PRELIMINARY DRAFT REPORT.

OSOYOOS LAKE DISCHARGES DURING HIGH SIMILKAMEEN RIVER FLOWS

1973 Oct 05

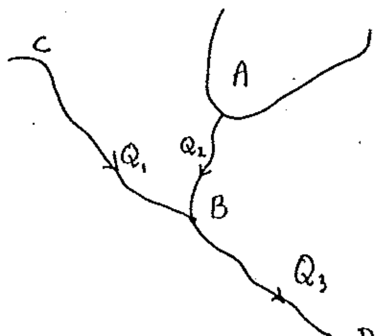
1. INTRODUCTION

The flow in the Similkameen River can, under certain circumstances, have a marked effect on the flow in the Okanagan River between the outlet from Osoyoos Lake and its junction with the Similkameen. This effect starts when the combined flow of the Okanagan and the Similkameen River exceeds 17,000 cfs and has the effect of reducing the discharge from Osoyoos Lake. Under extreme circumstances the flow in the Okanagan can be reversed with water flowing from south to north. This phenomenon only occurs when there is an extremely rapid increase in the stage of the Similkameen River with insufficient inflow to Osoyoos Lake from the Okanagan River at the north end to keep the level of the lake higher than that of the Similkameen River.

This report describes a method for predicting the outflow from Osoyoos Lake under Similkameen backwater conditions which requires only knowledge of the Similkameen flow and the level of Osoyoos Lake. The method is used to reconstruct the recorded levels in Osoyoos Lake and to show the effect on Osoyoos Lake levels of changing releases from Okanagan Lake during the ~~initial~~ critical flood period and the effect of reducing flows in the Similkameen.

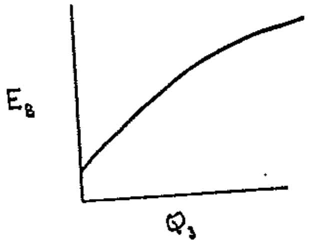
2. THEORY AND GENERAL METHOD

In the system shown below, A would represent Osoyoos Lake, AB the Okanagan River, CB the Similkameen River and BD the combined rivers.

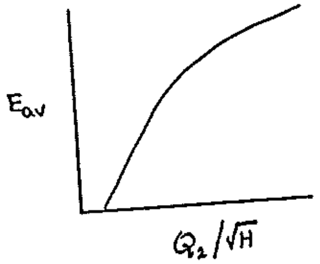


Let the flow in the Similkameen be Q, the flow in the Okanogan $_2$, the elevation of Osoyoos Lake E_A and the elevation of the combined rivers at B, E_B.

If the stage is measured at B (E_B) and either Q_3 is measured or Q_1 and Q_2 known ($Q_3 = Q_1 + Q_2$) then, assuming there are no obstruction downstream of B causing backwater to B, there should be a single valued curve relating E_B and Q_3. If, in addition, measurements are taken of E_A and the corresponding discharge Q_2 then the functions $E_{av} = (E_A+E_B)/2$ and $Q_2/\sqrt{H}$ where $H = E_A-E_B$ can be evaluated. A plot of E_{av} and $Q_2/\sqrt{H}$ normally gives a reasonably defined curve. Thus, it should be possible to construct two graphs:

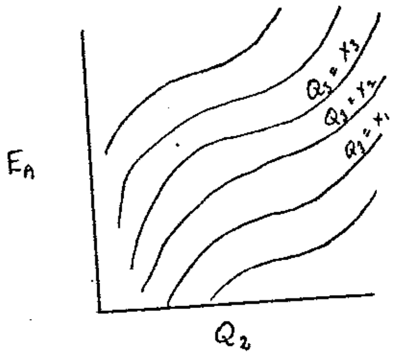


Graph # 1

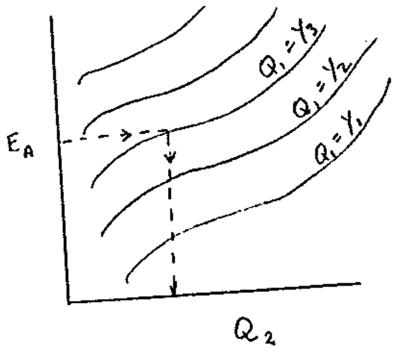


Graph #2

For each of several values of Q_3 assume several values of E_A and determine corresponding values of E_B from Graph No. 1 to calculate E_{av} and H. Then, entering Graph No. 2 with value E_{av}, determine $Q_2/\sqrt{H}$ and hence Q_2. It is then possible to construct a family of curves of E_A plotted against Q_2 for a variety of values of Q_3:



