Lesser Slave River at Slave Lake Low Flow Frequency Analysis

Water Sciences Branch, Hydrology/Forecasting Section
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1.0 Introduction

Lesser Slave Lake has experienced extreme fluctuations in its water level during the past four years, going from near-record high levels during 1996 and 1997 to the recorded historic low levels that were occurring by the end of 1999. Lake levels dropped to the level of the weir crest at the outlet, resulting in a disruption of flow into the Lesser Slave River, an event that had never before been recorded. Measures taken to siphon water past the weir during the winter of 1999-2000 maintained flows in the river. As a result of these events, it was deemed prudent to re-evaluate the 7Q10[1] discharge for the river, which was last calculated in 1988. This report outlines the procedures that were used to determine the annual 7Q10 and 1Q10[2] discharges. It does not analyze nor discuss the causes of the recent fluctuations in levels.

2.0 Background

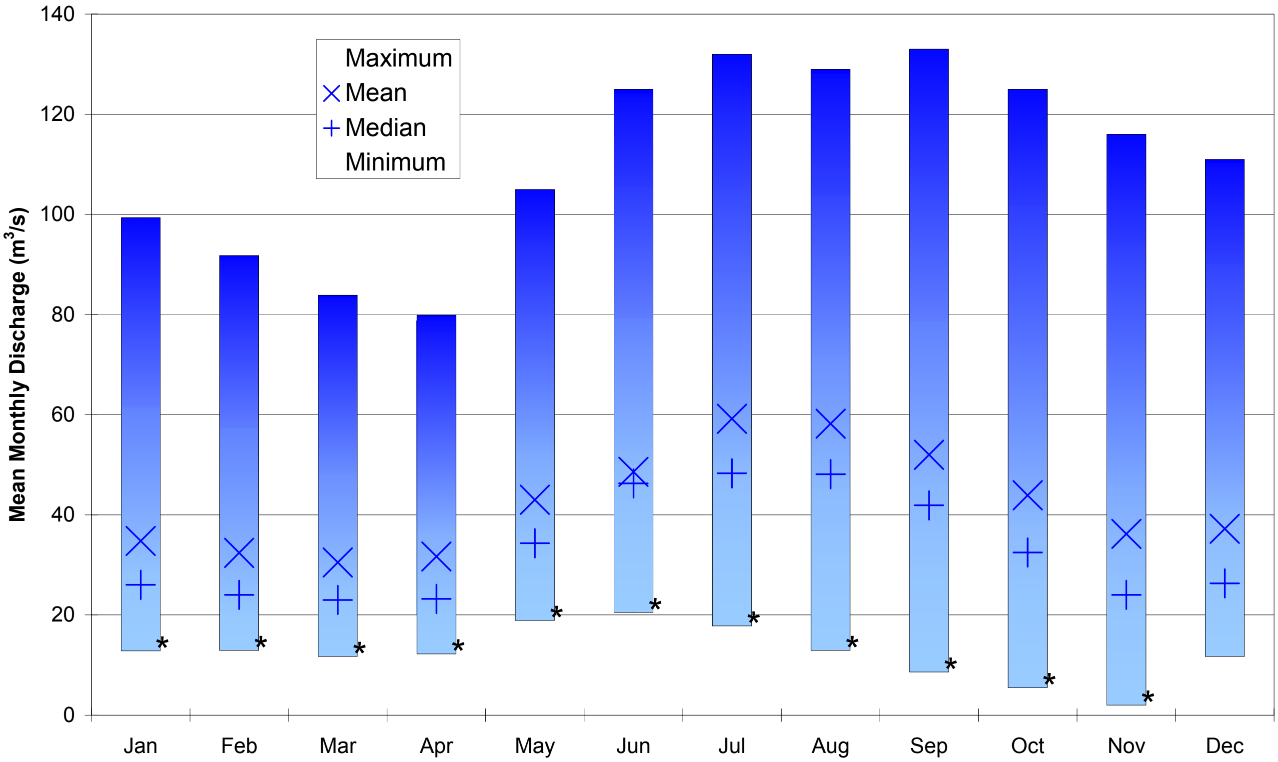
The Lesser Slave River originates at the outlet of Lesser Slave Lake at the Town of Slave Lake. It travels in an easterly direction approximately 70 km (river distance) before finally draining into the Athabasca River near Smith. Major tributaries include Sawridge Creek, the Otawau River, the Saulteaux River, and the Driftwood River. Due to the large surface area of Lesser Slave Lake and the large drainage area (13,575 km^2) that supplies the lake, the flow in the river does not typically fluctuate widely on a seasonal basis, compared to what is normally observed in other rivers and streams. This is due to the buffering effect of the lake, which not only dampens runoff events that occur during the year, but also provides longer-term attenuation from one year to the next. This can be observed in Figure 1, which depicts the mean monthly flow ranges in the Lesser Slave River since 1988.

