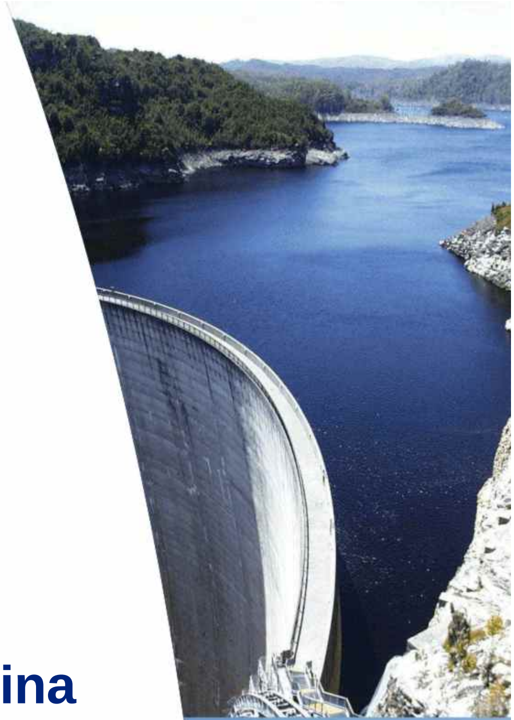
Hydro Tasmania Consulting

Whangaehu and Turakina Rivers - Flood and Hazard Mapping

Study Report



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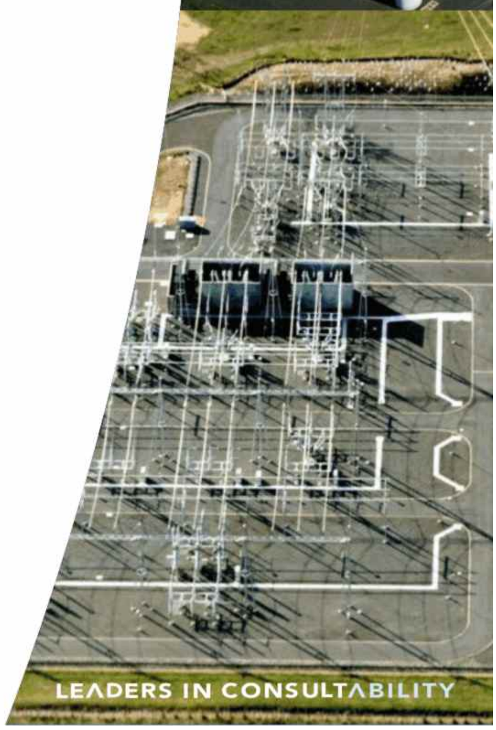

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1. Introduction

Hydro Tasmania Consulting (HTC) was commissioned by Horizons Regional Council (HRC) to develop a single two-dimensional hydraulic model incorporating both the Whangaehu River and Turakina River. The downstream boundary of both of the rivers is the ocean. The upstream ends of the Whangaehu River and Turakina River in the model are approximately 65km and 30km respectively from the ocean.

The scope of the project involved developing a calibrated hydraulic model and then using that model to estimate flood inundation extents, flood depths and flood hazards for the 1 in 100 AEP and 1 in 200 AEP design events.

Subsequently HTC was commissioned by HRC to separate the single MIKE FLOOD model containing the two rivers was into separate models for each river. These separate models were used to run a series of intermediate floods between the breakout flow for the rivers and the 1 in 100 AEP peak discharge for the purpose of obtaining individual result files for each river. It is understood that the results files will be used in the waterRIDE software package to view real-time estimates of flood extents based on output from the flood warning system of the river that was previously developed by HTC.

This report summarises the hydrologic and hydraulic modelling that was carried out for the model calibration and the design and intermediate flood events.

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2. Inflow Derivation

Inflow hydrographs have been derived for input to the hydraulic model for the purposes of model calibration, design flood inundation runs and subsequent intermediate model runs. The hydrographs are based on the measured flow records supplied by HRC at the following sites:

- Whangaehu River at Kuangaroa,
- Whangaehu River at Aranui,
- Mangawhero River at Ore Ore, and
- Turakina River at Oneills Bridge (named SH3 in Figure 2-1 below).

Inflow hydrographs have been produced for four input locations for Whangaehu River and three input locations for Turakina River in the hydraulic model. These locations can be seen in Figure 2-1 below.

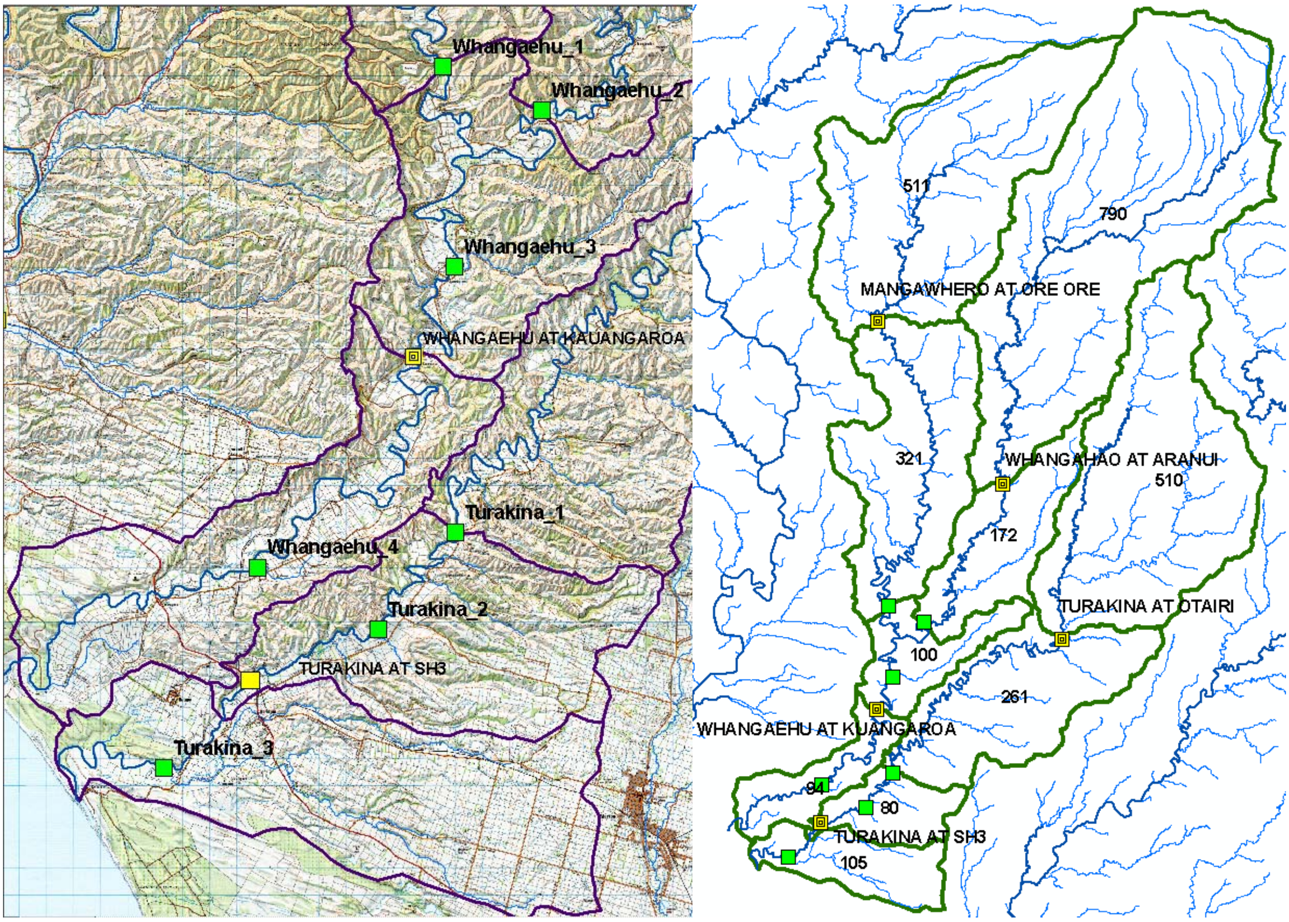

Figure 2-1 Maps of Whangaehu Turakina catchment showing catchment areas of significant sub catchments (Right image) and a close-up showing the inflow locations (Left image)

To derive the inflows, all available measured flow data was considered. In the Whangaehu catchment, upstream flow gauges were used to estimate the inflow upstream of the Whangaehu/Mangawhero river confluence. The Turakina River utilized the flow record at Oneills Bridge (SH3) only. Generally this site data was factored based on catchment area and rainfall in the upper reaches of the Whangaehu catchment to estimate hydrographs for the Turakina River sub-catchments upstream of the SH3.

Timing differences between the origin of the flow data and the model inflow location was accounted for either by:

- Hydrological non-linear channel routing equations (in the upper reaches of the Whangaehu catchment), which also provide some flow attenuation to the flow hydrograph. The flows in these rivers have also been lagged (delayed) by an hour.
- Direct time offsets of the measured flow hydrograph.
- If the inflow location is near the flow site, no time offset has been applied.

Table 2-1 provides details of each inflow location including location, catchment area and method of derivation.

Table 2-1 Inflow location details and method of derivation

Inflow ID	Easting	Northing	Catchment Area (km^2)	Inflow Derived From
Whangaehu_1	2705579	6150366	832	Mangawhero at Ore Ore factored by 1.25, channel routed (Alpha=0.28, n=0.8, Dist=63.3km), lagged by 1 hr
Whangaehu_2	2709195	6148759	962	Whangaehu at Aranui factored by 1.05, channel routed (Alpha=0.35, n=0.8, Dist=35.5km), lagged by 1 hr
Whangaehu_3	2705981	6143034	100	Whangaehu at Kuangaroa factored by 0.042
Whangaehu_4	2698783	6132021	94	Whangaehu at Kuangaroa factored by 0.039
Turakina_1	2706014	6133293	771	Turakina at Oneills Bridge factored by catchment area scaling (771/851). Timing offset so that flood peak arrives 3 hrs earlier than at Oneills Bridge.
Turakina_2	2703202	6129744	80	Turakina at Oneills Bridge factored by catchment area scaling (80/851). Timing offset so that flood peak arrives 1.5 hrs earlier than at Oneills Bridge.
Turakina_3	2695335	6124656	105	Turakina at Oneills Bridge factored by catchment area scaling (105/851). Timing offset so that flood peak arrives 1.5 hrs after Oneills Bridge.

