Article, Published Version

Dick, Geoff; Ede, Mike; Nguyen, Duc; Wadsworth, Val

The Wairau River Flood of July 2021

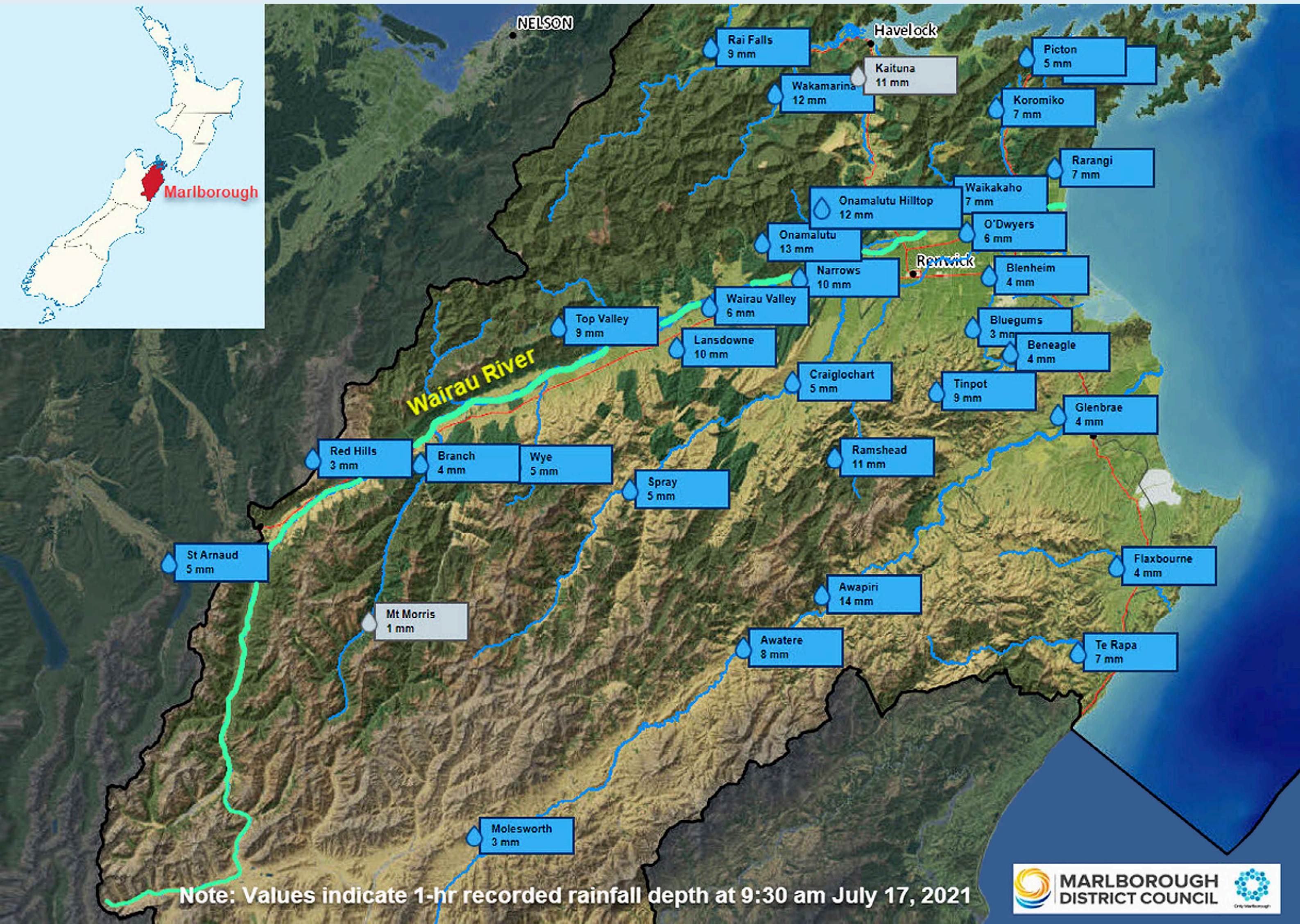
Hydrolink

The Wairau River Flood of July 2021

By Geoff Dick, Mike Ede, Duc Nguyen and Val Wadsworth

The Wairau River, in the Marlborough Region at the north end of the South Island, is subject to some of the largest floods in New Zealand. In July 2021, the river flooded sharply, with peak flows well over 5,000 m³/s near its mouth. This was the second highest Wairau discharge observed in some 70 years of systematic records. However, New Zealand is a mountainous country, so the catchment is relatively short and steep, and the time above average annual flow was a little over 24 hours. This foreshortened time scale requires adaptation of forecasting and civil defence procedures so that evacuation of threatened areas can be activated at short notice. In recent years, the Marlborough District Council has been building up technical capability in the flood risk management team, and this was the first test of their response to the challenge of a major event. Figure 1 shows the location of rainfall stations in the Wairau River basin and the amount of one-hour rainfall recorded at 9:30 am of 17 July 2021.

Figure 1 | The Wairau River and Marlborough District rain recorders (Inset: Location in New Zealand).



	3 hour max	3 hr ARI	6 hour max	6 hr ARI	12 hour max	12 hr ARI	24 hour max	24 hr ARI	2 day total
Tunakino							240 mm	4 yr	255mm
Kenepuru			71 mm	3 yr	137 mm	10 yr	196 mm	15 yr	271mm
Onamalutu	61 mm	20 yr	112 mm	60 yr	201 mm	215 yr*	291 mm	290 yr*	320mm
Top Valley	57 mm	24 yr	108 mm	88 yr	194 mm	395 yr*	282 mm	510 yr*	308mm
Branch	28 mm	2 yr	50 mm	3 yr	87 mm	6 yr	127 mm	11 yr	142mm
Wye	23 mm	1.5 yr	39 mm	2 yr	69 mm	3 yr	96 mm	5 yr	108mm
Spray	23 mm	2 yr	40 mm	3 yr	75 mm	14 yr	102 mm	23 yr	112mm