The calculation of a 7Q10 for a river is relatively straightforward providing that flow is measured on the river. Due to several complicating factors, the analysis for the Lesser Slave River requires additional analyses. Both lake levels and river flow have been recorded at various times and at various locations as early as 1915, but since the records are not fully continuous and

[1] The 7Q10 discharge is defined as the low flow, averaged over a 7-day period that would be expected to occur once every ten years.

[2] The 1Q10 discharge would be the one-day low flow expected to occur once every ten years

Figure 1. Lesser Slave River at Slave Lake (07BK001)
Historical Monthly Discharge Statistics
(for the available period of record after the construction of Lesser Slave Lake weir)



* Minimums occurred during 1999. December data is missing.

are not measured at the same sites, further modeling and interpretation would be required. However, the largest complication in evaluating the data stems from the fact that a fixed-crest outlet weir and downstream channel improvements were completed in 1984. This effectively modified the flow rate out of the lake into the Lesser Slave River from the natural outlet condition, making recorded flow data non-homogeneous for the pre- and post-weir periods.

Lesser Slave Lake levels are currently recorded at the lake outlet, at the Town of Slave Lake water intake by Water Survey of Canada (WSC) Station 07BJ006. Flow in the Lesser Slave River is measured at the outlet weir, located a short distance downstream, at WSC Station 07BK001 (since May 1988). Although both high and low extreme events have been recorded in the post-weir period, the length of record (12 years) is too short to adequately define the extent of natural fluctuation. However, since the 7Q10 discharge should be representative of the current conditions, i.e. under the regulating influence of the weir, the following procedure was adopted to incorporate pre-weir data into the analysis in order to develop a long-term frequency analysis for low flows:

1) Make the recorded lake levels for the two periods homogeneous by modeling the pre-weir period lake levels under the assumption that the weir control is in place as an outlet condition.

2) Relate the lake levels as recorded at 07BJ006 to the recorded river flow at 07BK001 to obtain a stage-discharge rating curve for the regulated period.

3) Reconstruct the flows in the Lesser Slave River for the period prior to 1988 using the simulated (regulated) lake level series and the outlet rating curve.

3.0 Analysis

Previous modeling work completed by the Hydrology Branch provided a regulated lake level data set for the period back to 1916 and up to 1992. Although the weir construction and river works were completed during 1984, the recorded lake level data at 07BJ006 is generally continuous after March of 1985. For this reason, the simulated series was used for January 1916 to March 1985, and recorded levels were used thereafter (March 1985 to December 1999). This also allows for a short period of adjustment after construction, as the river regime begins to re-establish under the altered conditions. The reconstructed lake level data set is shown in Figure 2. Also shown in the Figure for comparison are the recorded historical levels.

The next step in the analysis was to establish a stage-discharge rating curve for the weir outlet. Figure 3 shows the correlated values between lake elevation (x-axis) and discharge (y-axis) between the two sites. Note that a datum of 575.45 m was established for lake elevation, i.e.