Graph # 3



Graph # 4

However, if Q_3 is not measured directly and is only known by summing Q_1 and Q_2, Graph No. 3 cannot be used directly for finding Q_2. Graph No. 4 is therefore, constructed from Graph No. 3 with the result that, given E_A and Q_1, a unique value of Q_2 can be determined.

3. DATA

To establish the relationships described above, data taken during periods when the Similkameen was sufficiently high to cause Okanagan backwater are required. Only two such substantial periods have occurred since the necessary records were kept of gauge heights and stream flows. These occasions were linked with extremely high flows in both the Similkameen and Okanagan River basins in the spring freshets of 1948 and 1972. On other occasions there has undoubtedly been a backwater effect in the Okanagan but the durations of these events have been insufficient to establish the necessary relationships.

The Similkameen River is gauged at Nighthawk about ten miles above its junction with the Okanogan. No major tributaries join it between the gauge and the junction so it is assumed that the flow measured at Nighthawk (Gauge #8NL-022) gives a reasonable estimate of the flow at the mouth of the Similkameen.

The Okanogan is extensively gauged both in Canada and the U.S. upstream of the junction with the Similkameen. Downstream of the junction, the first gauge is not until Tonasket some 20 miles distant. For the purpose of this study it was necessary to have an estimate of the water surface elevation at the junction - a measurement which is not made per se. To measure the flow in the Okanogan, the U.S. Department of the Interior, Geological Survey - Water Resources Division (USGS) established a gauge south of Oroville - published in Canada as Gauge #08NM-127. As this area is subject to Similkameen backwater and, occasionally, reversing flows, a~~x~~n auxilliary gauge was also established a short distance downstream of the main gauge. The flow in the Okanogan during high water periods is than calculated using the slope between the main gauge and the auxilliary gauge. The auxilliary gauge is situated within ¼ mile of the junction of the two rivers and, as the area is generally pretty flat, it was assumed that the actual elevations recorded at the auxilliary gauge could be considered to represent those at the junction of the two rivers. The flow in the Okanogan at the junction was taken from published data for gauge 8NM-127 Okanogan River at Oroville and the level of Osoyoos Lake from data from gauge 8NM-73 Osoyoos Lake near Oroville. Data for all of the above gauges were obtained for both 48 and 1972.

4. CALCULATIONS

Using data recorded between May 20 and June 20, 1948 and between May 15 and June 15, 1972 a plot was made of the auxilliary gauge height vs. the combined Okanogan and Similkameen flows as recorded at Gauges 8NL-22 at Nighthawk and 8NM-127 at Oroville. As would be expected there was some scatter in this plot with a noticeable difference between readings taken as the stage was rising and those taken as the stage was falling. However, it was possible to draw a "best fit" line through these points and this is shown in Fig. 1.

Using other data for the same periods, calculations were made of the average elevation between Osoyoos Lake and the junction with the Similkameen. These were plotted against the corresponding values of the recorded flow in the Okanogan at Oroville divided by the square root of the difference in the elevation of the water surface between Osoyoos Lake and the junction with the Similkameen. While the data for 1948 and 1972 were of comparable magnitudes, two distinct sets of data emerged when the two year's data were plotted. The data for 1948 plotted above the 1972 data at low elevations and below 1972 data at higher elevations. Rather than attempt to establish a curve to suit both data sets, for the purpose of these calculations, the 1972 data were assumed to be correct and the best fit curve through the points drawn. This curve is shown in Fig. 2.

