PRELIMINARY DRAFT FOR DISCUSSION PURPOSES

Memorandum

MWH
MONTGOMERY WATSON HARZA

To: David Thompson
From: John Haapala
CC: Dan McDonald
Bob Montgomery
Date: February 24, 2003 File #: 1003551
Re: Lake Wenatchee Historic Water Levels, Operation Model, and Flood Operation

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This memo provides preliminary results for the Lake Wenatchee Water Storage Feasibility Study. The topics covered include Lake Wenatchee historic water levels, the development and initial results from a daily Lake Wenatchee storage operation model, and an analysis of potential future flood operation.

1.0 Lake Wenatchee Historic Water Levels

This section provides statistical input to Task 2.1.D, the determination of the normal 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.

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. 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 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 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 potential reference for normal high water.

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

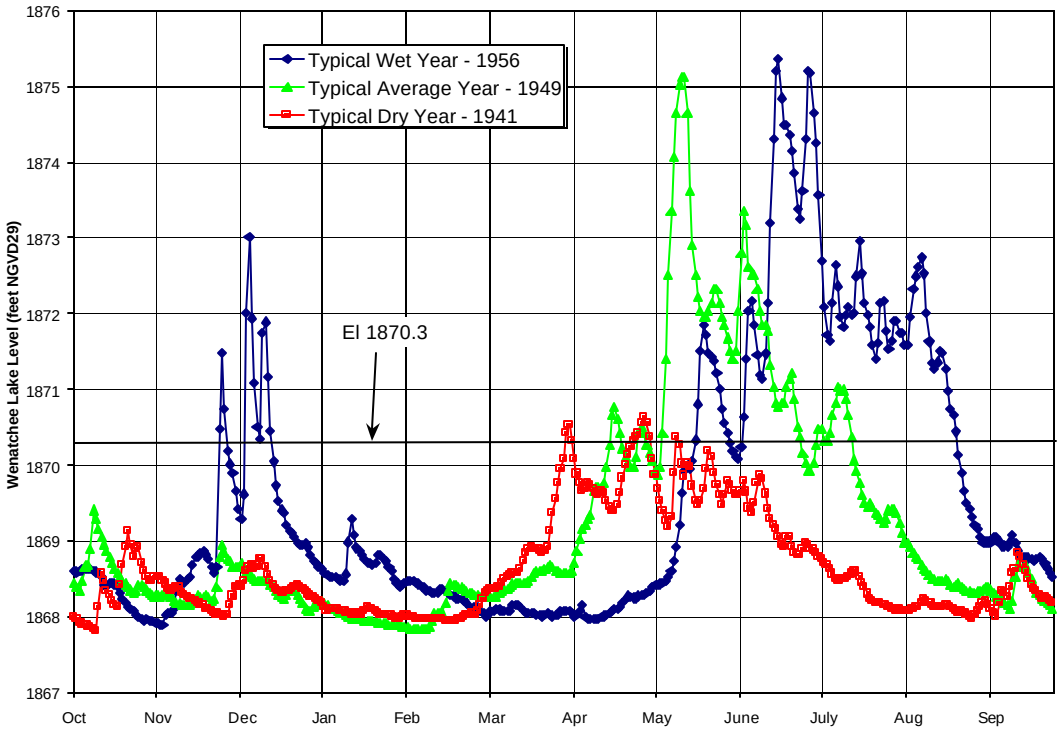

Figure 1: Representative Wet, Dry, and Average Year Lake Levels

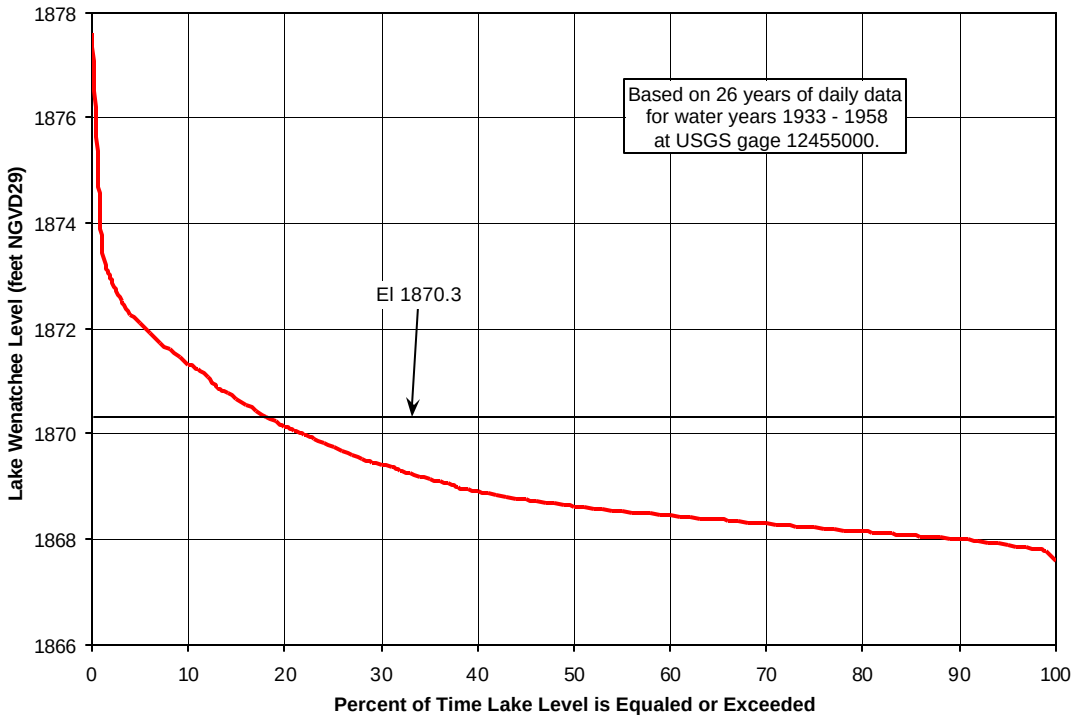

Figure 2: Lake Wenatchee Level Duration Curve

Figure 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 2 also indicates that daily water levels above El 1871.3 occur about 10% of the time.