Lake Elevation (x) = Recorded Elevation – 575.45 ....(1)

Although the weir crest elevation is at 575.50 m, a better mathematical result was obtained using 575.45. Although only for a relatively short period, flow over the weir was observed even as recorded lake levels dropped below 575.50 m. The difference might be due to ice effects, wind

Figure 2. Lesser Slave Lake Levels, 1915-1999

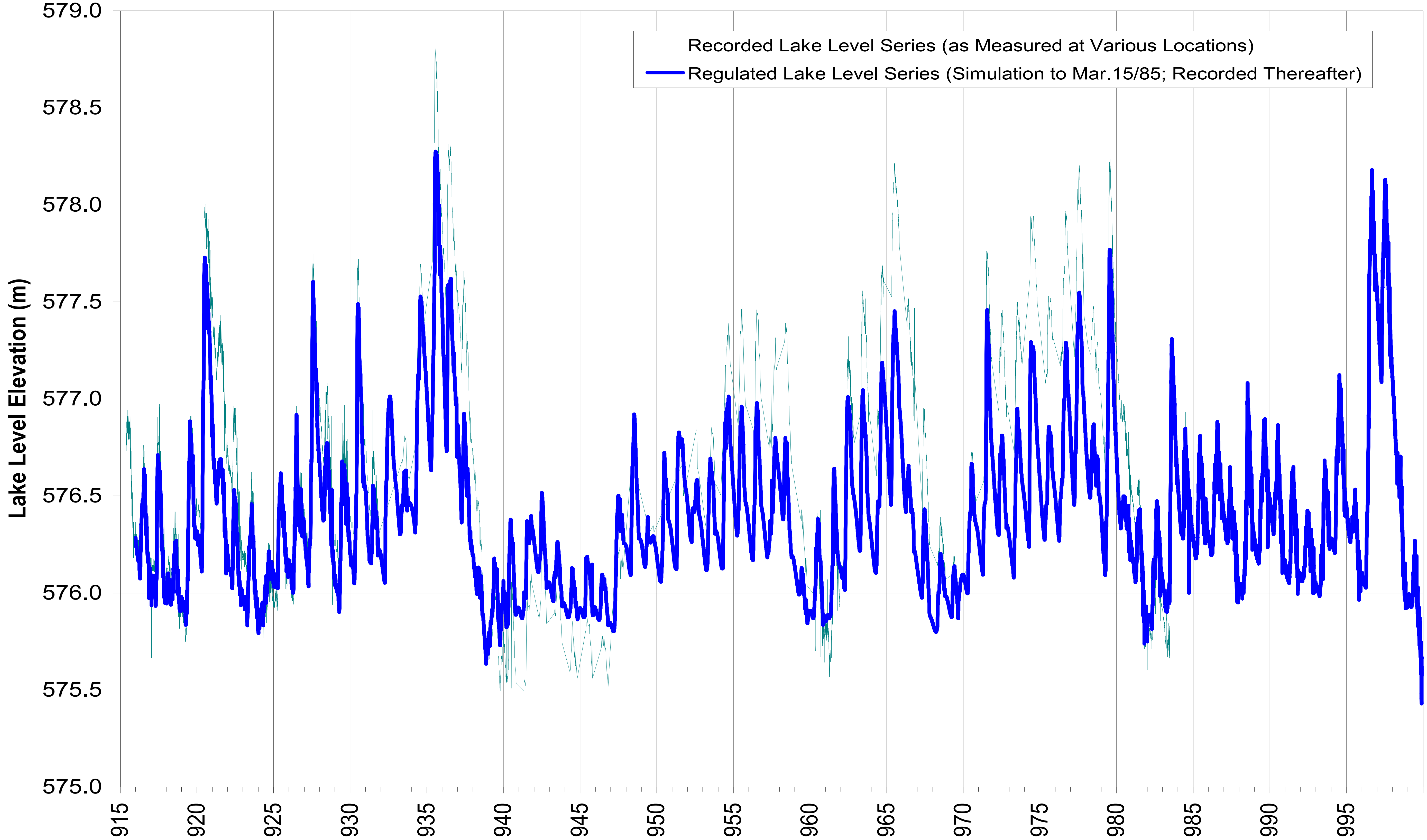
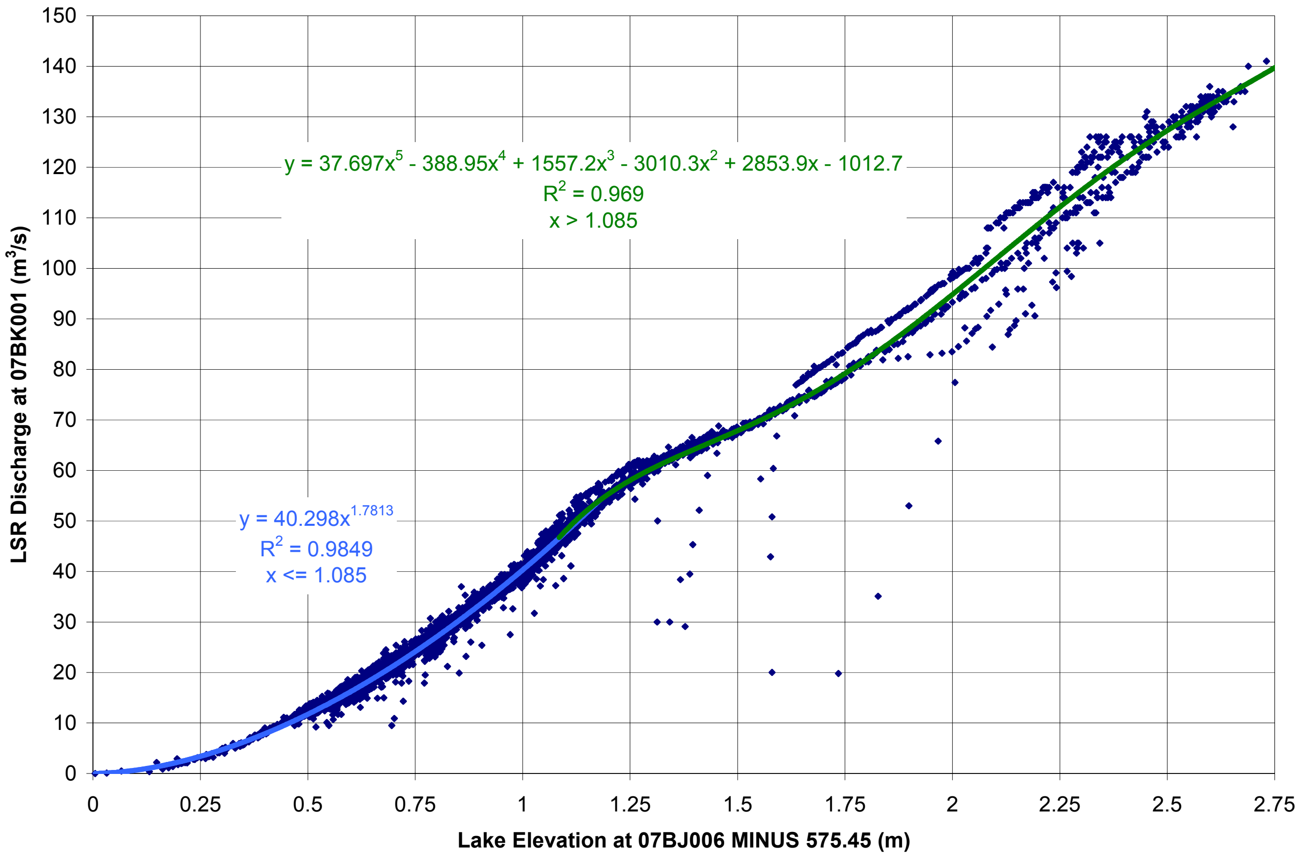


Figure 3. Lesser Slave Lake Rating Curve



set up, or perhaps a slight difference in reference elevations, however, the curve produced is a very good representation of observed outlet conditions.