Tinpot			30 mm	1.6 yr	50 mm	1.8 yr	71 mm	2 yr	76 mm
Awapiri	41 mm	13 yr	73 mm	28 yr	131 mm	94 yr*	181 mm	125 yr*	188mm

Table 1 | Selected rainfall statistics for the storm of 16-17 July 2021.

Hydrology

The meteorological context of the July 2021 event was a classic Wairau flood situation, with a deep low approaching the West Coast, a blocking high to the east of New Zealand, and a NNW front crossing Marlborough. As the forecasts progressed it became apparent that this had the potential to be a significant event, and monitoring staff were placed on standby on Friday afternoon for flood monitoring through the weekend. Over the previous months there had been frequent rainfall in northern Marlborough. Therefore, the catchments were well saturated, resulting in high runoff. The main rainfall event was centred on the Richmond Range, which has mountain peaks over 1700 m high near the Onamalutu Stream (see box centre top in Figure 1). There, with 24-hour rainfall up to 291 mm, an indicative annual recurrence interval (ARI) of 290 years was estimated (see Table 1). A very similar 24-hour rainfall in a site at Top Valley with less extreme exposure rated an estimated ARI of 510 years. The lesser runoff from the southern tributaries was interesting, as usually major Wairau floods have significant contribution from those catchments as well. Table 1 presents rainfall statistics at selected stations within the Wairau River basin.

Flood narrative

The storm affected much of Marlborough, with associated flooding and roading damage. However, the key Wairau flood protection scheme is considered to have performed well and consequently saved an enormous amount of associated flood damage across the lower Wairau plains (Figure 2). There were three stopbank failures and a number of sections of stopbank overtopping, causing flooding above the floor level of a small number of houses as well as restricting road access.

