapid drawdown of lake level because the augmentation objective is 200 cfs rather than 100 cfs.

Alternative 3 begins both storage and release earlier in the year in comparison to Alternative 1 and Alternative 2. In 1949, the maximum additional storage impounded by the rubber dam in excess of historic conditions was 6,445 acre-feet on June 30. Due to the higher natural lake levels at the time of year scheduled for storage and release, the amount of storage impounded by the rubber dam to be used for flow augmentation is less for Alternative3 than for Alternatives 1 or 2 in 1949 and other similar years.

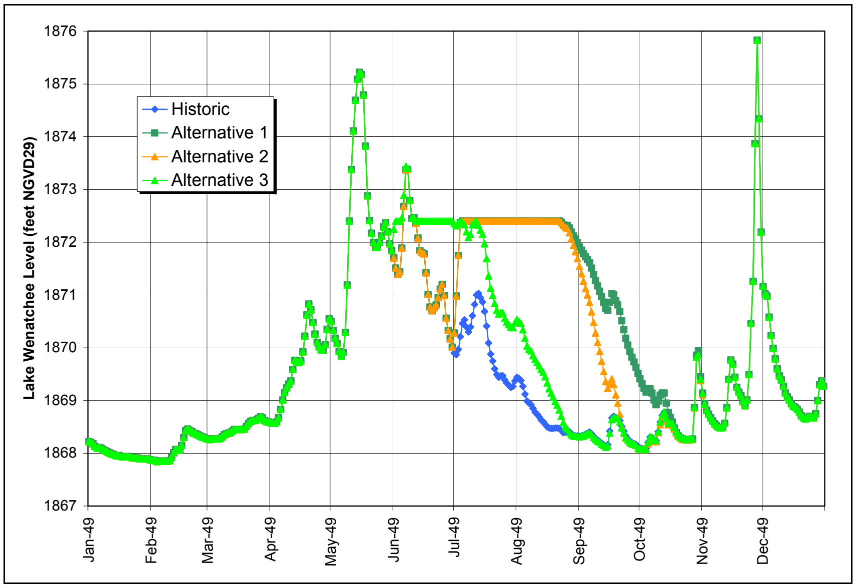


Figure 3.3-11. Alternatives 1, 2, and 3, and historic lake levels for an average water year – 1949.

Alternative 4 is similar to Alternative 1, except with a lower maximum lake level controlled by the rubber dam and with flow augmentation objectives cut in half. The maximum storage attained by the rubber dam in excess of historic conditions during 1949 was 4,653 acre-feet on August 22. Because this is about half of the amount available for Alternative 1 and the release schedule is also 50% of Alternative 1, flow augmentation is provided for almost the same time period as for Alternative 1. Lake levels for Alternatives 4 and 5 are shown on Figure 3.3-12 for an average water year.

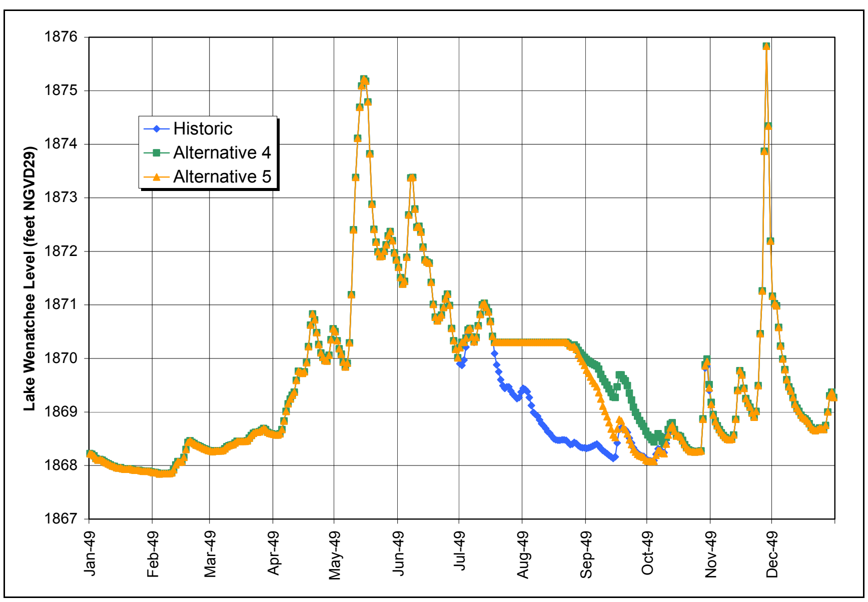


Figure 3.3-12. Alternatives 4 and 5, and historic lake levels for an average water year – 1949.

Alternative 5 is similar to Alternative 2, except with a lower maximum lake level controlled by the rubber dam and with flow augmentation objectives cut in half. Flow augmentation occurs for a period similar to that for Alternative 2.

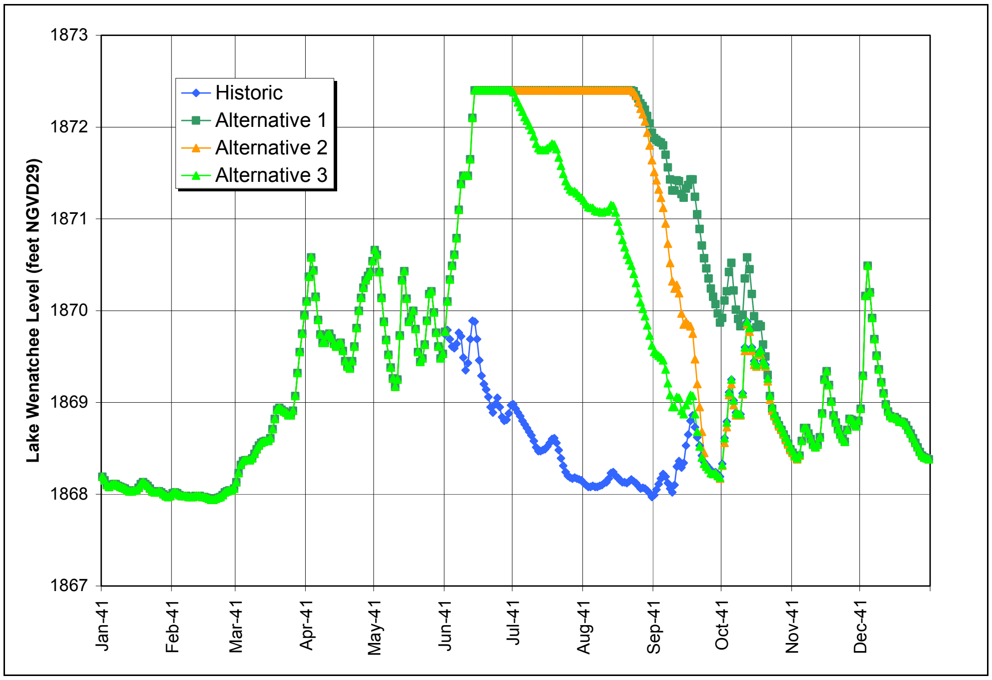


Figure 3.3-13. Alternatives 1, 2, and 3, and historic lake levels for a dry water year – 1941.

Lake level plots for all of the Alternatives are shown on Figure 3.3-13 and Figure 3.3-14 for a dry water year, which is 1941. Figure 3.3-13 shows storage beginning at the beginning of June and reaching a higher level during the dry year than was historically attained. This means that the storage project will provide maximum flow augmentation benefits during a dry year. Figure 3.3-14 shows that the maximum pool level controlled by the Alternative 4 and 5 rubber dam would be less than the maximum level that occurred historically in 1941.

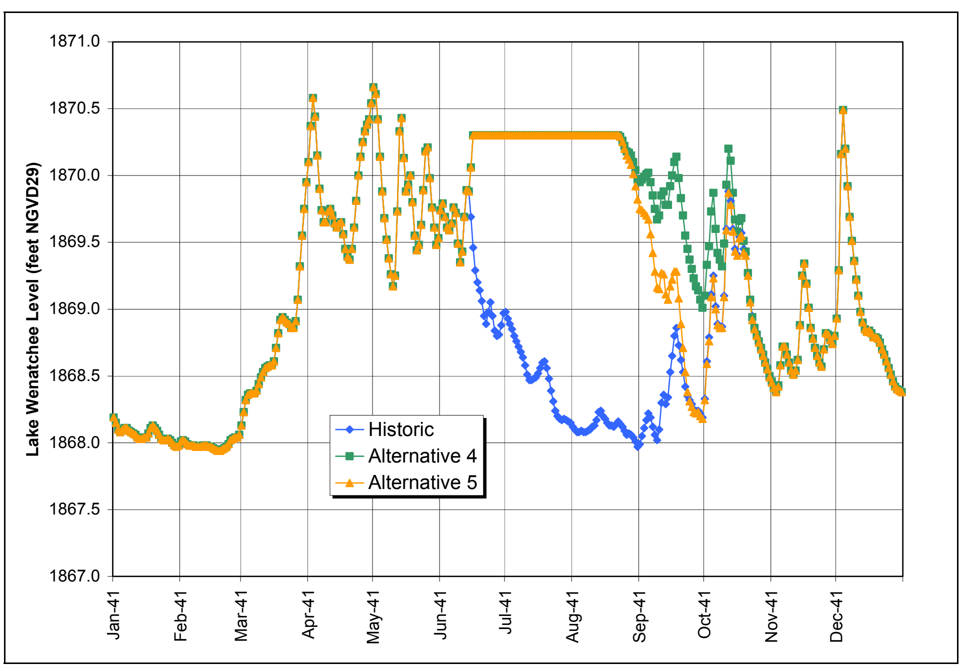


Figure 3.3-14. Alternatives 4 and 5, and historic lake levels for a dry water year – 1941.

Table 3.3-19. Alternative 1 Lake Wenatchee Elevation-Frequency Difference (feet) From Historic.

% of Time Lake Level is Equaled of Exceeded	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Maximum	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	2.6
5	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	2.7	3.1
10	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	3.1	3.2
15	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	3.3	3.1
20	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	1.4	3.5	3.1
25	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	1.7	3.6	3.0
30	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	2.0	3.7	2.9
35	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	2.2	3.8	2.8
40	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	2.4	3.8	2.7
45	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	2.5	3.9	2.7
50	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	2.7	3.9	2.6
55	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	2.8	4.0	2.5
60	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	3.0	4.0	2.4
65	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	3.1	4.1	2.3
70	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	3.2	4.1	2.2
75	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	3.4	4.1	2.1
80	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	3.5	4.1	2.0
85	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	3.6	4.1	1.9
90	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	3.7	4.0	1.8
95	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	3.5	4.0	1.6
Minimum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	1.4	3.6	0.7

The elevation-frequency difference data tables presented in this section provide a great deal of precise numerical information. Rather than focusing on individual values, it is suggested that the reader should look for the broader trends in the results. The elevation-frequency difference tables are developed by subtracting corresponding values from the elevation-frequency table developed for each Alternative from the historic elevation-frequency table, which was presented as Table 3.3-1.

Table 3.3-20. Alternative 2 Lake Wenatchee elevation-frequency difference (feet) from historic.

% of Time Lake Level is Equaled of Exceeded	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Maximum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	2.2
5	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	2.7	2.7
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	3.1	2.6
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	3.3	2.4
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	1.4	3.5	2.3
25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	1.7	3.6	2.1
30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	2.0	3.7	1.9
35	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	2.2	3.8	1.7
40	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	2.4	3.8	1.5
45	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	2.5	3.9	1.3
50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	2.7	3.9	1.1
55	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	2.8	4.0	0.9
60	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	3.0	4.0	0.7
65	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	3.1	4.1	0.5
70	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	3.2	4.1	0.4
75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	3.4	4.1	0.3
80	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	3.5	4.1	0.2
85	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	3.6	4.0	0.1
90	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	3.7	3.9	0.0
95	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	3.5	3.8	0.0
Minimum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	1.4	3.3	0.0

Table 3.3-21. Alternative 3 Lake Wenatchee elevation-frequency difference (feet) from historic.

% of Time Lake Level is Equaled of Exceeded	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Maximum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.3
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.7	1.4	0.2
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.0	1.4	0.1
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	1.1	1.3	0.1
25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	1.3	1.3	0.1
30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	1.4	1.2	0.1
35	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	1.5	1.1	0.0
40	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	1.6	1.1	0.1
45	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.6	1.0	0.1
50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	1.6	0.9	0.0
55	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	1.7	0.9	0.0
60	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	1.8	0.8	0.0
65	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	1.8	0.7	0.0
70	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8	1.8	0.7	0.0
75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	1.8	0.6	0.0
80	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	1.7	0.5	0.0
85	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.3	1.6	0.4	0.0
90	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5	1.5	0.3	0.0
95	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.7	1.4	0.2	0.0
Minimum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.6	0.0	0.0

As shown on Table 3.3-21, the water level differences from historic for Alternative 3 are less than for Alternative 1 and Alternative 2. This is due to the earlier release schedule for Alternative 3, which is clearly exhibited on Figure 3.3-11 and Figure 3.3-13.

Table 3.3-22. Alternative 4 Lake Wenatchee elevation-frequency difference (feet) from historic.

% of Time Lake Level is Equaled of Exceeded	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Maximum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7
5	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	1.3
10	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.4
15	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	1.4
20	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	1.4
25	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	1.4
30	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	1.3
35	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.7	1.3
40	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	1.7	1.2
45	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	1.8	1.2
50	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	1.8	1.1
55	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	1.9	1.1
60	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	1.9	1.0
65	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	2.0	1.0
70	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	2.0	1.0
75	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	2.0	0.9
80	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	2.0	0.9
85	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.5	2.0	0.8
90	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	1.6	2.0	0.8
95	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.8	2.0	0.7
Minimum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	1.4	1.6	0.3

Table 3.3-23. Alternative 5 Lake Wenatchee elevation-frequency difference (feet) from historic.

% of Time Lake Level is Equaled of Exceeded	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Maximum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	1.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	1.0
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	0.9
25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.9
30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	0.8
35	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.7	0.7
40	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	1.7	0.6
45	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	1.8	0.6
50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	1.8	0.5
55	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	1.9	0.4
60	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	1.9	0.3
65	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	2.0	0.3
70	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	2.0	0.3
75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	2.0	0.2
80	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	2.0	0.1
85	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.5	2.0	0.1
90	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	1.6	2.0	0.0
95	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.8	1.9	0.0
Minimum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	1.4	1.5	0.0

A comparison between Alternatives 4 and 5 in Tables 3.3-22 and 3.3-23 shows the effects of the more rapid releases for Alternative 5 (100 cfs versus 50 cfs). By October, Alternative 5 would have returned to historic lake levels.

3.3.2.6.2 Lake Wenatchee Outflow Results

This section provides a number of plots to visually compare the Lake Wenatchee outflows for average and dry water years as developed by the Alternatives in comparison to the historic outflows. Figure 3.3-15 presents the Lake Wenatchee outflows for Alternatives 1, 2, and 3 and the historic condition for the average water year of 1949. Figure 3.3-15 shows that outflow with the rubber dam would be the same as for the historic condition for much of the year. The area of greatest interest, the primary potential augmentation season from August 1 through October 31, is not distinctly visible on a graph that shows the entire year and is scaled to include higher flows. To more clearly present the augmentation effects, additional graphs that focus only on the augmentation season are presented for each of the Alternatives. For example, Figure 3.3-16 presents the same data as shown on Figure 3.3-15, except in a graphically expanded form for the augmentation season.

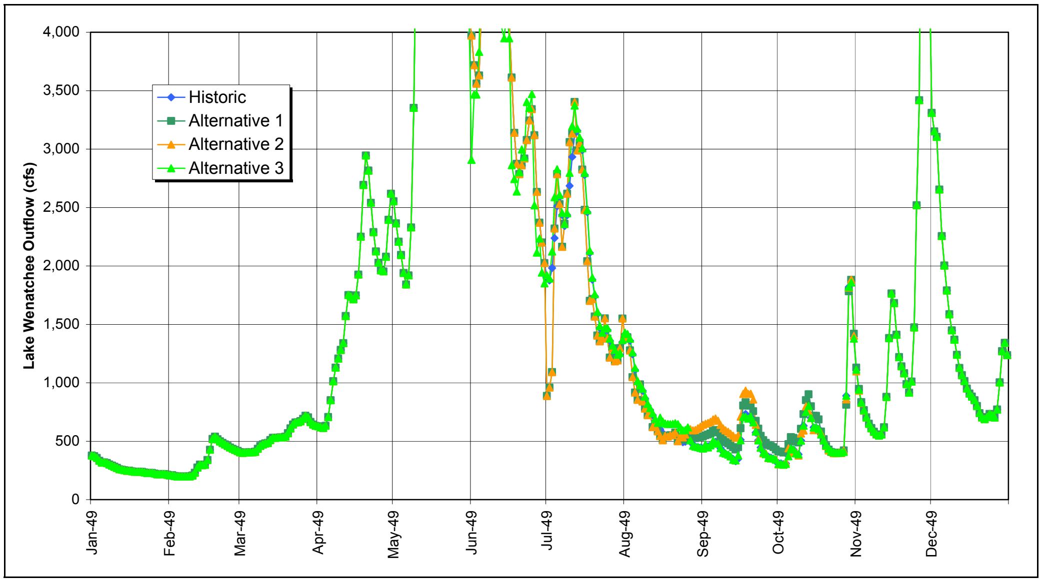


Figure 3.3-15. Alternatives 1, 2, and 3, and historic lake outflows for an average water year – 1949.

