Gisborne District Council

Bridge Replacement Project

Pauariki Bridge– Hikuwai Road

Hydrology & Hydraulics Report

16 November 2023

Aquaviser Ltd
WATER RESOURCE ADVISERS

ENGINEERING
FOR TOMORROW

Report prepared for Roadlab Limited by Aquaviser Limited in conjunction with McCaffrey and Cable Limited.

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Introduction

Several bridges were washed away during Cyclone Gabrielle in February 2023 and there needs to be rapid replacement of these bridges. Gisborne District Council (GDC) have engaged McConnell Dowell to develop and price concept and preliminary designs. McConnell Dowell have engaged RoadLab to provide the design services. RoadLab have engaged specialist sub-consultants Gaia Engineers for geotechnical design and Aquaviser for hydraulic design.

This report is Aquaviser's contribution and outlines the approach to and results of the hydrologic and hydraulic assessment at Pauariki Bridge on Hikuwai Road. The bridge was destroyed in Cyclone Gabrielle in February 2023. The bridge is one of eight bridges that are part of the GDC Bridge Replacement Project.

Project Scope

The broad scope for the hydrologic and hydraulic work package is to undertake hydraulic modelling with specific reference to Waka Kotahi Bridge Manual SP/M/022 to estimate flood levels and flood velocities for various return period flood events.

Design Philosophy

Approaches to estimating the design flood event are outlined in the Bridge Manual *(Waka Kotahi, effective from May 2022).*

Flow estimates could be determined from recorded flow at the bridge site if there is a recorder station, scaled flow where the bridge is in the same catchment as the recorded flow, using available hydrologic catchment rainfall – runoff models, or recognized acceptable formula or model-based methodologies.

For all the bridge sites under consideration virtually all are in catchments with recorded flows and /or NIWA has estimated flood flows in their online flood tool (NIWA, 2018). The Pauariki Bridge is across the Hikuwai River. There are flow recorder stations some distance downstream of the Pauariki Bridge at the No 4 Bridge and at Willow Flat.

Where variables such as mobile riverbeds or high sediment loads may have impacted the accuracy of river flow measurement additional methodologies to estimate or scale flows will be considered.

The design flood frequencies will be determined by recognised probability analysis methods as noted in the Bridge Manual. The frequencies will be 1/100 AEP, 1/500 AEP, and 1/1000 AEP events. Where a flow record that includes 2023 is available any flood frequency analysis will include 2023 cyclone flood peak flow despite the year not being complete at the time of preparation for this report.

Assessment of design flood water levels will be undertaken with a hydraulic model. A 1D steady state model is proposed as floods appear to be mostly constrained within any incised channel or a defined floodplain. Changes in flow patterns will be considered if the modelling shows significant out of channel flow.

Climate change will be allowed for as outlined in the Bridge Manual and/or more recent advice – RCP 6.0 and RCP 8.5 scenarios will be considered.

Methodology

Hydrology

The Pauariki bridge site is located on the Hikuwai River as shown in Figure 1.

The Hikuwai River rises as the Waiau River at an altitude of 675m. The Waiau River drains northeast to join the Mangaraku Stream becoming the Hikuwai River before turning south just upstream of the Pauariki Bridge. The Pauariki Bridge site is at an altitude of approximately 40m with a catchment area of 181.9km^2.