The July 2006 event was selected for calibration as estimates of actual flooding were available for this extent for use in checking the hydraulic model results.

When passing the inflows derived for the July 2006 event through a hydrological routing model, it compared well with the Kuangaroa hydrograph as shown in Figure 2-2.

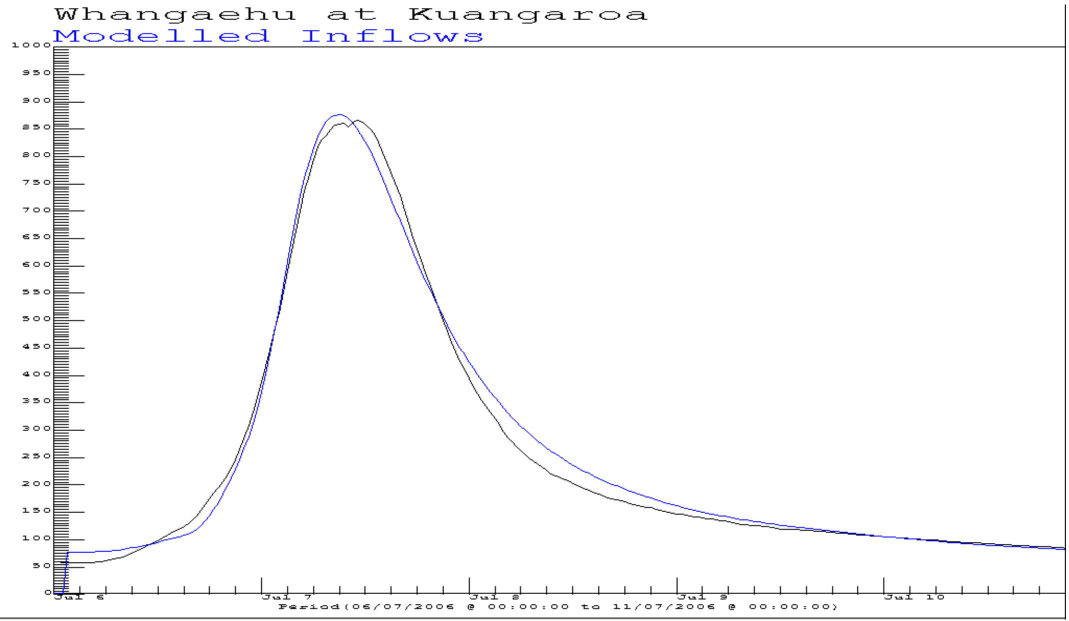

Figure 2-2 July 2006 event check of derived inflows at Kuangaroa

The estimated inflow hydrographs for the July 2006 flood event are provided in Appendix A. Appendix A also contains the design input hydrographs which have been derived by using the shape of this event and scaling so that the peak matches the 1:100 AEP and 1:200 AEP design flood peaks. Refer to Section 5 for further details on the design flood events.

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3. Hydraulic Model Set-up

3.1 Introduction

The hydraulic modelling for this project was carried out using the MIKE FLOOD (version 2008) software package. This software package combines both the MIKE 11 1D and MIKE 21 2D software packages into a single model, where the significant river channels are modelled using MIKE 11 cross sections and out of channel flooding is modelled using the MIKE 21 grid.

3.2 General Setup

The MIKE FLOOD model developed for the Whangaehu and Turakina Rivers extended from the ocean to approximately 65 km upstream in the Whangaehu River and 30 km upstream in the Turakina River. The extent of the MIKE FLOOD model is shown in Figure 3-1 with the model boundary, inflow locations, hydraulic structures and river gauge sites highlighted.

3.3 River Cross Sections

River channel cross sections at middle and downstream reaches of the Whangaehu River were provided by HRC based on detailed survey carried out in January 2009. This survey was commissioned by HRC as part of this project to obtain cross sectional information for the waterways.

Some of the 2009 survey cross sections did not include the river banks. These sections were extended to both sides of the river channel using recent LiDAR survey (also provided by HRC). Figure 3-2 shows a cross section at Chainage 31379 of Whangaehu River where the surveyed section and LiDAR were combined.

The cross sections for the upstream reach of the Whangaehu River and for the full length of the Turakina River were extracted from the recent LiDAR data. The invert levels for some of the cross sections in the Turakina River were unavailable due to presence of water in the river when the LiDAR was flown. At these cross sections the invert levels were estimated by interpolating between cross sections whose invert levels were known.

Cross sections at the mouth of both the Whangaehu and Turakina Rivers were assumed to be deep with the invert level at an elevation of -3m.