As most clearly shown on Figure 3.3-16, Alternative 2 provides the greatest augmentation, but for a shorter period of time than for Alternative 1, which augments flows through much of October. Alternative 3 has less water to store and release because it has different storage and release seasons in comparison to Alternatives 1 and 2. During 1949, Alternative 3 achieves a maximum storage (in excess of historic) of 6,445 acre-feet on June 30. Both Alternative 1 and 2 achieve a maximum storage (in excess of historic) of 10,199 acre-feet on August 22. Because of this, Alternatives 1 and 2 can augment flow in a total amount greater than Alternative 3.

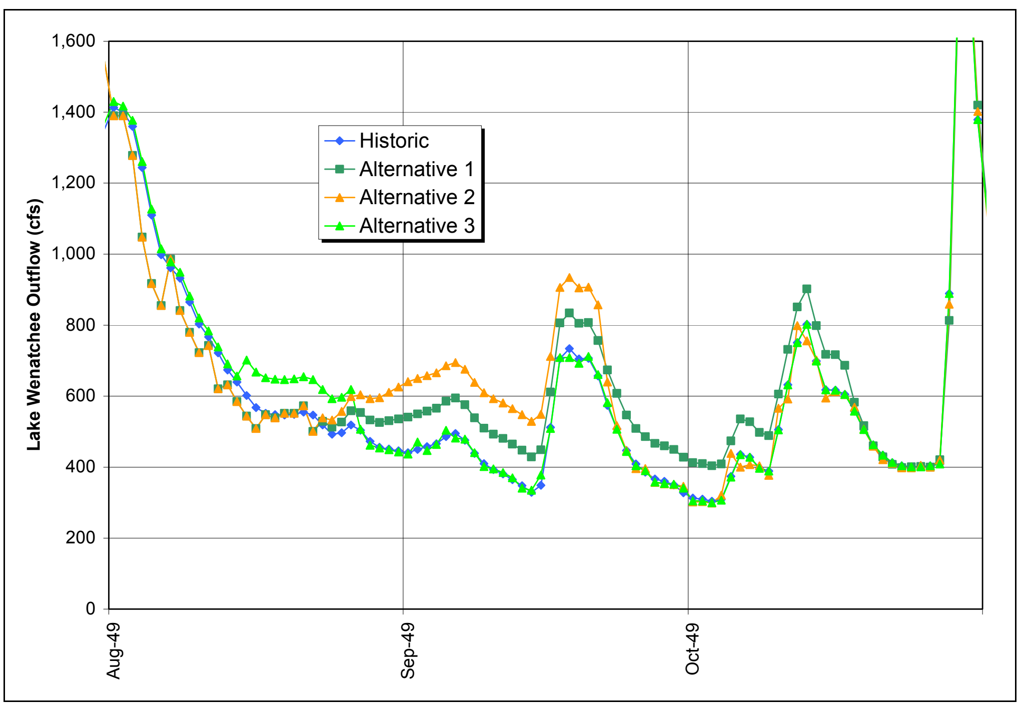


Figure 3.3-16. Alternatives 1, 2, and 3, and historic lake outflows for the 1949 augmentation season.

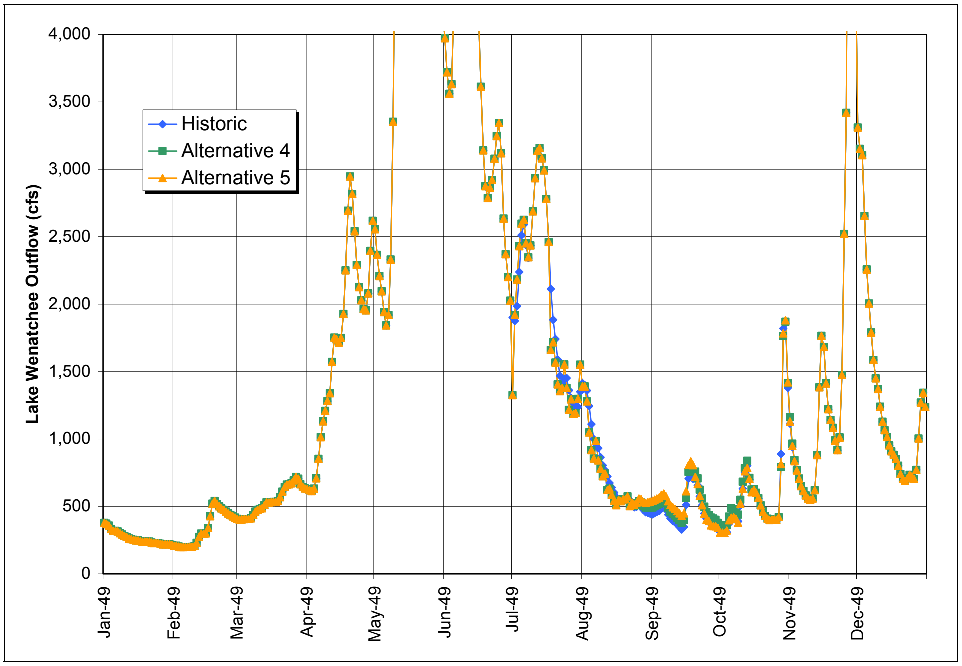


Figure 3.3-17. Alternatives 4, and 5, and historic lake outflows for an average water year – 1949.

Figures 3.3-17 and 3.3-18 show that augmentation flow for Alternatives 4 and 5 have a similar pattern to those for Alternatives 1 and 2. The primary difference is in the magnitude of augmentation, with more minor differences in the augmentation season.

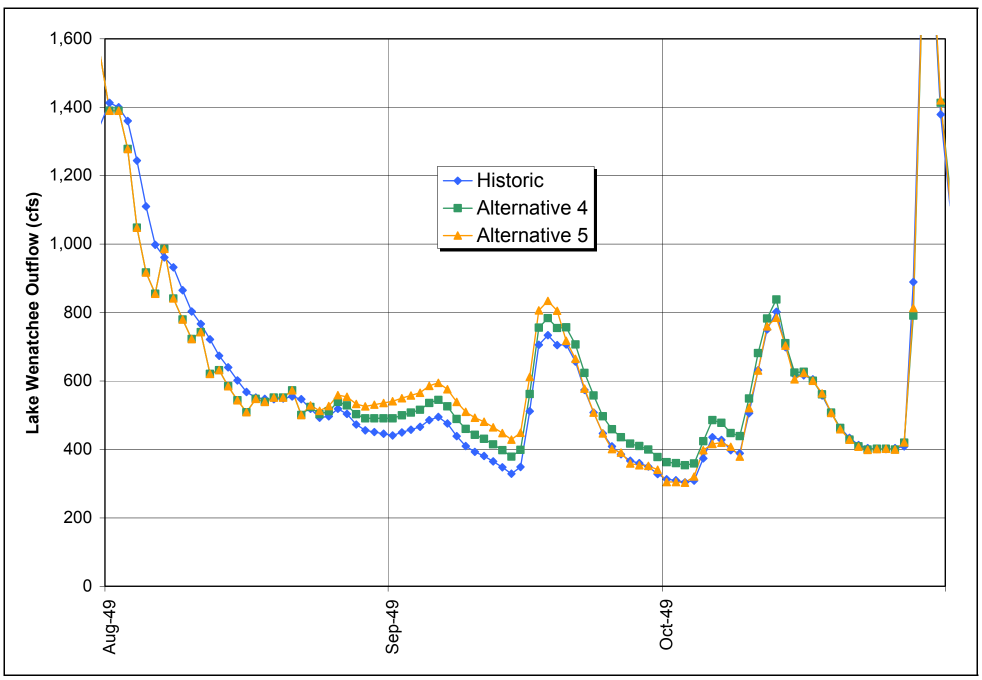


Figure 3.3-18. Alternatives 4, and 5, and historic lake outflows for the 1949 augmentation season.

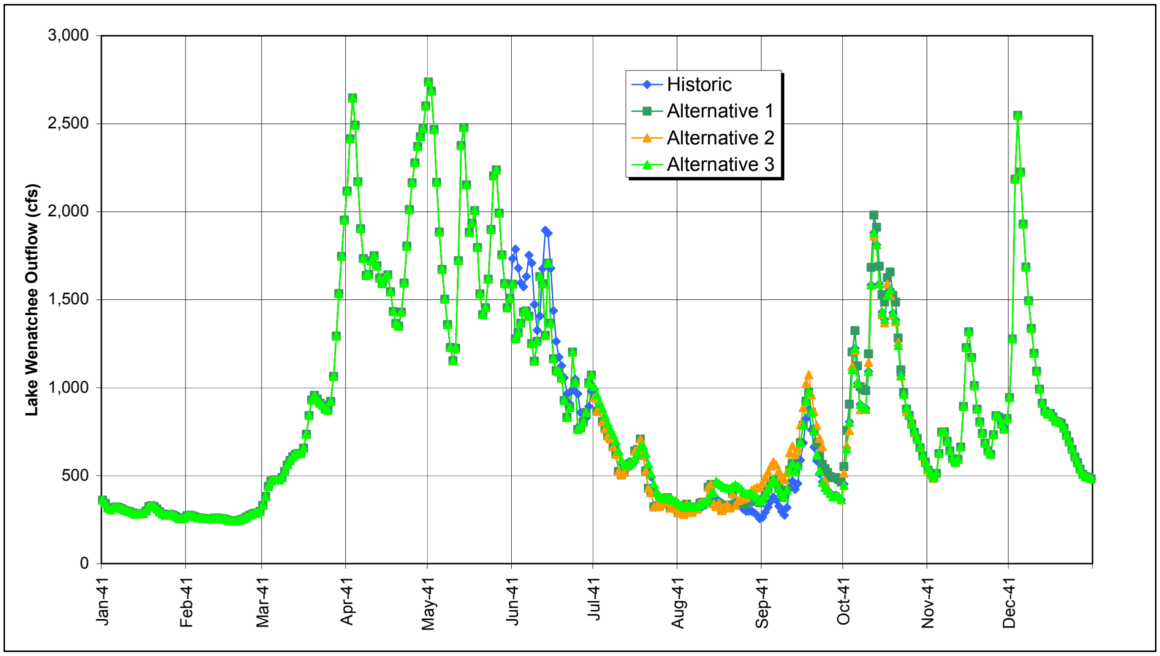


Figure 3.3-19. Alternatives 1, 2, and 3, and historic lake outflows for a dry water year – 1941.

During a dry water year, the flow augmentation would be most pronounced. Figure 3.3-20 highlights that flow augmentation can be a substantial percentage of total outflow during the driest periods.

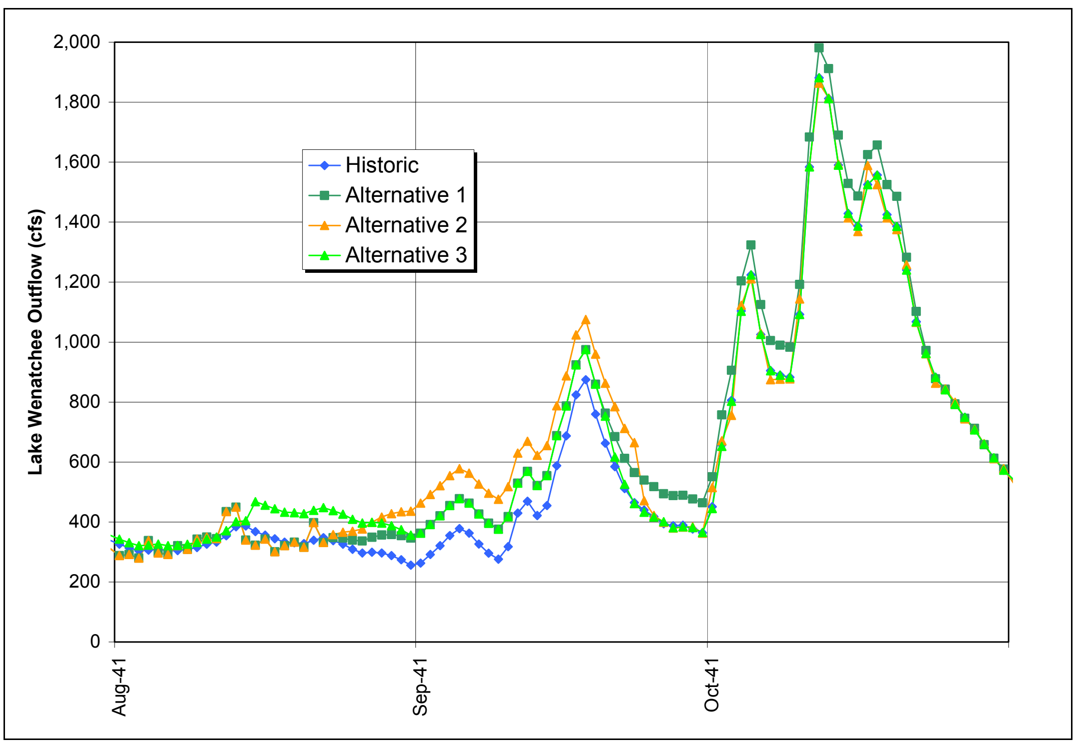


Figure 3.3-20. Alternatives 1, 2, and 3, and historic lake outflows for the 1941 augmentation season.

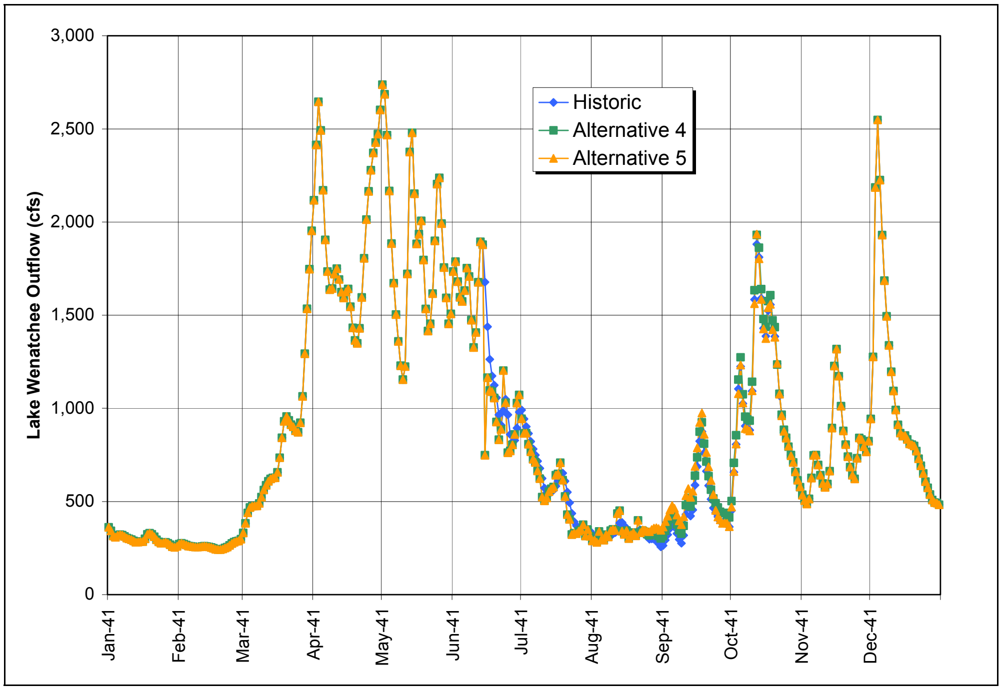


Figure 3.3-21. Alternatives 4 and 5, and historic lake outflows for a dry water year – 1941.