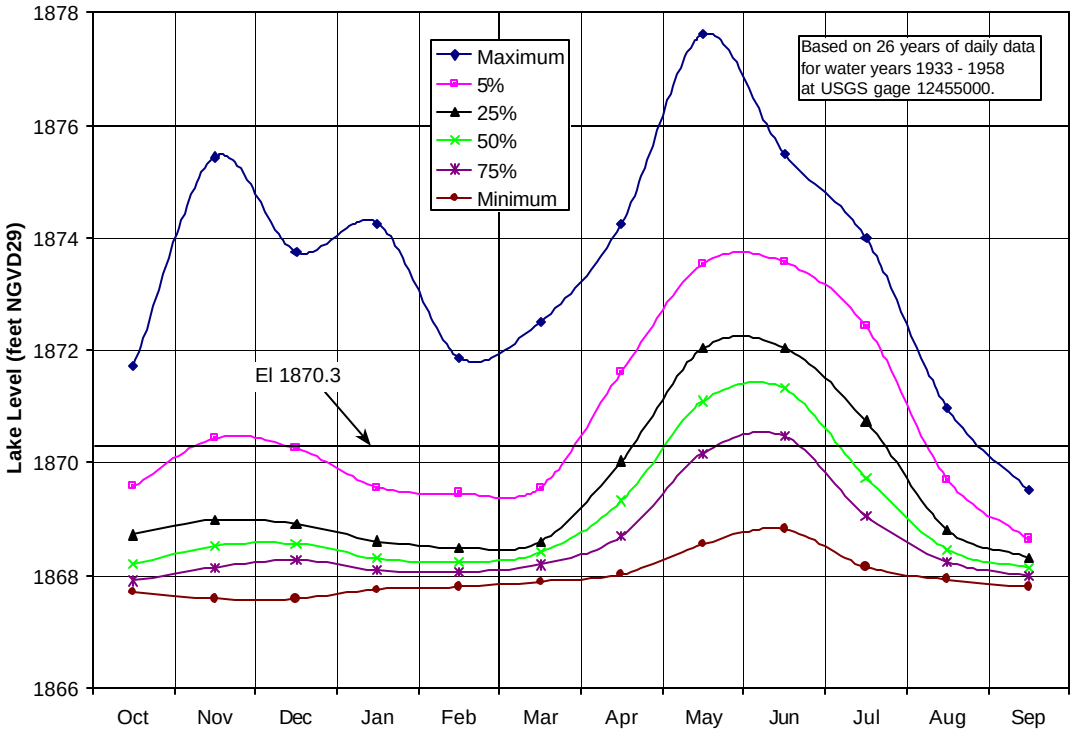

Figure 3: Lake Wenatchee Monthly Lake Level Frequency Curves

Figure 3 provides monthly lake level frequency data, based on the available daily data within each month. The information on Figure 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 2.

Table 1 provides the detailed lake level frequency data by month from which the curves on Figure 3 were plotted. Daily data for the available 26-year period were used to develop the information in Table 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.

Table 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

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 2. The data is sorted in two ways, both by chronological order and rank ordered by maximum lake level. The data in Table 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.

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 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 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 2: Lake Wenatchee Annual Instantaneous Peak Lake Level Data for USGS Gage 12455000

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

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

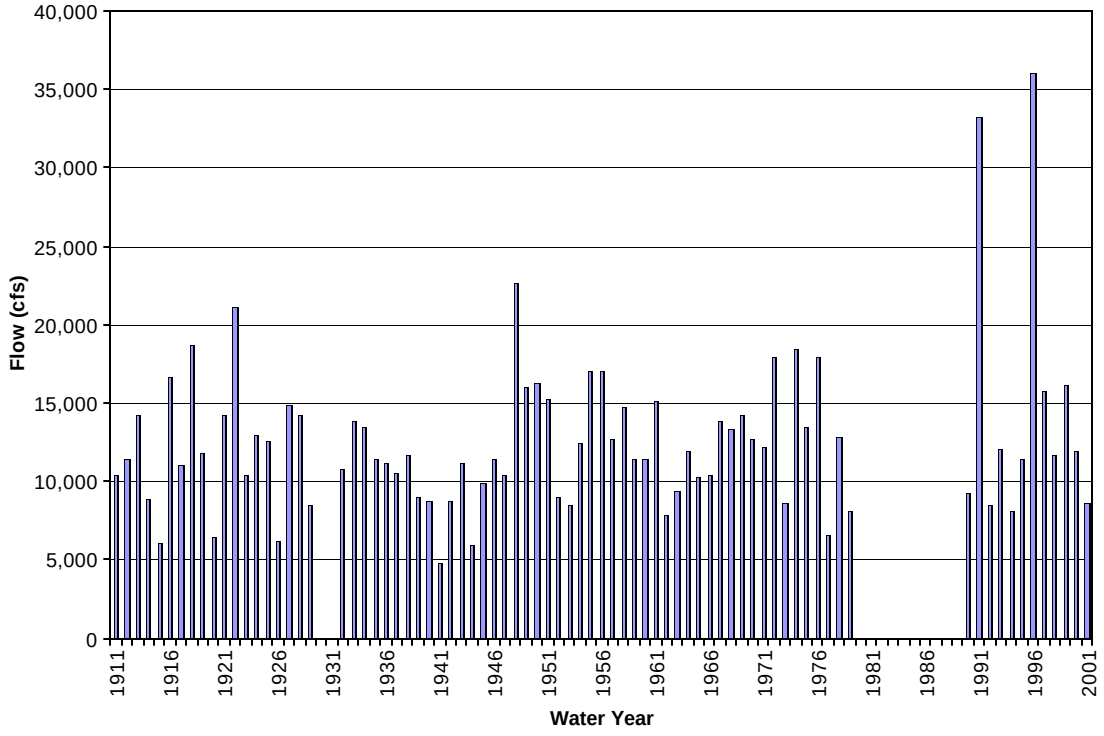

Figure 4: Peak Annual Flows at USGS Gage 12457000, Wenatchee River at Plain

2.0 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 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.

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.

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.