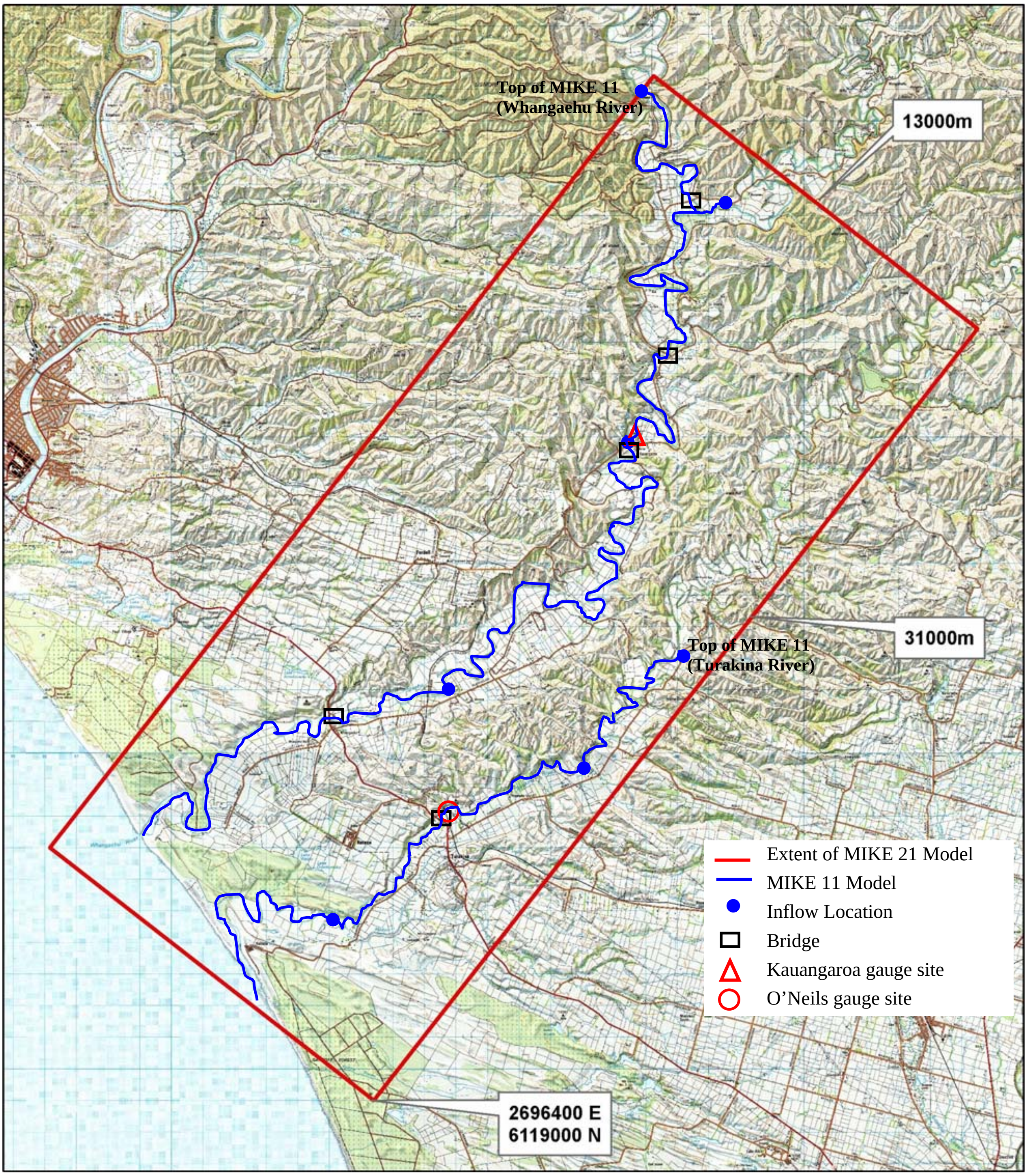

Figure 3-1 MIKE FLOOD Model Extent

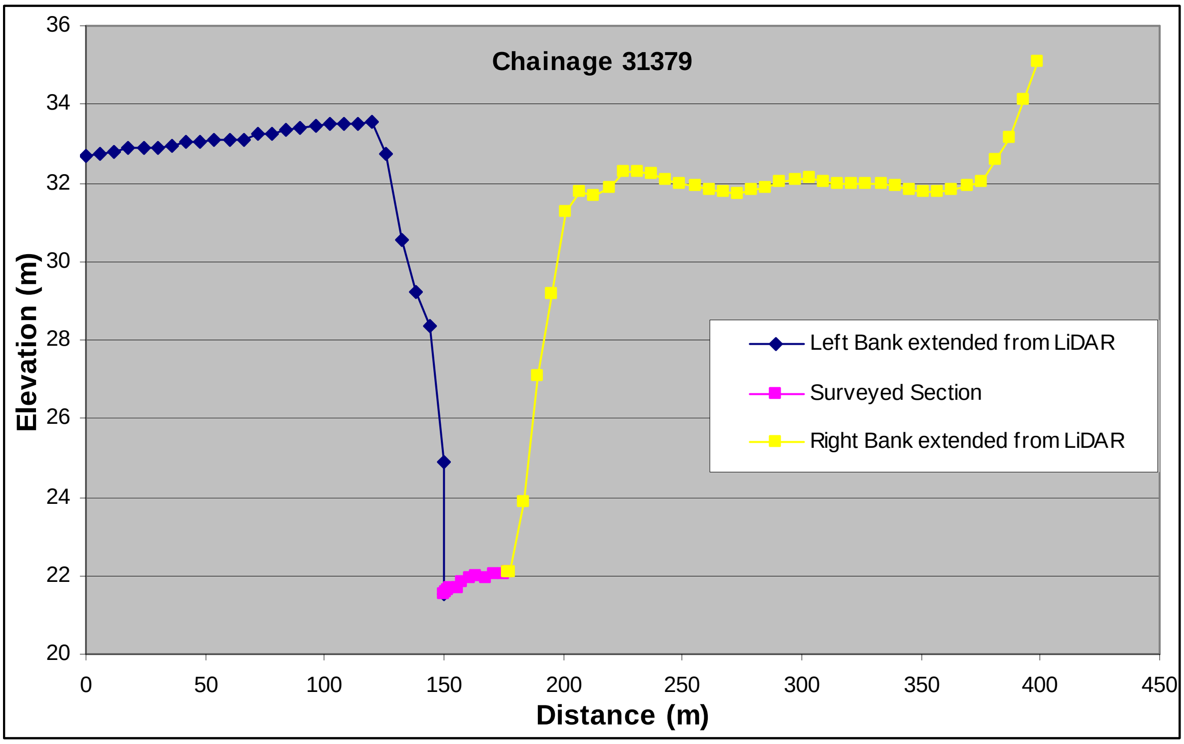

Figure 3-2 Combined Surveyed and LiDAR Cross Section

3.4 Floodplain DEM

A 20 m grid size was used for the MIKE 21 model, using the LiDAR data provided by HRC. This grid size was chosen for the purpose of reducing the run-time of the MIKE FLOOD model. As a reference, the design flood events described below, had a run-time of approximately 48 hours.

The LiDAR data, which had a very high resolution, was resampled to create a digital elevation model (DEM) with a 20 m grid size using ARC GIS software. Relevant features such as levees, roads and creek inverts were identified and given priority to ensure they were included in the re-sampled DEM. This re-sampled grid then formed the bathymetry for the MIKE 21 model.

3.5 Hydraulic Structures

The bridge openings and weirs representing flow at bridges were based on combining the 2009 cross section survey with the LiDAR data. An example of how the data sets were combined at Kauangaroa Bridge is shown in Appendix B.

Table 3-1 and Table 3-2 show the bridges within the model extent and define how they were incorporated into the MIKE FLOOD model.

Table 3-1 Whangaehu River Bridges Included in MIKE 11 Model

Bridge	MIKE 11 Chainage (m)	Comment
Mangamahu Bridge @ Kowhai Street	8186	Bridge opening based on cross section derived from LiDAR data and Information provided by HRC.
CNR Mangamahu Road and Kauangaroa Road Bridge	19083	
Kauangaroa Bridge	26282	
Whangaehu SH3 Bridge	52364	

Table 3-2 Turakina River Bridge Included in MIKE 11 Model

Bridge	MIKE 11 Chainage (m)	Comment
Turakina SH3 Bridge	14600	Bridge opening based on cross section derived from LiDAR data and Information provided by HRC.

3.6 Inflow Locations

The MIKE FLOOD model was set up to read four inflows at the Whangaehu River and three inflows at the Turakina River as shown in Figure 3-1.

The inflows for Whangaehu River are located at:

- Mangawhero River far upstream of Mangamahu Bridge at Kowhai Street.
- Whangaehu River at upstream of confluence of Mangawhero River and Whangaehu River.
- Whangaehu River at upstream of CNR Mangamahu Road and Kauangaroa Road Bridge.
- Whangaehu River at upstream of New Plymouth Railway Bridge.

The inflows for Turakina River are located at:

- Turakina River near the Suspension Bridge.

- Turakina River at confluence of Wainiutu Stream.
- Turakina River at confluence of Makiriki Stream.

3.7 Roughness and Manning's Values

The Manning's n values were taken as 0.05 for the upstream reach (from top of MIKE 11 model to the confluence of Whangaehu River and Mangawhero River) and 0.06 for the downstream reach (from confluence of Whangaehu River and Mangawhero River to the Ocean) of the Whangaehu River and 0.04 for the entire length of the Turakina River and were based on the model calibration process.

The roughness and equivalent Manning's n values for the MIKE 21 grid were based on land use information provided by HRC. The adopted values are shown in Table 3-3. These values have been successfully used for similar flood mapping projects on the Manawatu, Rangitikei, Mangatainoka and Whanganui Rivers.

Table 3-3 MIKE 21 Roughness and Manning's Values

Land Type	Roughness	Equivalent Manning's 'n' (1/Roughness)
Built up Areas	6	0.167
Dense Vegetation	15	0.067
Open Space	27	0.037
Waterways	35	0.029
Roads	56	0.018

3.8 Link Structures

A total of 357 lateral links, 106 links in Turakina River and 251 links in Whangaehu River, were set-up for transfer of flow between the MIKE 11 cross sections and the MIKE 21 grid. The link structure type used for all the links are summarised in Table 3-4 below.

Table 3-4 Link Structure Details (Common for all 357 links)

Parameter	Value	Comment
Method	Cell to cell	
Type	Weir 1	$Q = W \cdot C \cdot (H_{us} - H_w)^k \cdot \left[1 - \left(\frac{H_{ds} - H_w}{H_{us} - H_w}\right)^k\right]^{0,385}$ Refer to MIKE 11 reference manual for details.
Source	HGH and M21	HGH grid cell levels at lateral links were used in Turakina Rivers. In Whangaehu River, M21 grid cell levels in upstream reach (from top of MIKE 11 to the confluence of Whangaehu River and Mangawhero River) and HGH grid cell levels in downstream reach (from the confluence of Whangaehu River and Mangawhero River to the Ocean) of the river were used at lateral links of the river. HGH was initially trialled at the upstream reach but unrealistically restricted breakout flow.
Depth Tolerance	0.1m	For model stability.
Weir C	1.838	Default discharge coefficient.
Manning's n	0.05	Adopted value.

3.9 Other Parameters

Other critical parameters for the MIKE FLOOD model are provided below:

- Calculation time-step: 2 seconds for July 2006 flood event and intermediate flood events and 1 second for 1 in 100 AEP and 1 in 200 AEP design flood events.
- Flooding and drying enabled:
  - Drying depth: 0.02m.
  - Flooding depth: 0.03m.
- Eddy viscosity: 0.10m^2/s.

3.10 Downstream Model Boundary

The downstream model boundary for both the Whangaehu and Turakina Rivers is the ocean. A dynamic tidal boundary was used for the calibration model run while constant tide levels were used for the design and intermediate event runs.

3.10.1 Calibration Event

As there is no recorded tide data for the July 2006 calibration flood event, a timeseries of synthetic tide data (developed by NIWA and provided to HTC by HRC) was used to estimate the tide timeseries at the Whangaehu and Turakina River mouth. The synthetic tide data does not include storm surge which was estimated by using recorded atmospheric pressure at Foxton during the storm event. Storm surge was approximated as being = 2 x (standard atmospheric pressure – recorded atmospheric pressure). Storm surge thus estimated was added to the synthetic tide timeseries and the new timeseries converted to Wellington datum. The synthetic tide timeseries for Whangaehu and Turakina adjusted for storm surge and Wellington datum for July 2006 is provided in Figure 4-1. This method of estimating the downstream MIKE FLOOD boundary condition was agreed to by HRC.

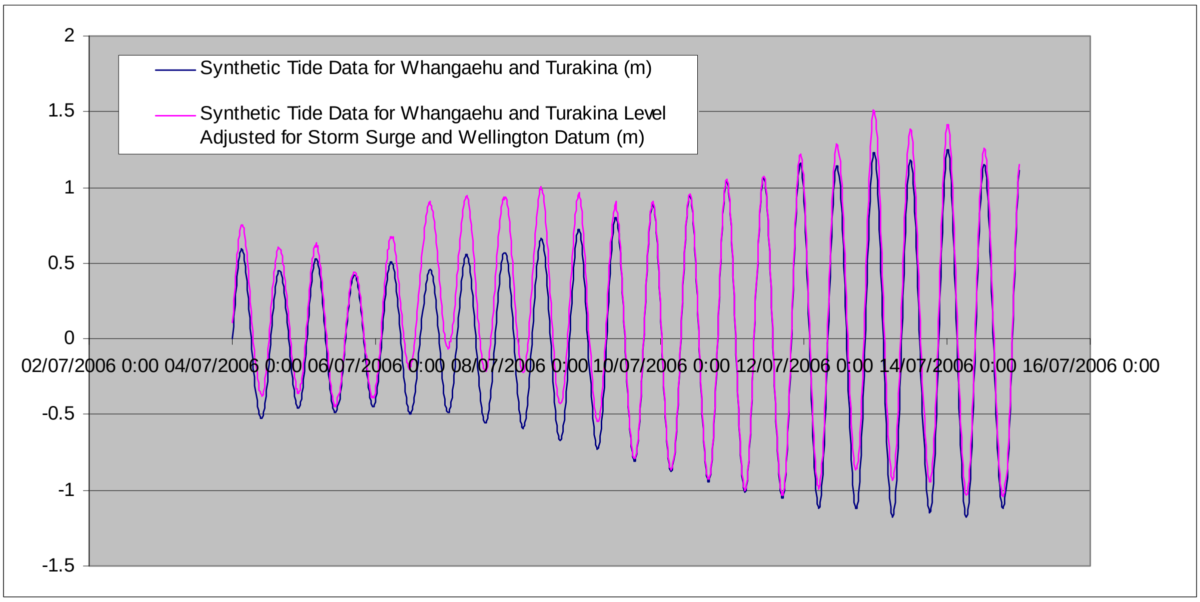

Figure 3-3 Synthetic Tide Timeseries for July 2006

3.10.2 Design Events

The 1 in 100 and 1 in 200 AEP design events were both run for a “low” and “high” constant tide level.