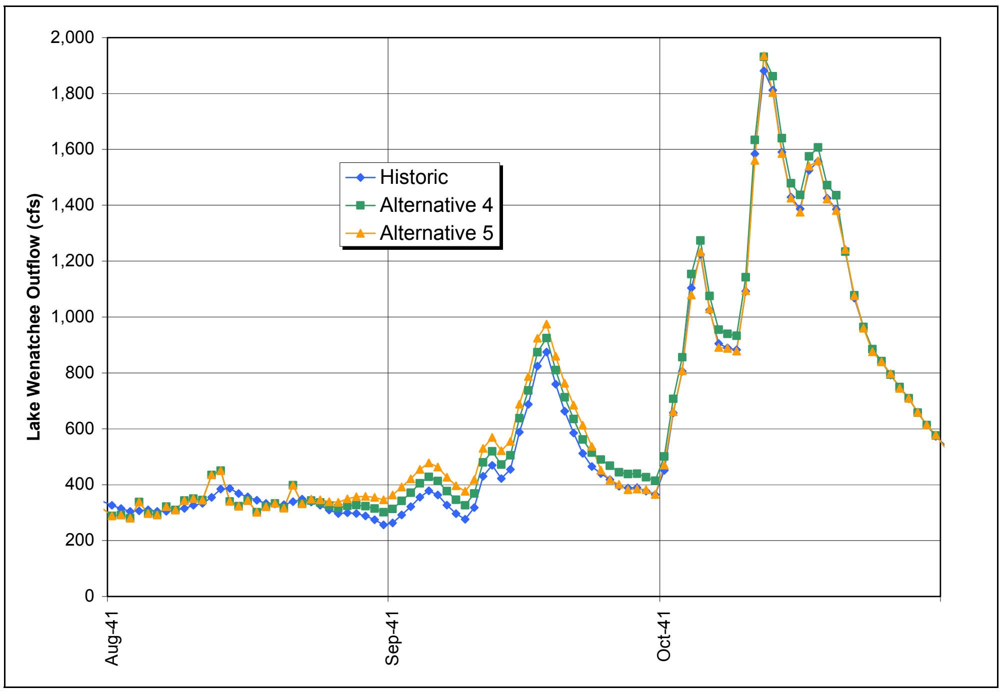


Figure 3.3-22. Alternatives 4 and 5, and historic lake outflows for the 1941 augmentation season.

Table 3.3-24 shows that the objective for Alternative 1 of augmenting historic flows by 100 cfs on each day in September is essentially fully accomplished. During October, the objective can be met on some days, but not on others. This causes the flow frequency difference from historic conditions to be less than 100 cfs in October. The negative values during parts of June, July, and August are indications of flow being taken into storage.

Table 3.3-24. Alternative 1 Lake Wenatchee outflow-frequency difference (cfs) from historic.

% of Time Flow is Equaled of Exceeded	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Maximum	100	0	0	0	0	0	0	0	0	0	166	100
5	42	0	0	0	0	0	0	0	0	92	-80	100
10	39	0	0	0	0	0	0	0	0	-80	-63	96
15	41	0	0	0	0	0	0	0	0	-81	-45	98
20	28	0	0	0	0	0	0	0	0	-147	-55	100
25	55	-3	0	0	0	0	0	0	0	-269	-12	100
30	30	0	0	0	0	0	0	0	0	-196	-20	100
35	51	0	0	0	0	0	0	0	0	-176	-10	100
40	45	0	0	0	0	0	0	0	-2	-174	4	100
45	42	0	0	0	0	0	0	0	-1	-173	-3	100
50	45	0	0	0	0	0	0	0	0	-165	-4	100
55	75	-3	0	0	0	0	0	0	-2	-186	1	100
60	77	-1	0	0	0	0	0	0	-12	-172	5	100
65	76	0	0	0	0	0	0	0	-9	-194	-4	100
70	79	-2	0	0	0	0	0	0	-12	-138	7	100
75	77	-1	0	0	0	0	0	0	-2	-144	7	100
80	78	0	0	0	0	0	0	0	-24	-101	4	100
85	76	0	0	0	0	0	0	0	-60	-80	13	100
90	69	-2	0	0	0	0	0	0	-23	-43	23	100
95	26	-1	0	0	0	0	0	0	-202	-49	21	100
Minimum	3	0	0	0	0	0	0	0	-59	-27	-9	100

The indication to be taken from Table 3.3-25 is that the full 200 cfs flow augmentation can be provided for most, but not all of the month of September.

Table 3.3-25. Alternative 2 Lake Wenatchee outflow-frequency difference (cfs) from historic.

% of Time Flow is Equaled of Exceeded	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Maximum	67	0	0	0	0	0	0	0	0	0	166	7
5	-22	0	0	0	0	0	0	0	0	92	-80	144
10	-1	0	0	0	0	0	0	0	0	-80	-60	152
15	19	0	0	0	0	0	0	0	0	-81	-45	172
20	-4	0	0	0	0	0	0	0	0	-147	-41	175
25	-15	-3	0	0	0	0	0	0	0	-269	0	174
30	-1	0	0	0	0	0	0	0	0	-196	8	178
35	7	0	0	0	0	0	0	0	0	-176	1	169
40	-1	0	0	0	0	0	0	0	-2	-174	19	167
45	-3	-1	0	0	0	0	0	0	-1	-173	23	169
50	1	0	0	0	0	0	0	0	0	-165	7	171
55	3	-3	0	0	0	0	0	0	-2	-186	7	173
60	3	-1	0	0	0	0	0	0	-12	-172	17	163
65	1	0	0	0	0	0	0	0	-9	-194	23	164
70	0	-2	0	0	0	0	0	0	-12	-138	29	162
75	1	-1	0	0	0	0	0	0	-2	-144	30	158
80	1	0	0	0	0	0	0	0	-24	-101	26	145
85	-1	0	0	0	0	0	0	0	-60	-80	32	82
90	-1	-3	0	0	0	0	0	0	-23	-43	35	34
95	1	-1	0	0	0	0	0	0	-202	-49	27	20
Minimum	2	0	0	0	0	0	0	0	-59	-27	-9	-8

Table 3.3-26 can be used to highlight the difference in storage and release characteristics between Alternatives 1, 2, and 3. Tables 3.3-27 and 3.3-28 present the Lake Wenatchee outflow results in relation to historic conditions for Alternatives 4 and 5.

Table 3.3-26. Alternative 3 Lake Wenatchee outflow-frequency difference (feet) from historic.

% of Time Flow is Equaled of Exceeded	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Maximum	0	0	0	0	0	0	0	0	0	16	12	39
5	0	0	0	0	0	0	0	0	25	68	3	8
10	0	0	0	0	0	0	0	0	92	7	0	8
15	-1	0	0	0	0	0	0	0	130	54	6	7
20	0	0	0	0	0	0	0	0	260	34	11	13
25	0	0	0	0	0	0	0	0	90	17	10	16
30	0	0	0	0	0	0	0	0	-77	18	17	19
35	0	0	0	0	0	0	0	0	-45	17	20	19
40	0	0	0	0	0	0	0	0	-57	28	38	24
45	0	0	0	0	0	0	0	0	-92	19	39	31
50	-2	0	0	0	0	0	0	0	-122	3	40	26
55	-2	0	0	0	0	0	0	0	-143	18	43	25
60	-1	0	0	0	0	0	0	0	-143	17	41	24
65	-1	0	0	0	0	0	0	0	-127	17	48	17
70	0	0	0	0	0	0	0	0	-127	17	64	17
75	-1	0	0	0	0	0	0	0	-188	11	62	12
80	0	0	0	0	0	0	0	0	-130	17	59	6
85	0	0	0	0	0	0	0	0	-254	14	63	7
90	-1	0	0	0	0	0	0	0	-235	17	67	3
95	0	0	0	0	0	0	0	0	-265	17	59	-1
Minimum	0	0	0	0	0	0	0	0	-59	17	34	-4

Table 3.3-27. Alternative 4 Lake Wenatchee outflow-frequency difference (cfs) from historic.

% of Time Flow is Equaled of Exceeded	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Maximum	9	0	0	0	0	0	0	0	0	0	0	50
5	25	0	0	0	0	0	0	0	0	0	-60	36
10	-2	0	0	0	0	0	0	0	0	0	-68	51
15	8	0	0	0	0	0	0	0	0	0	-45	50
20	3	10	0	0	0	0	0	0	0	0	-58	50
25	17	-2	0	0	0	0	0	0	0	0	-14	49
30	1	0	0	0	0	0	0	0	0	5	-22	49
35	20	0	0	0	0	0	0	0	0	-23	-31	49
40	19	3	0	0	0	0	0	0	0	-104	-8	50
45	10	0	0	0	0	0	0	0	0	-147	-15	50
50	13	0	0	0	0	0	0	0	0	-89	-13	50
55	29	-2	0	0	0	0	0	0	0	-98	-8	50
60	28	0	0	0	0	0	0	0	0	-78	-2	50
65	27	0	0	0	0	0	0	0	1	-112	-9	50
70	31	-2	0	0	0	0	0	0	0	-96	-4	50
75	31	0	0	0	0	0	0	0	0	-93	-3	50
80	36	0	0	0	0	0	0	0	7	-67	-5	50
85	34	0	0	0	0	0	0	0	6	-65	2	50
90	35	-1	0	0	0	0	0	0	-19	-38	11	50
95	10	-1	0	0	0	0	0	0	-25	-49	10	50
Minimum	5	0	0	0	0	0	0	0	-73	-27	-9	50

Table 3.3-28. Alternative 5 Lake Wenatchee outflow-frequency difference (cfs) from historic.

% of Time Flow is Equaled of Exceeded	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Maximum	5	0	0	0	0	0	0	0	0	0	0	39
5	-27	0	0	0	0	0	0	0	0	0	-60	60
10	-2	0	0	0	0	0	0	0	0	0	-63	64
15	7	0	0	0	0	0	0	0	0	0	-45	75
20	-11	0	0	0	0	0	0	0	0	0	-55	78
25	2	-3	0	0	0	0	0	0	0	0	-12	74
30	-4	0	0	0	0	0	0	0	0	5	-20	77
35	1	0	0	0	0	0	0	0	0	-23	-10	65
40	-3	0	0	0	0	0	0	0	0	-104	4	68
45	-2	0	0	0	0	0	0	0	0	-147	-7	76
50	2	0	0	0	0	0	0	0	0	-89	-7	75
55	-1	-3	0	0	0	0	0	0	0	-98	0	82
60	4	-1	0	0	0	0	0	0	0	-78	4	75
65	0	0	0	0	0	0	0	0	0	-112	-4	74
70	1	-2	0	0	0	0	0	0	0	-96	7	72
75	1	-1	0	0	0	0	0	0	0	-93	7	74
80	2	0	0	0	0	0	0	0	7	-67	4	64
85	-1	0	0	0	0	0	0	0	6	-65	13	56
90	0	-2	0	0	0	0	0	0	-19	-38	23	32
95	2	-1	0	0	0	0	0	0	-25	-49	21	18
Minimum	2	0	0	0	0	0	0	0	-73	-27	-9	-4

3.3.2.6.3 Results for Flow at the USGS Gage at Plain

The effects on flow of storage and release by the rubber dam will be carried downstream. This section provides graphical indications of flow changes due to the rubber dam as focused on the primary augmentation season between August and October. The augmentation flows are mostly at a constant rate for long periods, which means that they can be assumed to translate directly downstream. There is a substantial intervening drainage area between Lake Wenatchee and Plain that supplies significant local inflow. Note that the figures in this section start at flows greater than zero to highlight differences among the alternatives and historic conditions at a location with substantial base flow. Because there are established instream flow requirements at Plain, these values have also been included on the figures as a reference point.

During 1949, flows at Plain were historically in excess of the instream flow requirement during all of August, with a few days below the requirement in September and October. Figures 3.3-23 and 3.3-24 show the effectiveness of each Alternative at increasing flows and reducing the number of days below the instream flow requirements.

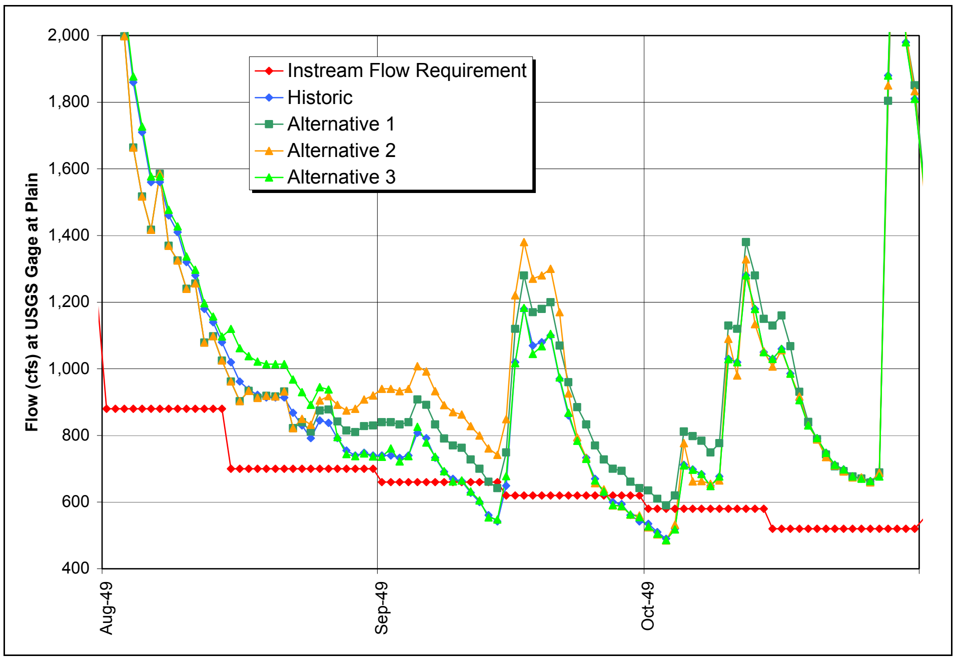


Figure 3.3-23. Alternatives 1, 2, and 3, and historic flows at Plain for the 1949 augmentation season.

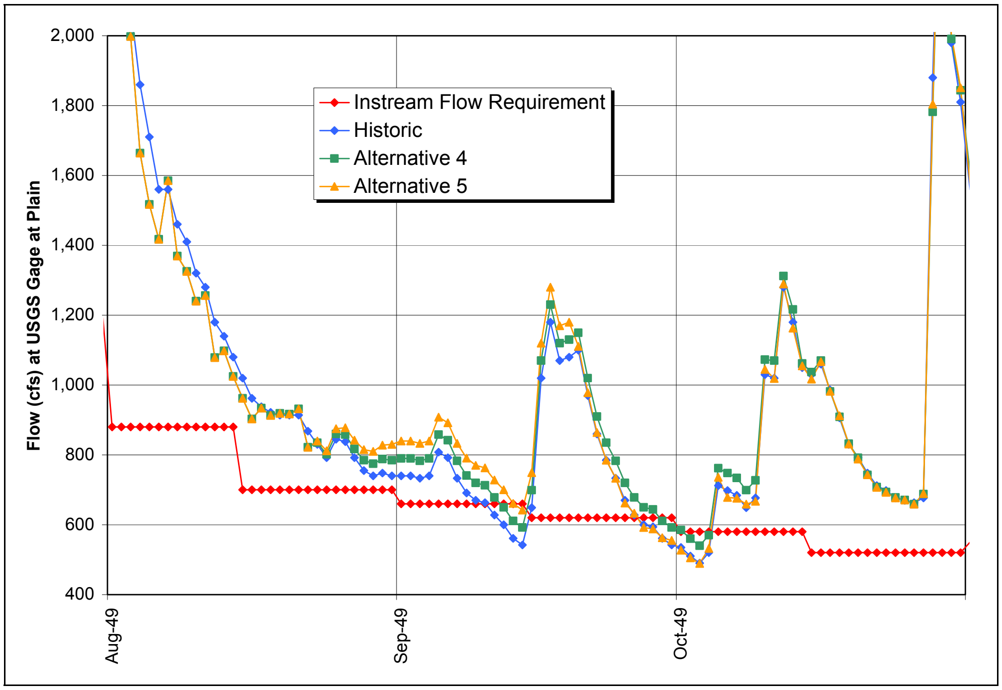


Figure 3.3-24. Alternatives 4 and 5, and historic flows at Plain for the 1949 augmentation season.

Figures 3.3-25 and 3.3-26 highlight the difficulty of a very dry year in which the historic flows were at times several hundred cubic feet per second below the instream flow requirements. Augmentation flows could make up a substantial part of the shortfall if they were properly timed. With regards to instream flow requirements, the greatest need was during August, with reduced needs due to rainfall in September, but this would be impossible to predict several weeks in advance.