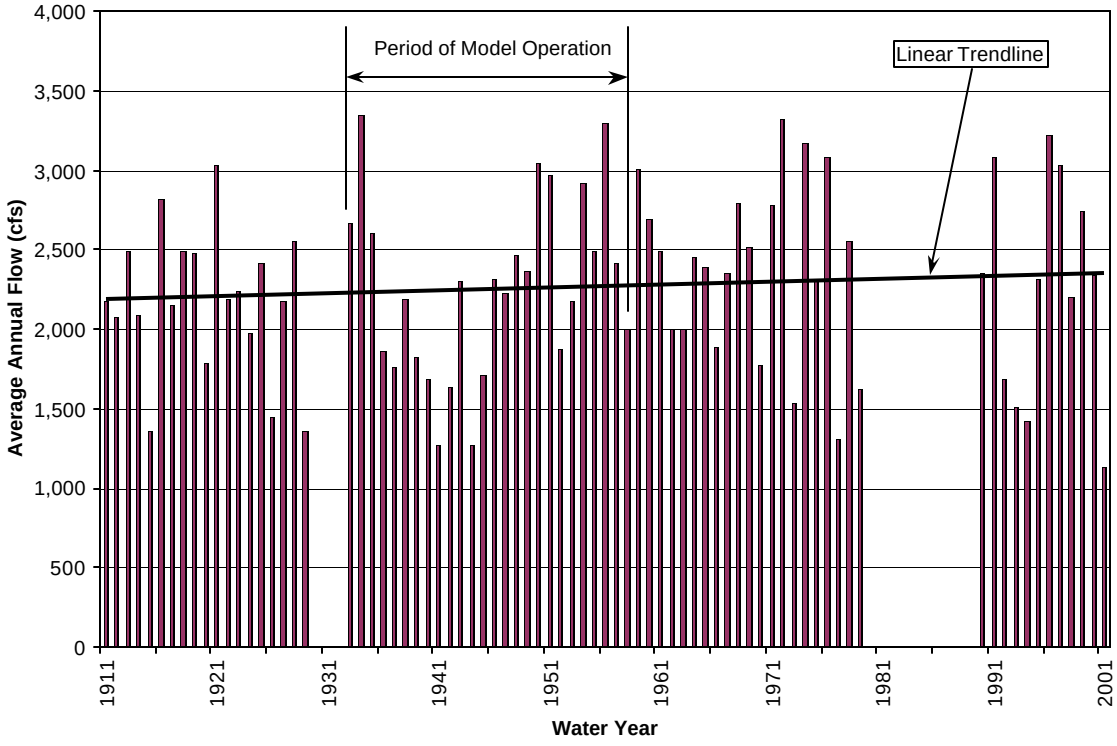

Figure 5: Annual Average Flow (cfs) at USGS Gage 12457000, Wenatchee River at Plain

Figure 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.

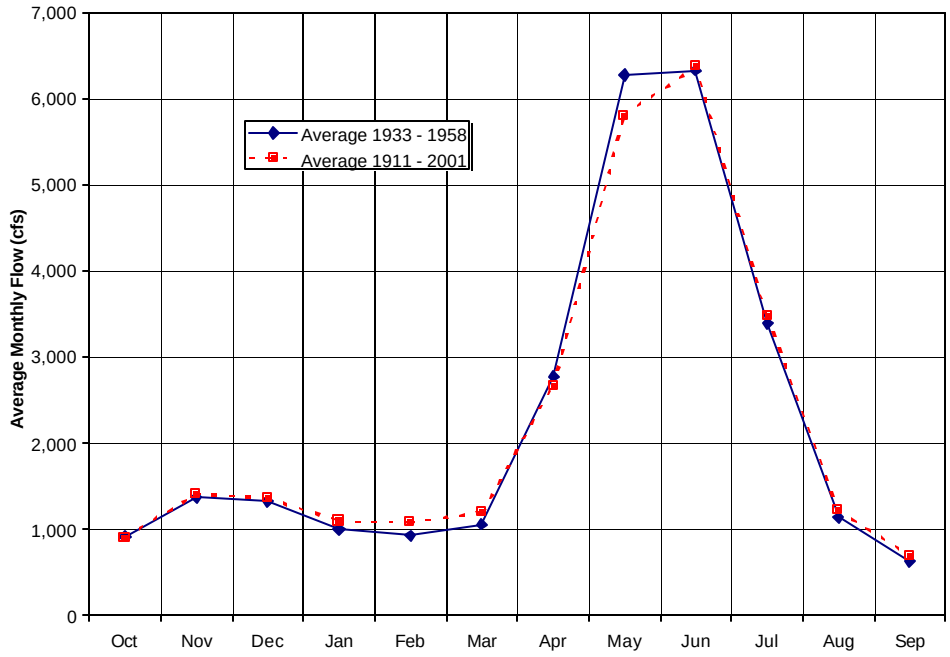

Figure 6: Monthly Average Flow (cfs) at USGS Gage 12457000, Wenatchee River at Plain