Low tide level = 0 m Wellington datum

High tide level = 2 m Wellington datum

3.11 Model Datum

The modelling was carried out in Wellington Vertical Datum.

4. MIKE FLOOD Model Calibration

Calibration of the hydraulic model was required to provide confidence that the outputs of the model were reasonable. The hydraulic model was calibrated by comparing:

- Modelled and measured discharges of Whangaehu River at Kauangaroa and Turakina River at O'Neils Bridge.
- Modelled flood extents against observed flood extents using surveyed flood levels and available flood photographs provided by HRC.

The July 2006 flood event was used for model calibration.

July 2006 Flood

The results from the model calibration at the Whangaehu River at Kauangaroa and Turakina River at O'Neils Bridge gauge site are shown on Figure 4-1 and 4-2 respectively. These figures show that at both locations the modelled duration along with timing and magnitude of the peak discharge compares well with the observed hydrographs. For the Whangaehu River the modelled peak discharge is slightly higher than recorded while for Turakina River the modelled peak is slightly lower.

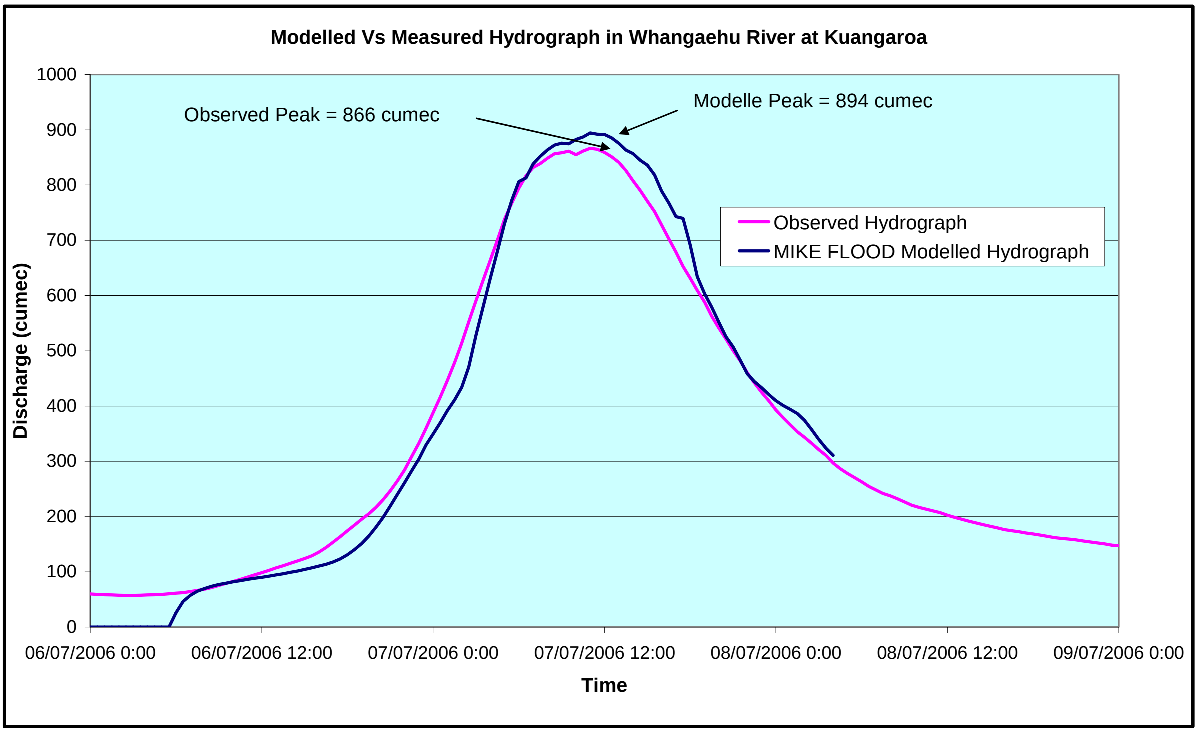

Figure 4-1 Observed Vs Modelled Hydrograph at Kauangaroa for July 2006 Flood

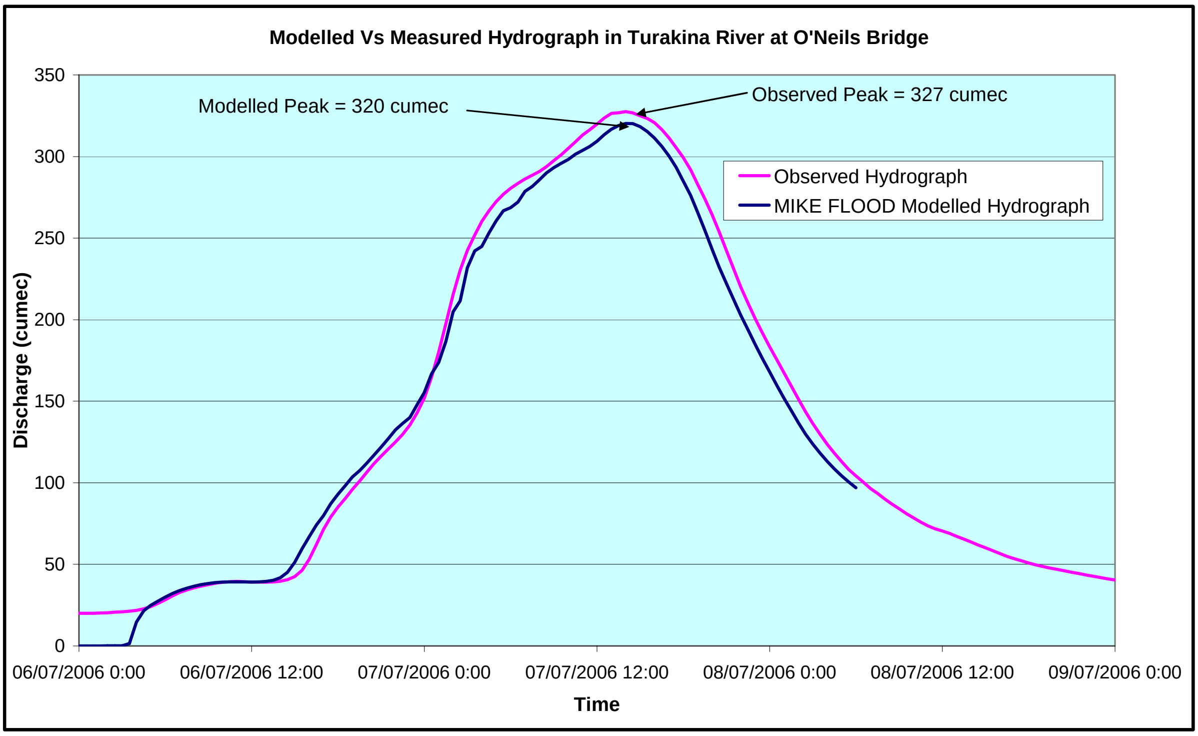

Figure 4-2 Ovserved Vs Modelled Discharge at O'Neils Bridge Gauge Site for July 2006 Flood

The modelled flood levels in Whangaehu River and Turakina River for July 2006 flood event were plotted and the inundation map is shown in Figure 4-4. HRC provided photographs of flooding that occurred during the July 2006 flood event. It is assumed that these photos show the peak of the flood. The locations of these photos are also shown on Figure 4-4. A selection of the photographs are shown in Figure 4-5 to Figure 4-16. The extent of inundation from the MIKE FLOOD modelling shown in Figure 4-4 compares well with the flooding at the confluence of Whangaehu River and Mangawhero River, around Kauangaroa Bridge, around New Plymouth Railway Bridge, downstream of New Plymouth Railway Bridge and Whangaehu Village in Whangaehu River and around New Plymouth Railway Tunnel and SH3 Bridge in Turakina River.

HRC also compared the modelled flood extent map with oblique aerial photos of the July 2006 flood event and found a good match between them.