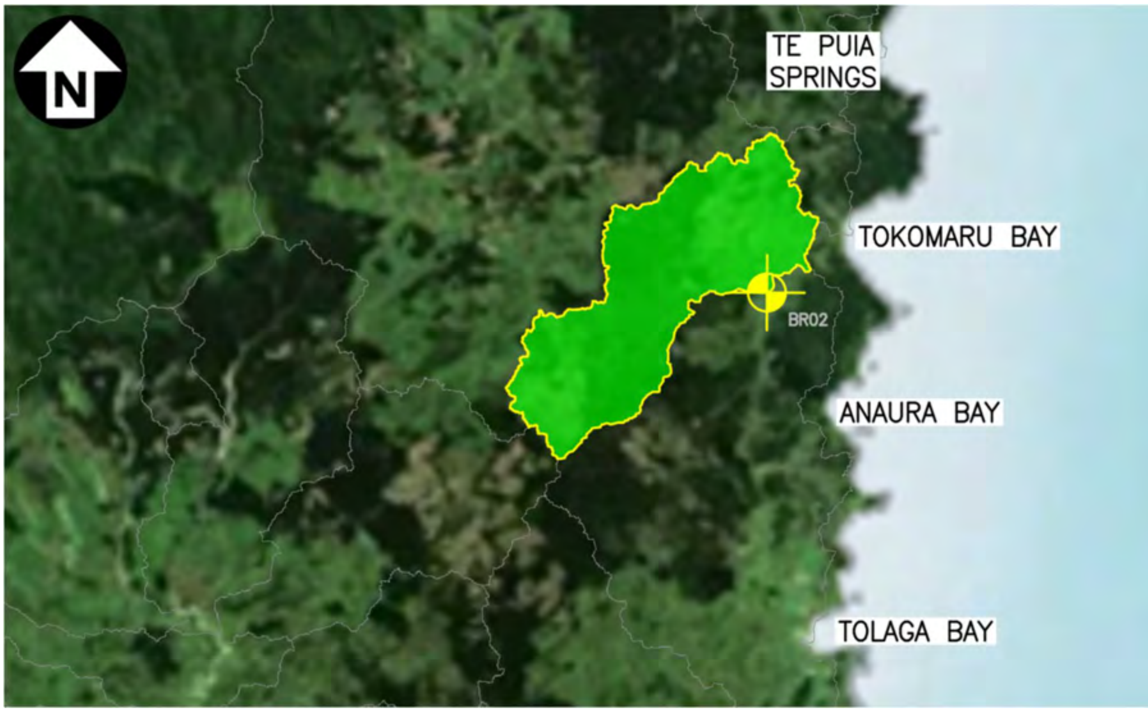


Figure 1 Hikuwai Catchment and Pauariki Bridge Location

Flow Estimation

The Bridge Manual (2022) outlines flow estimation methods that are acceptable.

- from recorded flow at a bridge site,
- scaled flow where a bridge is in the same catchment as the recorded flow,
- using available hydrologic catchment rainfall – runoff models, or
- recognized acceptable formula or model-based methodologies, such as the rationale formula or regionalisation methodologies.

There is no flow recorder at the Pauariki Bridge. There is a recorder site downstream at Willow Flat. The catchment area at Hikuwai River at Willow Flat is 307km^2.

Uncertainty in flow estimates

Within Gisborne District there is a network of river recorder stations. Most of these were used in NIWA's online "New Zealand River Flood Statistics" *NIWA (2016 & 2018).* The flow frequency estimates for several of these has been downloaded and converted to specific discharge for comparison of unit runoff from a range of catchments. The results are tabulated in Table 1. As an example, the results for 1/100 AEP event have specific discharges ranging from 2.0m^3/km^2/s to 9.9m^3/km^2/s. This is approximately a 500% difference in peak flow across the Gisborne District for the same unit area of catchment. While some variability would be expected the magnitude of the range creates uncertainty when estimating flow in ungauged catchments. The Hikuwai River at Willow Flat has some of the highest specific discharges in the district.

Table 1 Gisborne District Flow Station Specific Discharges (m^3/km^2/s)

	1/5 AEP	1/10 AEP	1/20 AEP	1/50 AEP	1/100 AEP	1/250 AEP	1/500 AEP	1/1000 AEP
Ruakituri at Sports Ground	1.1	1.3	1.5	1.8	2.0	2.2	2.4	2.6
Hangaroa at Doneraille Park	1.1	1.3	1.5	1.8	2.0	2.3	2.5	2.7
Wharekopae at Rangimoe Station	2.3	3.1	3.9	4.8	5.5	6.5	7.2	7.9
Waihuka at No 3 Br	4.4	5.7	6.9	8.5	9.7	11.3	12.5	13.7
Waikohu at No 1 Br	1.6	1.9	2.2	2.7	3.0	3.4	3.7	4.1
Waikohu at Mahaki	4.0	5.4	6.8	8.6	9.9	11.6	13.0	14.3
Mangatu at Omapere	2.8	3.5	4.3	5.3	6.0	7.0	7.7	8.4
Waingaromia at Terrace Station	3.4	4.4	5.5	6.8	7.8	9.1	10.1	11.1
Waihora at No 3 Br	3.1	4.1	5.0	6.1	7.0	8.1	9.0	9.8
Waimata at Monowai	2.0	2.3	2.6	3.1	3.4	3.8	4.1	4.4
Mangaheia at Willowbank	2.9	3.5	4.0	4.7	5.3	6.0	7.4	8.1
Hikuwai at Willow Flat	4.8	6.0	7.2	8.7	9.8	11.3	12.4	13.5

Flood Frequency Analysis

The flood frequency analysis for the Hikuwai River at Willow Flat is based on the 49 years (1975 – 2023) of annual maximum flow data with the fit of statistical distributions tested to determine best fit for estimating long term flows of specific AEPs. The distributions tested a were EV1, Log Pearson2, and Log Pearson 3.

NIWA's online "New Zealand River Flood Statistics" also provides flood frequency estimates for rivers throughout the country. This tool is also used to provide flood estimates, and it is based on data up to 2018 for the Waipaoa Catchment and its tributaries. *NIWA (2016 & 2018).* The tool is a revision of the regional flood frequency method by NIWA in the 1980s *(Beable M E and McKerchar A I (1982) and (McKerchar A I and Pearson C P (1989).*

Climate Change Factors

The Bridge Manual outlines a requirement that climate change impacts be considered in design. Climate change scenarios to be considered are RCP6.0 and RCP8.5. For this assessment the source of the factors applied to existing flow estimates is *Ministry for the Environment (2018).*

Tables 7 and 13 of that report (MfE,2018) are the source of the base information. Table 7 provides the projected temperature change up to 2120. Table 13 provides the percentage change factor per degree temperature rise for storm durations from 1 hour to 120 hours. This is defined for storm annual exceedance probability events from 1/2 to 1/100. For this assessment the average annual predicted temperature change has been adopted along with a storm duration of 6 hours. In table 7 there is no predicted increase for RCP6.0. This has been estimated by interpolating from a trendline established for the three other climate change scenarios. The estimated temperature increases by 2120 is shown in Table 2.