Figure 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 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.

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: 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 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 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 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 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 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

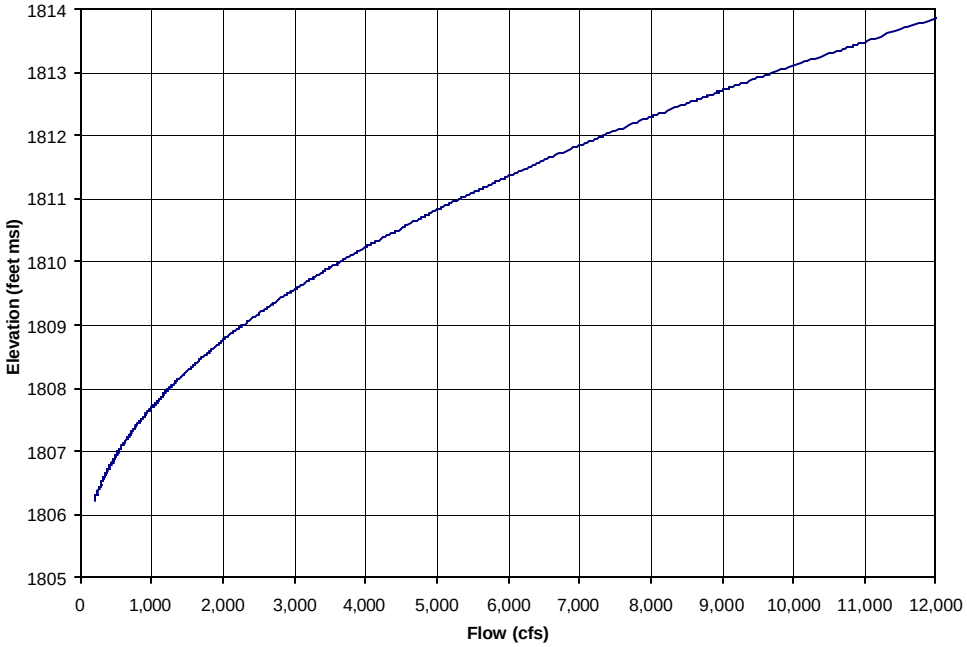

Figure 7: Rating Curve for USGS Gage 12457000, Wenatchee River at Plain

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 7. In a similar manner, the rating curve for the Wenatchee River at Peshastin is provided on Figure 8.