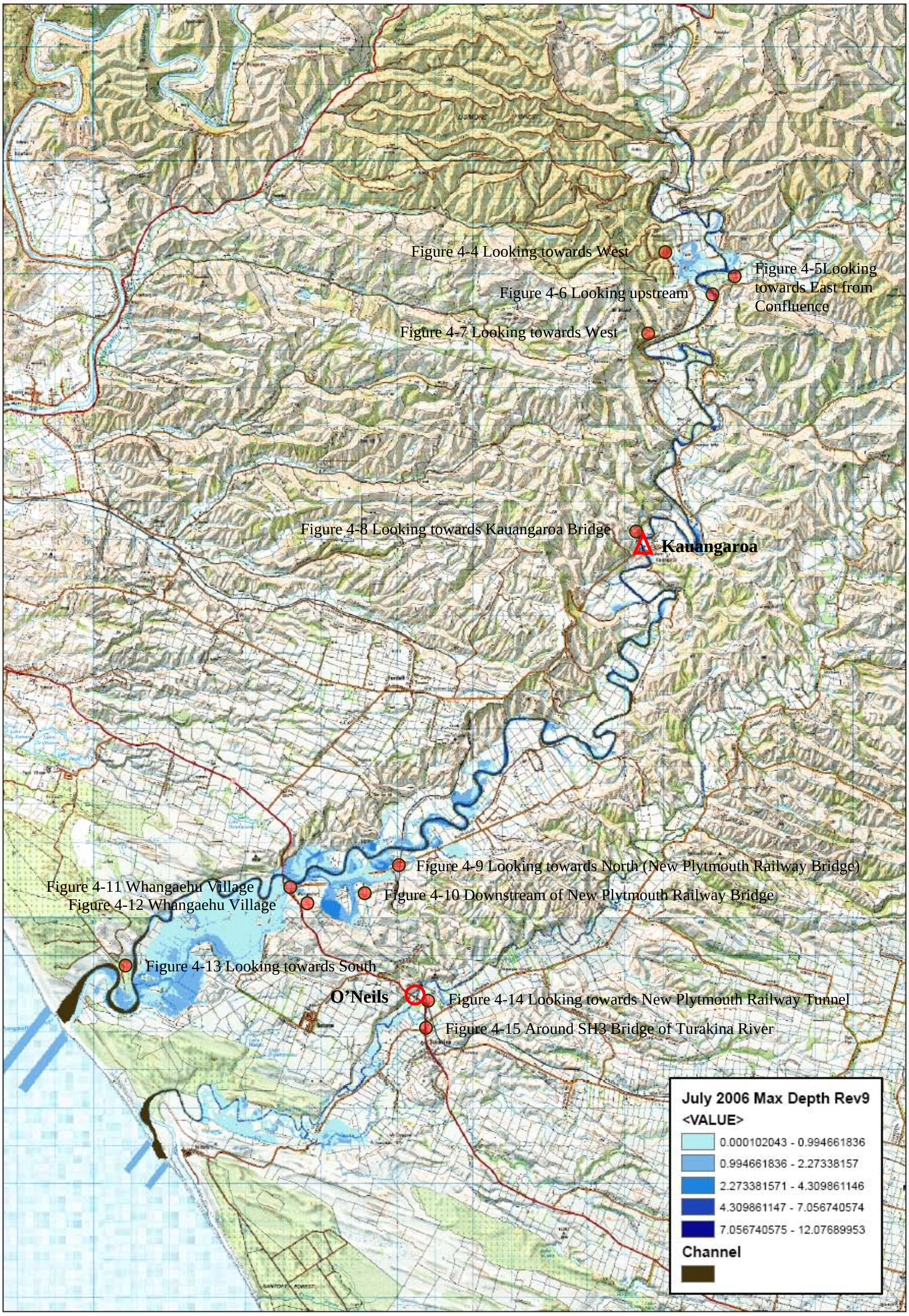

Figure 4-3 Flood Extent Map of July 2006 Flood Event

Figure 4-4 Looking towards west from floodplain downstream of confluence of Mangawhero and Whangaehu River

Figure 4-5 Looking towards east from confluence of Mangawhero and Whangaehu River

Figure 4-6 Looking upstream to confluence of Mangawhero and Whangaehu Rivers

Figure 4-7 Looking towards west towards Orchard Road

Figure 4-8 Kauangaroa Bridge looking downstream

Figure 4-9 Flooding around New Plymouth Railway Bridge, looking upstream

Figure 4-10 Flooding downstream of New Plymouth Railway Bridge

Figure 4-11 Flooding at Whangaehu Village, looking north west

Figure 4-12 Flooding at Whangaehu Village

Figure 4-13 Looking towards South near the mouth of Whangaehu River.

Figure 4-14 Looking towards the New Plymouth Railway Tunnel in Turakina River.

Figure 4-15 Flooding around Turakina at SH3 Bridge

5. Design Flood Runs

The MIKE FLOOD model was used to develop a set of electronic flood extent inundation and flood depth maps for the 1 in 100 AEP and 1 in 200 AEP flood discharges as measured at Kauangaroa gauge site in Whangaehu River and O'Neils Bridge gauge site in Turakina River. Flood frequency results at these locations were provided by HRC and are shown in Table 5-1.

Table 5-1 Flood Frequency Result

Flood AEP	Discharge (m^3/s)	
	Whangaehu at Kauangaroa	Turakina at O'Neils Bridge
1:100	1500	570
1:200	1900	670

The July 2006 flood event hydrograph was used as the basis of the design runs and the inflow hydrographs to the MIKE FLOOD model for this event were scaled so that the peak discharge at the Kauangaroa of Whangaehu River and O'Neils Bridge of Turakina River gauge sites matched the required peak flow for the 1 in 100 and 1 in 200 AEP design events. The design flood runs were carried out for "low" (0 m) and "high" (2 m) constant water levels at the ocean boundary condition.

5.1 Flood Extent Maps

Flood extent maps for the 1 in 100 AEP and 1 in 200 AEP design flood events were prepared using the results form MIKE FLOOD model runs. The maps were provided to HRC electronically in ARC GIS format. Plots of the flood 1 in 100 AEP and 1 in 200 AEP extents for a constant tail water level of 2 m representing high tide level are shown in Figure 5-1 and Figure 5-2.

5.2 Flood Hazard Maps

From the MIKE FLOOD Model results of 1 in 100 AEP and 1 in 200 AEP flood events, hazard grid files were generated which were used to prepare Flood Hazard Maps to show the flood hazard categories based on the CSIRO Flood Hazard Guideline. According to this guideline, the flood hazard is categorized into four degrees of hazards, namely 'Low', 'Medium', 'High' and 'Extreme Hazard'. The maps thus prepared were provided to HRC electronically in ARC GIS format. Plots of 1 in 100 AEP and 1 in 200 AEP flood hazards of the Whangaehu and Turakina Rivers are shown in Figure 5-3 and Figure 5-4.

5.3 Flood Hazard Animation

Animations of changing flood hazard were developed for the 1 in 100 and 1 in 200 AEP flood events. The hazard animations are based on variable time steps and were provided to HRC in ArcGIS format.