Table 2 Forecast temperature increase by 2120.

Climate Scenario	Forecast Temperature Increase
RCP 2.6	0.7
RCP 4.5	1.7
RCP 6.0	2.8
RCP 8.5	3.8

In table 13 *(Ministry for the Environment, 2018)* the percentage change factors by storm duration and average recurrence interval (ARI) are only provided up to the 1/100 AEP event. A trendline has been fitted to the data and extended to provide factors for the 1/500 AEP event and 1/1000 AEP event.

The Increase per degree rise in temperature and the resultant factors for RCP 6.0 and RCP 8.5 are provided in Table 3.

Table 3 Flow adjustment factors for RCP 6.0 and RCP 8.5

AEP	Percentage flow increase per 1 degree	Percentage Flow adjustment factor RCP 6.0	Percentage Flow adjustment factor RCP 8.5
1/10	10.8	30.2	41.0
1/20	11.1	31.1	42.2
1/50	11.3	31.6	42.9
1/100	11.5	32.2	43.7
1/500	12.2	34.2	46.4
1/1000	12.5	35.0	47.5

Hydraulics

The method of determining flood water levels is to apply the hydrologic estimates to a hydraulic model and route the flows through the defined reach upstream and downstream of the bridge site. Model runs undertaken are for the natural waterway without any constrictions.

Modelling

The *US Army Corp of Engineers* HECRAS modelling package version 6.4.1 has been used to model flows in the 1D option for a mixed flow regime with reference to *(Austroads, 2019).*

Model Build

The process applied to building the base model has been as follows.

- Existing ground surface data was obtained covering the site extent (i.e., ~1km upstream and downstream of the bridge site). The following is a list of the key data sets utilised for the Pauariki site.
    - Gisborne LiDAR 1m DEM 2018-2020 (sourced from LINZ data service)
    - Drone survey dated April 2023 (obtained by Civil Assist & translated by McDowell Dowell)
- *NB: all survey information noted above is in New Zealand Transverse Mercator 2000 projection and in reference to the New Zealand Vertical Datum 2016*

- The use of Lidar means that where water bodies occur the ground surface is taken as the water surface. Detailed channel survey will be required for detailed design.
- A terrain model was generated from the ground surface data using 12d Model software.
- The geometric cross sections were extracted from the surface data at intervals (~50m separation) upstream and downstream of the bridge site.
- The cross sections were imported into HECRAS and reviewed to identify/correct any data gaps or anomalies (i.e. trees or irregular landform as assessed from aerial photos). Data points within cross sections were also reduced (or smoothed) for modelling purposes without impacting the assessed landform. Examples of the extent of editing are in Appendix 2 - Figure 12 Example of cross section editing. Figure 12 and Figure 13.
- Roughness markers set within HECRAS model from aerial photography and oblique site visit photographs.
- The streamline was generated by the centre of the outer most banks and there is a potential for the centreline to pass through riffles and islands.
- The following diagrams show the data sets obtained and generated during the building process:

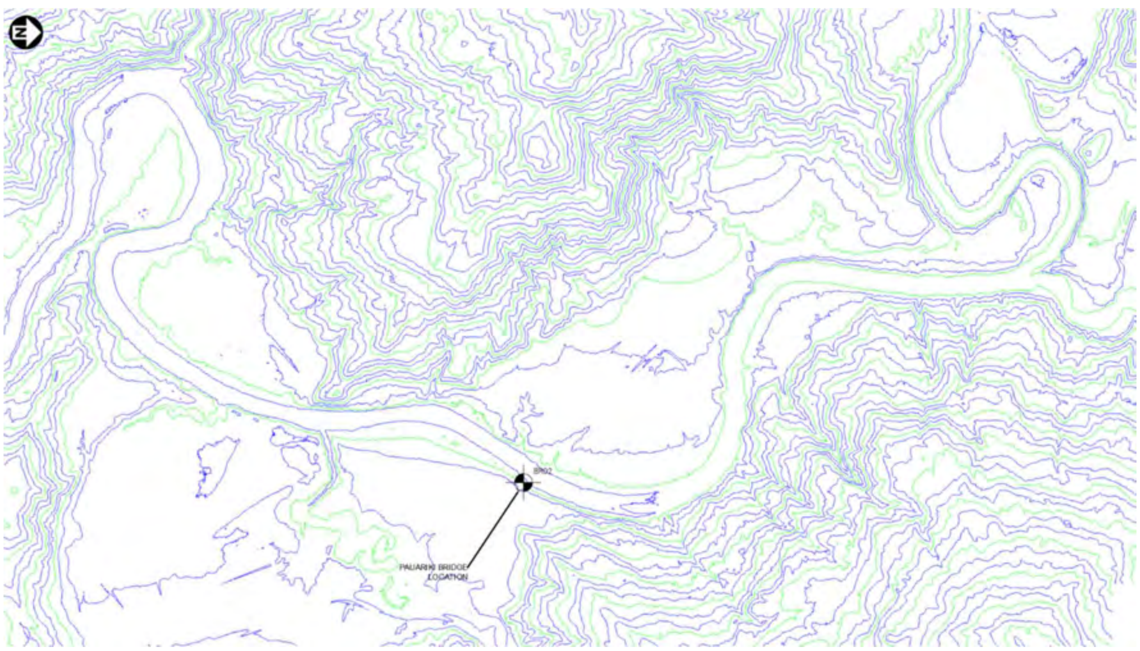


Figure 2 Existing ground surface data

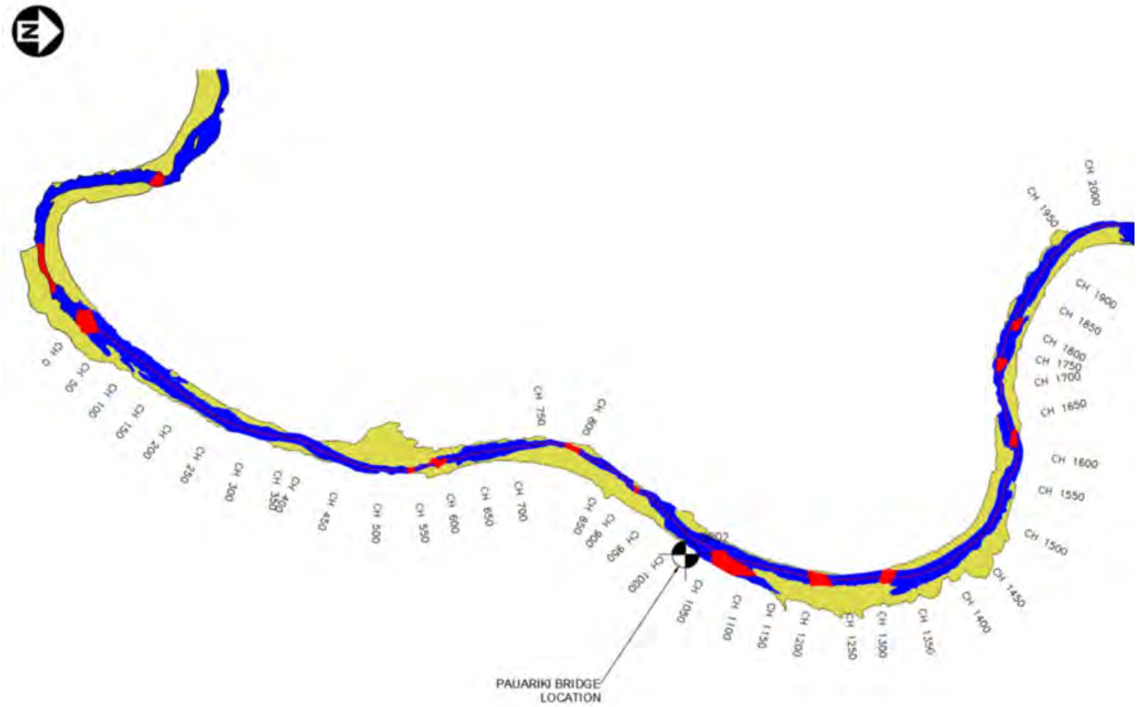


Figure 3 Site Overview

Figure 4 Model overview and cross sections

Data

Hydrology

GDC is the authority that operates the water level recorder and flow monitoring station at the Hikuwai River at Willow Flat site. GDC have supplied the record to Aquaviser Ltd for the purposes of supporting the technical assessment for the bridge replacement in the upstream catchment. The data has been provided with disclaimers and assumptions in the site record relating to quality assurance. GDC advised *higher flow gaugings after 2015 are with an ADCP meter. The ADCP meter does not work in extreme flood events when the river contains high levels of sediment. GDC is moving towards using hand-held radars (and surveyed cross-sections) & drones (Space-Time Image Velocimetry).*

The river flow record spans 1975 to 2023, with maximum flow data provided for that period. The recording device at present is radar with a pressure transducer backup. The catchment area at the river station is 306.56km^2. The high suspended sediment load during flood events may impact the flow measurement accuracy.

Other data used in this assessment come from NIWA's online "New Zealand River Flood Statistics" flood frequency estimates for rivers throughout the country.

Figure 5 Water Level Sensor Location- Hikuwai River at Willow Flat

Photo Courtesy of GDC.

Appendix 1 contains the annual maxima flood series and the flood frequency analysis summary output.

Results

Hydrology

The flow record from Hikuwai River at Willow Flat as provided by GDC has been used to estimate flood frequency approach outlined in the Methodology section. Flows were scaled to the Pauariki Bridge and the results have been compared with estimates at the gauging station and at Pauariki Bridge from the NIWA online Flood Statistics of New Zealand. The online tool flow estimates at Pauariki Bridge have been adopted.

It is understood that NIWA are currently undertaking revision of the flood frequency analysis for the Hawkes Bay and Gisborne regions. This update is anticipated in October 2023. The current NIWA work may lead to changes in the estimates derived during July/August 2023 for this report. Any changes may result in a need to change aspects of bridge design.

The flood extent during the cyclone is largely contained within the river channel or the low terrace on the left bank as shown by the silt deposit and debris in Figure 6.

Figure 6 Flood extent immediately downstream of Hikuwai River at Pauariki Bridge.