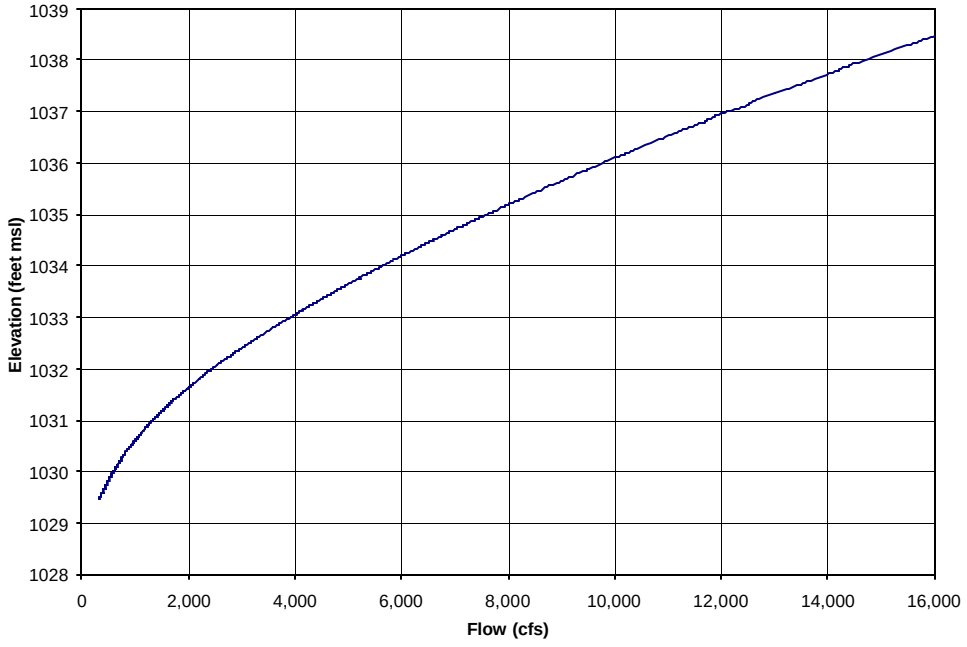

Figure 8: Rating Curve for USGS Gage 12459000, Wenatchee River at Peshastin

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 9.

Table 9: Lake Wenatchee Elevation-Area-Storage

Elevation (feet NGVD29)	Area (acres)	Storage Capacity (acre-feet)
1867	2,380	0
1868	2,440	2,410
1869	2,500	4,880
1870	2,560	7,410
1871	2,619	9,999
1872	2,679	12,648
1873	2,739	15,357
1874	2,799	18,126
1875	2,858	20,954
1876	2,918	23,842
1877	2,978	26,790
1878	3,038	29,798
1879	3,097	32,865
1880	3,157	35,992

The Lake Wenatchee storage capacity was arbitrarily set to zero at El 1867. 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 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 through 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

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 10. By comparison to Table 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 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 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 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 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.

2.4 Operating Criteria

Operating criteria are intended to provide guidelines and objectives for beneficial use of the rubber dam. The intended operation would collect water to storage during periods of high flows in the late spring or early summer and release 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 this objective, the implied storage capability of the rubber dam is 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 on 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 12 on a half-month basis.

Table 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 13 and Table 14, respectively.

Table 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	15	30	103
1940	22	3	0	4	0	0	0	0	0	22	31	30	112
1941	11	14	0	29	28	0	0	0	14	31	31	15	173
1942	0	0	0	1	17	21	0	0	0	5	27	30	101
1943	30	18	9	4	0	10	0	0	0	0	0	22	93
1944	30	25	5	29	23	8	0	0	0	26	31	18	195
1945	18	6	3	0	0	1	14	0	0	7	30	27	106
1946	24	0	15	11	25	6	0	0	0	0	0	23	104
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	26	15	0	0	0	0	0	0	8	49
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	11	19	0	0	0	0	12	30	95
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	2	14	3	0	0	0	0	0	24
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	8	7	7	2	0	1	4	11	19	86

Table 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	19	0	0	0	0	16	30	102
1940	23	3	0	1	0	0	0	0	0	20	31	30	108
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	23	31	15	192
1945	15	9	0	0	0	0	18	0	0	2	28	25	97
1946	24	0	14	0	23	0	0	0	0	0	0	22	83
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	3	10	18	77

Table 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 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	16	30	105
1940	23	3	0	4	0	0	0	0	0	22	31	30	113
1941	11	16	0	29	28	0	0	0	14	31	31	15	175
1942	0	0	0	1	17	21	0	0	0	5	27	30	101
1943	30	18	9	4	0	10	0	0	0	0	0	25	96
1944	30	27	7	29	23	9	1	0	0	26	31	18	201
1945	19	9	3	0	0	1	18	0	0	7	30	27	114
1946	24	0	15	11	25	6	0	0	0	0	0	23	104
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	26	15	0	0	0	0	0	0	8	49
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	11	22	0	0	0	0	12	30	98
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	2	14	3	0	0	0	0	0	24
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	4	8	7	7	3	0	1	4	12	20	88

The information presented above indicates that it would be beneficial to have some latitude regarding the initiation of storage by use of the rubber dam. To provide guidance for the beginning of storage, the water years were classified as shown in Table 16 as wet, dry or normal based on flow during May, June and July.