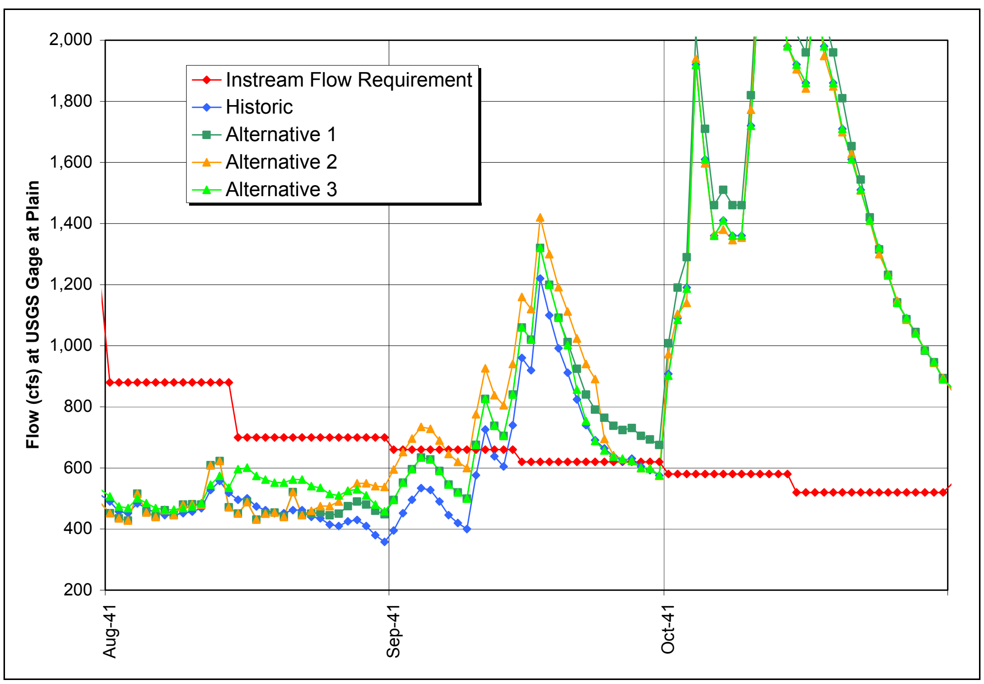


Figure 3.3-25. Alternatives 1, 2, and 3, and historic flows at Plain for the 1941 augmentation season.

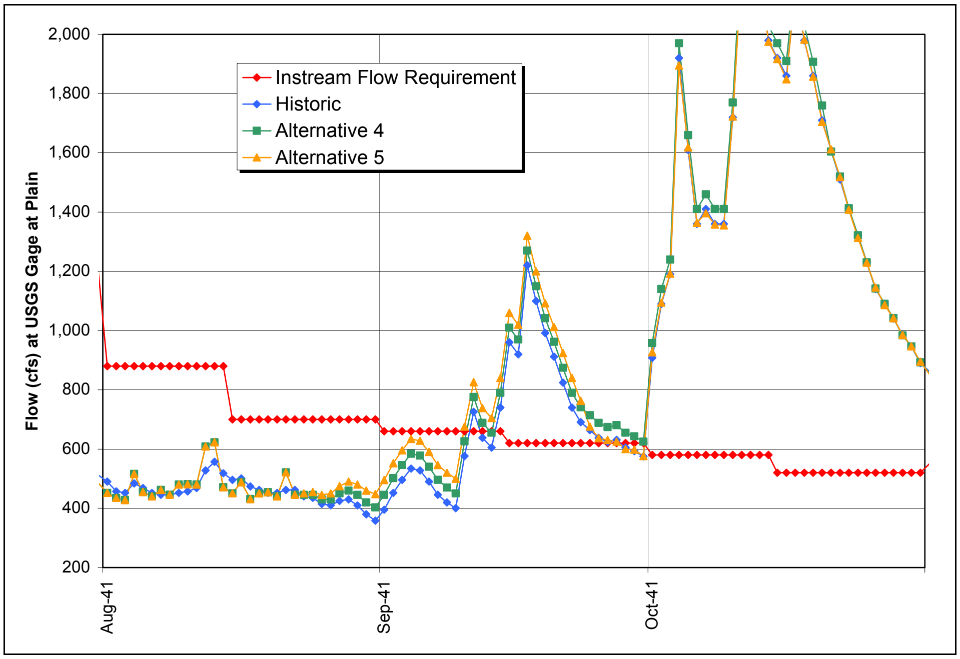


Figure 3.3-26. Alternatives 4 and 5, and historic flows at Plain for the 1941 augmentation season.

A final comparison of historic and alternative operation is provided in Table 3.3-29. For the months when the rubber dam would be storing or releasing flows for the various alternatives, Table 3.3-29 presents the average number of days with flow less than the instream flow requirement at the USGS gage at Plain. In comparison to the historic condition, it can be seen that all alternatives would result in fewer days below minimum requirements, ranging from 1 to 8 fewer deficient days on the average for the June through October season. Alternative 2 would be the most effective, reducing the days below minimum flow requirements by an average of 16% in comparison to the historic condition during the rubber dam operation season.

Table 3.3-29. Average number of days with flow less than instream flow requirement at USGS Gage 12457000, Wenatchee River at Plain – Historic and Alternative Operation.

Case	June	July	August	September	October	Total
Historic	1	4	12	19	14	50
Alternative 1	1	5	12	13	12	43
Alternative 2	1	5	11	11	14	42
Alternative 3	1	4	9	18	14	46
Alternative 4	1	5	12	17	14	49
Alternative 5	1	5	12	15	14	47

3.3.2.7 Future Operation Model Refinements

The operation model results revealed some areas where the operation of the rubber dam impoundment structure could be potentially refined. These refinements could improve the rubber dam operation as the project progresses to more detailed phases. Some areas where the operation model could be improved in future project phases are as follows:

- The rubber dam could be inflated (raised) later in many years and still achieve its maximum storage level. During wet years when all water needs can be met by natural flows, it may be unnecessary to raise the rubber dam at all. Mountain snowpack could be used as a reliable predictor of seasonal flow.
- The rate at which water is collected to storage could be reduced in most years. This would result in less change to downstream flow rates on collection to storage days.
- Releases from storage behind the rubber dam could be focused on lower flow days when the water is most needed, rather than being released at a constant rate.

3.3.4 Flood Operation

This section responds to Task 2.1.C Flood Operation Model of the scope of work. The primary issue is regarding whether the impoundment structure rubber dam bladder can be deflated (lowered) at a rate that would not increase historic maximum lake elevations. Another issue relates to the potential downstream impact of flood operation of the rubber dam. Where uncertainty exists, conservative assumptions were made throughout this analysis.

To provide estimates of the required deflation rate for the rubber dam, several data sources were checked. The rate of increase of Lake Wenatchee water levels during floods that have continuous records was examined. The period of record was also searched for maximum daily increases in water levels regardless of flow rate or time of year. A partial record of lake levels during the November 1990 flood was also examined.

The water level in Lake Wenatchee normally changes slowly, less than one foot in a day. Records indicate that day-to-day average lake level increases of more than one foot occur only about two times per year on the average. For the period of record for which continuous lake level records are available, January 1932 through September 1958, the lake levels during the four largest floods of record are plotted on Figure 3.3-27.

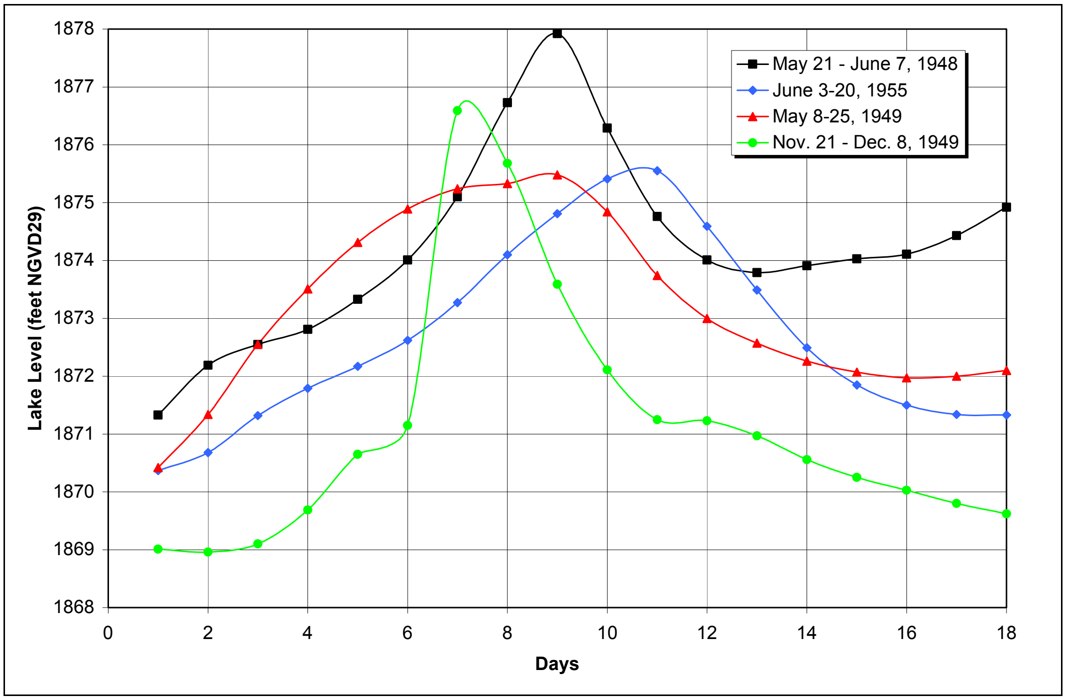


Figure 3.3-27. Lake levels during maximum floods having continuous records.

The values plotted on Figure 3.3-27 represent daily average levels except on the day of the maximum level. The instantaneous maximum level was substituted for the daily average level on the day of maximum water level.

The rubber dam would probably be partially or fully inflated (raised) from June or July through about October. For the purposes of the flood operation analysis, it was assumed that the rubber dam could also be raised during May, at a time when peak flows frequently occur. The maximum daily rate of change for the floods during the time period when the rubber dam could be inflated is 1.63 feet on May 27-28, 1948. This lake level change occurred a day before the peak, so the lake level was probably rising all of the day. A lake level rise of 1.63 feet over 24 hours is an average rise of 0.068 feet per hour. Assuming some variation during the day, the maximum hourly rate of rise is estimated to be 0.1 foot per hour, equivalent to a rate of rise of 2.4 feet per day.

The November-December 1949 flood shows a far more rapid rate of rise than any of the flood occurring in May or June. This would be as expected because the November-December floods probably result primarily from rainfall, while the May-June floods probably result primarily from snowmelt. On November 27, 1949, the average lake level was 3.55 feet above the previous day, and the instantaneous peak lake level was 5.44 feet above the average lake level the day before. Because the lake level on the following day was much higher than on the previous day, the lake level probably peaked late in the day on November 27. The conservative assumption will be made that the 5.44 feet of lake level rise occurred over 12 hours, which equates to 0.45 feet per hour. This maximum rate of rise was rounded off to 0.5 foot per hour to represent the fall-winter flood season when the rubber fabric dam would probably be fully down.

The maximum recorded day to day lake level rise appears to be 4.00 feet, which occurred on February 27-28, 1932. The lake level continued to rise on February 29. A rise of 4.00 feet in 24 hours would equate to an average rate of rise of 0.17 feet per hour.

Three water levels were recorded at the Kane boathouse on Lake Wenatchee during the November 1990 flood. The following data is approximate based on scaling the available diagram. The water level increased by about 3.0 feet from Saturday evening to 5 AM on Sunday. Assuming that Saturday evening would mean 11 PM, the lake level rise would be 3.0 feet in 6 hours, or 0.5 feet per hour.

It is currently estimated that the rubber dam bladder at the Lake Wenatchee outlet would be 10-feet high at most. Bridgestone Industrial Products America, the manufacturer of rubber dams, has indicated that rubber dams are designed for deflation times of 30 minutes or less. A conservative assumption will be made that it would take one hour for the rubber dam to go from fully inflated to fully deflated. The maximum historic rate of lake level rise during the period when the rubber dam is likely to be up was found to be 0.1 foot per hour. This means that the dam can be lowered at least 100 times faster than the lake level rises. Including the entire year, the maximum rate of lake level rise is 0.5 foot per hour. This means that even during periods when the dam would not be raised, it could be moved at least 20 times faster than necessary. With extremely large margins of safety on the rate of deflation, more detailed analysis of historic hourly lake levels is not warranted.

Anticipated rubber dam operating criteria would include a maximum lake level that would be controlled by the rubber dam. The maximum lake level controlled by the rubber dam could be at about El. 1872.4, for example. If natural lake inflows caused the lake level to be higher than El. 1872.4, the rubber dam would be automatically deflated to maintain a lake level of El. 1872.4. Figure 3.3-27 indicates that if the rubber dam had been raised before the occurrence of large floods, it would have been lowered several days before the peak lake levels and peak lake outflows would have occurred. This indicates that operation of the rubber dam would have no affect on peak flood levels at downstream locations.

From the above information it is concluded that the rubber dam could be lowered at a rate fast enough so that it would not increase the historic maximum lake elevations or outflows during periods of high inflow. There is a very substantial margin of safety to the rate at which the rubber dam could be lowered in relation to the rate of rise of the lake level.

For the majority of the year, 8 or 9 months from mid-October to early to mid-summer, the rubber dam bladder would be totally deflated and lie flat on its concrete foundation. The concrete foundation, as described in Section 3.5, would be sized to simulate the Lake Wenatchee outlet channel in shape and flow-carrying capacity. Therefore, neither the rubber dam impoundment structure foundation or the rubber bladder, when deflated, will restrict flows nor raise lake levels above historic levels currently experienced.

3.4 WIND AND WAVE EROSION ASSESSMENT

This section assesses the potential change in shoreline erosion that would likely result from maintaining a higher than typical water level in Lake Wenatchee during summer and fall. The shoreline, docks and bulkheads along Lake Wenatchee are subject to wave erosion because of high winds that occur on the lake. The aspect of the lake lines up well with the direction of wind blowing off of the east slopes of the Cascade Mountains creating conditions conducive to wave generation and erosion.

The assessment methodology is to first characterize the wind regime on Lake Wenatchee throughout the year, estimate the wave heights that occur for different wind speeds, and estimate the potential wave energy that occurs at different lake elevations for existing conditions. The potential wave energy that occurs for the two potential operating scenarios (maintain lake levels at elevations 1870.3 and 1872.4) are calculated and compared to the potential wave energy that occurs for existing conditions. One location, on the south shore of the lake, was selected for the analysis.

This assessment only calculates the potential wave energy and does not correlate that energy to a change in shoreline, dock or bulkhead erosion. Additional information on the erosion resistance for each would be required to make that assessment.

3.4.1 Wind Data

Wind data was collected from two sources: the Remote Automated Weather System (RAWS) and WeatherFlow, Inc. The RAWS network is used by federal agencies to obtain wind and weather data for use in predicting, preventing, and fighting forest fires. The RAWS network has two stations located near Lake Wenatchee. The two stations are Viewpoint and Dry Creek. The Viewpoint station is located approximately seven miles northeast of Lake Wenatchee State Park, on the northeast facing slope of Wenatchee Ridge. The Dry Creek station is approximately 10 miles southwest of Lake Wenatchee State Park, on the southeast facing slope of Miners Ridge. Each station record begins in 1993, with stations collecting average daily data. Beginning in mid-August of 2001, hourly wind records are available. The majority of the data collected was obtained in the spring, summer and fall months.

WeatherFlow, Inc. provides wind data through www.iwindsurf.com for many locations throughout the United States. A wind monitoring station was installed in July of 2002 on the north shore of Lake Wenatchee. The data from the station is posted on the Internet in 15-minute intervals for use by windsurfers to track favorable wind conditions. The wind data from July 2002 to the present was obtained from the WeatherFlow, Inc. web-site in graphical format.

3.4.2 Wind Analysis

The Lake Wenatchee wind data available from the WeatherFlow, Inc. site will be most representative because of its location adjacent to the lake. However the length of the data set available from WeatherFlow, Inc. is very short so that data was only used to compare to the data available from the two RAWS stations.

The wind data from the Dry Creek and Viewpoint sites were obtained and analyzed for wind speed and duration throughout the year. Figure 3.4-1 shows the percent of time wind blows at a given speed and direction. The time period of July through October 2002 was used because it contains hourly data for the months of potential reservoir operation. The average wind speed for the period of record for Dry Creek station is calculated to be 5.1 mph, whereas the Viewpoint station is only 2.6 mph.

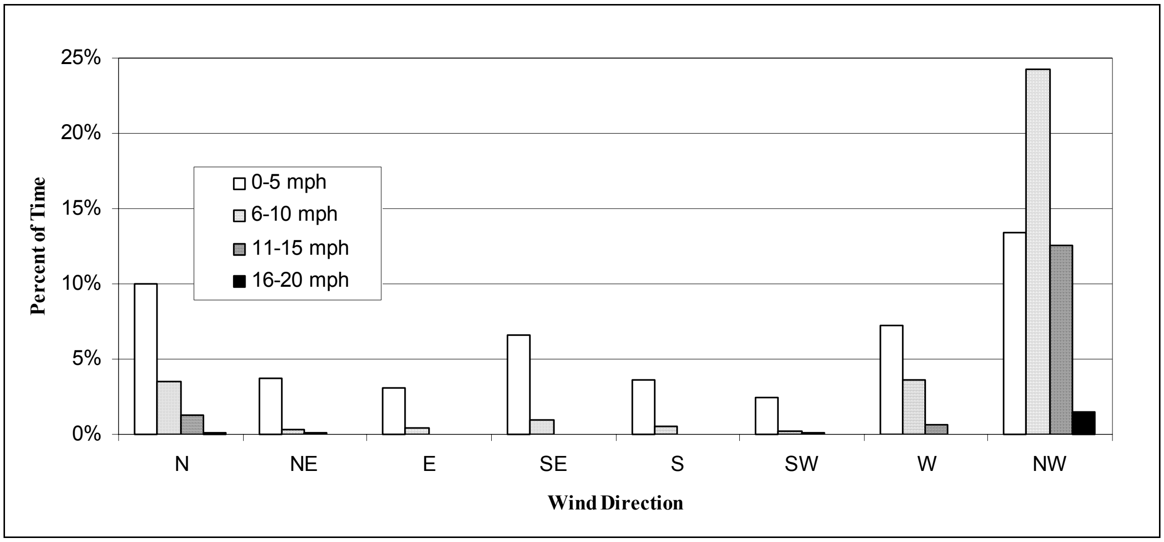


Figure 3.4-1. Prevailing Wind Velocity Occurance, RAWS Dry Creek Station, July-October, 2002.