The adopted flood estimates are based on the NIWA flood tool flow estimates at Pauariki Bridge rather than scaled flow estimates from the Hikuwai River at Willow Flat site. Because of GDC comments on sediment loads, the rating extrapolation, along with the high specific discharge of the NIWA estimates the flood frequency flow estimates were not used but may need to be considered further at future design stages. The flood modelled extents align with the photography of silt and debris deposition during the February 2023 event which provides confidence that the estimates used may be the most appropriate. The estimated flood flows at the Pauariki Bridge are provided in Table 4 along with the flood estimates under the RCP 6.0 and RCP 8.5 climate change scenarios.

Table 4 Flood flow estimates for Pauariki Bridge

AEP	Existing Climate	RCP 6.0 (m^3/s)	RCP 8.5 (m^3/s)
1/100	1057.3	1397.7	1519.3
1/500	1305.9	1752.5	1911.8
1/1000	1411.0	1904.8	2081.2

Hydraulics

The previous Methodology and Data sections outline the approach to the hydraulic modelling. This section provides the results of that modelling.

The water levels and mean velocity for the channel at the Pauariki bridge are given in Table 5 and Table 6.   Maximum water depth is provided in Table 7. The range in flood extents between the 1/100 AEP event existing climate flood and the 1/1000 AEP RCP 8.5 event is shown in Figure 7.

Table 5 Modelled water levels for design floods (mRL)

AEP	Existing Climate	RCP 6.0	RCP 8.5
1/100	46.82	48.03	48.42
1/500	47.73	49.17	49.69
1/1000	48.08	49.67	50.18

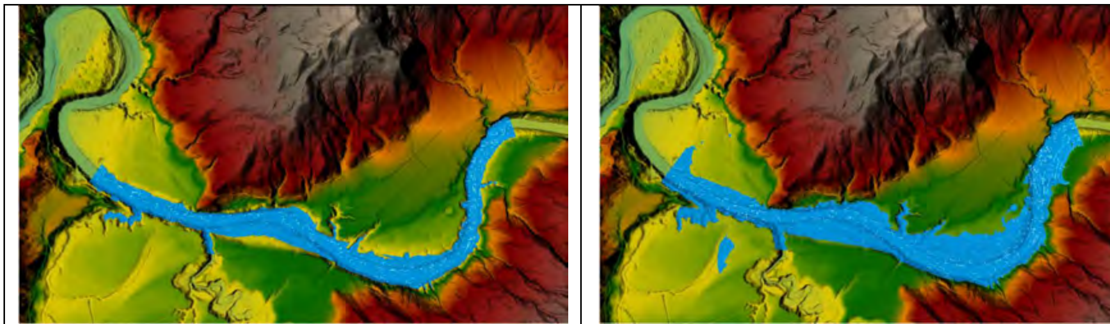
Table 6 Modelled mean velocity for design floods (m/s)

AEP	Existing Climate	RCP 6.0	RCP 8.5
1/100	2.92	3.27	3.41
1/500	3.16	3.63	3.72
1/1000	3.28	3.71	3.81

Table 7 Modelled water depth(m)

AEP	Existing Climate	RCP 6.0	RCP 8.5
1/100	8.56	9.77	10.16
1/500	9.47	10.91	11.43
1/1000	9.82	11.41	11.92

