NIWA
Taihoro Nukurangi

McCulloughs Creek Low Flow Estimation

Prepared for Jeremy Kent-Johnston

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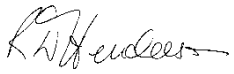	Reviewed by:	Roddy Henderson
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Executive Summary

This report is to provide an estimate of the 7-day mean annual low flow (MALF) for two sites on McCulloughs Creek in South Westland. A short period of data collected at the lower site (NIWA recorder station McCulloughs Creek at Bottom of Gorge) in 2017 and 2018 has been combined with long-term data collected at other flow sites nearby to provide a regression-based estimate of the MALF. This estimate is 0.58 m^3/s with a standard error of 12.5%.

The upper site (McCulloughs at Intake) is estimated to have a MALF of 0.33 m^3/s, based on simple pro-rating by catchment areas. Because of the possible error generated by the proration process, the standard error for this MALF is estimated at 15%.

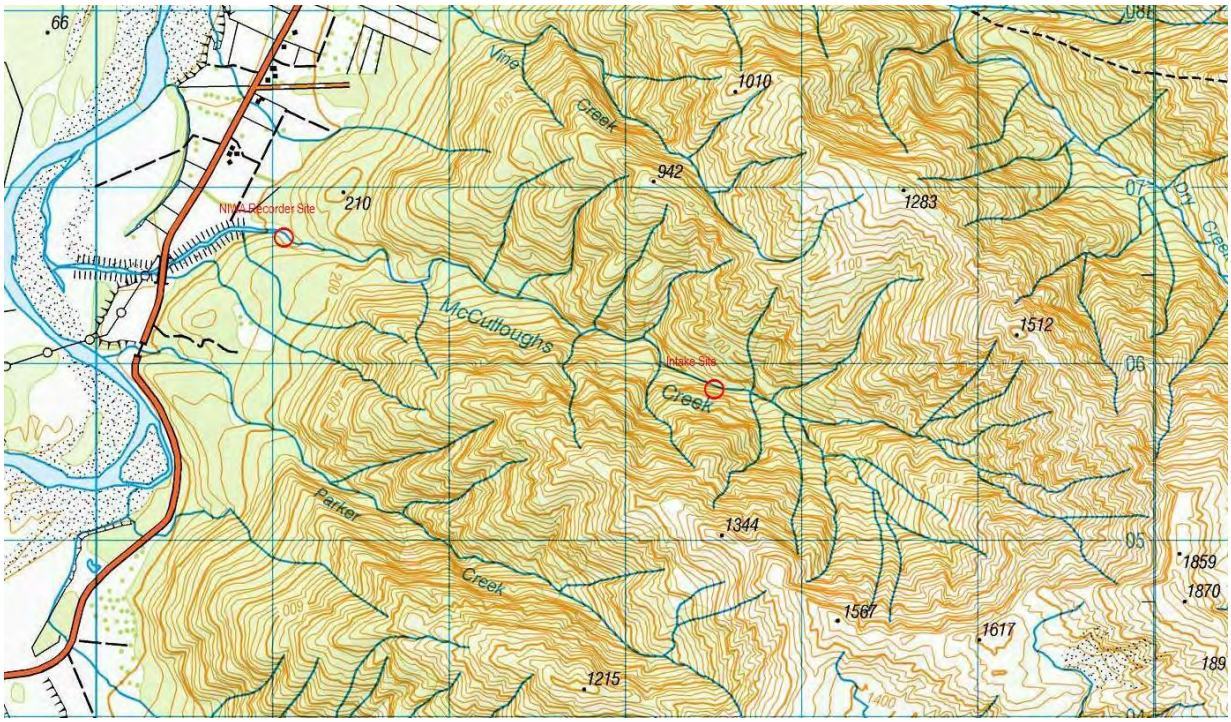

Figure 1: Map of McCulloughs Creek.

1 Introduction

The purpose of this data collection and analysis is to derive the 7-day mean annual low flow (7-day MALF) for the McCulloughs Creek at the proposed intake site. This is to be used for water extraction consent purposes.

The MALF estimate for the intake site is based on a MALF estimate for the NIWA recording station.

The MALF estimate for the NIWA recording station is based on the 12 months of continuous data collected at the NIWA recording station, 800 m upstream of the State Highway Bridge along with long term data from two larger catchment sites.