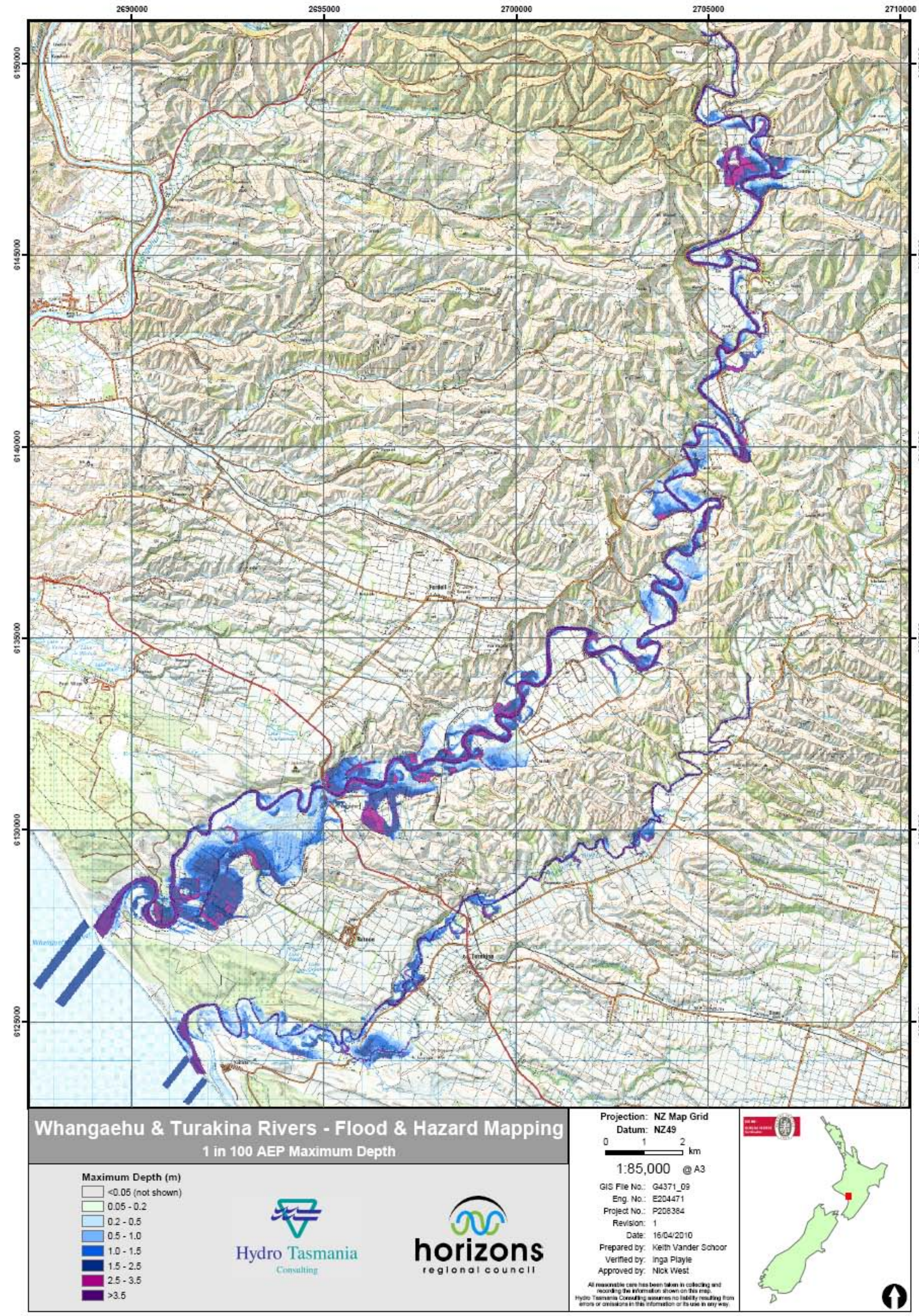

Figure 5-1 1 in 100 AEP Flood Extent Map for High Tide

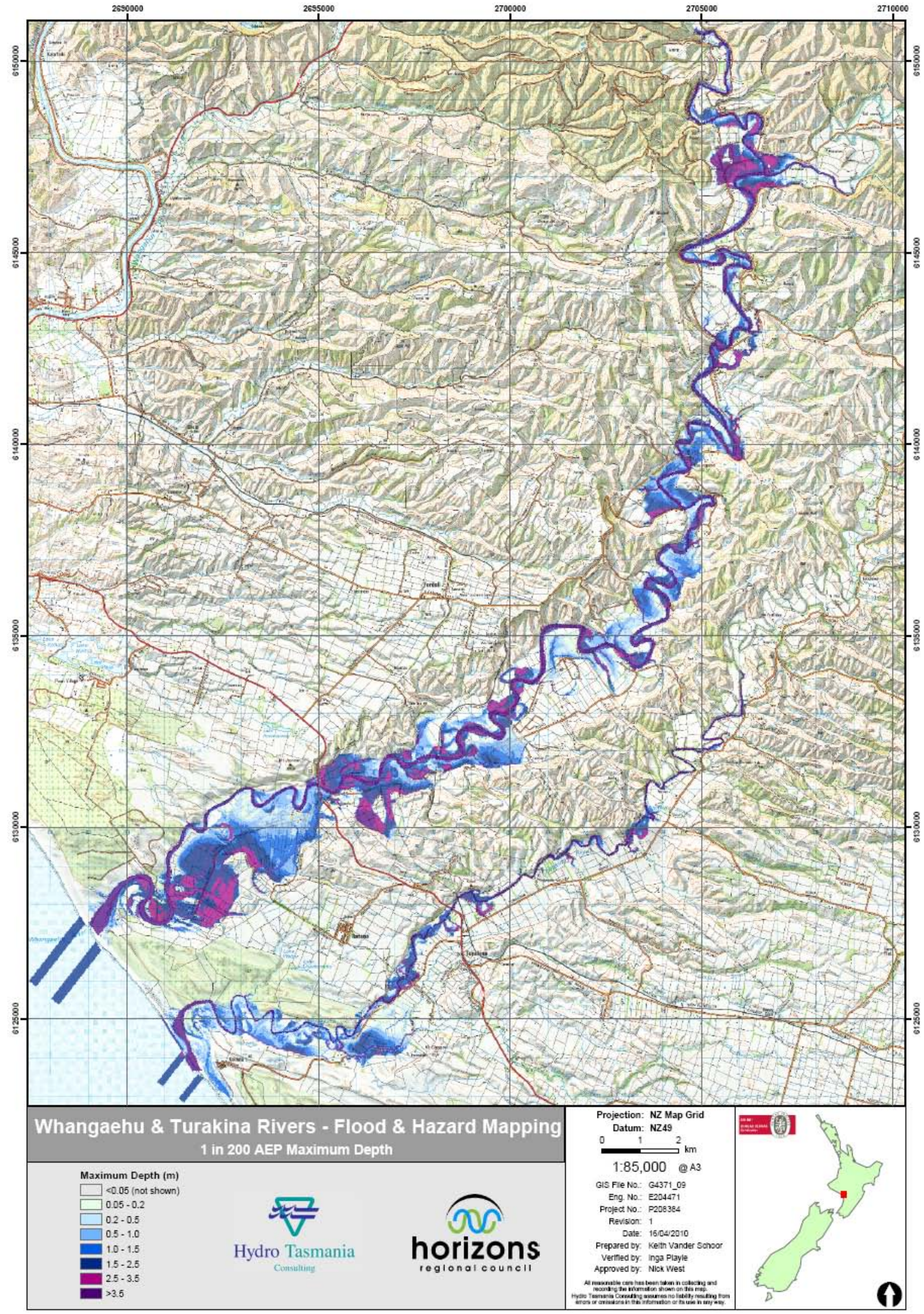

Figure 5-2 1 in 200 AEP Flood Extent Map for High Tide

Figure 5-3 1 in 100 AEP Flood Hazard Map

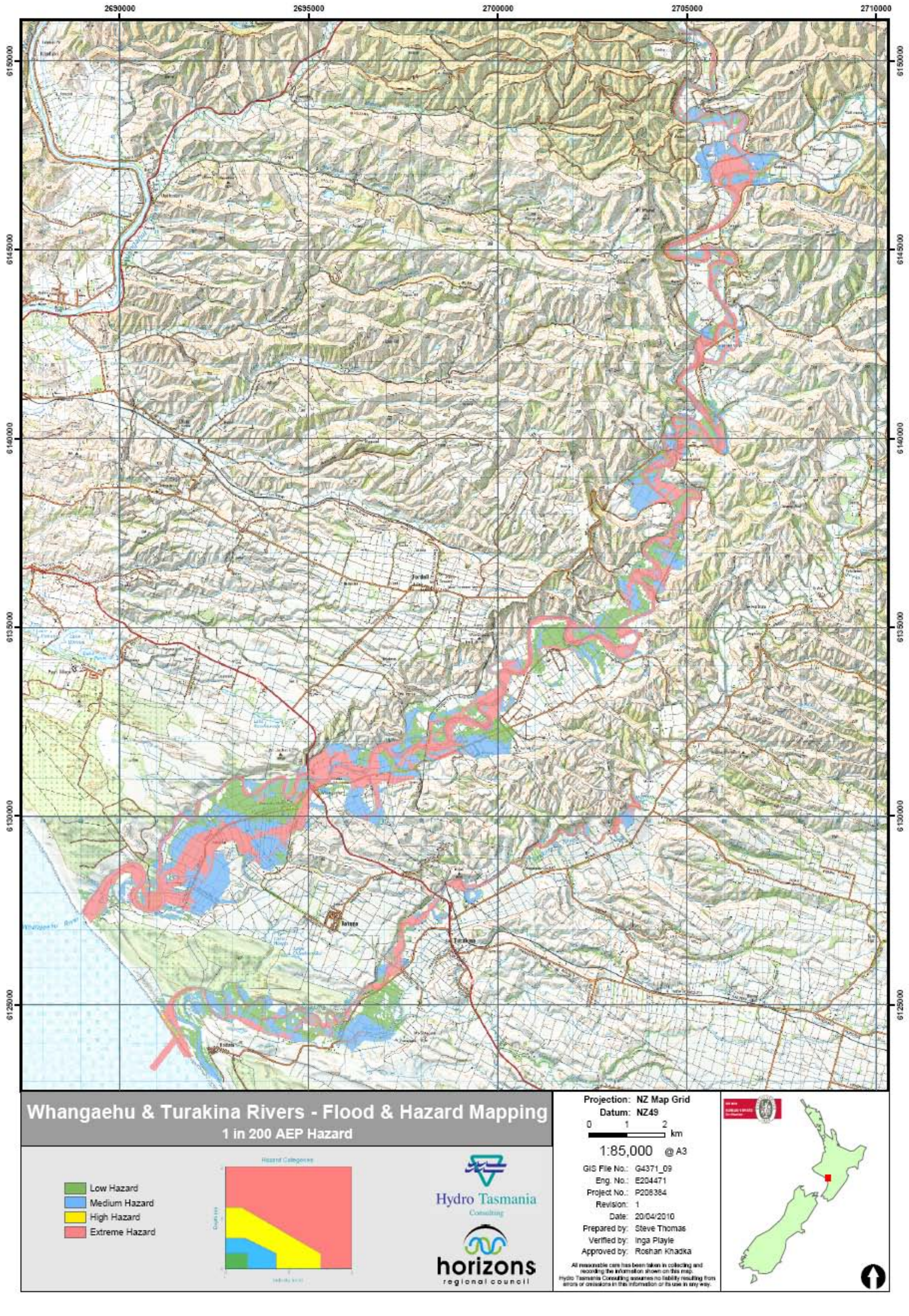

Figure 5-4 1 in 200 AEP Flood Hazard Map

6. Intermediate Flood Runs

A series of intermediate floods between the breakout flow for the rivers and the 1 in 100 AEP peak discharge were run through the Whangaehu and Turakina MIKE FLOOD models to provide HRC with a series of raw results files. These results files will be used in the waterRIDE software package to view real-time estimates of flood extents based on output from the flood warning system of the river that was previously developed by HTC.

The single MIKE FLOOD model containing the two rivers was split into two separate models for the intermediate flood runs for the purpose of obtaining individual result files for each river that could then be used separately in waterRIDE.

The July 2006 flood hydrograph was used as the basis of the intermediate floods and the inflow hydrographs to the MIKE FLOOD model for these events were scaled to achieve the required peak flow in the Whangaehu River at Kauangaroa and the Turakina River at O'Neills Bridge. The modeled intermediate floods for the Whangaehu River and Turakina River are provided in Table 6-1 and Table 6-2.

The raw results files were provided to Worley Parsons on behalf of HRC.

Table 6-1 Peak discharge, Whangaehu at Kauangaroa

Intermediate Flood	Modelled Peak at Kauangaroa (m^3/s)
1	428
2	495
3	663
4	821
5	1067

Table 6-2 Peak Discharge, Turakina at O'Neills

Intermediate Flood	Modelled Peak at O'Neills (m^3/s)	Comments
1	238	
2	335	
3	431	
4	566	1 in 100 AEP
5	670	1 in 200 AEP
6	745	

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7. References

Hydro Tasmania Consulting, *Horizons Regional Council Flood Forecasting System – Upper Manawatu Catchment Operating Manual*, 121040-Report-03, November 2008.

CSIRO, 2000, *Flood Management in Australia: Best Practice Principals and Guidelines*, SCARM Report 73.

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Appendices

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Appendix A Flood Hydrographs

Flood hydrographs used for Model Calibration.