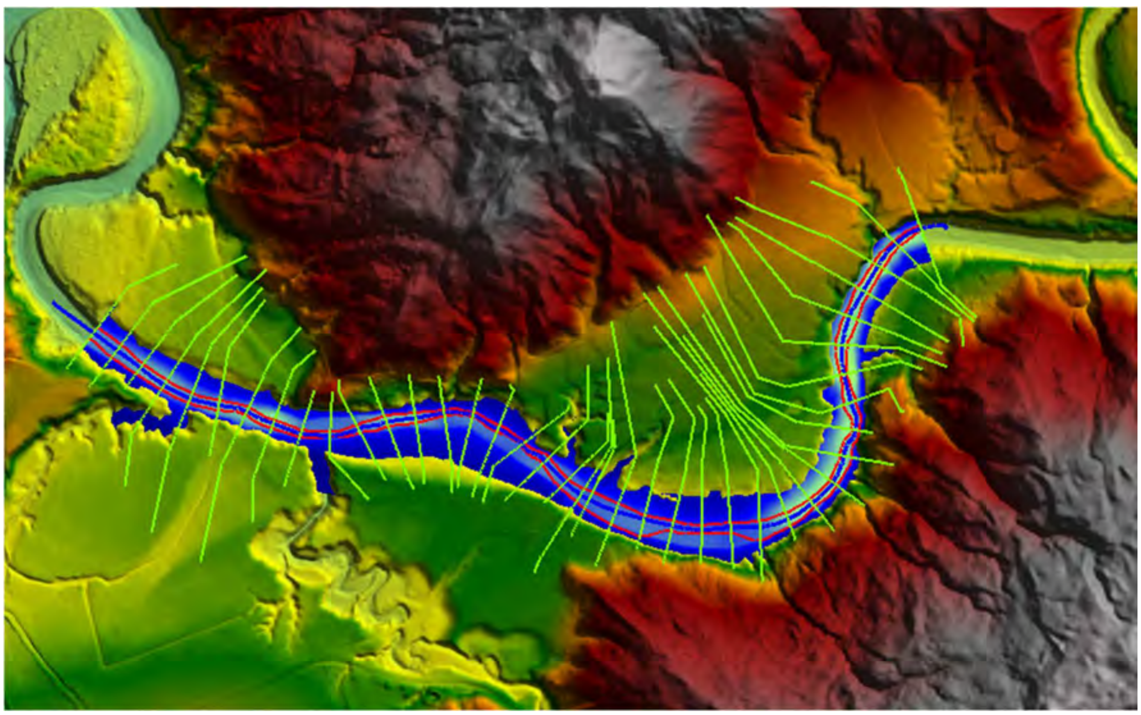
Figure 7 Comparison of flood extents



1/100 AEP Event - Existing Climate	*1/1000 AEP Event - RCP 8.5*

The distribution of velocity along the channel is shown in Figure 8 by the changes in the density of the green and yellow shading in the channel. The blue is the flood extent. The lines are model cross section locations.

Figure 8 Velocity distribution along the channel



Summary & Recommendations

Flood Levels

Flood levels to be used at this time for concept design are in Table 8 .

Table 8 Design flood levels (mRL)

AEP	Existing Climate	RCP 6.0	RCP 8.5
1/100	46.82	48.03	48.42
1/500	47.73	49.17	49.69
1/1000	48.08	49.67	50.18

Velocity

Mean channel velocities to be used in concept design are in Table 9.

Table 9 Channel mean velocity (m/s)

AEP	Existing Climate	RCP 6.0	RCP 8.5
1/100	2.92	3.27	3.41
1/500	3.16	3.63	3.72
1/1000	3.28	3.71	3.81

Recommendation

For preliminary and final design, it is recommended,

- The hydraulic model be updated with in channel survey to define below water level channel shape, and that a 2D model be considered,
- Consideration be given to reviewing the hydrology estimates once the NIWA review is completed for GDC, and that a catchment rainfall – runoff model be developed as an additional flood flow estimation method, and
- Flood modelling is updated accounting for the constriction effect of the new bridge, new embankments and potential debris rafts attached to the piers.

Assumptions & Limitations

The hydrologic data used in this assessment has been supplied by GDC. The data has been monitored and collated by GDC in accordance with accepted management of hydrometric data in New Zealand.

One of the methods for flood estimation that has been used is NIWA online Flood Statistics of New Zealand. It is understood that NIWA is currently updating the flood estimates for the Region. Given that regional flood estimation is being updated this design should be considered incomplete as it is based on incomplete information that will be updated in October. These flood estimates shall not be used for detailed design until the NIWA updates are available and reviewed/updated for Pauariki Bridge.

The hydraulic model cross section data has been derived from LINZ Lidar database and processed using 12D. Obvious spikes in the base data have been edited to remove influence of trees. For concept design no river channel surveys have been undertaken. The Lidar surface will be limited where water bodies exist. It may lead to modelled water levels changing significantly over a short distance because of this assumption whereas with a full channel survey the change may not be as significant.

The hydraulic model has been operated as an open watercourse without bridges or culverts. Preliminary design will need to include the preferred bridge option and may result in elevation of the modelled water surface.

In preparing this report the authors have used the best currently available data and have exercised all reasonable skill and care in presenting and interpreting these data. Nevertheless, Aquaviser Ltd does not accept any liability, whether direct, indirect, or consequential, arising out of the provision of the data and associated information within this report.

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Ministry for the Environment 2018. Climate Change Projections for New Zealand: Atmosphere Projections Based on Simulations from the IPCC Fifth Assessment, 2nd Edition. Wellington: Ministry for the Environment.

NIWA, 2016 Regional Flood Estimation Tool for New Zealand Part 1

NIWA, 2018 Regional Flood Estimation Tool for New Zealand Part 2.

US Army Corp of Engineers HECRAS modelling package version 6.4.1

Waka Kotahi, Bridge Manual (Bridge Manual SP/M/022, 3rd Edition, Amendment 4, effective from May 2022).

