Clutha River Mainstem Flows and 7-day Mean Annual Low Flow at Balclutha

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1. Background

There have been many developments in the last 170 years in the Clutha Catchment which have altered the catchment to a greater or lesser degree. Some of these include goldmining, hydro electricity generation, irrigation and tributary and lake storage.

Hydro electric generation development has had the greatest influence of the flow regime of the Clutha from the Hawea/Clutha Rivers confluence to Balclutha whereas goldmining, irrigation and tributary storage have had major impacts on tributary river flows and land use but less impact on the main river system. This report focuses on the Clutha River main stem including the headwaters Lakes Wanaka, Hawea and Wakatipu and the Kawarau River only so goldmining, irrigation and tributary storage are not considered here.

In 1945, investigations into the potential of the Clutha River for hydro electricity development began and three years later, construction of the Roxburgh Hydro scheme commenced. The Roxburgh Dam was commissioned in 1956 and was completed in 1964. Since August 1956, flows in the Lower Clutha River downstream of the Roxburgh Dam have been highly modified due to Roxburgh Hydro being a peak load station. Section 3 of this report shows the flow patterns at Balclutha pre- and post-Roxburgh hydro.

Construction of the Lake Hawea outlet control began in 1954 and was completed in 1958, raising the normal level in Lake Hawea by 20m. The purpose of this dam was to provide storage for Roxburgh power station generation, but it now provides for both Clyde and Roxburgh power stations. The purpose of this storage was to store water with minimal outflows through to about June/July and release it through the main winter months when outflows from Lakes Wanaka and Wakatipu were traditionally at their lowest, As a result, since 1958, natural flows in the Clutha River downstream of the Clutha/Hawea Rivers confluence have been altered, at times significantly so, since Hawea can discharge at 200 cumecs for weeks on end usually when outflows from Wanaka are around 100 cumecs or less. At 200 cumecs discharge, the lake level falls about 0.1m per day. The natural lake level in Lake Hawea of highest levels in the months November to January and lowest levels in July to September was significantly altered to one of highest levels from about January/February to June and lowest levels in August to October. Currently Lake Hawea remains the only significant controlled storage in the Clutha catchment and is likely to remain so since both Lakes Wanaka and Wakatipu are protected by Acts of Parliament from any further controls on their outflows.

Construction of the then controversial and very costly Clyde Dam began in 1982 and was completed in 1993. The dam was constructed on an earthquake fault which required considerable extra work and costs to make it safe. In addition, significant stabilisation of landslides in the Cromwell Gorge was required and there are 18 tunnels throughout the Gorge for draining purposes. Like Roxburgh Hydro, the Clyde Hydro scheme is also a peak load station but its effects on flows extends only from downstream of the Clyde dam to Lake Roxburgh.

2. The Clutha Catchment

2.1 General

The Clutha River is the largest river by area and volume and the second longest river in New Zealand. It rises in the Southern Alps where 6m or more of rain can fall in any one year. Snow blankets the mountains in winter and some of this mountainous area still has remnant glaciers in their upper reaches. The three large natural Lakes Wanaka, Wakatipu and Hawea, which were created in the last major glaciation thousands of years ago, receive most of the headwaters runoff and the combination of their outflows provides 75% of the flow measured at the Balclutha recorder site. Figure 1 shows the catchment.

The catchment has had significant changes to its vegetation and flow regime since the 1850's. Much of the original tussock and forest covered country has been replaced with exotic grasses and various crops including extensive pasture and horticultural activities.

The natural flow regime has been altered due to the three dams which have been constructed in the river for hydro electricity generation purposes including a control structure at Lake Hawea outlet and the Clyde and Roxburgh hydro dams.