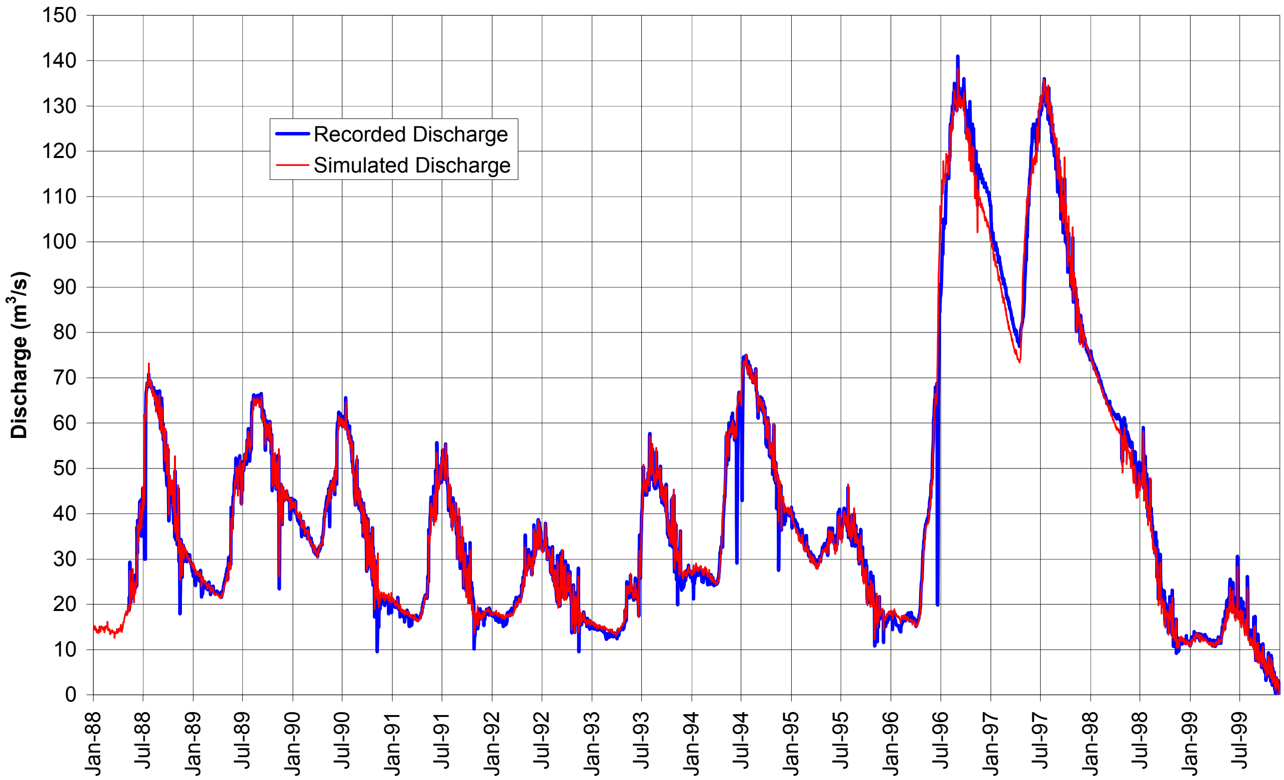
As shown in Figure 3, it was determined that two equations for discharge (y) would best represent the observed data. They are as follow:

$$y = 40.298\, x^{1.7813}, \;\; x \le 1.085 \quad \text{(2)}$$

$$y = 37.697\, x^5 - 388.95\, x^4 + 1557.2\, x^3 - 3010.3\, x^2 + 2853.9\, x - 1012.7, \;\; x > 1.085 \quad \text{(3)}$$