Appendix 1 – Hydrology

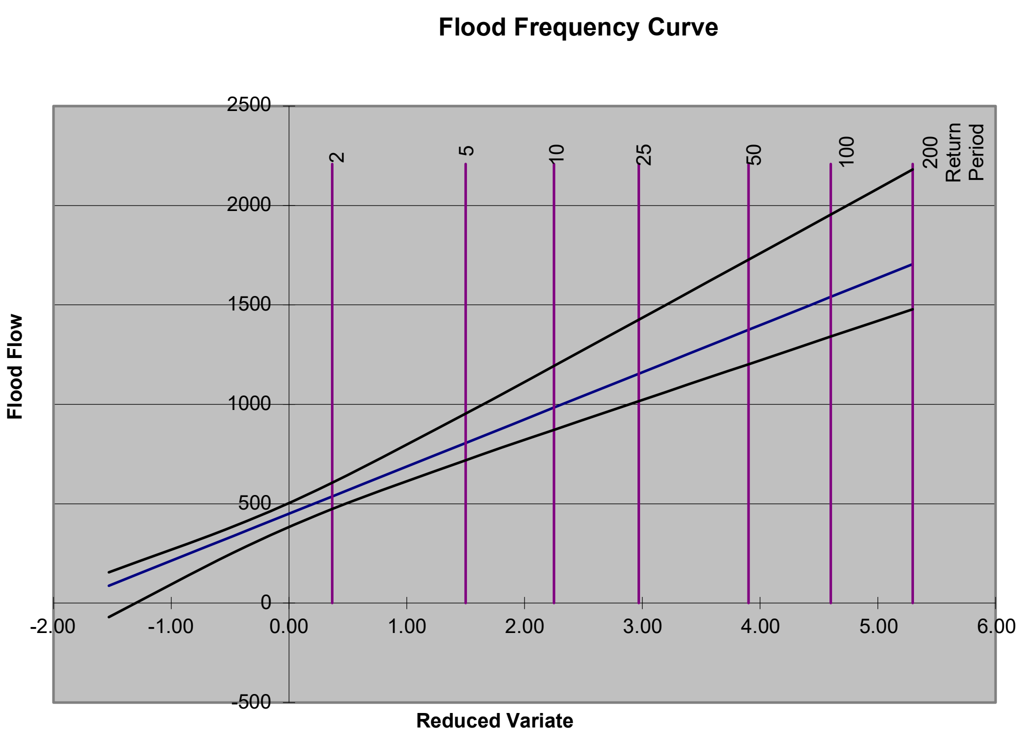
Table 10 Annual maximum flood peaks – Hikuwai River at Willow Flat

Flood Frequency Analysis		
Year	**Flow Peak (m^3/s)**	**Rank**
1988	1688.282	1
2023	1397.691	2
2022	1023.999	3
1980	931.214	4
2013	924.039	5
1982	921.978	6
2020	868.875	7
1978	866.913	8
1976	842.11	9
1984	827.43	10
1995	819.559	11
2018	753.341	12
2009	737.477	13
2011	707.387	14
2004	692.319	15
1977	659.421	16
1994	641.808	17
1996	624.788	18
2010	621.773	19
2012	593.665	20
1987	586.439	21
2003	574.878	22
2005	566.67	23
2014	566.502	24
1993	565.68	25
1989	555.003	26
1981	545.227	27
1975	532.475	28
2002	509.763	29
2008	498.096	30
2017	474.356	31
2001	460.052	32
1985	450.737	33
2021	428.181	34
1997	422.369	35
1979	406.257	36
1990	394.474	37
2006	375.598	38
2019	346.25	39
1992	321.141	40
2015	312.659	41
1999	306.929	42
1998	299.84	43
2016	298.103	44
1983	241.297	45
2000	168.695	46
1986	157.405	47
1991	130.491	48
2007	97.953	49

Table 11 Flood frequency analysis results

	Hikuwai River @ Willow Flat		Hikuwai River @ Pauariki Br
AEP	**EV (m^3/s)**	**NIWA Online Tool (m^3/s)**	**Adopted Flow (m^3/s)**
1/100	1540	3009	1057
1/500	1923	3803	1305
1/1000	2087	4144	1411

Figure 9 Flood Frequency



Appendix 2 – Hydraulics

The following diagrams show the long section of the modelled reach and the cross section at the old Huiarua bridge site. The water levels are for the 1/100 AEP event under existing climate and the 1/1000 AEP event under RCP 8.5 climate change scenario.

Figure 10 Channel section with flow envelop.