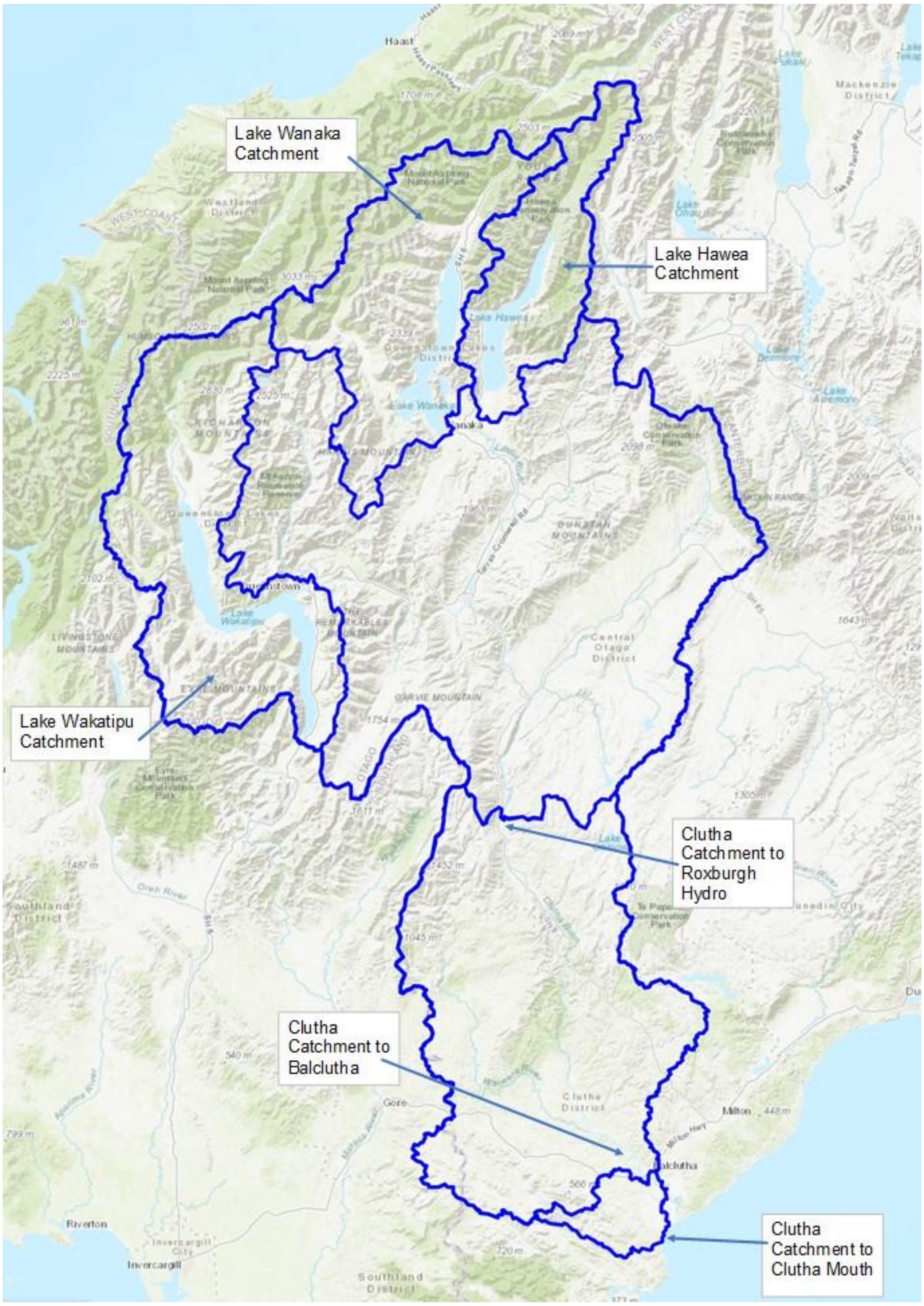
2.2 Catchment Areas

Table 1 lists the relevant catchment areas in the Clutha Catchment. The table lists the various increasing catchment areas progressively down the catchment along with some other specific areas.