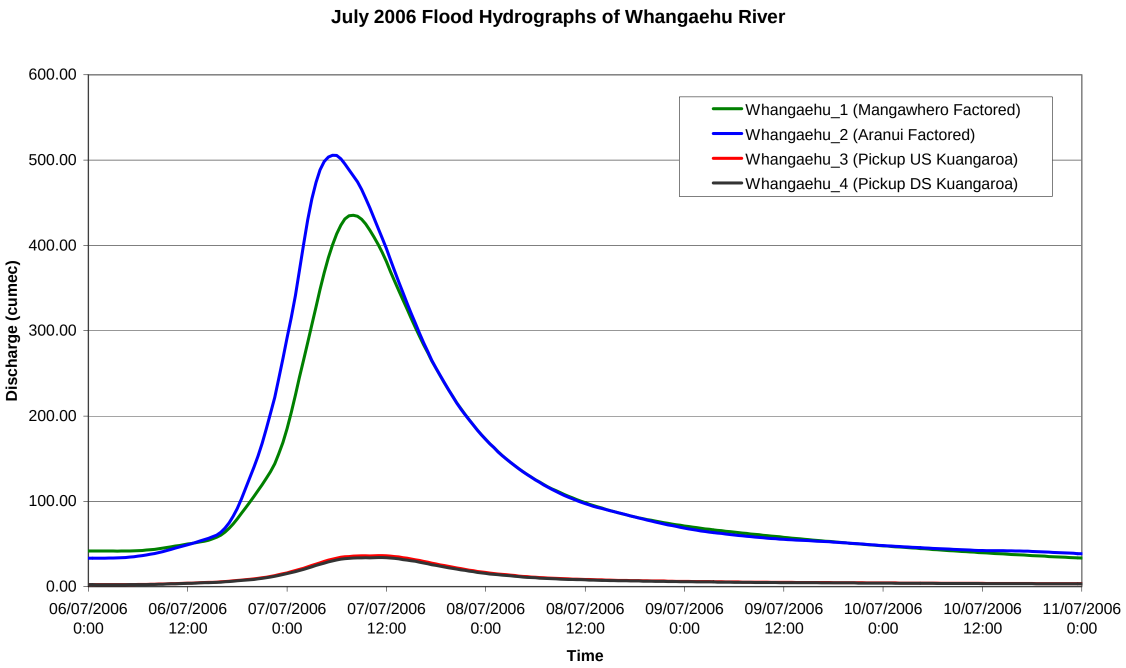

Figure A-1: July 2006 Flood Hydrographs of Whangaehu River

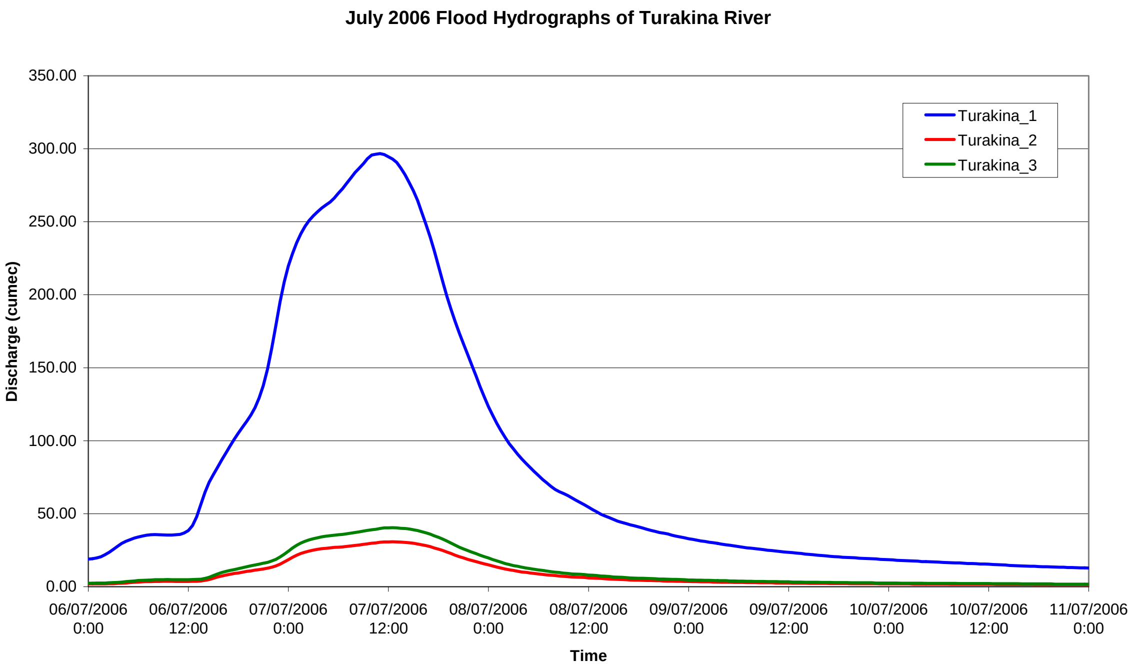

Figure A-2: July 2006 Flood Hydrographs of Turakina River

Flood hydrographs used for Designed Model Run.