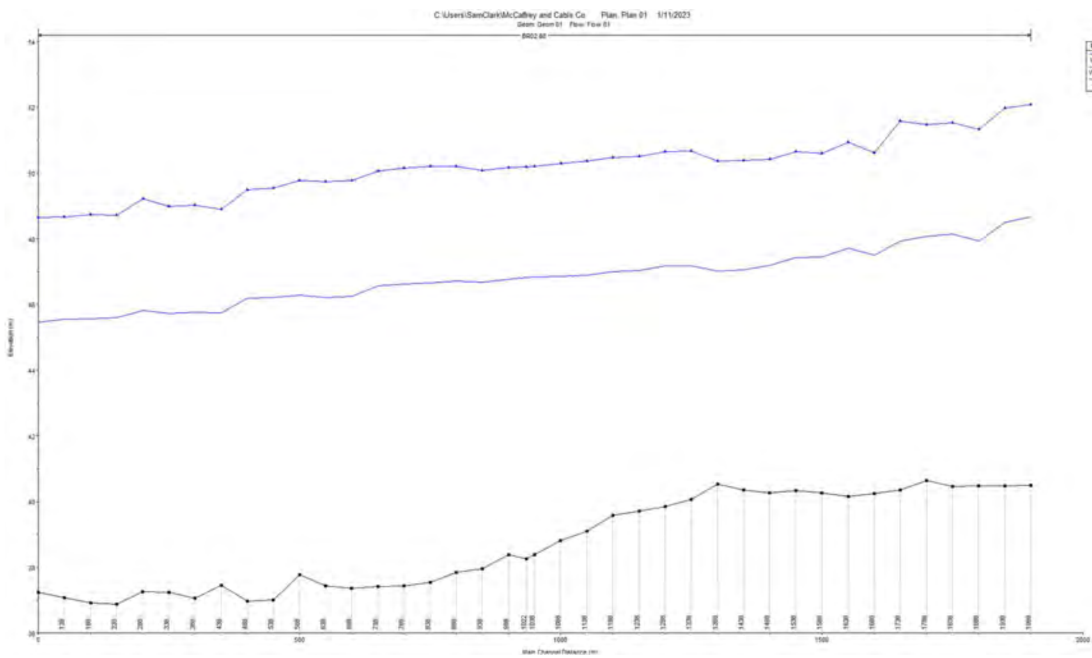


Figure 11 Cross section upstream of bridge with flow and velocity distribution

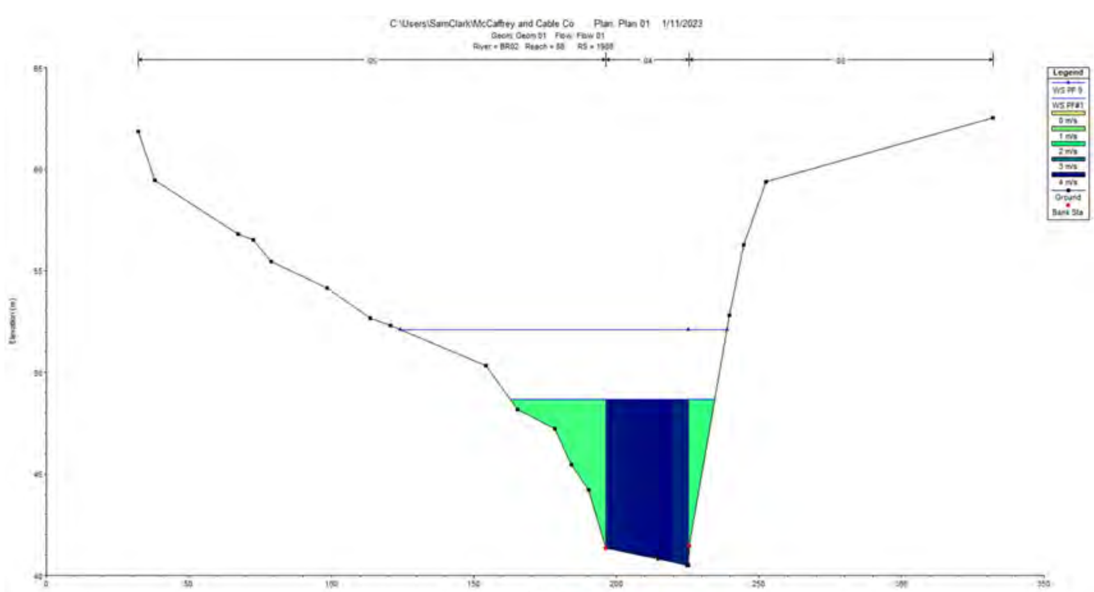


Figure 12 Example of cross section editing.

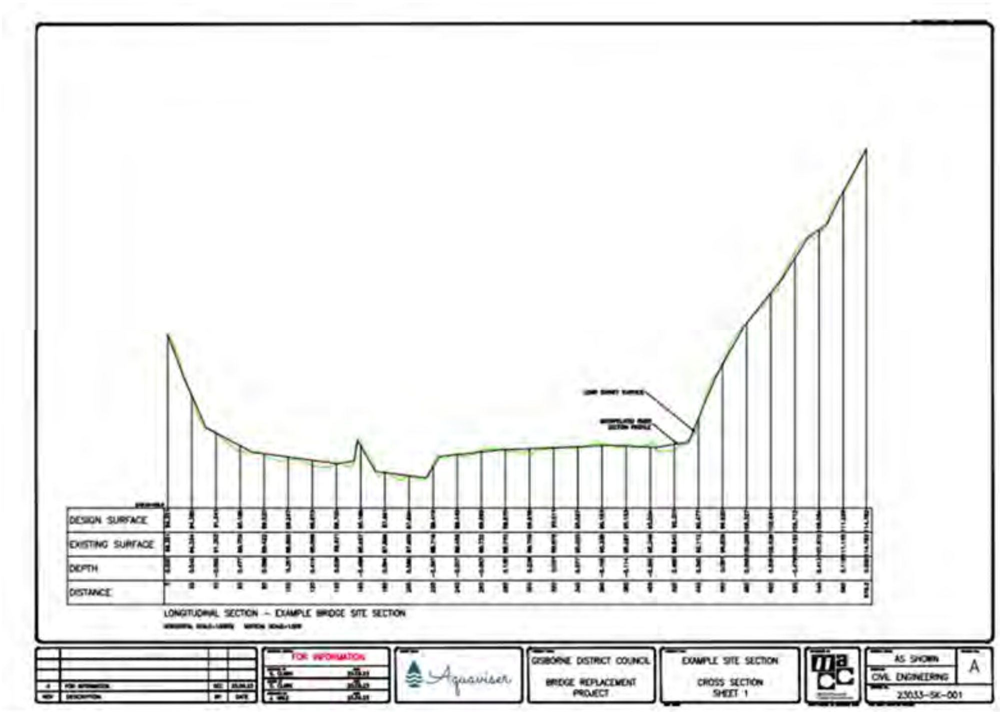


Figure 13 Example of cross section editing.