The two larger sites are the Poerua River at Lower Gorge: a larger, but similar catchment very near to McCulloughs Creek, and the Hokitika River at Gorge, a much larger catchment, and less hydrologically similar, which nevertheless gives a good low flow correlation with McCulloughs Creek.

The Poerua River at Lower Gorge site was in operation from June 1981 to January 1993. It is from this data that the low flow statistics for the Poerua River have been derived. The site was not reopened for this investigation, but gaugings were carried out during periods of low flow during this investigation, and the gauged flows were correlated against those gauged (or recorded if no gauging was done that day) at the McCulloughs Creek at Bottom of Gorge site.

The Hokitika River at Gorge site was installed in March 1996 and is still in operation. The low flow statistics from this site have been derived from the full period of record up to the present date. During the investigation period the lowest flow for each month at this site was correlated against the flow at the McCulloughs Creek at Bottom of Gorge site on the same day.

2 Data collection

A flow recording station was installed on McCullough's Creek during March 2017 near the proposed powerhouse site (at approximately the 110-m elevation contour).

Flow gaugings were carried out at each visit, and 15-minute interval stage height data collected, through until March 2018. Data are still being recorded, but no more will be available until the next site visit to download data. A stage-discharge rating curve was created, using the seven spot gaugings that have been done to date, the result being greater than 12 months continuous flow record.

Note that the stage-discharge rating relationship was found to be stable, with all seven gaugings plotting within 6% of the rating curve. This indicates reliable flow data can be generated from the recorded stage-height data.

A graph of the stage-discharge rating is shown in Figure 2-1, with the gaugings marked.