The wind direction recorded by the Dry Creek station appears to correspond well to that recorded by the WeatherFlow, Inc. station. The wind direction recorded by the Viewpoint station did not correspond to wind direction recorded by the WeatherFlow, Inc. station or the Dry Creek station. The Dry Creek data more closely resembles the wind data from Lake Wenatchee because it is located in a valley that is more aligned to the prevailing winds than the Viewpoint station.

Wind speed data from twenty randomly selected days in the WeatherFlow, Inc. data set were compared to wind speed data from the Dry Creek Station. The WeatherFlow, Inc. station recorded wind speeds on average 1.5 times greater than the wind speeds from the Dry Creek station.

A multiplier factor of 1.5 was applied to the Dry Creek data to use in calculating wave height and wave energy on Lake Wenatchee. Figure 3.4-2 presents the average monthly wind speeds at the Dry Creek Station and the predicted average monthly Lake Wenatchee wind speeds.

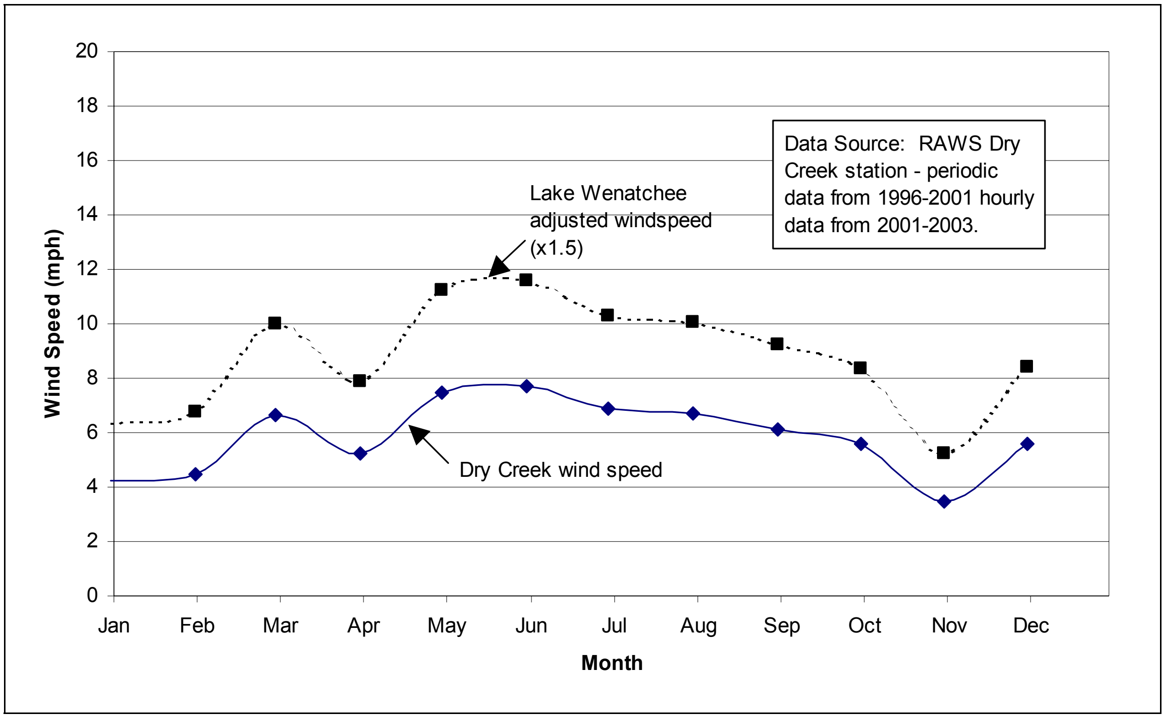


Figure 3.4-2. Monthly Average Wind Speed

3.4.3 Wave-Height Analysis

Wave heights were estimated using hourly and daily Dry Creek wind data adjusted to Lake Wenatchee along with the geometry of Lake Wenatchee. Wave heights were calculated using methods as described in *Wind-Wave Generation on Restricted Fetches* (Smith, J.M. 1991).

The methodology presented in *Effects of Simulated Water Level Management on Shore Erosion Rates* (Saint-Laurent, et al, 2001) was used to determine fetch lengths for wave-height calculations. Fetches were measured by a radial for each set of wind direction. These values are then interpolated, varying one degree at a time, after which a moving average is obtained for 15 consecutive values. For a given wind direction, the fetch retained (F = fetch length) among these values will be the one at an angle φ to the direction of the wind, such that the product

$$F_{\varphi}^{0.28} (\cos \varphi)^{0.44}$$

has a maximum value where F_{φ} is the linear fetch measured along the angle φ. The fetch and the angle φ can then be calculated for each wind direction and site being studied. A wind speed U (in m/s) acting along a fetch, defined by a length F (m) and a direction measured in relation to that of the wind generating waves of height H_s (m) and period T (s) from the following equations:

$$H_s = 0.0015\, g^{-0.5} F^{0.5} (U \cos \varphi)$$

$$T = 0.385\, g^{-0.72} F^{0.28} (U \cos \varphi)$$

where g is the gravitational acceleration (m/s^2).

Wind data from the WeatherFlow, Inc. station on Lake Wenatchee indicates that the prevailing winds are from the west-northwest (WNW). Twenty-one locations around Lake Wenatchee were mapped and wave heights estimated from the above equations using a WNW wind of 25 mph (represents typical medium-high wind) to illustrate the wave height calculation. Figure 3.4-3 shows the wave height contours approximated for this wind speed and direction. The southeast end of the lake, at Lake Wenatchee State Park, receives the largest waves. The wave height is estimated to be 1.4 feet high for a 25 mph wind from the WNW direction.

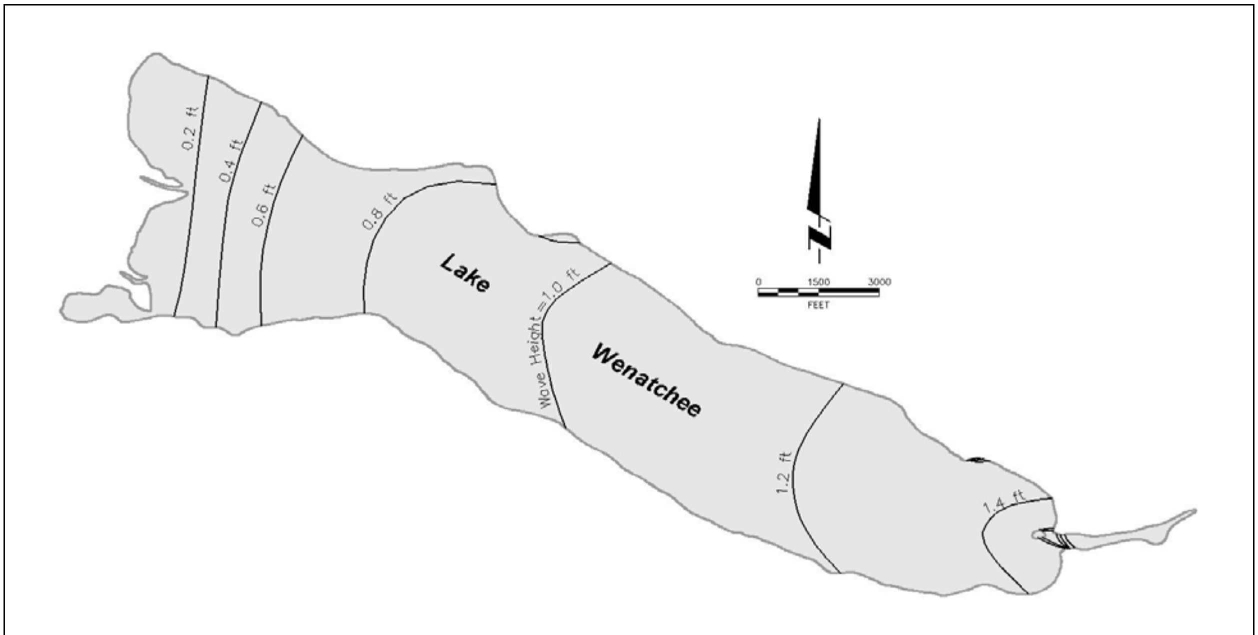


Figure 3.4-3. Wave Height Contours for 25 mph Wind Speed from WNW Direction

3.4.4 Wave-Energy Analysis

The wave heights and periods are such that it can be assumed that they are generated and travel in deep water. When approaching the shore, the waves are bent by refraction and (or) diffraction but the power remains constant provided there is no surf and that the frictional dissipation on the bed is negligible (Saint-Laurent, 2001). Wave power is calculated using the following equation:

$$P = 956\,(H_s)^2\,T$$

The unit of power is watts per meter of wave crest. Wave energy is calculated by multiplying the power by time, and is presented in the unit kilowatt-hours (kWh).

A single point on Lake Wenatchee was selected on the east end of South Shore Drive for calculating the wave energy generated during an average wind year. The wave power was calculated for this distinct location for each wind speed and wind direction value. The Dry Creek wind data adjusted to Lake Wenatchee was used for this analysis. Monthly average wind power and resulting wind energy was calculated for the period of record of wind data. To simplify the calculations, wind directions were grouped into two directions, WNW and ESE, assuming that the winds generally align with the valley of Lake Wenatchee.

The monthly average wind energy values were used in conjunction with the frequency of recurrence of lake levels to estimate total annual wind energy at different lake levels. The frequency of recurrence of lake levels for existing conditions and with the two potential operating scenarios are listed by month in Tables 3.3-19 through 3.3-23 of this report. Monthly average wave energy values were assigned to each lake level exceedence value, according to month. Note that each exceedence value represents an equal amount of time. In this case, the exceedence values are in 5% increments by month, so each value represents 5% of a month, which is approximately 1.5 days. The complete year of exceedence values with the associated wave energy were reordered by lake elevation. Wave energies were summed for every 0.5 feet of lake water level.

A comparison of wave energy between existing conditions and for the operational scenario that would impound water to El. 1872.4 is shown in Figure 3.4-4. This operating scenario would result in approximately 1.9 times more potential wave energy at or above the ordinary high water (OHW) lake level at the site along South Shore Drive. The wave energy above the OHW level was used in the comparison as our site reviews at the OHW showed little potential for wave erosion to occur. The threshold elevation where increased wave energy will cause increased erosion is not known, but is likely higher than the OHW. This analysis presents a conservative (high) estimate of the potential increase in wave energy. The potential increase in other parts of the lake is likely lower because of the lower wave energy at other locations.

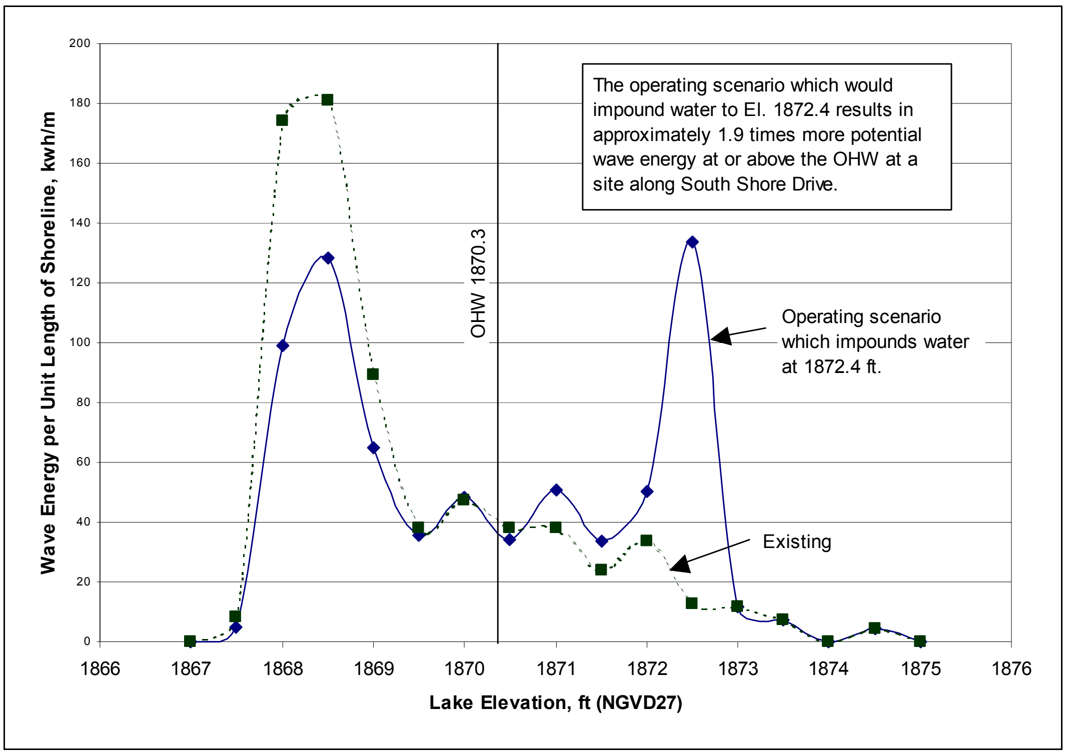


Figure 3.4-4. Comparison of Wave Energy at Site on South Shore Drive between Existing Conditions and the Operational Scenario that Impounds Water at El. 1872.4.

A comparison of wave energy between existing conditions and for the operational scenario that would impound water to El. 1870.3 is shown in Figure 3.4-5. This operating scenario would result in approximately 1.3 times more potential wave energy at or above the ordinary high water (OHW) lake level at the site evaluated on South Shore Drive.

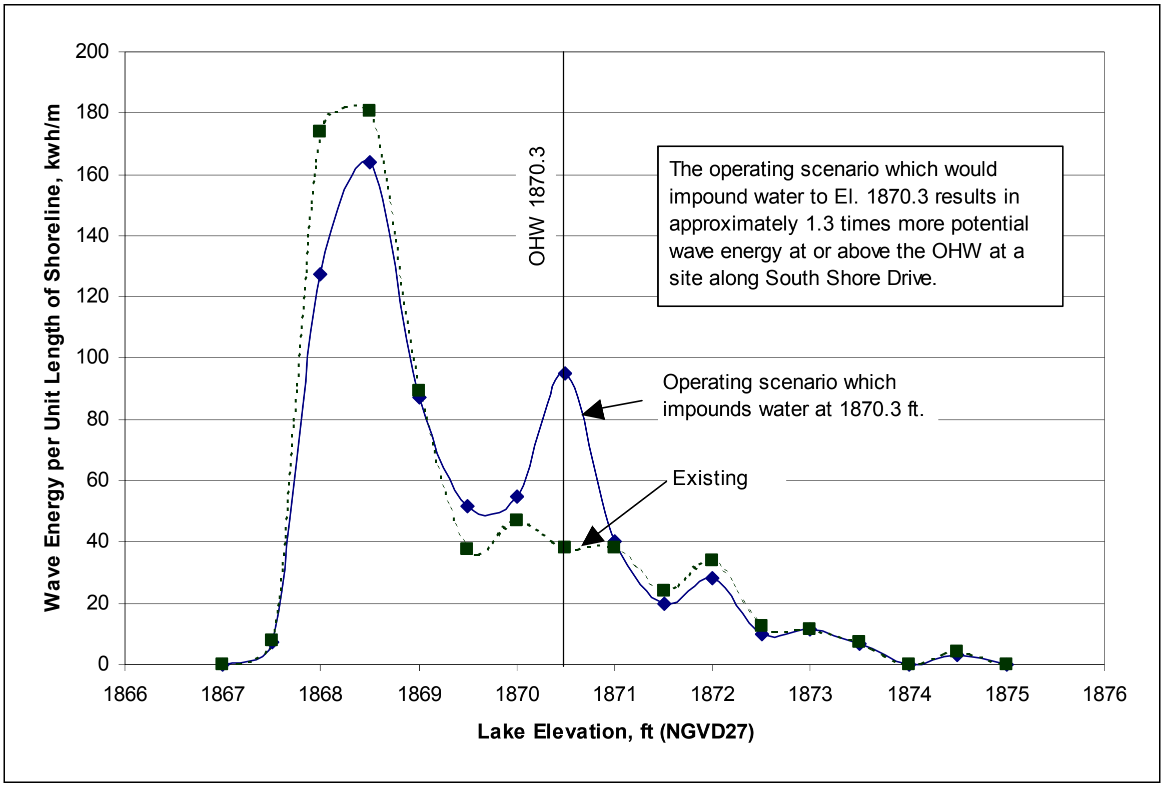


Figure 3.4-5. Comparison of Wave Energy at Site on South Shore Drive between Existing Conditions and the Operational Scenario Which Impounds Water at El. 1870.3.