Of the three key stopbank failures, preliminary assessment suggests two were due to a combination of overtopping and poor to variable stopbank quality, and one due to piping under the bank via an underlying fine sand layer. As expected on a large, powerful fast flowing river like the Wairau there are now numerous areas suffering erosion, bank slumping, and silting of some drainage outlets.

On the positive side, modern upgraded stopbanks stood up very well, withstanding significant overtopping in places. Also, the highway and railway bridges are the only links connecting the South Island to the North Island via the interisland ferry, and both appear to be undamaged (Figure 3).

Figure 2 | Flood peak against a key stopbank (dyke) with emergency work to limit overtopping.

Figure 3 | Key transport links survived peak flows.

Flood prediction modelling

Considerable effort has been put into numerical modelling of Wairau floods, so that forecasting and flood protection design can be improved. Current forecasting models have been fairly successful for prediction of medium floods, but they underpredicted this flood size. Part of the problem was the unusually low proportion of precipitation south of the river, and part was the lack of calibration data at the high stages encountered during this flood. The rating curves then required significant extrapolation, and confidence in the results was correspondingly lower.

Gauging techniques

As well as traditional mechanical current meters, the Marlborough District Council has progressively been introducing Acoustic Doppler Current Profilers (ADCP) since 2007. Figure 4 shows an example of gauging using an ADCP unit installed on a small boat, which may be either remotely controlled or tethered to a structure such as a bridge. The use of ADCPs greatly speeds up the sampling of current velocities over an entire cross-section.

Space Time Image Velocity (STIV) gauging was then purchased, and was tried during the July flood, sometimes with simultaneous ADCP as a control. The equipment can be used from a fixed site on the river bank, or from a drone or helicopter, to track current velocity by recognizing and following visual features on the surface.

For discharge measurements, the STIV method requires correction from surface velocity to depth averaged velocity, but there are promising signs that a systematic correction will be developed from the analysis of large quantities of ADCP profiles.

Figure 5 shows the STIV surface velocities (blue line markers) measured across the standard cross-section at "Barnetts Bank", some 500 m upstream (to the right) of the bridges shown in Figure 3. These velocities are compared with depth averaged velocities obtained by modelling. 2D modelling provides depth averaged velocities by dividing specific discharge (m^3/s per m) by depth, after which the chosen correction factor is applied to recognise that surface velocities are expected to be greater than depth averaged velocities. In this case a good fit (brown line) was obtained by dividing by 0.95 the model depth averaged velocities corresponding with a total discharge of 5,280 m^3/s.

Summary

The current Wairau peak flow assessment of the July 2021 flood is 5,280 m^3/s. The uncertainties involved in making high flow assessments must be recognized, and further work will be done which may refine this figure further. The design flood for the Wairau River is 5,500 m^3/s. This near-design peak flow tested existing flood protections to their limit.