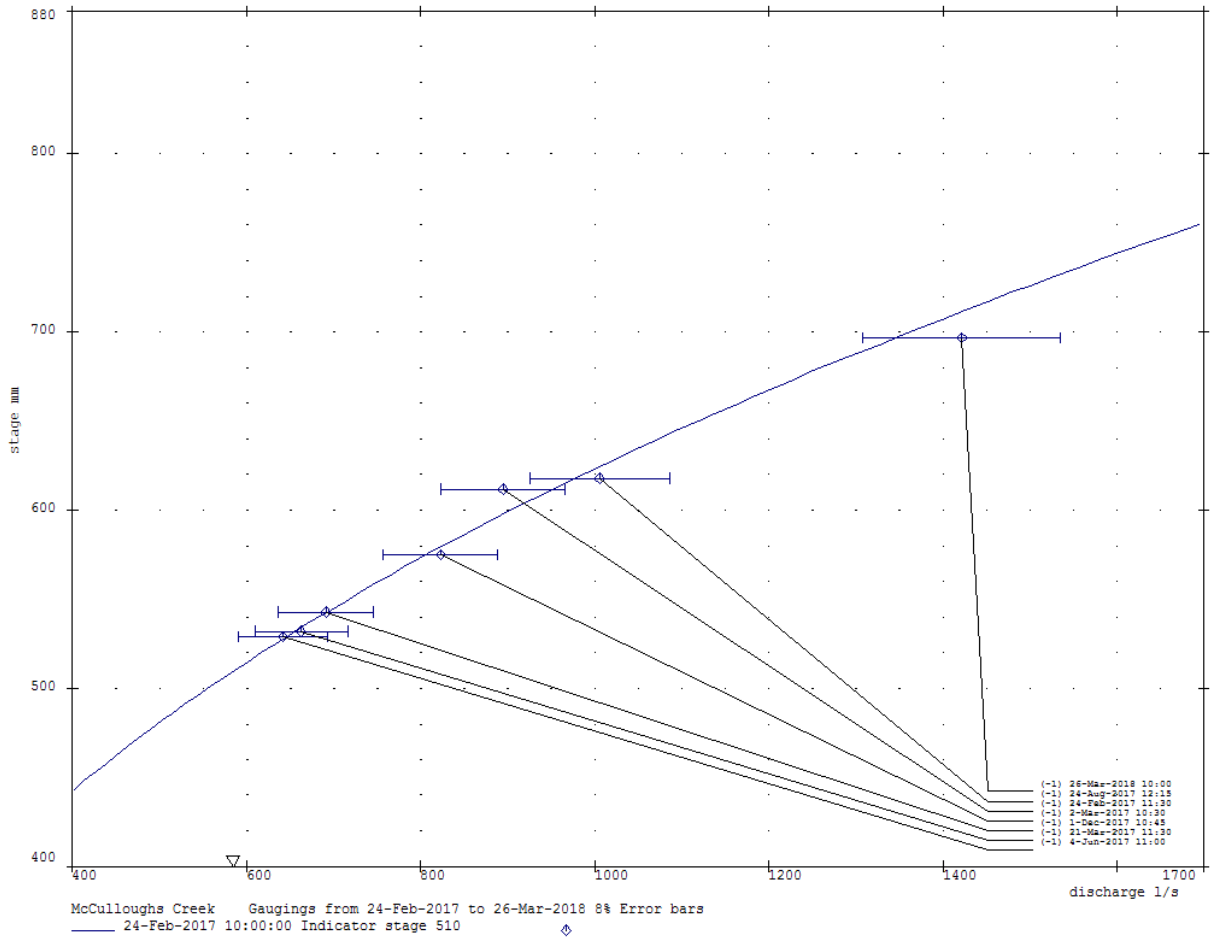

Figure 2-1: McCulloughs Creek at Gorge Bottom stage-discharge rating.

3 Related data sources

The data from the short term McCulloughs Creek site were compared with long term Crown-funded sites, and correlations derived to obtain information for McCulloughs Creek that could not normally be obtained from only a few months of data. The sites from which data were used are listed in Table 3-1.

Table 3-1: Site information.

Site Number	Site Name	NZMG Map reference	Catchment area (km^2)
89302	McCulloughs Creek at Bottom of Gorge	2301042E, 5768357N	7.66
89601	Poerua River at Lower Gorge	2303720E, 5785805N	148
90612	Hokitika at Gorge	2348410E, 5803880N	367

4 Flow statistics

Below are some useful hydrological statistics for the three sites for comparison purposes. Table 4-1 presents the statistics for the McCulloughs Creek record from the twelve-month period of record together with statistics from the Hokitika site for the corresponding period.

Table 4-2 gives statistics from the Hokitika and Poerua sites for the full periods of their records. In Table 4-2, the length of record on which the statistics are based is given in the right-hand column.

Table 4-1: Investigation period data statistics (2 March 2017 to 26 March 2018).

Site Number	Minimum Flow (m^3/s)	Minimum 7-Day Low Flow (m^3/s)	Flow Exceeded 95% of the time (m^3/s)	Median Flow Exceeded 50% of the time (m^3/s)	Mean Flow (m^3/s)
McCulloughs Creek (89302)	0.553	0.601	0.638	0.975	1.175
Hokitika River (90612)	24.0	26.1	29.2	55.3	80.6

Table 4-2: Full period data statistics.

Site Name and Number	Lowest Recorded Flow (m^3/s)	Mean Annual 7-Day Low Flow (m^3/s)	Flow Exceeded 95% of the time (m^3/s)	Median Flow – Exceeded 50% of the time (m^3/s)	Mean Flow (m^3/s)	Number of Years of Record
Poerua River at Lower Gorge (89301)	3.55	6.67	7.02	17.9	33.7	11.5
Hokitika River at Gorge (90612)	16.5	26.7	27.2	61.3	100.5	22

Table 4-3 shows the drought frequency statistics for the Poerua and Hokitika sites using the full period data series available. The methodology for deriving the drought statistics for the McCulloughs Creek is described in Section 6.

Table 4-3: Drought frequency statistics for the three sites (full record).

Drought recurrence interval of 7-day low flows (year)	McCulloughs Creek at Bottom of Gorge (m^3/s)	Poerua River at Lower Gorge (m^3/s)	Hokitika River at Gorge (m^3/s)
Mean annual	0.585	6.67	26.7
5	0.508	4.95	20.2
10	0.484	4.40	18.7
20	0.467	4.01	17.7
50	0.449	3.61	16.6
100	0.439	3.37	16.0

5 Flow distribution

Figure 5-1 shows the flow distribution for McCulloughs Creek at Bottom of Gorge. The vertical scale is flow in l/s, and the horizontal scale is the fraction of the time for which the river flow was equalled or exceeded. For example, 2000 l/s (2.0 m^3/s) was exceeded 0.075 (or 7.5 %) of the time.