This analysis provides an indication of the additional wave energy directed at one site evaluated on South Shore Drive where wave heights and energy are the highest for the lake. There is not a direct relationship between wave energy and erosion as there are many factors that affect the potential for shoreline erosion, such as beach slope, beach material and presence of vegetation. For structures on the lake, factors such as deck elevation and structure strength are important. Our review of shoreline conditions at the OHW lead us to the opinion that very little additional erosion would occur if the lake were to be maintained at El. 1870.3 (OHW). There is likely to be more wave erosion occurring if the lake is maintained at El. 1872.4 as the higher lake level would more deeply submerge structures and would submerge portions of shoreline that aren't usually submerged and therefore more likely to be susceptible to erosion.

A more detailed study of shoreline and structure conditions would need to be performed to more definitely address the erosion impacts from the two operating scenarios.

3.5 IMPOUNDMENT STRUCTURE

3.5.1 Background

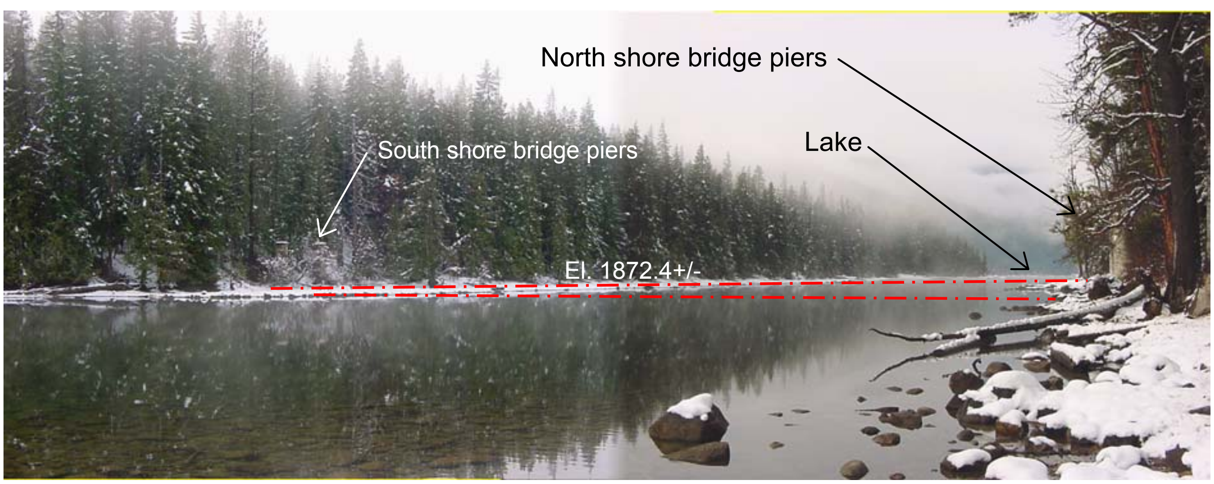
Currently, the Wenatchee River flows in an uncontrolled manner from Lake Wenatchee. As the lake level rises with increased inflow, more flow discharges from the lake into the Wenatchee River. An impoundment structure would be required to allow seasonal storage and release of water from Lake Wenatchee. The structure would span from the north shore to the south shore, across the entire width of the river, and would be raised and lowered on demand to allow storage of water during the late spring and summer and for controlled release of stored water during the late summer and early fall, respectively. During the remainder of the year the structure would be lowered such that lake outflows would pass unimpeded. This subsection addresses the technical features for constructing an impoundment structure downstream of Lake Wenatchee and proposes a potential layout for such a structure.

3.5.2 Field Reconnaissance

On December 13, 2002 MWH visited Lake Wenatchee for the purpose of walking the outlet to select a suitable potential location for a low-level impoundment structure. The structure would have a moveable crest that would allow impoundment of water in Lake Wenatchee during the summer and early fall when the lake level typically falls to its lowest annual levels. Choosing a suitable location for an impoundment structure is one aspect in determining the technical feasibility of seasonally raising the water surface in the lake.

The Wenatchee River (outlet channel) from Lake Wenatchee extends eastward about 3,300 feet from the mouth of the lake to the State Highway 207 Bridge. For the first 1,800 feet of the outlet channel, the river's hydraulic grade line closely matches that of the lake (i.e., the river water level is approximately equal to that of the lake). Downstream of that reach to the bridge, the water surface gradient is steeper with gravel bars and riffles (Photograph 3.5-1). Therefore, to minimize the height of a new impoundment structure, a location within the upstream most 1,800 feet of the outlet channel, at least 1,500 feet upstream of the bridge, was considered. The location selected in the field for the impoundment structure is located approximately 1,600 feet downstream of the mouth of the lake at a point where the river is about 200 feet wide. This is a location where there had previously existed a bridge crossing of the river and where four concrete piers, two on each bank, still exist (Photograph 3.5-2). This is a location where the river is the narrowest and, therefore, the structure length would be minimized. In addition, there are access roads to each bank from the north and the south, which would aid in construction and minimize ground disturbing activities away from the river. For the sake of the site visit, it was assumed that the lake/river level would be raised not more than 5 feet above the lowest recorded lake level. The overbanks adjacent to the preferred structure location slope steeply up and away, approximately at 1.5 or 2 horizontal to 1 vertical on both sides of the river (Photographs 3.5-3 and 3.5-4).

Photograph 3.5-1. Wenatchee River, looking upstream (westward), immediately downstream of Lake Wenatchee and upstream of the State Highway 207 Bridge.



Photograph 3.5-2. Potential location of impoundment structure on Wenatchee River, looking upstream.

Photograph 3.5-3. North shore overbank.

Photograph 3.5-4. South shore overbank.

The river depth was estimated at 4 to 5 feet at the potential location of the impoundment structure. Bedrock was not detected in the area and would not likely to be found during excavations for the structure foundation. The area selected for the impoundment structure is alluvium, which is likely from reworked glacial outwash. This means that the soils underlying the outlet channel are a fairly well graded mixture of silt, sand, gravel, cobbles, and boulders. These soils are strong enough to support a structure of the proportions contemplated. The depth to bedrock is not known. It is suspected that bedrock will be the Chumstick sandstone to be found at a depth of at least 200 feet.

During our trip we also visited with the Wenatchee Reclamation District and obtained copies of historical survey drawings of the Lake Wenatchee outlet channel. The survey information included cross-sectional information in the area where the impoundment structure is being considered to be located. For the sake of this feasibility study, and verified with field observations, we believe that the historical survey data to be accurate enough to allow structure layout and feasibility cost estimating.

3.5.3 Rubber Dam Impoundment Structure

3.5.3.1 General

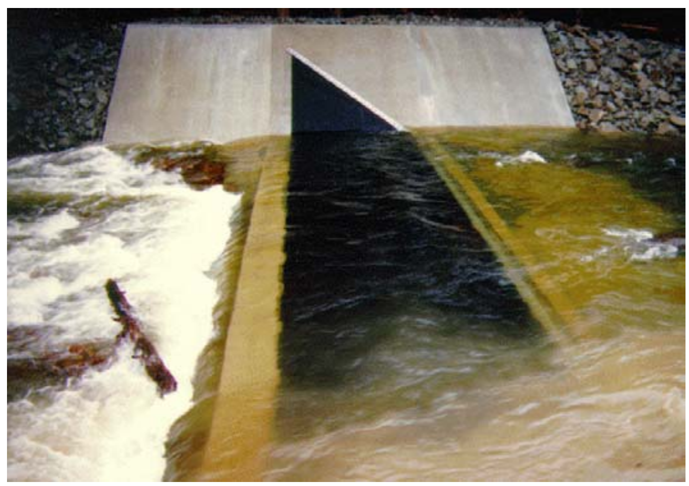
The site selected for the impoundment structure is approximately 1,600 feet downstream of the mouth of the lake as shown on Exhibit 3.5-1. There is a state park on both the north and south banks of the river at the mouth of the lake, which means that the public will have close access and viewing of the structure. The main criteria for choosing an impoundment structure type are as follows:

- Able to impound water to a depth of 4 to 5 feet
- Able to incrementally release water on demand
- Able to be lowered to allow all lake outflows to move unimpeded downstream without raising the water levels in Lake Wenatchee over historic levels
- Have automated controls
- Require minimal on-site operations and maintenance labor
- Be durable under all expected flows and debris loading

- Be vandal resistant
- Not cause any safety concerns to the public
- Be visually unobtrusive
- Allow passage of fish upstream and downstream of the structure
- Can be constructed in a single low flow season

A structure that meets these criteria is a so-called rubber dam structure. Other types of structures, which meet some of these criteria, involve steel gated structures that are extremely expensive to construct and maintain, and require a long instream construction timeframe. A rubber dam is a structure that consists of a concrete foundation, an air or water inflatable rubber bladder, associated equipment and controls, and a small equipment building. This technology has become quite popular in the U.S. in the last 20 years, and has a proven track record for reliability around the world. In 1987, MWH designed a rubber dam structure for the Weeks Falls Hydroelectric Project on the South Fork Snoqualmie River near North Bend, Washington, west of Snoqualmie Pass summit (Photographs 3.5-5 and 3.5-6). The rubber dam has been in operation for over 16 years in an isolated location without major problems or maintenance.

Photograph 3.5-5. Week Falls rubber dam; inflated with water over crest.



Photograph 3.5-6. Weeks Falls rubber dam; deflated.

3.5.3.2 Description of Rubber Dam Structure

Exhibits 3.5-1 and 3.5-2 shows a potential layout of a rubber dam structure on the outlet channel of Lake Wenatchee. The structure would be approximately 200 feet long from shore to shore and installed as a single span. The structure would be oriented at about a 5-degree angle with respect to a perpendicular line drawn from shore to shore to aid in the upstream passage of fish. The foundation of the structure would be of cast-in-place concrete slab with a flat surface at Elevation (El.) 1862.4, as indicated in Exhibit 3.5-3, and would be about 5 feet below the minimum lake level and about 8 feet below the Ordinary High Water line. The foundation would be constructed on structural fill and have a sheet pile cutoff wall. Sheet piling would be installed for three reasons; (1) to prevent scouring and undermining of the upstream side of the rubber dam foundation, (2) to reduce uplift pressures under the dam foundation, and (3) to prevent seepage immediately under the foundation that would cause piping of foundation material and failure of the foundation. It should be noted that the estimated depth of 25 feet is based on experience and not by specific analysis. It should be noted that a cutoff wall would not reduce or stop subsurface flow. A cutoff would lengthen the seepage path to reduce uplift on the structure and on the foundation downstream. If the Wenatchee River is typical of other rivers in the area, a large quantity of flow in the substrate would not be expected because the river bottom tends to seal itself and carry almost all of its flow in the channel. It would not be expected that much change would occur in subsurface flow resulting from the lake raise or the sheet piles. The feasibility of installing a sheet pile cutoff would need to be determined based on further study and explorations.

Heavy stone riprap would be placed upstream and downstream of the concrete foundation to inhibit scouring. The concrete abutments of the rubber dam foundation would be sloped at about 2.5 horizontal to 1 vertical.

The rubber dam bladder would be 10 feet tall when inflated and have a crest elevation of 1,872.4. A different bladder height and crest elevation could be selected based on the finally selected maximum lake level. The rubber bladder would be air-inflated and constructed of multiple layers of vulcanized heavy-duty, nylon-reinforced rubber, similar to an automobile tire, with an EPDM (Ethylene Propylene Diene Monomer) cover to withstand ozone and ultraviolet light. The thickness of the bladder would be in the range of 0.625 to 0.75 inches. The rubber body would be attached to the foundation with two sets of stainless steel anchor bolts and clamping plates.

There are only a few manufacturers of rubber dam products worldwide, with Bridgestone Industrial Products America, Inc. being the major supplier in the U.S. Another company, Obermeyer Hydro, Inc. markets an air-inflated bladder product that raises and lowers upstream steel gates (plates). The steel gates are purported to protect the rubber body against ice and debris. For the purpose of this study we have assumed that a Bridgestone Rubber Dam would be installed in the Lake Wenatchee outlet channel.

It is proposed that a cast-in-place concrete building or vault be located on the right (south) bank of the river adjacent to the right rubber dam abutment. The vault would essentially be constructed below grade so as to be hidden from view and would contain air-inflated rubber bladder blowers, automated air valves, and operational electronic controls. 120/240 volt AC power would be brought into the equipment vault via an underground or overhead distribution line. A fish ladder would be located on the left (north) shore of the river.

3.5.3.3 Operation of Rubber Dam System

Typical operation of the rubber dam would be in a totally deflated mode with the rubber bladder lying flat against its foundation. This mode of operation would occur for 8 to 9 months each year during the historically higher flow season. The foundation would be designed such as to simulate the shape of the river channel and would not impede flows or raise historic water levels in the lake.

Once inflated, the rubber bladder would impound water to a proposed depth of about 10 feet over the foundation or up to about 4 feet above historic lake levels depending on the operational alternative selected (see Section 3.3). Water on the downstream side of the bladder would be on the order of 4.5 feet deep, depending on river flow. When inflation takes place in the late spring or summer, the rubber bladder would be inflated gradually with air based on certain operating criteria (to be determined). Once the desired inflation is reached (about 2 pounds per square inch) and the proper lake level is obtained, the bladder would be switched to automatic mode, which monitors and maintains the upstream water level.

Storage and release algorithms would be part of a computer-based control system that would regulate the internal pressure of the bladder and inflation and deflation. A computer monitor, through various screens, would allow the operator to control set points, operate individual devices (blowers, discharge and crossover valves), monitor alarms and evaluate historical data.

The rubber bladder would be inflated with an air compressor to impound water. The internal air pressure would be adjusted automatically to maintain a constant upstream water level during storage and amount of deflation during periods of water release. The rubber dam would be operated in partially-deflated state during periods of release. The ability to control the rate of outflow, if required to be more precise, may require that a gage be installed downstream and tied to the rubber dam control system. Alternately, a separate slide gate or short-span Obermeyer gate may be required and installed adjacent to the fish ladder (not shown on Exhibit 3.5-2), and a rating curve developed to release a controlled amount of water. The rubber bladder would be automatically deflated to pass high flows. When fully deflated the rubber bladder would lay flat on its concrete foundation.

3.5.3.4 Performance and Maintenance of Rubber Dam Structure

Typically large woody debris, such as root balls, large trees and snags pass down the river during large storm events. At Lake Wenatchee such storms typically occur from about November through February. During those months the rubber bladder would be deflated and lying flat on its concrete foundation. The stage of the river at such events would be at least over 10 feet over the deflated bladder when such debris passes the dam and there would only be a limited possibility of puncturing the rubber bladder. In addition, Lake Wenatchee acts to attenuate the possibility of neutrally buoyant and sinking debris from passing downstream.

Rubber dam structures have been in operation in severe locations for many years. As previously mentioned, MWH designed a rubber dam structure on the South Fork Snoqualmie River, about 60 miles from Lake Wenatchee. It is 8 feet high by 75 feet wide, in a narrow river channel, and has been in service for over 16 years. Over the years it has passed a large quantity of gravel and woody debris. Though there have been major events (November 1995 and February 1996) at Weeks Falls, there has not been any damage to the bladder caused by woody debris. Over the years there has been the need to do some minor plugging and patching, but nothing that can be classified as serious. Damage to date has involved minor holes caused by rifle fire. Such holes are of minor concern to a rubber dam because the rubber bladder is maintained at such a low pressure (2 psi). These type of punctures cause slow leaks from the bladder that are compensated by occasional air being added automatically by the air compressor system. Holes can be repaired with plugs similar to those used on automobile tires while the bladder is still inflated. The operator of the Weeks Falls rubber dam, CHI Energy, Inc., is very supportive of the technology and vouches for the durability of rubber dams in northwestern riverine environments.

Also within the last 12 years, Dryden Dam on the Wenatchee River has been retrofitted with an inflatable rubber bladder to aid in diverting water into Wenatchee Reclamation District's Dryden Canal. The Dryden rubber dam is 3 feet high and inflated with water and has performed without major problems.

Rubber dams have been installed in steep gradient streams around the world that move massive amount of gravel and sharp rocks. Testing and in-service operation has found that the rubber bladders to have a life of 30 years or longer. In addition, testing for damage caused by ozone and ultra-violet (UV) light has found an insignificant amount of deterioration.