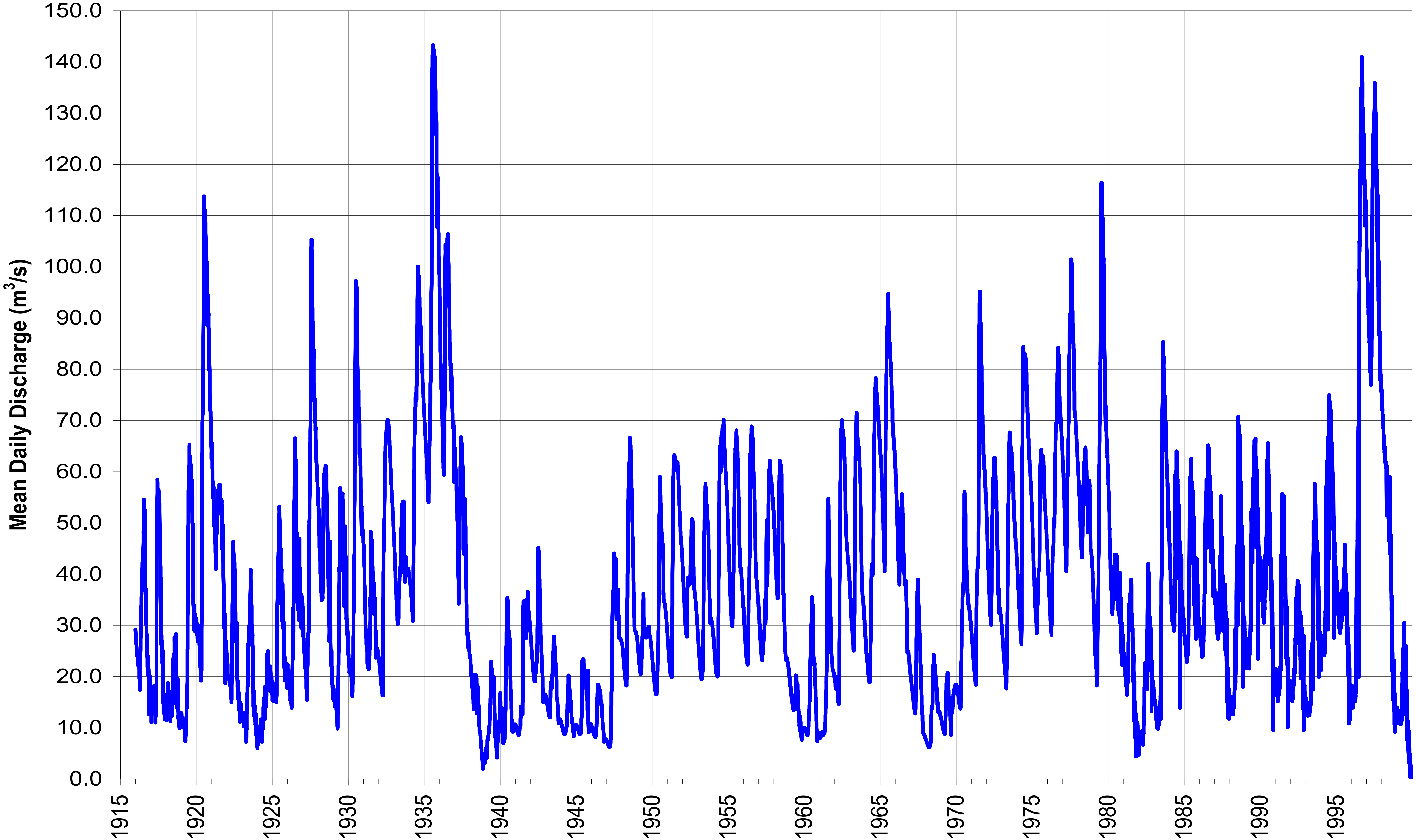
The regressions for each of these equations were excellent, providing an r^2 correlation of 0.985 and 0.969, respectively. Figure 4 shows the comparison of recorded data from 07BK001 versus simulated data using lake levels and the rating curve for the available period of record from 1988 to 1999. The rating curve reproduces the levels very well, although it can not replicate the day-to-day variability that can occur, say, due to wind set up on the lake. Over the long term, this effect would tend to balance out and therefore be inconsequential to the frequency analysis.