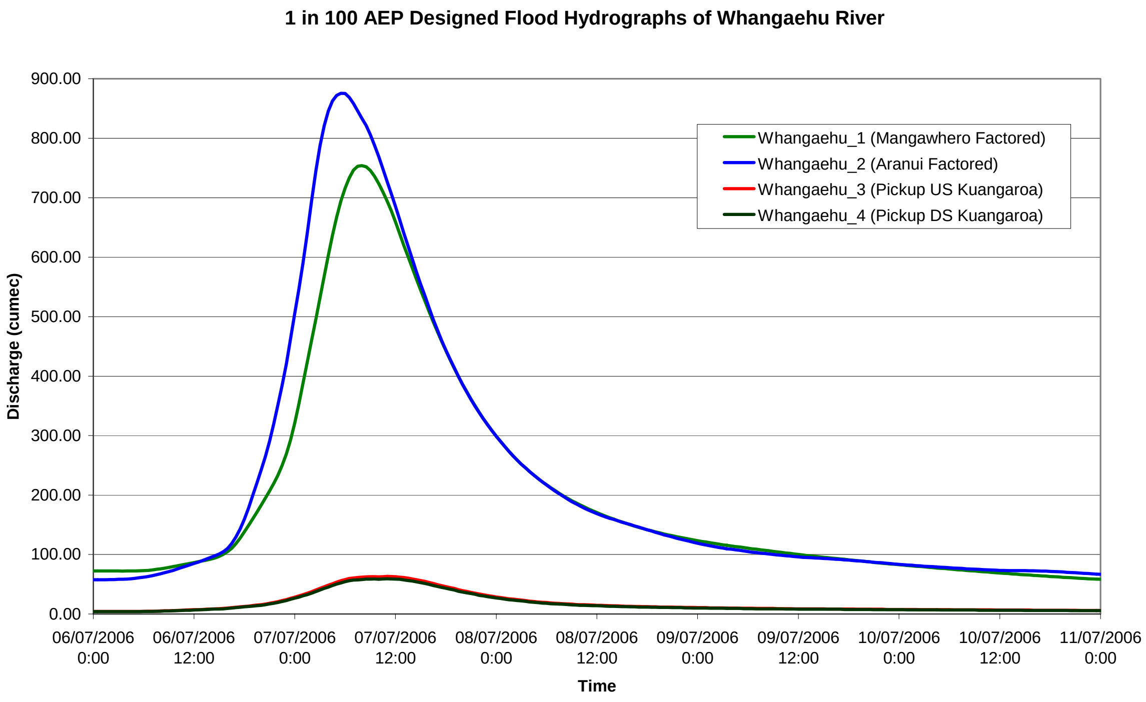

Figure A-3: 1 in 100 AEP Designed Flood Hydrographs of Whangaehu River

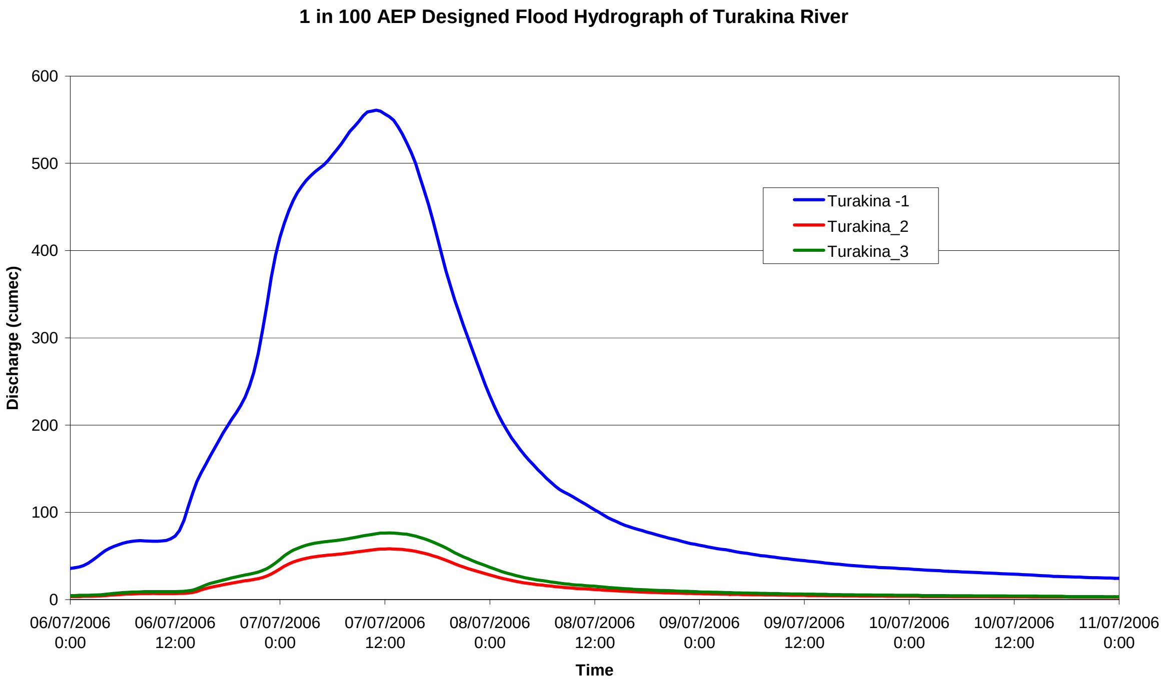

Figure A-4: 1 in 100 AEP Designed Flood Hydrographs of Turakina River

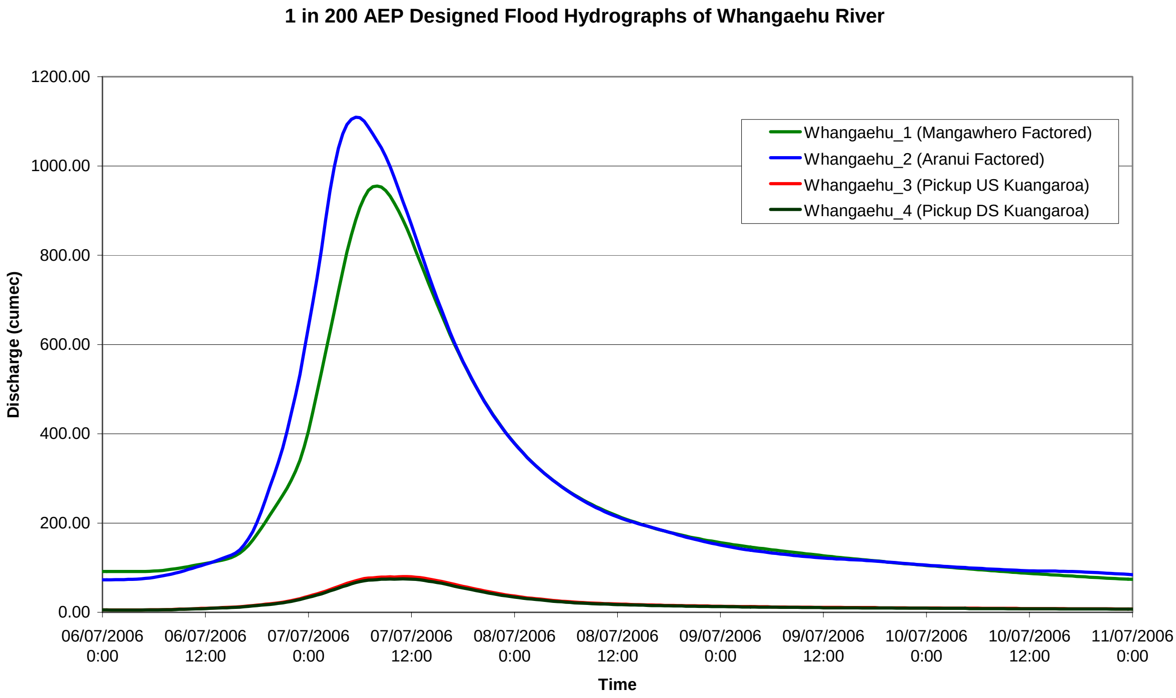

Figure A-5: 1 in 200 AEP Designed Flood Hydrographs of Whangaehu River

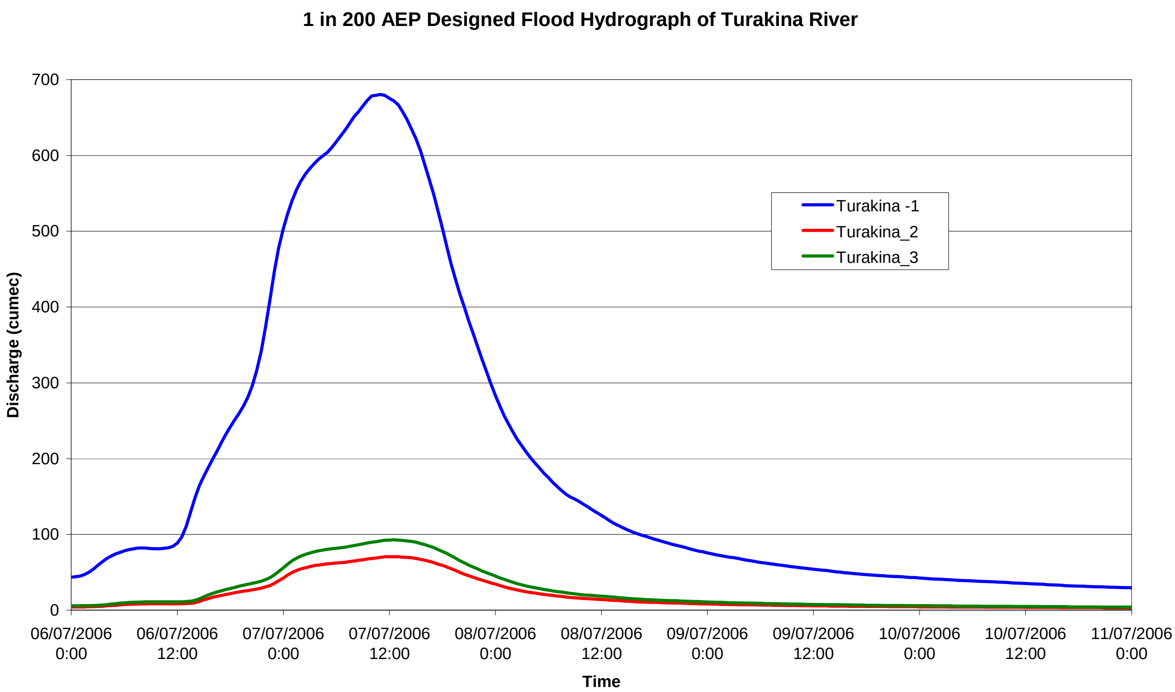

Figure A-6: 1 in 200 AEP Designed Flood Hydrographs of Turakina River

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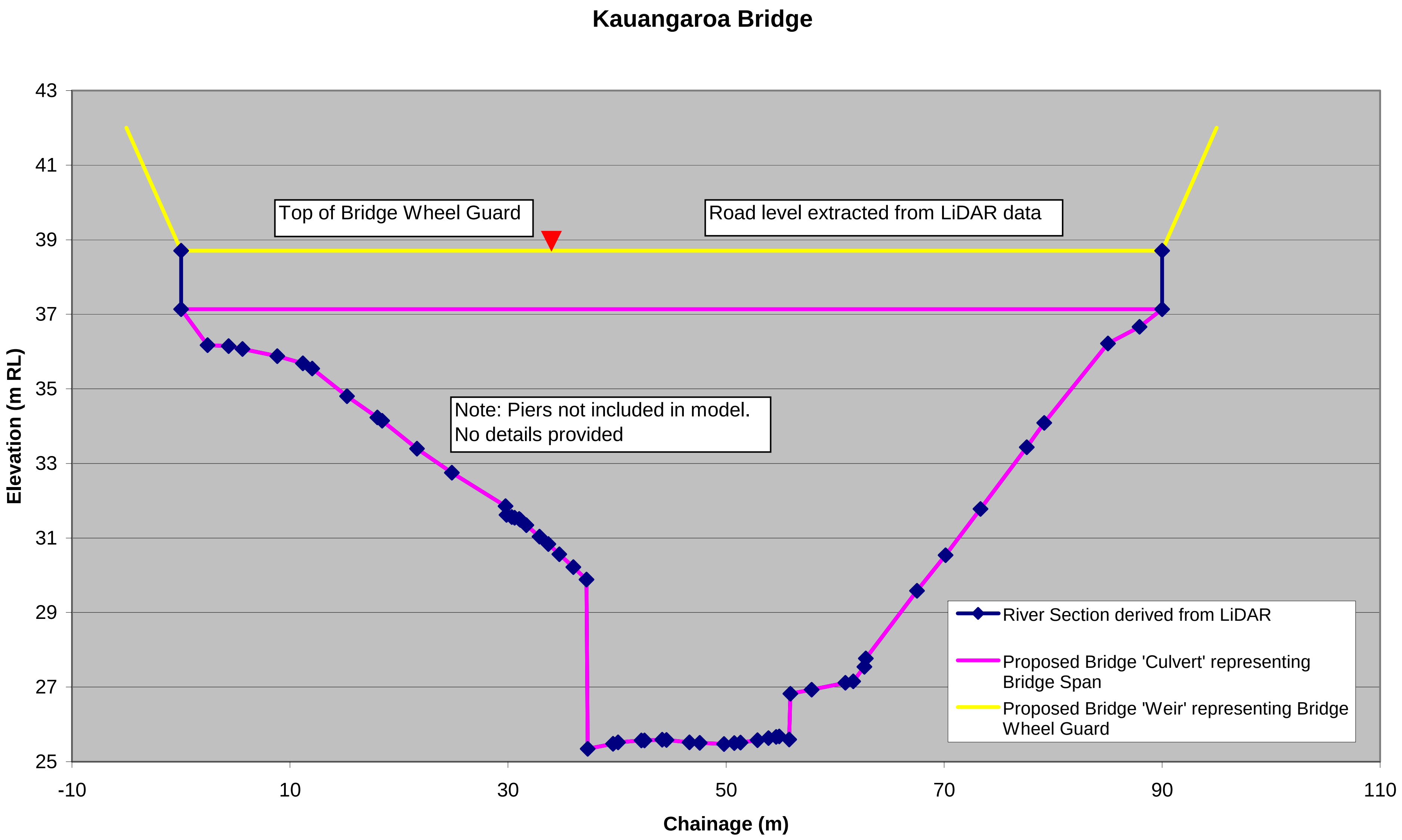
Appendix B Typical Cross Section of Bridge

Cross Section derived from LiDAR Data

Offset (m)	Wellington Vertical (m)	Offset (m)	Wellington Vertical (m)
0	38.7	42.514	25.57
0	37.137	44.136	25.589
2.437	36.172	44.537	25.581
4.357	36.147	46.64	25.521
5.637	36.071	47.574	25.506
8.838	35.875	49.82	25.471
11.185	35.682	50.757	25.496
12.039	35.545	51.322	25.511
15.239	34.805	52.872	25.576
18.013	34.234	53.882	25.631
18.44	34.147	54.58	25.663
21.641	33.393	54.88	25.675
24.841	32.751	55.798	25.593
29.782	31.855	55.911	26.824
29.865	31.618	57.852	26.933
30.334	31.562	60.942	27.115
30.61	31.544	61.657	27.158
31.025	31.511	62.695	27.547
31.135	31.483	62.818	27.768
31.687	31.342	67.5	29.582
32.884	31.035	70.139	30.54
33.688	30.838	73.342	31.775
34.712	30.561	77.583	33.435
36.001	30.218	79.185	34.084
37.209	29.884	85.028	36.218
37.312	25.348	87.928	36.666
39.623	25.482	90	37.137
40.084	25.518	90	38.7
42.243	25.569		



Note: Road Level is extracted from LiDAR data. Level of top of Bridge Wheel Guard and bottom of Girder are derived from the extracted road level using the information provided by HRC.