Table 1. Relevant Clutha River Catchment Areas

Catchment	Area (km^2)
Lake Wanaka at Roys Bay	2628
Lake Hawea at Outlet	1384
Lake Wakatipu at Willow Place	3133
Clutha at Clyde	12018
Clutha at Roxburgh	15606
Clutha at Tuapeka Mouth	17167
Clutha at Balclutha	20582
Clutha at Clutha Mouth	20892
Roxburgh Hydro to Balclutha	4676
Roxburgh Hydro to Clutha Mouth	4986
Balclutha to Clutha Mouth	310

Figure 1. Clutha River Catchment



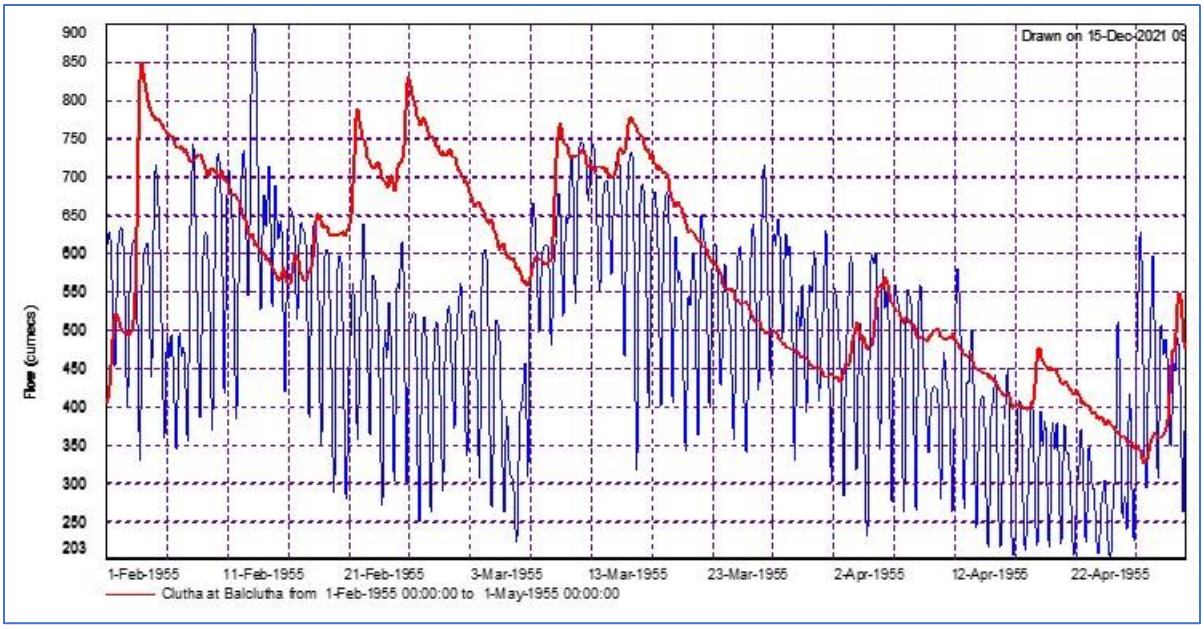
3. Flow Information and Statistics

The Clutha River has the largest flow of any river in New Zealand. Seventy-five percent of that flow originates in the catchments of the three main lakes of Wanaka, Wakatipu and Hawea with a combined catchment area of 7145 km^2. This is about 35% of the total catchment area to Balclutha and means that the remaining 65% of catchment area (13437 km^2) produces only 25% of all flow measured at Balclutha.

Flows in the Clutha at Balclutha have been recorded since 6 July 1954 and continue today.

The hydrograph at Balclutha is mostly highly modified by power generation flow releases from the Roxburgh hydro station. Figure 2 shows the natural flow pattern before Roxburgh Hydro for the 3-month period February to April 1955 (red line) and contrasts it with the current flow pattern (blue line) for the same period in 2005.

Figure 2. Flow Patterns at Balclutha pre (red) and post (blue) Roxburgh Hydro



However, flow statistics can still be derived from the data. Table 2 lists the basic flow statistics of flows measured at Balclutha.