For combined Okanogan-Similkameen flows ranging from 15,000 to 50,000 cfs and for Osoyoos Lake elevations from 910 to 917 ft. (USCGS datum) calculation were made of the corresponding outflow from Osoyoos Lake in the Okanagan River. The calculations were made by assuming a combined flow and determing the corresponding elevation at the junction from ~~for~~ Fig. 1. Using this with an assumed elevation of Osoyoos Lake a value of $Q/\sqrt{H}$ was obtained from Fig. 2 and thus a value of the flow in the

Okanagan River corresponding to a unique combination of Osoyoos Lake level and combined flow below the junction. The family of curves thus obtained is shown in Fig. 3. Given this family of curves it is a simple matter to construct Fig. 4 in which each curve is for a flow in the Similkameen River rather than a flow in the Okanogan south of the junction.

Thus, using Fig. 4, it is possible, given the level of Osoyoos Lake and the flow in the Similkameen River at Nighthawk, to predict the corresponding flow in the Okanogan River out of Osoyoos Lake.

5. RESULTS

Having achieved the relationships expressed by the curves shown in Fig. 4, it would be desirable to check their validity. The obvious choice is to attempt to reproduce the fluctuations in Osoyoos Lake level during a period of high flow such as 1948 and/or 1972 using the published data for the flow in the Similkameen and the inflow to Osoyoos Lake. This latter requirement presents somewhat of a problem as, while the flow in the Okanagan River at Oliver is measured, any local inflow to Osoyoos Lake and losses due to irrigation withdrawals and to evaporation are not measured. The net local inflow can be calculated as the residual quantity if the measured inflow, discharge and storage change are summed, but this is unsatisfactory as it can only be done with hindsight data on lake levels and discharges. It was therefore assumed that the local inflow between the gauges at Oliver and Oroville would balance the losses due to consumptive use and evaporation from the lake.

5.1 1972 Reconstitution

Using the published data for discharges of the Okanagan River at Oliver, Similkameen flows at Nighthawk and the discharge relationships shown on Fig. 4, standard lake flood-routing techniques were used to calculate the daily change in Osoyoos Lake levels for the period 14 May to 15 June 1973. The results of this excercise are shown on Fig. 5 and it can be seen that, while the peak level on Osoyoos Lake is quite accurately modelled, the predicted lake level is generally lower than that which is actually recorded. It was surmised that one reason for this general lowness might be the fact that local inflows were ignored as mentioned above. Accordingly, estimates were made of the local inflow by summing the recorded Okanagan River inflows at Oliver, the Okanogan River outflow at Oroville and the change in storage. This, of course, requires knowledge of lake level changes and outflows from the lake which are the "unknowns" in the main calculations and so could not be used in predicting lake level fluctuations. As can be seen from Fig. 5, this assumption of knowledge of total net inflow to Osoyoos Lake improves the simulation considerably although the peak is overestimated by about 3 inches.

5.2 1948 Reconstitution

An attempt was made to perform the same calculation for the period 23 May to 7 June 1948 using recorded data of inflow, outflow and change in lake level to calculate net local inflow to the region between the Oliver and Oroville gauges. This procedure however, indicates that there were considerable net losses during the period May 25 to May 30 but substantial net inflows thereafter. This period (May 25-30) corresponds to the period when the records show reverse flows in the Okanogan River and this leads to the conclusion that the published estimates of flow out of Osoyoos Lake may be in error.

As mentioned previously, the gauge at Oroville is used in conjunction with an auxilliary gauge downstream of the main gauge during periods when the Okanogan flow is affected by the Similkameen River. The U.S. Geological Survey have a graph (the derivation of which is not clear) relating the main gauge height to "Discharge" where "Discharge" = $Q/F^{0.4}$ where F is the head difference between the main and the auxilliary gauge. An example may make this clearer:

May 27, 1948

Okanogan R. @ Oroville main gauge 13.78 ft.
auxilliary gauge 13.81 ft.