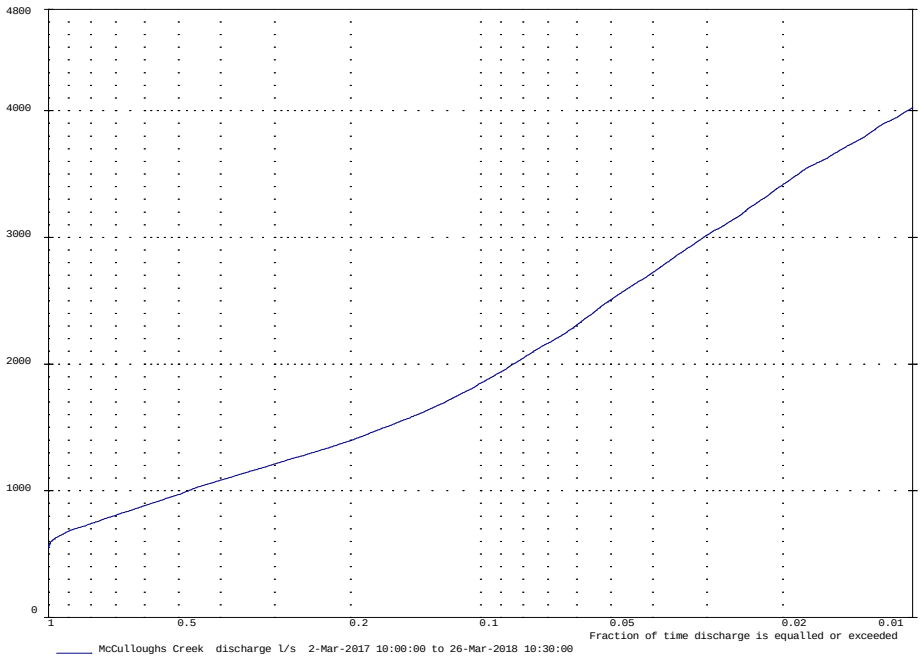

Figure 5-1: Flow distribution in m3/s for McCulloughs Creek at Bottom of Gorge.

Figure 5-2 shows an expanded view of the low flows of the same distribution. An example here would be 1200 l/s (1.20 m^3/s) being exceeded 0.31 (or 31 %) of the time.

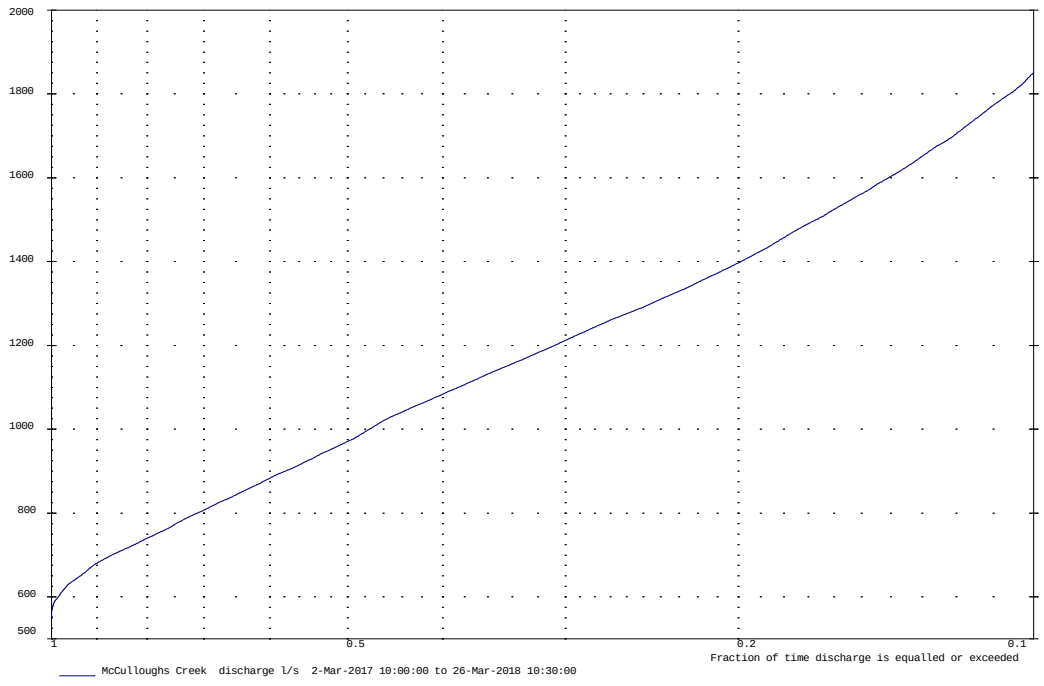

Figure 5-2: Low end of flow distribution in litres/second for McCulloughs Creek at Bottom of Gorge.