Table 2. Hydrology Statistics - Clutha at Balclutha (cumecs)

Mean	Median	Minimum	Maximum	7DMALF*
575	535	37	4581	298

* Is the 7-day mean annual low flow

The minimum flow of 37 cumecs was recorded in July 1956 when the Roxburgh hydro dam was being filled. The next lowest flow recorded was 94 cumecs in May 1960.

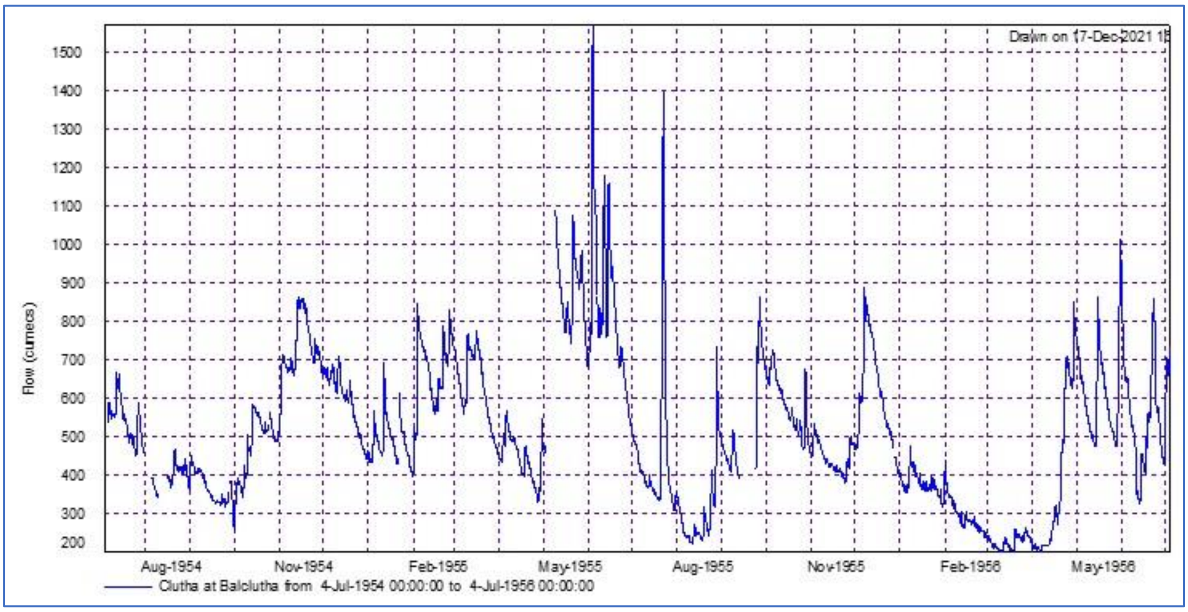
The maximum flow was that recorded in the October 1978 flood event. The next highest flood flow was 4167 cumecs in November 1999.

3.1 7-Day Mean Annual Low Flow

The 7-day mean annual low flow (7DMALF) of 298 cumecs is unusually high compared with other flow statistics. This will be due to the wildly fluctuating flows in the river and is unlikely to be the normal, natural 7-day low flow. There are no long periods of stable low flow at

Balclutha in any year except the 2 years pre–Roxburgh Hydro July 1954 to July 1956 so an acceptable natural 7DMALF cannot be calculated from all the data. For the 2 years of natural flow, the 7DMALF was 200 cumecs but this would be indicative only as 2 years of record is not long enough to establish such a value. Figure 3 shows the two-year natural flow period.

Figure 3. Natural Flow Record for Clutha at Balclutha



A review of 7DMALF's in other rivers showed that natural 7DMALF is usually about 20% or less of mean flow but this is in rivers which do not have the storage buffer of three large lakes which contribute most of the flow.

The Hurunui River in North Canterbury is a river that drains the Southern Alps and has a large natural lake (Lake Sumner) in its headwaters. There are several flow measurement sites in this river that will be used to give an indication of what the natural 7DMALF may have been in the Clutha River at Balclutha under natural circumstances with no hydro dams and Hawea not controlled. Table 3 shows the sites along with comments about each site. The flow data at these sites except for the most downstream site, is natural since any abstractions are small and within the margin of error of flow measurement.