$\therefore F = -0.03$

"Discharge" corresponding to gauge height of 13.78 ft. = 4740

$(0.03)^{0.4} = 0.246$

$\therefore Q = -4740 \times 0.246 = -1170$

i.e. a reverse flow of 1170 cfs to Osoyoos Lake.

On this day the recorded inflow to the lake at the Oliver gauge was 1770 cfs and the lake level changed from 13.12 to 13.77 ft. or a change of 1850 cfs days. Thus the apparent net local inflow to Osoyoos Lake on May 27 was 1850+(-1170) - 1770 = -1090 cfs. Local withdrawals and evaporation could not account for more than 100 cfs.

It is therefore apparent that something is in error for this period as the reverse flows published are too great to "fit the facts" assuming that the records of the lake level fluctuations are accurate. It is also interesting to consider the following data:

Day (1948)	Gauge Height		
	Osoyoos Lake	Okanogan at Oroville	
		Main	Auxilliary
24 May	12.21	11.05	10.96
25	12.57	12.30	12.32
26	13.12	13.06	13.09
27	13.77	13.78	13.81
28	14.61	14.63	14.68
29	15.59	15.59	15.69
30	16.40	16.34	16.39
31	16.73	16.40	16.31
1 June	16.60	15.87	15.65

The main gauge for the Okanogan at Oroville is, geographically, the central of the three gauges listed above but on May 25, 26 and 30 it is given as the lowest of the three - an obviously impossible condition.

As calculations of flow are based only on the main to auxilliary uge head difference the published data gives reverse flows each day for the period May 25 to 30.

It does not, therefore, seem to be possible to estimate the local inflows on the basis of published data.

If it is assumed that the local inflow during this period balanced the losses due to evaporation and withdrawals, a reconstitution of the period using the relationships shown on Fig. 4 results in somewhat low lake levels. If a steady local inflow of 300 cfs/day is assumed, however, the reconstitution becomes very accurate with the exception that the peak elevation reached by the lake is about three inches lower than that actually recorded. This is shown in Fig. 6.

6. APPLICATIONS

Having shown that the model can reproduce the recorded lake levels with a reasonable degree of accuracy, it is then possible to estimate what would have happened had different water management options been available and followed. Two such options are apparent. First, the flow in the Okanagan north of Osoyoos Lake can be controlled to the extent that that part of the flow originating from Okanagan Lake can be regulated. Second, several potential dam sites exist on the Similkameen River and its tributaries and, while none of these are presently built, it is possible to postulate the effect on the level of Osoyoos Lake of storage on the Similkameen. In all the following discussions, comparisons and "savings" in lake levels are calculated as the difference between two simulated runs rather than the simulated run and the recorded level. This assures meaningful comparisons are made.

6.1 Regulation of Okanagan Lake Releases

To investigate the effects of changing releases from Okanagan Lake it was decided to make the assumption that any change in the discharge at Penticton would affect the discharge at Oliver by that amount the next day. This is somewhat simplistic, particularly if the change in release at Penticton is substantial when in-channel storage changes would cause a greater or lesser effect at Oliver spread out over a longer period. For the purpose of this analysis, however, the assumption seems reasonable.

(a) 1972 Flood

It was found that the maximum reduction in the peak elevation of Osoyoos Lake which could be achieved by totally stopping the releases from Okanagan Lake for a short period prior to the flood peak was 0.67 ft. This was achieved by closing the Penticton gates from May 27 to June 2. It is of interest that exactly the same result was achieved with the gates at Penticton being closed on May 24 as an increase in the reverse flow into the south end of Osoyoos Lake balances the reduction at the north end. By again closing the gates from 10 - 12 June, the second peak on Osoyoos Lake could have been reduced by about the same amount. The "gain" on Osoyoos Lake has, however, to be balanced against the "loss" or increase in level on Okanagan Lake of 0.29 ft. due to stopping all releases for 10 days. This is shown on Fig. 7.