At the project site vandalism may be of concern. Vandalism may be in the form of knife slashes to the rubber bladder or breaking into the air handling/equipment vault. Since the project is in the vicinity of Lake Wenatchee State Park on both the north and south shores of the river, the public would have convenient access. It would be important to consider public access and safety in the design of the impoundment structure. The rubber bladder can be manufactured with ceramic chips embedded in the rubber layers to make slashing difficult. At some rubber dam installations, beavers gnawing on the rubber bladders have caused severe damage. Ceramic chips have also been used as a deterrent against beavers. The equipment vault would be constructed of reinforced concrete with heavy steel hatches and intruder alarms. Chain link fencing would be provided adjacent to the fish ladder and areas where the public would be protected against fall hazards and to limit access.

Access to the rubber dam via boat or by swimming would be possible from either the upstream or downstream side. Floating protective barriers would be installed approximately 100 feet upstream and downstream of the rubber dam to prevent boaters from falling over the rubber bladder or having access for purpose of vandalism. The rubber bladder may be considered an attractive nuisance and could attract people walking on or diving from the bladders. Since there will always be water on both sides of the rubber dam, fall danger will not be severe. Such activities are difficult to prevent but the aforementioned chain link fencing and warning signs would be provided to warn and restrict access. Regular patrol of the rubber dam installation by project operators or law enforcement personnel would be encouraged.

Road access would be provided to both the north and south end of the rubber dam structure. Primary access would be to the south end where the equipment vault is located. Daily visits by operations personnel may be necessary if vandalism is a problem. Otherwise, semi-weekly or bi-daily visits may appropriate to monitor and perform regular maintenance. Since the operation and control functions can be transmitted to a remote location for monitoring and manual control of the rubber dam, the facility would be unmanned. An abandoned access road exists from the south bank access road to the south shore of the proposed impoundment structure. This road would be upgraded, gated and used for access to the rubber dam and equipment vault. Access to the north end of the rubber dam and fish ladder would be through the state park on the north side of the river and may require access on a weekly basis. Since access to the facility would be infrequent, there would only be a minor impact to local traffic and recreational activities.

The rubber bladder requires no long-term maintenance except for patching and plugging of minor holes as may be required. The other features of the rubber dam system should require only nominal maintenance except for the electronic and electrical systems which would require periodic maintenance, replacement and upgrading of parts.

3.5.3.5 Rubber Dam Structure Aesthetics

The rubber dam impoundment structure requires construction of concrete, steel fencing and installation of a 10-foot tall by 200-foot long black rubber bladder. The majority of the concrete would be constructed in the river and be continually inundated and hidden from view. Only the upper portions of the sloping concrete foundations at each side of the river and the fish ladder would be visible. From the upstream side, the viewing corridors from the state parks would not see the bladder when inflated. From the downstream side the rubber dam would be visible when inflated. However when deflated the bladder would not be visible from the upstream or downstream sides. For fish passage reasons it is recommended that released flow pass over a partially-deflated rubber dam and adjacent to the fish ladder on the north bank. Alternately, and without regard to fisheries concerns, released water can be released over the entire length of the rubber dam (Photograph 3.5-5), which is more aesthetically pleasing, but creates a false attraction to upstream migrating fish.

3.5.3.6 Fish Ladder

A primary species of concern for adult upstream passage is Spring Chinook, which is an Endangered Species Act (ESA) listed fish that is present in the Wenatchee River during the period when the dam would be operated. Bull Trout and Westslope Cutthroat trout are resident species that also exist in the Wenatchee River. The resident trout are less capable swimmers than adult Spring Chinook and require lower steps for passing over ladders. Therefore, the conceptual design ladder proposed would step up in 6-inch vertical steps, which would enable passage of all the fish species present in the Wenatchee River.

The conceptual design of the fish ladder is called a pool and chute ladder, which is shown on Exhibit 3.5-2, and is considered to be more like a roughened channel fishway than a traditional stepped fish ladder such as a pool and weir or vertical slot ladder. The pool and chute ladder would consist of 15-foot wide V-shaped weirs with a 3-foot rectangular notch positioned in the base of the weir for each step. It would be located on the north side of the river adjacent to the state park. The orientation of the rubber dam would be angled upstream from the south to the north sides of the river, positioning the ladder entrance at the furthest point upstream. There would be 9 to 10 steps in the ladder, for a total rise of approximately 4.5 to 5 feet. This layout is based on the preliminary hydraulic design and operation of the rubber dam, in which the water surface upstream will be maintained at a high water surface elevation of 1872.4, and minimum tailwater surface at El. 1867.7 during the period of regulation. Flows in the pool and chute ladder would depend on the elevation setting of the base of the weir notch relative to the water surface upstream. Flows of 30 cfs to 40 cfs could be expected through the ladder under normal conditions for the configuration shown. Instream organic (rock and wood) structures may be required to maintain a channel to the ladder. Examples of these structures would be an excavated pool below the ladder entrance, and rock weirs positioned in the river upstream and downstream. Such structures would be designed and installed if they would not impede or raise the historical water surface in the lake under all flow conditions.

Advantages of the pool and chute ladder are an ability to easily pass debris and that it is hydraulically self-regulating. The pool and chute design would require less maintenance and operation for cleaning debris and regulating flow. The major disadvantage of the pool and chute ladder is that it is normally recommended for use in passing heights of 6 feet or lower due to the minimal energy dissipation in the small pools during high flows. The pool and chute design is appropriate for this design considering that it will be in operation only during the water storage months and its operating height will be less than 5 feet under all conditions. During other times of the year the rubber dam will be partially or fully deflated and a fish ladder will not be required. The timing of actual ladder use would become more refined as the operational hydraulics of the rubber dam is further developed during final design.

It is possible that a more traditional type of fish ladder such as a pool and weir or a vertical slot may be required if the design process proceeds. This may occur after the hydraulic details are more refined, and the resource agencies have reviewed the design. Agency input would be expected from NOAA Fisheries (formerly known as National Marine Fisheries Service or NMFS), the Washington Department of Fish and Wildlife (WDFW), and the U.S. Fish and Wildlife Service (USFWS). A higher capacity ladder may be necessary due to the numbers of fish in the river at the time of impoundment. Also, the hydraulic operation of the dam may require a fishway with higher capacity and additional attraction flow at the entrance depending on the flow in the river at the time of migration. The concrete foundation slab of the rubber dam would be recessed at its left end to allow the first point of deflation of the bladder to be adjacent to the fish ladder to provide attraction flow. It is not anticipated that a second fish ladder to be required on the right bank if water releases from the rubber dam are made adjacent to the left bank fish ladder.

3.5.3.7 Rubber Dam and Fish Ladder Construction Permitting Considerations

In order to construct the impoundment structure, or any structure within navigable waterways, certain permits and consultations would be required. Such permits may include U.S. Army Corps of Engineers Section 404 (Clean Water Act) permit, U.S. Fish and Wildlife Service/ NOAA Fisheries Section 7 or Section 10 ESA compliance, Washington Department of Fish and Wildlife Hydraulic Project Approval, and Washington Department of Ecology Short-term Water Quality Waiver, etc. The more pertinent of these permits and associated requirements are described in Section 4.0.

3.5.3.8 Rubber Dam and Fish Ladder Construction Considerations

The rubber dam impoundment structure would require excavation, installation of sheet piles, and construction of a concrete foundation in the river. All this construction must be performed while the outlet channel is continually flowing, therefore it would be desirable to perform instream work during a period of lower flow (summer and early fall). Installation of a cofferdam would be required to construct these features in the dry and to maintain water quality standards downstream of the project. An estimated construction schedule is shown in Figure 3.5-1. Times to design the project, obtain permits, purchase land, perform legal activities, etc. are not included in the schedule.

It is estimated that the project can be constructed on site in about 6 months with instream construction taking just over 4 ½ months with the use of a Portadam® cofferdam. Portadams consist of steel A-frames set in the river side-by-side and covered with an impermeable membrane to form a cofferdam around the required work area as shown in Photographs 3.5-7 and 3.5-8. Resource agencies have accepted this type of cofferdam in the past because it does not require water-polluting activities as occurs when installing an earthen cofferdam. In addition, Portadam cofferdams are much less expensive and quicker to install than cellular type cofferdams.

Photograph 3.5-7 Typical Portadam river crossing. (Photo courtesy Portadam, Inc.)

Photograph 3.5-8. Portadam at MWH Wynoochee Hydro Project on the Wynoochee River near Montesano, WA

ID	Task Name	Duration
1	**Bidding**	**10 wks**
2	Plans and specs complete	0 days
3	Advertise for bids	0 days
4	Bidding period	6 wks
5	Bid opening	0 days
6	Award construction contract	2 wks
7		
8	**Construction**	**44 wks**
9	Notice to proceed with construction	0 days
10	Procure rubber dam equipment	32 wks
11	Deliver rubber dam embedded parts	0 days
12	Deliver rubber dam body	0 days
13	Order cofferdam material	6 wks
14	Mobilize to project	3 wks
15	Improve access roads	1 wk
16	**In-River Work**	**18.8 wks**
17	Install Stage 1 (North) cofferdam and dewatering system	1 wk
18	Excavate fish ladder and left rubber dam foundation	1 wk
19	Install left side sheet piles	9 days
20	Form and place fish ladder slab	1 wk
21	Form and place fish ladder walls/weirs	4 wks
22	Complete excavation and install structural fill	1 wk
23	Form and place left side rubber dam foundation	4 wks
24	Install rubber dam body on left side	1 wk
25	Remove Stage 1 cofferdam and install Stage 2 (South)	1 wk
26	Excavate equipment building right rubber dam foundation	1 wk
27	Install right side sheet piles	9 days
28	Form and place equipment building slab	1 wk
29	Form and place equipment building walls/roof	3 wks
30	Complete excavation and install structural fill	3 days

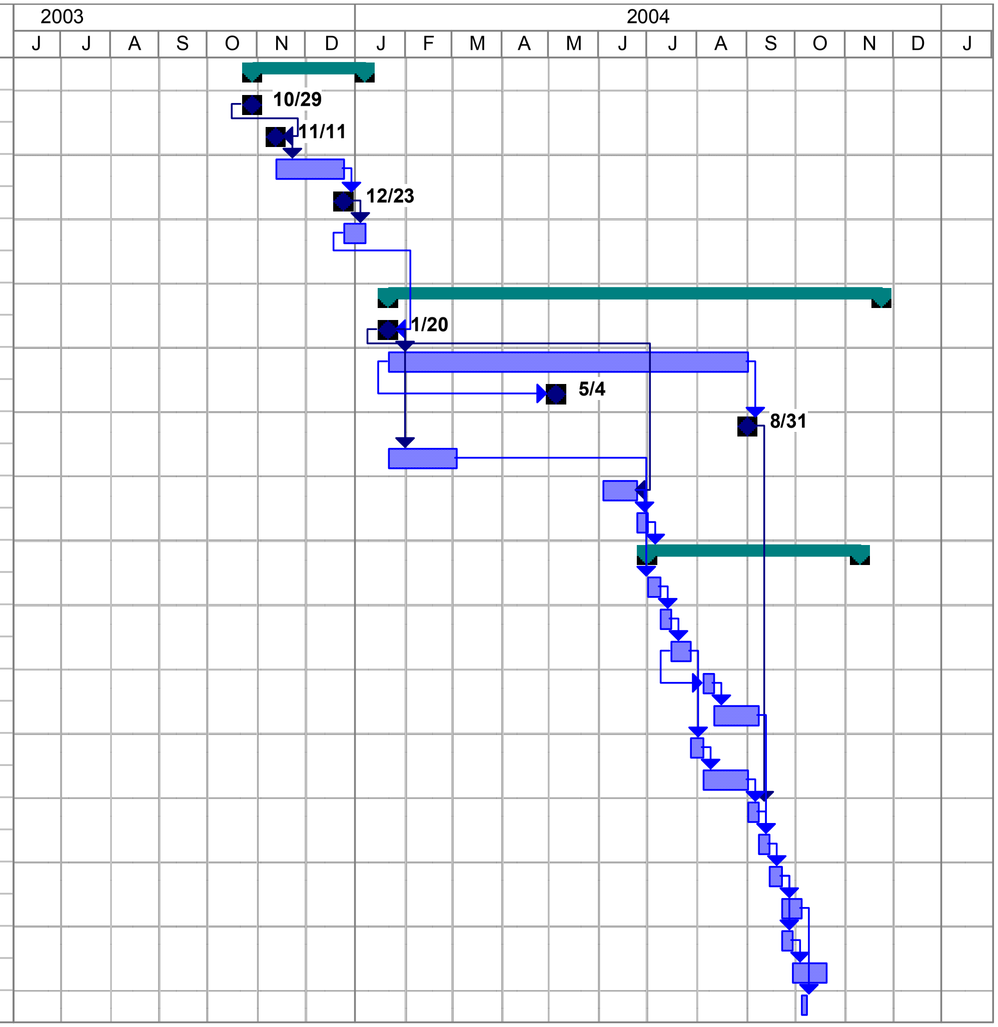


Figure 3.5-1. Lake Wenatchee Impoundment Structure – Construction Schedule.

It is proposed that the cofferdam be constructed in two halves or stages. The first stage would include installing the cofferdam around the north half of the structure (similar to Photograph 3.5-7), constructing the north half of the rubber dam foundation, attaching half of the rubber bladder, and constructing the fish ladder. Construction of the second half of the structure would require removing the first stage Portadam and reinstalling it around the south half of the construction area for construction of the remainder of the rubber dam structure and the equipment vault. Upon completion of the second half of the structure, the Portadam would be removed from the river. Instream construction would commence about July 1 and be completed by about the first of November. This time of year has generally been acceptable to the agencies, but is dependent on specific fish species present in the river downstream and their life stage.

Prior to mobilization to the site and construction of the impoundment structure, materials and equipment would need to be ordered. It is estimated that the rubber dam equipment would require a lead-time of 6 months from approval of shop drawings to delivery of the equipment. Therefore, award of a contract and notice to proceed would be given in early January with bidding 2 or 3 months prior to that.

3.5.3.9 Rubber Dam and Fish Ladder Cost Estimate

The anticipated total cost of the impoundment structure that would impound water to El. 1872.4, as shown in Table 3.5-1 is $5,777,000. The estimated construction costs include the major anticipated cost items only and are based on the construction schedule described in paragraph 3.5.3.8. Other minor items required to complete construction of a similar project are included as a line item called “Unlisted Items”. Unlisted items may include erosion control, dust control, construction permits, floating safety booms, etc. We have assumed that “Unlisted Items” to be 5 percent of the total construction cost. All construction costs are assumed to include contractor overhead, profit, insurance, and bonds.

Other development costs for geotechnical explorations, environmental studies and permitting, preliminary and final design engineering, and construction management have been estimated based on experience. These costs are based either on typical percentages of construction costs or past projects similar in nature and are not quotations to perform the work. Financing, legal, owner administration, land purchase, easements, mitigation, socioeconomic, and interest during construction costs are not included in the estimate.

In addition a construction contingency of 20 percent has been included and reflects the preliminary nature of engineering and the accuracy of estimating at this stage of study. The contingency is a percentage of both construction and development costs and attempts to cover the costs of the many unknowns at this stage of development. For example, if foundation conditions are substantially different than anticipated, then the contingency is a lump sum amount that can contribute to covering unanticipated costs and overruns. If the project is pursued and further engineering studies are undertaken, then the number of unknowns and contingency would be reduced.

It is estimated that the total cost of a structure to impound water to the Ordinary High Water level of El. 1870.3 would be approximately $5,400,000, or only about 6.5 percent less than the taller (El. 1872.4) structure.

The enclosed feasibility level cost estimate is our opinion of the cost of construction based on the limited information provided and gathered within our scope of work. Costs are for construction in 2003 and may vary based on future increased costs of labor and materials (inflation), competitive bidding environments and procedures, unknown field conditions, financial and/or market conditions, or other factors affecting the cost of the construction and the operation of the facilities, the design of which is not totally defined at this time, all of which are and will unavoidably remain in a state of change.

Table 3.5-1. Lake Wenatchee Impoundment Structure - Feasibility Cost Estimate*.