Table 3. Hurunui River Flow Measurement Sites

Hurunui Site	Area (km^2)	Flows (cumecs)		7DMALF as % of Mean	Comments
		Mean	7DMALF		
No. 2 Hut	182	17.6	4.8	27	Upstream of Lake Sumner
Lake Sumner Outlet	317	25.5	8.3	33	Lake Outlet
Jollie Brook	484	33.8	10.5	31	
South Branch	305	14.2	5.0	35	No lake in headwaters
Mandamus	1070	52.6	17.0	32	Total headwaters catchment
State Highway 1	2518	73.0	21.1	29	Total catchment

Table 3 shows that in a catchment with one natural storage lake, the 7DMALF is possibly about one third that of the mean flow at the site. Applying this to the Clutha at Balclutha (mean flow 575 cumecs) would give a 7DMALF at Balclutha of 190 cumecs, very close to the estimate based on 2 years of natural data. However, in the case of the Clutha where storage lakes provide most of the flow, the 7DMALF may be more than a third of the mean flow. The 7DMALF calculated from all the available flow data (1954 to present) is about 50% of the mean flow and this is likely too high. The short period of natural data shows naturally flows will fall to 200 cumecs so the 200 cumecs value will be adopted as the natural 7DMALF for the flow record at Balclutha.

4. Power Generation Surges

Power generation from the Roxburgh Hydro station began in late 1956. Roxburgh Hydro is a peak load station, and it generates at up to maximum rate during periods of high demand (usually from about 6am to 9pm) and shuts down to a residual generation station for several hours overnight because demand is at its lowest at this time. This is also the time that prices for power are at their lowest.

Flows immediately downstream of the Roxburgh Dam can rise from around 270 cumecs to around 850 cumecs in a few hours. While the consents for the dam will have ramping restrictions on them, that magnitude of rise is not natural. Also, in nature, such rapid rises and falls do not happen every day. These abrupt rises and falls at Roxburgh travel down the river and are somewhat modified as they do so due to in-channel storage and tributary inflows. By the time the flows reach Balclutha, the maximum rises of around 600 cumecs at Roxburgh have become 400 cumec rises and the changes in flows are not as abrupt as they were at Roxburgh. Figure 2 shows the natural river flow over a 2-month period before hydro generation along with what can happen now over the same 2-month period.

Flows at Balclutha can vary by more than 400 cumecs between the lowest and highest flow during the day and for many consecutive days. Figures 4 and 5 show the now normal flow pattern at Balclutha caused almost entirely by flow releases for power generation at the Roxburgh hydro station. Figure 4 is the change in flows during an eleven-day period in April 2018 and Figure 5 is the change in stage (water level) for the same period. The magnitude of these fluctuations can be significantly modified by freshes and floods in the lower catchment tributaries with the Pomahaka River having the greatest influence.