The problem with this hypothetical operation is that, while easily calculated with hindsight, some method of predicting the Similkameen flows is necessary so that the releases from Penticton can be cut back in time to have an appreciable affect on the peak Osoyoos Lake level. As the heavy snowpack was well appreciated in 1972 it is conceivable that a five-day forecast of hot weather ahead might have allowed the decision to close off the Okanagan River at Penticton to be taken on May 27th to give the above results for the first peak, but it does not seem likely that the second peak would have been anticipated. An attempt to define a rational "rule" for stopping or restricting releases at Penticton was made: the releases at Penticton would be totally stopped whenever the flow in the Similkameen exceeded 20,000 cfs; the gates would be re-opened as soon as the discharge of the Similkameen started falling unless the flow ~~discharge~~ were greater than 30,000 cfs. This rule was applied to the 1972 operation with the result shown on Fig. 7 with a saving of 0.69 ft. on Osoyoos Lake on the first peak and 0.73 ft. on the second peak. Due to several "false alarms" however, the cost of this is 0.48 ft. on anagan Lake with the gates at Penticton closed for a total of 18 days.

(b) 1948 Flood

The 1948 peak on the Similkameen was much shorter and more abrupt than that of 1972. The result is that with the rapid increase in the flow of the Similkameen, any reduction in the inflow from the Okanagan is substantially counterbalanced by an increase in the reverse flow in the river at the south of the lake. Closing off the flow from Okanagan Lake from May 25-31 results in a reduction of the maximum level of Osoyoos Lake of only 0.26 ft. at a cost of .09 ft. on Okanagan Lake. The volume of water entering Osoyoos Lake from the south is almost doubled from 1280 to 2440 cfs/days.

6.2 Regulation of Flow in the Similkameen

Studies have been made of the storage possibilities on the Similkameen River and its tributaries and several potential dam sites have been identified in both countries. (See Appendix IV of Report to I.J.C., U.S. and Canada, Water Resources of the Columbia River Basin, Okanagan Similkameen Basin; and two memoranda from W. Obedkoff to H. Hunter dated Dec. 13 and 19, 1972.) A total potential storage in Canada of 563,000 acre-feet is identified, of which almost half would be at one site near Bromley.

(a) 1972 Flood

Two sets of calculations were made - the first assuming that sufficient storage was available to limit the peak flow in the Similkameen at Nighthawk to 25,000 cfs while the second limited the peak flow to 30,000 cfs. These showed that the peak level in Osoyoos Lake could have been reduced by 1.57 and 0.99 ft. respectively on the first peak and 1.11 and 0.57 ft. respectively on the second peak. Plots of the lake levels for these calculations and of the simulated "historic" are shown on Fig. 8. In the calculations, flow in the Okanagan River ~~of~~ at Oliver, was assumed to be unaltered from the recorded 1972 flows.

To limit the peak flow to 25,000 cfs would require storage of

286,000 acre-feet to absorb the excess in the period 29 May to 13 June. .e projected site at Bromlwy even if empty on ~~13th June~~ 29th May, would not have had quite sufficient capacity to absorb this and it seems improbable that it would be possible to keep a reservoir empty as late in the runoff season. To limit the peak to 30,000 cfs, storage of 152,000 acre-feet would have been required starting on 30 May.

As 100,000 acre-feet would have been sufficient storage to limit the 1948 flood to a maximum flow in the Similkameen of 25,000 cfs, a calculation was made which assumed that 100,000 acre-feet of storage was available to be used in 1972 to attempt to keep the Similkameen maximum discharge at 25,000 cfs. This storage would have been fully utilized in the four days May 30 to June 2 after which it was assumed that the flows would have been as recorded, reaching a peak of 40,000 cfs on June 11. The calculation showed that there would have been a reduction in the first peak on Osoyoos Lake of 0.92 ft. but that the second peak then becomes the major one (by 0.23 ft.) with no reduction from the "natural flow".

(b) 1948 Flood

As mentioned above, the volume of the 1948 flood as well as the peak flow on the Similkameen were considerably less than those occurring in 1972. Storage of slightly less than 100,000 acre-feet would be sufficient to have restricted the Similkameen flows to 25,000 cfs. This would have resulted in reducing the maximum Osoyoos lake level by 1.02 ft. with a peak elevation of about 915.7 ft.