Table 16: Classification of Wet, Dry, and Normal Years

Water Year	Year Type
1933	Normal
1934	Normal
1935	Normal
1936	Normal
1937	Normal
1938	Normal
1939	Normal
1940	Dry
1941	Dry
1942	Dry
1943	Normal
1944	Dry
1945	Normal

Water Year	Year Type
1946	Wet
1947	Normal
1948	Normal
1949	Normal
1950	Wet
1951	Normal
1952	Normal
1953	Normal
1954	Wet
1955	Wet
1956	Wet
1957	Normal
1958	Normal

In actual practice, years could be classified as wet, normal, or dry based on snowpack data for April. An unusually low snowpack would indicate the need to begin storage earlier in the year. For example, storage for an expected dry year could begin in May, while storage for a wet year might not begin until late July.

Operating alternatives were developed with consideration given to the following variables:

- Maximum storage level of rubber dam
- Time of year (by half-month) for initiation of storage with the rubber dam
- Maximum daily amount added to lake level by raising of the rubber dam
- Release schedule for stored water

Alternatives were judged by their ability to maximize the release of stored water during the July through October period at desired times. Releases of water were most desirable whenever flows were less than the median (50% exceedance level) at either Plain or Peshastin.

2.5 Operation Model Alternatives

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

- Alternative 1 – to be determined
- Alternative 2 – to be determined
- Alternative 3 – to be determined

2.6 Operation Model Results

In process

3.0 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 rubber fabric dam can be 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 7.

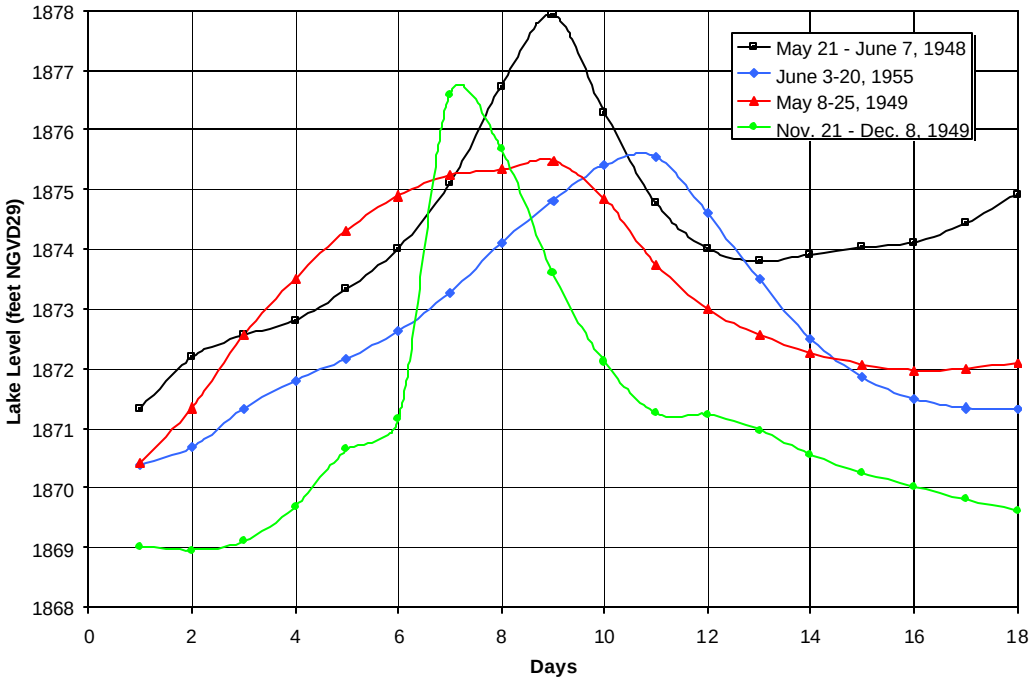

Figure 9: Lake Levels During Maximum Floods Having Continuous Records

The values plotted on Figure 9 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 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 fabric dam could be up 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 fabric dam at the Lake Wenatchee outlet would be 10-feet high at most. Mr. Andrew Parry of 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 fabric 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, for example. If natural lake inflows caused the lake level to be higher than El 1872, the rubber dam would be lowered. Figure 9 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.