Figure 4. Lesser Slave River at Lesser Slave Lake Weir
Recorded Discharge vs. Simulated Discharge
(using lake levels and derived rating curve, for the period of record)



Using the simulated lake levels and the rating curve, a continuous mean daily flow record for the Lesser Slave River was reconstructed for the period from 1916 to 1999. Simulated data was used for January 1916 to May 1988, while recorded data was used thereafter. Figure 5 shows the final flow data series for the Lesser Slave River. A second time series containing the average 7-day flow was also generated based on the mean daily discharges. Since annual low flows occur over the winter period, a water-year running from June to May was used, rather than the calendar year. This is to prevent the occurrence of counting the same "event" twice, and gives a true representation of the once-annual low flow. Since intervention measures were taken in order to pass flow over the weir in the 1999-2000 winter season, the recorded flows do not represent the "normal" condition. Therefore, the annual 7Q10 and 1Q10 values were assumed to be zero, i.e. it was assumed that without the use of siphons and other measures, flow would have stopped for at least seven days during the past winter.

Figure 5. Lesser Slave River Final Simulated Flow Data Set, 1916-1999



4.0 Results

The annual minimum 1-day and 7-day average flows were fit to a modified Pearson III distribution. The 7Q10 for the Lesser Slave River at Slave Lake under the present weir outlet condition is calculated to be 7.2 m^3/s. This compares to the previous value of 11.6 m^3/s, calculated in 1988. The results are summarized in Table 1.

Table 1. Low Flow Frequency Statistics, Lesser Slave River at Slave Lake.		
	7-day mean discharge (m^3/s)	1-day mean discharge (m^3/s)
1:10 year low flow	7.2	6.4
Mean annual low flow	20.8	20.1

5.0 Conclusions

The updated 7Q10 of 7.2 m^3/s represents a decrease of almost 40% from the previous annual 7Q10 value of 11.6 m^3/s. It must be clarified that this difference is not solely attributable to the recent low flow event of winter 1999-2000. Although the past year was unprecedented in terms of the interruption of flow to the river that was observed, removing this year from the analysis affects the 7Q10 only by about 0.35 m^3/s. Therefore, other factors must also be contributing to the reduction. For example, the alteration of the outlet condition due to the weir would also have tended to affect the 7Q10 flow, by reducing the magnitude and persistence of high lake levels because of the more efficient outlet. Lake levels, and therefore river flow, would be generally lower at the end of the open-water season during average to high years, as compared to under the natural outlet. Conversely, low years would have tended toward higher than natural levels. However, this would not necessarily have translated into significantly higher winter discharges, due to the weir sill elevation being higher than the outlet elevation of the natural channel.

Another issue relates to the use of a different data set in this analysis, versus what was used for the 1988 assessment. In the prior analysis, recorded flow data from the WSC gauge on the Lesser Slave River at Highway No. 2A (07BK006) was used. The gauge is located roughly 25 km downstream of the present weir structure and is also downstream of Sawridge Creek. The period of record extends from the mid-1960's to the late 1980's. It is possible that the data may be biased toward higher river flows, as lake levels are generally higher than the long-term average over that (roughly) 20-year period. The longer period of record used in the updated analysis should be more reflective of longer-term conditions in the river.

A final note regarding the applicability of the 7Q10 value throughout the Lesser Slave River system. It is recognized that the low flow analysis has been calculated in the vicinity of the Town of Slave Lake, and that there are some significant downstream tributary contributions to the River. The 7Q10 value of 7.2 m^3/s is readily applicable to the reach extending from Lesser Slave Lake to just upstream of the Saulteaux River confluence. After the confluence with the Saulteaux River, the local drainage area becomes increasingly significant and the 7Q10 as calculated may no longer be representative. However, the reach of the Lesser Slave River as described above contains the majority of industrial and municipal water users and is therefore of greatest interest.

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