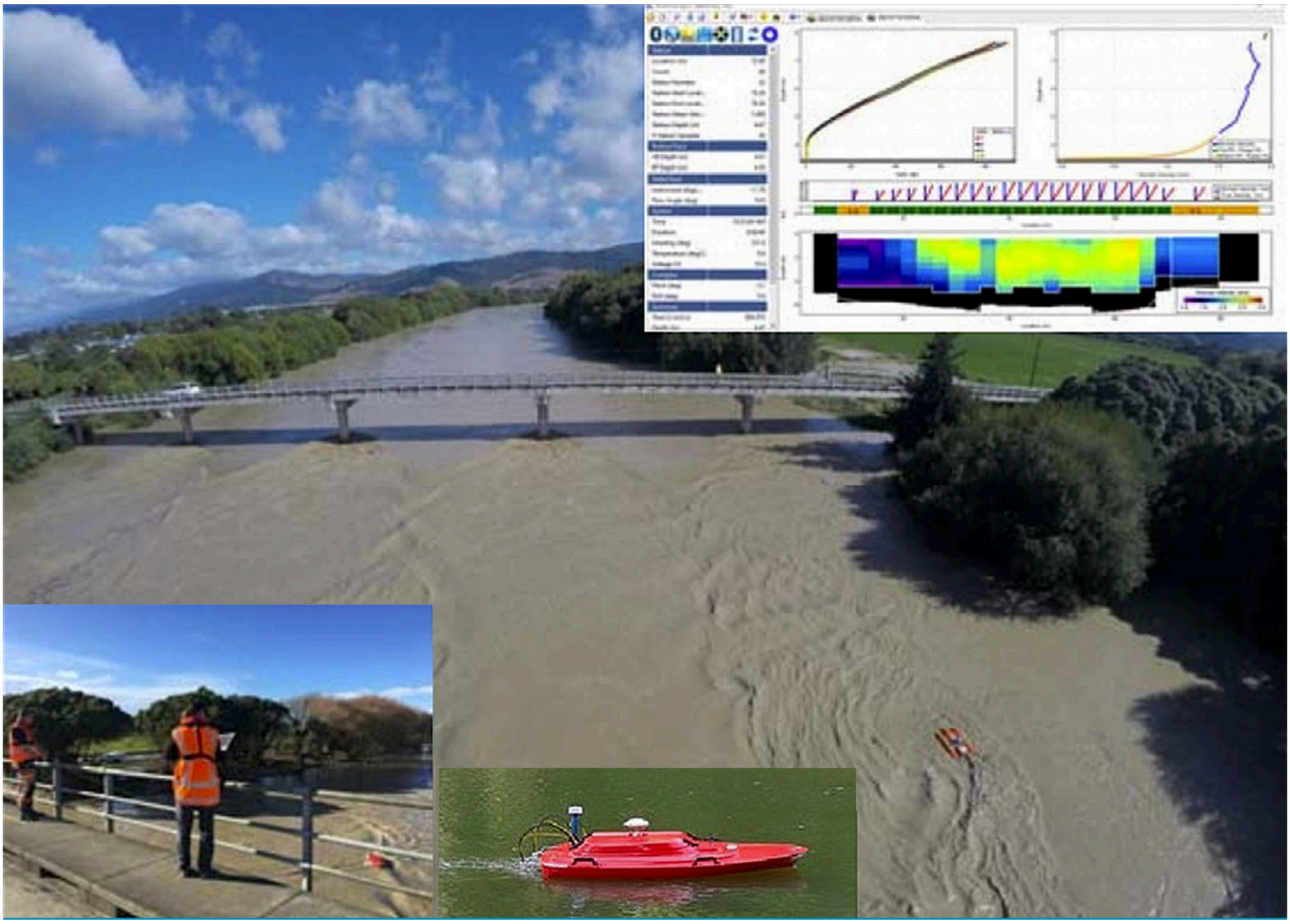


Figure 4 | ADCP gauging a major flood using a remote-controlled boat.

