REPORT

Nelson City Council

Maitai River Flood Hazard Mapping Modelling Report

Report prepared for:

Nelson City Council

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Executive Summary

Nelson City Council (NCC) has engaged Tonkin & Taylor (T&T) to produce flood hazard maps of the Maitai River to assist them with their planning and stormwater objectives. The mapping includes a series of 1% Annual Exceedance Probability (AEP) rainfall events as well as a series of hypothetical sunny day dambreak events of the Maitai Dam.

T&T has built a model that represents the Maitai River and all its contributing sub-catchments and tributaries.

The overall model is a combination of a 1D model from the dam to the city, and a coupled 1D and 2D model within the urban environment. Key assumptions are summarised in Sections 3 and 4.

The model includes inflows from the Brook Stream and York Stream catchments simply as point inflows at the confluences with Maitai River. No flood modelling has been carried out in these tributaries upstream of the confluence, and therefore the flood hazard maps do not show any localised flooding within either Brook or York Streams. Provision has been made to extend the current model into each of these sub-catchments at some point in the future.

The model has been calibrated with respect to a number of significant historical storm events for which both rainfall and flow records are available. We have assumed that the records for these historical events are reliable. The model has also been validated with respect to observed urban flood levels during the December 2011 storm event, and a good flood level and peak flow match at Avon Terrace match has been achieved for that event.

The available gauge records do not include any other significant storms suitable for validation of the model. We recommend that a model validation exercise be carried out following capture of data from the next two significant storm events.

We understand that a new flow gauge is to be installed in the lower Brook Stream in early to mid 2013. Data from this gauge during the next significant storm would be very useful in confirming or refining catchment parameters for the large Brook sub-catchment.

It is noted that the model does not account for the capacity of the primary (piped) stormwater system to return flood waters from the urban floodplain back into the Maitai River. Hence, in this respect, the model currently tends to overestimate flood recession time.

The model results clearly identify areas of flood hazard for the 1% AEP storm scenario. A secondary but significant outcome of the modelling exercise has been to highlight the flooding issues that will arise purely as a result of anticipated sea level rise. Using existing LiDAR data and current sea level rise estimates, Nelson city can expect significant flooding across the lower portion of the urban area purely as a result of the estimated 100% AEP tide event in the year 2100.

Modelled present-day 1% AEP flows in the urban area above Nile Street bridge are 7% higher than the statistically projected 1% AEP flow as derived by flood frequency analysis (based on the Girlies Hole gauge). Modelled present-day 1% AEP flows at Avon Terrace are about 26% higher than the statistically projected 1% AEP peak flow (based on the Avon Terrace gauge). It is noted that the projected value at Avon Terrace is based on a relatively short duration flow record, with the largest event on record being the 5-10% AEP event recorded in December 2011. Actual 1% AEP flood flows may therefore vary from those either modelled or statistically projected.

The results provided in Appendix D present 1% AEP flood depths caused by overland flow from storm runoff generated in the catchment. These flood hazard maps provide a starting point for NCC to begin developing flooding mitigation options to pursue. The model, with refinements in specific areas, can then be used to assess the effectiveness of proposed flood mitigation options.

1 Introduction

1.1 General

The Nelson City Council (NCC) commissioned Tonkin & Taylor Ltd (T&T) to carry out flood hazard mapping in the Maitai River from the Maitai Dam to the Nelson Haven at the coast. The flood hazard maps are required for a 1% Annual Exceedance Probability (AEP) design storm and for a dambreak scenario at the Matai Dam.

The two separate purposes of the flood hazard mapping were to refine and update an earlier flood hazard study (Worseldine & Wells, 1994) that highlighted extensive sections in the Nelson City centre that were prone to flooding, and to re-assess the extent of the floodplain from a hypothetical (and unlikely) dambreak of the Maitai dam. T&T's 2005 dambreak study noted that because of the lack of detailed survey data, the estimates for the flood wave propagation rate and flooding extents in the urban area (downstream of Hanby Park) were of limited accuracy.

This study can be used to assist NCC with their responsibilities relating to the following:

- The definition of flood prone areas;
- The provision of advice to the community, regarding the fixing of minimum floor levels, and the development of infrastructure within floodable areas;
- The provision of information to infrastructure owners, planners and developers within the region to enable flood risk to be considered in future planning, design or in the upgrade of existing facilities;
- The provision of engineering works to minimise or eliminate flood hazards;
- Emergency management.

1.2 Previous modelling and change of brief

The original scope of work and conditions of engagement are outlined in T&T's letter reference 870888 dated 19 March 2010.

Originally, the scope of works focused on understanding flood hazard associated with the 2% AEP design storm. The model was calibrated with respect to data from three flow gauges and two rainfall gauges, and then validated using the December 2011 storm event. A 2% AEP storm was then routed through the model to determine flood characteristics. A modelling report was issued in April 2012 titled "Maitai River Flood Hazard Mapping: Modelling Report, April 2012".

Subsequent to this, the hydrology department of Tasman District Council (TDC) advised that data from the Maitai at Girlies Hole flow gauge was no longer considered reliable. They advised that the gauge was overstating flow values by as much as 30%, most likely as a result of a change in vegetation immediately upstream of the gauge site.