6 Drought frequency analysis

The method used to estimate the 7-day mean annual low flow or MALF statistic is given in the following paragraph. The MALF is a common statistic used by hydrologists, and regulatory authorities also use it as a guide for assessing water resource availability.

The methods used below are:

1. Correlation of the gauged or rated flows during the investigation period for McCulloughs Creek at Bottom of Gorge with gauged flows done concurrently on the Poerua River.

2. Correlation of the rated flows during the investigation period for McCulloughs Creek at Bottom of Gorge with concurrent mean daily flows taken from the Hokitika at Gorge site.

The resulting regression equations are applied to the long-term low flow statistics from those sites to obtain estimates for the McCulloughs Creek at Bottom of Gorge. Results from the two sites were so similar that confidence can be placed in the results.

The 7-day mean low flows for recurrence intervals of 5 to 100 years, were calculated using the same regression equations, and the mean of the two results used in the table. The frequency analyses on which this calculation is based, used the GEV distribution for both comparison sites.

6.1 Correlation details

Regression analysis was carried out between McCulloughs Creek at Bottom of Gorge and the long-term flow sites Poerua at Lower Gorge and Hokitika at Gorge.

Figure 6-1 shows a scatter plot of the McCulloughs Creek vs Poerua flows. The red line is the geometric mean regression line.

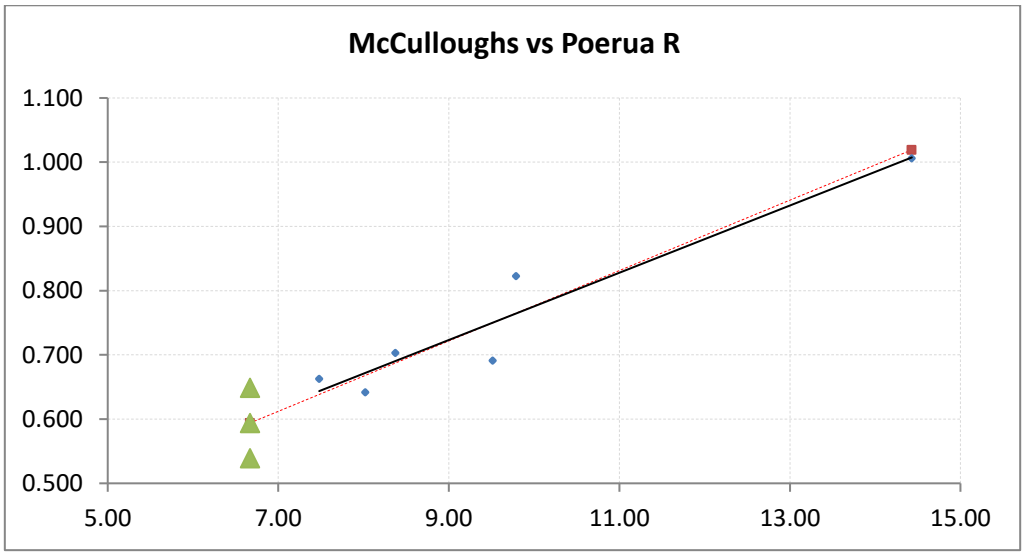

Figure 6-1: Scatter plot: McCulloughs Creek flows vs Poerua River flows.

The McCulloughs Creek flows are plotted on the vertical axis, and the Poerua River corresponding flows (all in m^3/s) are plotted on the horizontal axis. The three triangles represent the predicted MALF at the McCulloughs Creek site and the standard error of the prediction.

Figure 6-2 shows the same type of scatter plot, but uses the Hokitika River as the comparison site. The two triangles represent the predicted MALF at the McCulloughs Creek site and the upper standard error of the prediction range (the lower one is not shown as it is below the vertical axis).