6.3 Combined Okanagan Similkameen Control

There is obviously no limit to the number of permutations and combinations that are possible in hypothetical calculations of control of either the Okanagan or the Similkameen flows. One final calculation was made, however, to show the effect on the 1972 flows of one combination of control of both rivers simultaneously. The combination chosen was to restrict the flow in the Similkameen to a maximum value of 30,000 cfs (i.e. provide 152,000 acre-feet of storage on the Similkameen available at the peak of the flood) and simultaneously to operate the control gates at Penticton in such a manner that the flow in the Okanagan at Oliver .d not exceed 2,000 cfs when the flow in the Similkameen exceeded 20,000 cfs. Due to the time lag between adjusting the flow at Penticton and the effect reaching Oliver, it would not be possible to maintain an exact flow, but it is assured for this analysis that such control could be achieved. On two occasions during the 1972 freshet, the flow at Oliver was greater than 2000 cfs even with the release at Penticton reduced to zero.

The calculations showed that the first peak would be reduced by 1.87 ft. with the lake only rising to about elevation 915.5. With this particular set of assumptions, the resultant conditions are very stable in that there is no fluctuation in the inflow to the lake nor ~~not~~ in the flow in the Similkameen which controls the outflow. The result is that Osoyoos Lake stabilizes at about elevation 915.5 and there is no second peak as inflow and outflow are balanced. The cut-back in releases from Okanagan Lake results in an increase in level of Okanagan Lake of 0.26 ft. The Osoyoos Lake levels are plotted on Fig. 8.

7. CONCLUSIONS

It has been possible to construct a model which satisfactorily explains on a mean daily basis the hydraulics of the junction of the Similkameen and Okanagan Rivers at Oroville, Washington during flood periods. It is clear that when the combined flows exceed about 17,000 cfs, the discharge from Osoyoos Lake is reduced due to to the volume of water in the Similkameen. On occasions the normal direction of flow is reversed in the Okanogan with water flowing from south to north, but this phenomenon is associated with the rate of rise of the Similkameen River rather than any absolute discharge. Reverse flows could occur with flows as low as 18,000 cfs in the Similkameen if the rate of increase of discharge were sufficiently fast to "catch" Osoyoos Lake at a low elevation. On the other hand, on a daily basis, the 1972 freshet did not cause any reverse flows in the Okanogan despite the fact that the peak flow of 45,800 cfs was considerably greater than the previously recorded maximum.

The model can be used to predict discharges in Okanogan River d hence levels in Osoyoos Lake if forecasts of mean daily flows are available for the Similkameen River. Assumptions as to the local inflow to Osoyoos Lake would have to be made, but the effect of different discharges in the Okanagan River north of Osoyoos Lake on the lake levels could be gauged using this model. This will, therefore, enable the operators to assess quantitatively the effect on Osoyoos Lake of variations in the patterns of operating the storage further upstream. However, it is apparent that the limited amount of control of Okanagan River discharges available to the operators has relatively little effect on the peak stages reached by Osoyoos Lake.

The model has shown that the only way in which major flooding relief around Osoyoos Lake can be achieved is by the control of the Similkameen rather than the Okanagan River. The cost of building major storages on the Similkameen to reduce the peak flows to any marked extent cannot be justified by the benefits gained by reducing damage round Osoyoos Lake. However, were storage to be constructed for some other purpose, the "proper" management of such dams in year of high runoff could undoubtedly considerably reduce the peak level reached by Osoyoos Lake and thereby reduce damage caused by flooding.

The model appears to work well in that the simulations of both 1948 and 1972 lake level fluctuations are reasonably accurate. The major limiting factors in the model are that there is no actual stage measurement of the combined flows near the junction and, more importantly, that the fluctuations in any one day can be too great for a mean daily elevation or discharge to be a suitable measurement. To be of maximum use this model requires the input of forecasts of flows in the Similkameen on at least a daily basis and this would require a major undertaking as the Similkameen basin is fairly complex.

R.Y. McNEIL
– [illegible].1.72