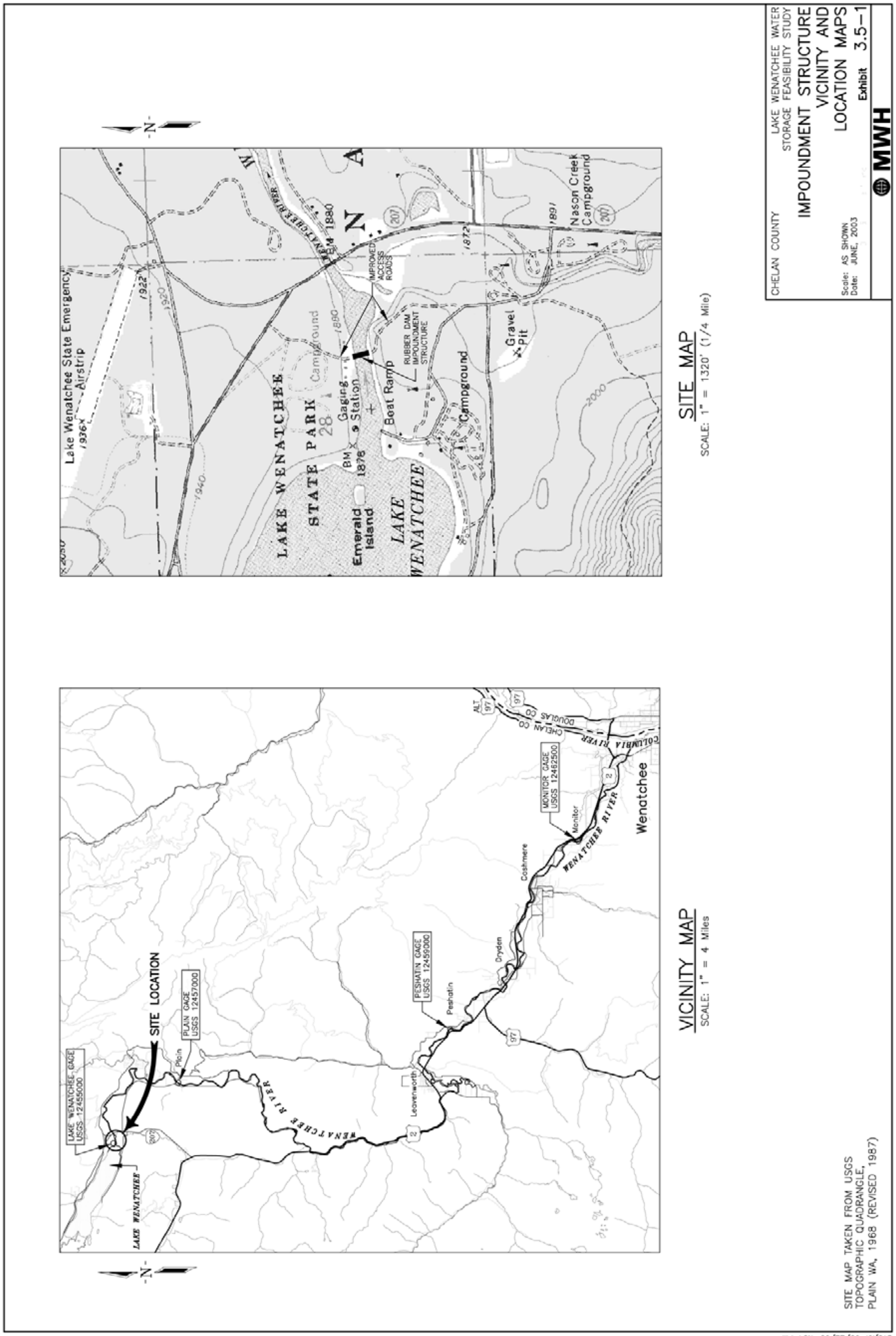
ITEM	UNIT	QUANTITY	UNIT PRICE	COST	SUBTOTALS
Mobilization	LS	1	$ 150,000.00	$ 150,000	
Clearing and Grubbing	AC	2	$ 5,000.00	$ 10,000	
Improve Access Roads	MI	0.6	$ 50,000.00	$ 30,000	
Access Gates	EA	2	$ 1,000.00	$ 2,000	
Cofferdams, install in halves	LF	600	$ 255.00	$ 153,000	
Dewatering	LS	1	$ 100,000.00	$ 100,000	
Underground Electrical Feed	LF	2,200	$ 25.00	$ 55,000	
Boat Ramp Access to River	LS	1	$ 165,000.00	$ 165,000	
					$ 665,000
Rubber Dam Structure					
Excavation	CY	2,000	$ 8.00	$ 16,000	
Structural Fill	CY	250	$ 56.00	$ 14,000	
Sheet Piles	SF	8,100	$ 30.00	$ 243,000	
Riprap	CY	1,200	$ 47.00	$ 56,400	
Concrete Foundation	CY	725	$ 310.00	$ 224,750	
Bladder/Associated Equipment	LS	1	$ 1,300,000.00	$ 1,300,000	
Piping, 4-inch black	LF	300	$ 6.00	$ 1,800	
					$ 1,855,950
Control Building					
Excavation	CY	1,000	$ 8.00	$ 8,000	
Structural Fill	CY	20	$ 55.00	$ 1,100	
Backfill	CY	700	$ 6.00	$ 4,200	
Concrete Foundation	CY	15	$ 300.00	$ 4,500	
Concrete Walls	CY	70	$ 350.00	$ 24,500	
Concrete Roof	CY	15	$ 450.00	$ 6,750	
Miscellaneous Metal	LBS	2,500	$ 3.00	$ 7,500	
HVAC	LS	1	$ 10,000.00	$ 10,000	
Electrical	LS	1	$ 15,000.00	$ 15,000	
					$ 81,550
Fish Ladder					
Excavation	CY	900	$ 8.00	$ 7,200	
Structural Fill	CY	60	$ 55.00	$ 3,300	
Sheet Piles	SF	1,300	$ 30.00	$ 39,000	
Concrete Foundation	CY	40	$ 300.00	$ 12,000	
Concrete Walls and Weirs	CY	100	$ 350.00	$ 35,000	
Miscellaneous Metal	LBS	9,600	$ 3.00	$ 28,800	
					$ 125,300
Subtotal				$ 2,727,800	
Unlisted Items	%	5	$ 136,400	$ 136,400	
Contstruction Cost	**LS**	**1**		**$ 2,864,200**	
Geotechnical Explorations	LS	1	$ 300,000	$ 300,000	
Environmental Studies/Permits	LS	1	$ 700,000	$ 700,000	
Engineering	LS	1	$ 500,000	$ 500,000	
Construction Management	MO	8	$ 56,250	$ 450,000	
Development Cost	LS	1		**$ 1,950,000**	
Contingency	%	20		**$ 962,800**	
TOTAL COST	**LS**	**1**		**$ 5,777,000**	

* For structure with a 10 foot high rubber dam (crest at El 1872.4).

3.6 ADDITIONAL STUDY NEEDS

The following is a list of future technical study needs that are likely to be required if the project is taken to preliminary and final design:

1. Further refinement and study of rubber dam operational scenarios (Section 3.3.2.7).
2. Surveying of impoundment structure site, including river soundings, and access roads.
3. Geotechnical subsurface investigations and soils testing, including installation of piezometers to monitor groundwater levels.
4. Location and availability of power and communication lines.
5. Further study and refinement of wind and wave affects on the shoreline.


CHELAN COUNTY
LAKE WENATCHEE WATER STORAGE FEASIBILITY STUDY
IMPOUNDMENT STRUCTURE VICINITY AND LOCATION MAPS
Scale: AS SHOWN
Date: JUNE, 2003
Exhibit 3.5-1
MWH
SITE MAP
SCALE: 1" = 1320' (1/4 Mile)
VICINITY MAP
SCALE: 1" = 4 Miles
SITE MAP TAKEN FROM USGS TOPOGRAPHIC QUADRANGLE, PLAIN WA, 1968 (REVISED 1987)
Lake Wenatchee State Emergency Airstrip
LAKE WENATCHEE STATE PARK
Emerald Island
LAKE WENATCHEE
Gaging Station
Boat Ramp
Campground
Gravel Pit
Nason Creek Campground
IMPROVED ACCESS ROADS
RUBBER DAM IMPOUNDMENT STRUCTURE
SITE LOCATION
LAKE WENATCHEE GAGE USGS 12455000
PLAIN GAGE USGS 12457000
PESHASTIN GAGE USGS 12459000
MONITOR GAGE USGS 12462500
Plain
Leavenworth
Peshastin
Dryden
Cashmere
Monitor
Wenatchee
WENATCHEE RIVER
COLUMBIA RIVER
CHELAN CO
DOUGLAS CO
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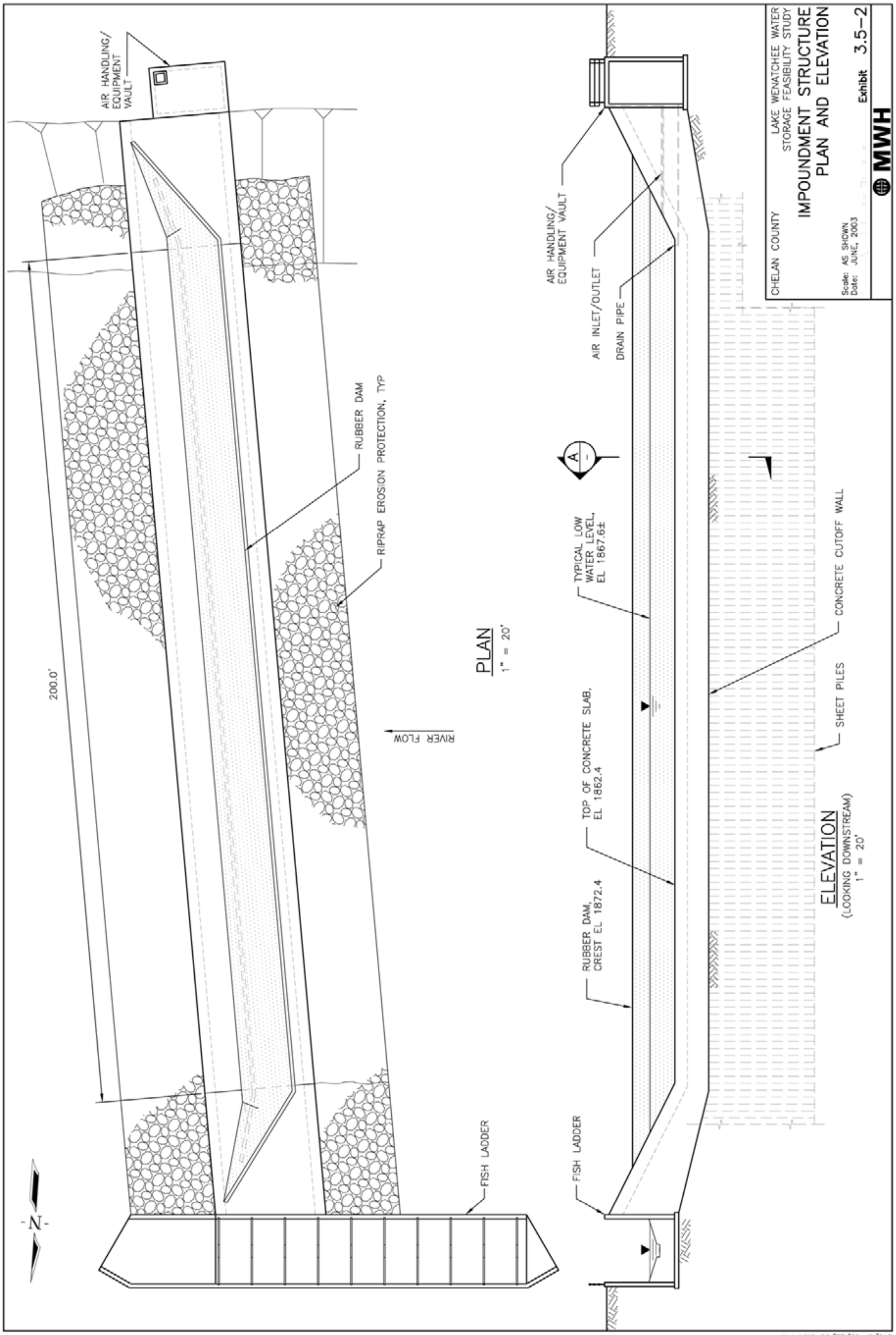
AIR HANDLING/ EQUIPMENT VAULT
RUBBER DAM
RIPRAP EROSION PROTECTION, TYP
200.0'
PLAN
1" = 20'
RIVER FLOW
FISH LADDER
-N-
AIR HANDLING/ EQUIPMENT VAULT
AIR INLET/OUTLET
DRAIN PIPE
TYPICAL LOW WATER LEVEL, EL 1867.6±
TOP OF CONCRETE SLAB, EL 1862.4
RUBBER DAM, CREST EL 1872.4
CONCRETE CUTOFF WALL
SHEET PILES
ELEVATION
(LOOKING DOWNSTREAM)
1" = 20'
FISH LADDER
CHELAN COUNTY
LAKE WENATCHEE WATER STORAGE FEASIBILITY STUDY
IMPOUNDMENT STRUCTURE PLAN AND ELEVATION
Scale: AS SHOWN
Date: JUNE, 2003
Exhibit 3.5-2
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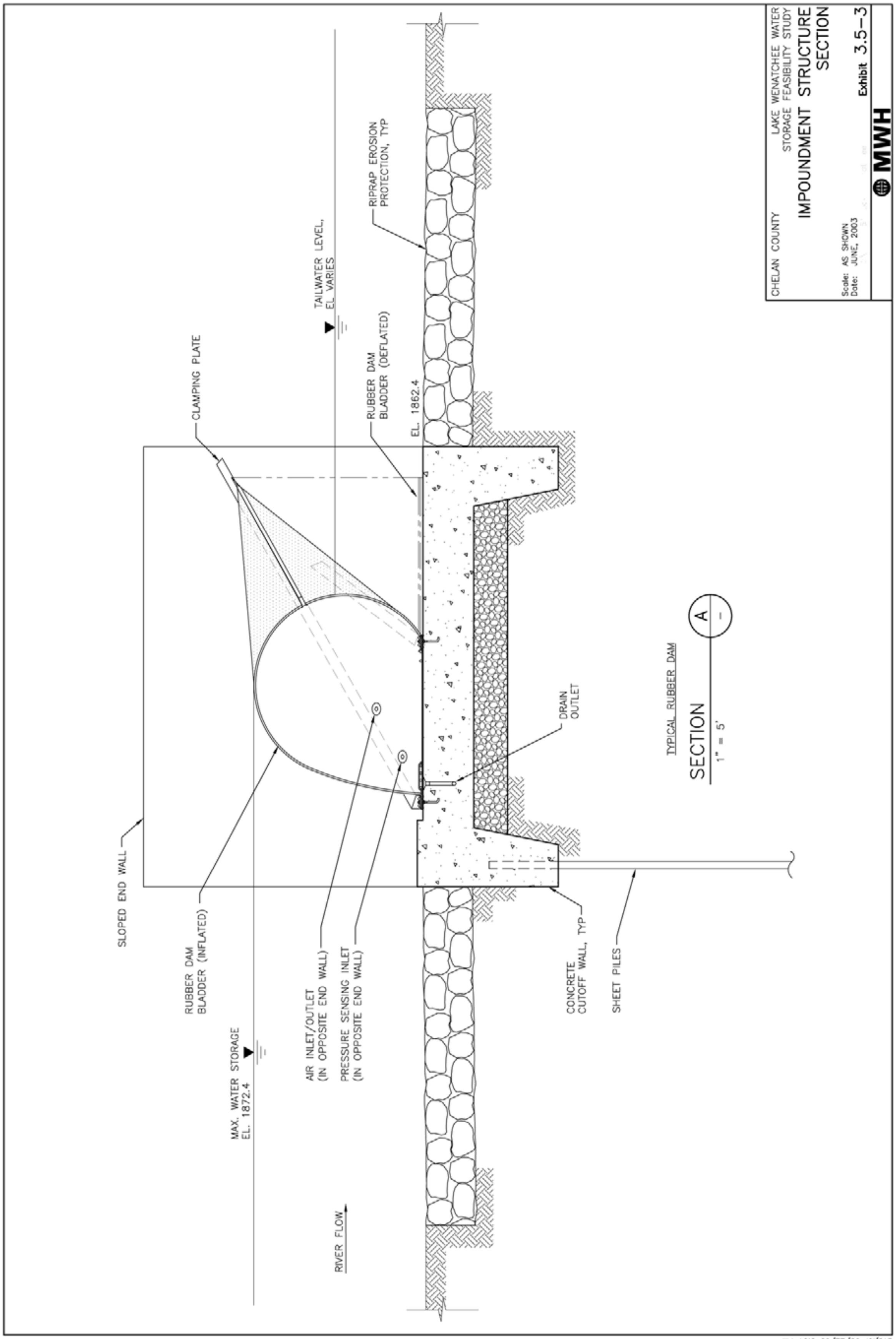
CHELAN COUNTY
LAKE WENATCHEE WATER STORAGE FEASIBILITY STUDY
IMPOUNDMENT STRUCTURE SECTION
Scale: AS SHOWN
Date: JUNE, 2003
Exhibit 3.5-3
MWH
TAILWATER LEVEL, EL VARIES
RIPRAP EROSION PROTECTION, TYP
CLAMPING PLATE
RUBBER DAM BLADDER (DEFLATED)
EL. 1862.4
SLOPED END WALL
RUBBER DAM BLADDER (INFLATED)
AIR INLET/OUTLET (IN OPPOSITE END WALL)
PRESSURE SENSING INLET (IN OPPOSITE END WALL)
MAX. WATER STORAGE EL. 1872.4
RIVER FLOW
DRAIN OUTLET
CONCRETE CUTOFF WALL, TYP
SHEET PILES
TYPICAL RUBBER DAM
SECTION
1" = 5'
A
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