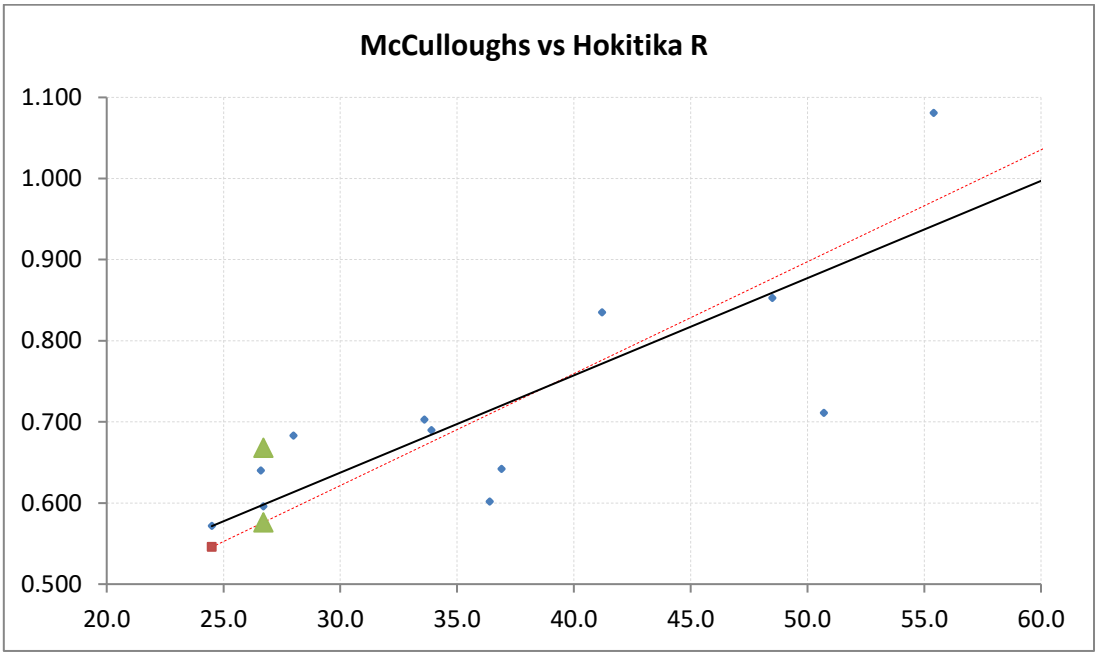

Figure 6-2: Scatter plot: McCulloughs Creek flows vs Hokitika River flows.

The regression line parameters are tabulated in Table 6-1, along with the predicted mean annual low flow (MALF) and the associated error.

Table 6-1: Results from regression of McCulloughs Creek flows against comparison sites.

Correlation data	Poerua River	Hokitika River
Slope	0.0548	0.0138
Offset (m^3/s)	0.228	0.208
MALF from comparison site (m^3/s)	6.67	26.7
Predicted MALF McCulloughs Creek (m^3/s)	0.594	0.576
Standard error for MALF prediction (m^3/s)	0.055 (9%)	0.092 (16%)

Taking the mean of the two results shown in Table 6-1 above gives a MALF estimate for McCulloughs Creek of 0.585 m^3/s with a mean standard error of ±12.5 %.

7 Estimation of MALF at the Intake Site

Based on the proportion of the catchment areas of the recorder site (7.66 km^2) to the intake site (4.40 km^2), the MALF at the intake site is estimated at 0.336 m^3/s. The uncertainty for this estimate cannot be calculated directly, but is estimated to be of similar magnitude to the MALF estimate for the lower site, but perhaps slightly larger because of possible rainfall variations within the catchment.

This result is consistent with the predictions of the national models, which have much larger uncertainties for such small catchments.

A table of MALFs and their specific discharges for various long-term sites operated by NIWA over the years is presented for comparison.

Table 7-1: Range of MALF Specific Discharges.

Site Number	Site Name	Catchment Area (km^2)	MALF (m^3/s)	Specific Discharge of MALF ($l/s/km^2$)
89303	McCulloughs Creek at Intake Site	4.40	0.336	76
89302	McCulloughs Creek at Bottom of Gorge	7.66	0.585	76
87301	Moeraki at Lake Outlet	98.4	5.18	52.6
87801	Makawhio at Rocks	135	7.10	52.6
89601	Poerua River at Lower Gorge	148	6.67	45.1
90101	Waitaha at SHB	223	11.2	50.2
91103	Taipo at SHB	181	13.6	75.1
90612	Hokitika at Gorge	367	26.7	72.8