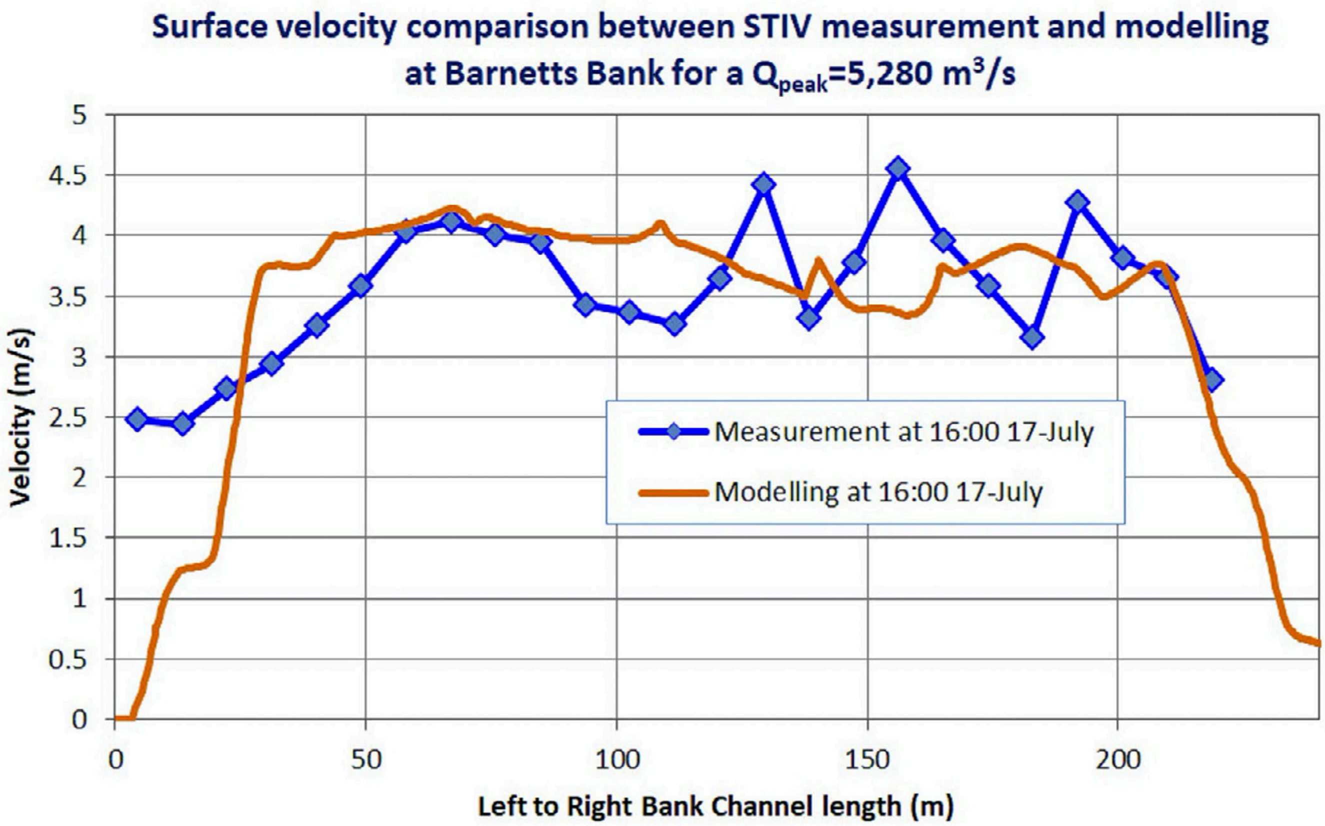


Figure 5 | Calibration of STIV velocity using model depth-averaged velocity.

Geoff Dick

Geoff Dick, Rivers & Drainage Engineering Manager, Marlborough District Council.

Mike Ede

Mike Ede leads the environmental monitoring team at the Marlborough District Council with thirty seven years of field hydrology experience principally in the Wellington and Marlborough regions and holds a New Zealand Diploma in Field Hydrology. He chairs the National Environmental Monitoring Standards Steering group who are responsible for the development of hydrology monitoring standards for New Zealand. Mike is also an executive member of the New Zealand Hydrological Society where he has led the establishment of annual technical workshops for the industry over the last ten years.

Duc Nguyen

Duc Nguyen is a rivers investigation engineer at the Marlborough District Council. Duc has been working in fields of river engineering and water resources management over the past nineteen years. He has participated in a number of water resources projects in Laos, Thailand, Vietnam, Japan, Netherlands, United State, and New Zealand taking responsibilities for the design of flood protection measures, river and stormwater modelling, estuarine sediment and salinity assessment, flood risk mapping and climate change projections.

Val Wadsworth

Val Wadsworth has been involved with Marlborough rivers for forty-seven years in engineering and hydrological roles. He is the Marlborough District Council's environmental scientist (Hydrology) responsible for analysis and dissemination of hydrological data.