Figure 4. Daily Flow Fluctuations in the Clutha at Balclutha

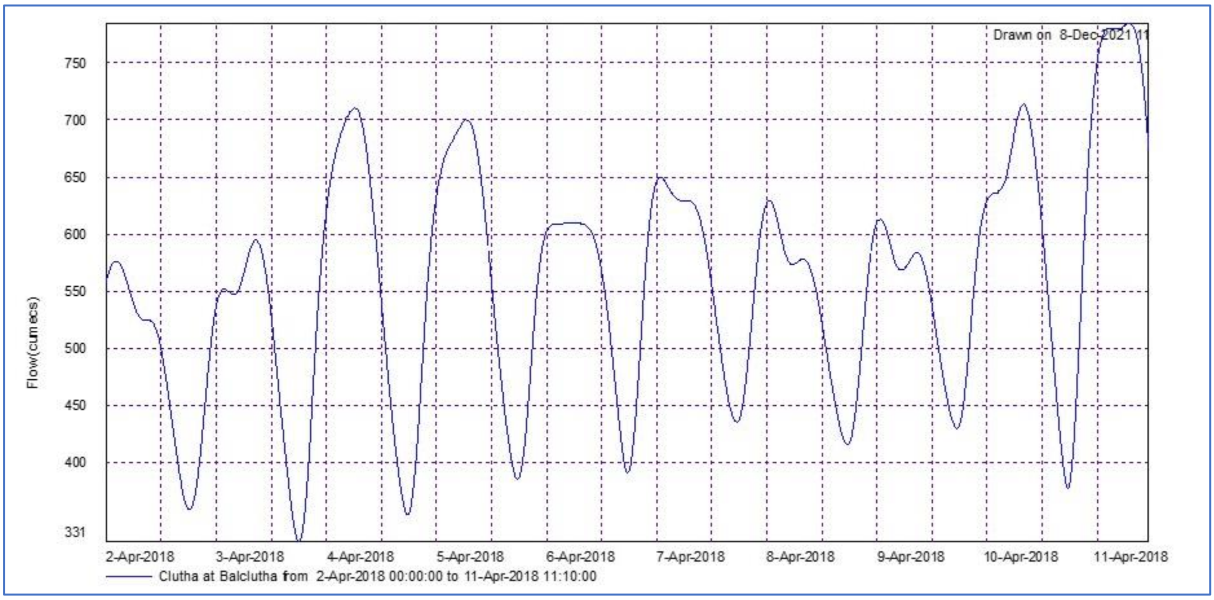


Figure 5. Daily Water Level Fluctuations in the Clutha at Balclutha

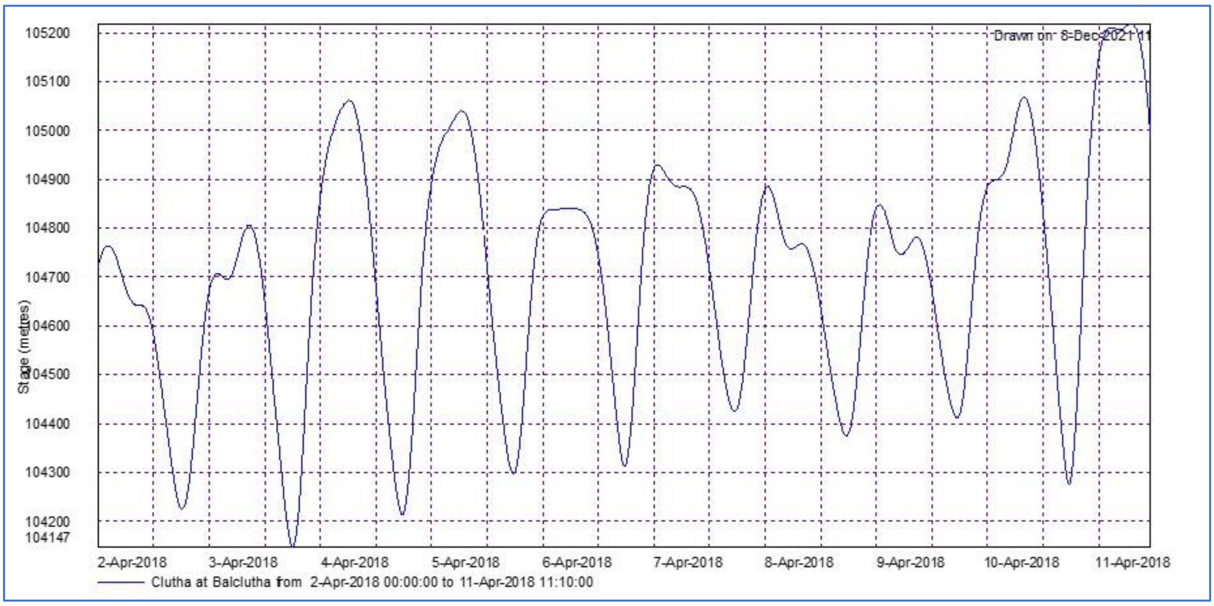
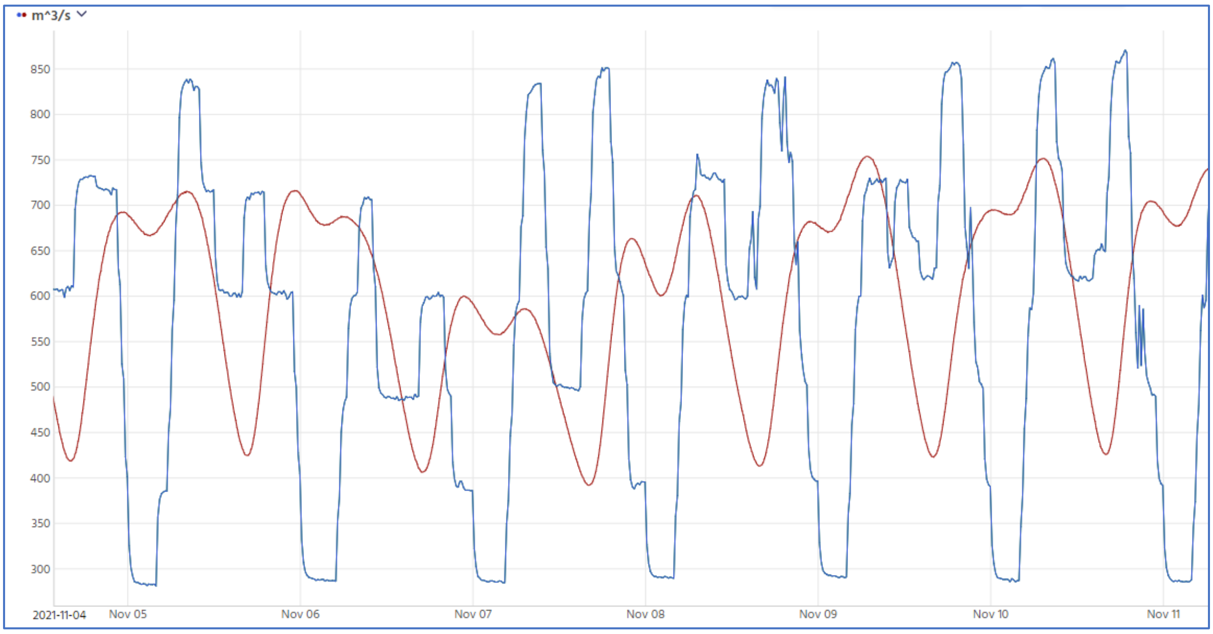


Figure 6 shows a period of flow in November 2021. It includes the water level and flow recorder site Clutha Below Roxburgh (blue line) along with that at Balclutha (red line).

Figure 6 shows simultaneous flows at both Clutha flow sites. Analysis of the data shows there is about a 15–16-hour lag between when flows begin ramping up at the Below Roxburgh site and when that rise begins at Balclutha. The changes in flows are abrupt at Below Roxburgh compared with those at Balclutha. These abrupt changes are smoothed out mainly due to in-channel storage and tributary inflows by the time they reach Balclutha.

Figure 6. Clutha Below Roxburgh (blue) and Clutha at Balclutha (red) flows (cumecs)



In Figure 6, flows at Clutha Below Roxburgh become steady at their lowest flow for several hours between about midnight and 5am.

In the above graph, flows fall to about 275 cumecs at the Clutha Below Roxburgh site but at Balclutha they fall to about 400 cumecs for the same low flow period at Roxburgh 15 hours previous. The reduction in fall is due to flow modification as they travel the 111km distance to Balclutha and the inflows from tributaries in the reach such as the Teviot, Tuapeka, Pomahaka and Waitahuna Rivers.

Acknowledgements

1. Otago Regional Council for the provision of the Clutha at Balclutha flow record

2. The National Institute of water and Atmospheric Research for the provision of the Clutha Below Roxburgh flow record.