In light of this gauge error, the computational model, calibrated to the Girlies Hole flow gauge, required recalibration. It was agreed (NCC and T&T) that the Girlies Hole gauge should be removed from the calibration process, and the model recalibrated.

At the same time, T&T were engaged to make the following changes to the model:

- increasing the resolution of the 2D grid from 10 m cell spacing to 2 m cell spacing;
- modelling of the 1% AEP rather than the 2% AEP event, as being of more interest to NCC's policy and planning process;
- new sea level criteria to match peak values recommended by the National Institute of Water and Atmosphere (NIWA). The new values were based on present day 100% AEP tide

level (approximately present day MHWS + 0.25 m) with allowance for climate change ranging between 0 and 1.0 m of sea level rise.

The above changes have now been incorporated into the model, and form the basis of the model build and results as presented in this report.

1.3 Model reliability

The hydrological and hydraulic models have been developed and calibrated with respect to the best currently available information. This information includes ground survey data (LiDAR data supplied by NCC), projected sea level and rainfall data supplied by NIWA and hydrological gauge data supplied by NCC and TDC.

Reasonable matches have been achieved between observed and modelled flows in the four significant storm events used for calibration and validation in the urban area (refer Appendix C3). The largest of these events was the December 2011 event, which was approximately a 5-10% AEP event. This gives a reasonable level of confidence in the way hydrological and hydraulic flows are conveyed to the sea for events of this order.

A flood frequency analysis of gauge data at Avon Terrace yields a statistical 1% AEP flow of 362 m^3/s, which is 21% lower than the modelled 1% AEP flow of 457 m^3/s (refer Appendix B). However, the frequency analysis is based on only nine years of data, and there is considerable uncertainty in projecting to the 1% AEP event based on the short duration record.

The updated flood frequency analysis for Girlies Hole, which is based on 22 years of data indicates a 1% AEP flow of 377 $m^3/s \pm 55\ m^3/s$, which is about 7% lower than the corresponding modelled flow of 405 m^3/s. Therefore, for the Girlies Hole analysis there is good agreement within the margin of error, and it may be concluded that results from the rainfall-runoff modelling is corroborated by the flood frequency analyses.

1.4 River description

The sub-catchments of the Maitai River are shown in Figure A6 in Appendix A. The alignment of the Maitai River from the Maitai Dam to the coast is shown on Figure A1. The modelled river chainage system runs from CH 0 m at the Maitai dam spillway outlet to CH 15469 m just downstream of the Queen Elizabeth II Bridge (SH6) at the coast.

The Maitai River rises in the Bryant Ranges to the east of Nelson at elevations up to 1100 m. The catchment is approximately 90.8 km^2 at the river's outfall into the Nelson Haven. The catchment is largely indigenous bush or exotic forest, with some cutover areas in scrub or pasture in the lower catchment, and an area of sparse vegetation in the upper South Branch catchment.

The Maitai dam and reservoir are located in the North Branch catchment, just upstream of the confluence between the South Branch and North Branch of the Maitai River.

For approximately 7 km downstream of the dam the river is contained in a relatively narrow gorge which includes the Maitai Valley road, and the water supply pipeline on a bench upslope. Several houses lie at low level close to the river between Poleford Bridge and the Maitai Campground. From the campground to Hanby Park the river is still within well-defined banks. However, the valley floor is wider and in addition to the campground includes the Waahi Taakaro Golf Course and numerous public reserves. Sharland Creek enters the Maitai River at approximate CH 9500 m, at the north (downstream) end of the golf course.

The first significant residential area is located at Hanby Park on the true left bank some 12 km downstream from the dam. A stopbank which extends from Clouston Bridge to Clouston Terrace separates the subdivision from the active river channel. Thereafter, the river flows through the city to the Haven with minimal stopbanking other than some locally raised roads. The Brook Stream enters the Maitai River channel within the residential area between Nile Street and Hardy Street at approximate CH 13600 m.

2 Methodology overview

This section provides an overview of the methodology adopted to carry out the 1% AEP flood assessment and dam break assessment.

Key project outcomes of this report are to provide flood hazard maps for the 1% AEP flood assessment and dam break assessment. Under the project brief, the modelling focused on the effects of the 1% AEP rainfall event, as stipulated in the current (2010) NCC Land Development Manual (LDM). The model is based on rainfall data derived from the NIWA High Intensity Rainfall Distibution System for each sub-catchment. This data has been adjusted to allow for the anticipated effects of climate change to 2100 (i.e. rainfall depths have been increased 16% to allow for a 2 degree Celsius temperature increase, in accordance with the NCC Land Development Manual 2010).

The hydrological model was calibrated to rainfall and stream flowgauging records,and hence catchment response is based on historical and current land use. It is outside the brief of this study to consider any long term changes in land uses patterns, including maximum probably development (MPD) scenarios within the urban catchments.

It is also outside the brief of this study to model the public stormwater pipe network. Consequently, urban flooding within Nelson City associated with insufficient pipe capacity, overland flowpaths and localised ponding may not be represented in the model results.

The flood hazard maps were assessed for a range of tidal boundaries (as advised by NIWA and reported in terms of NCC Datum):

- Present day one year ARI storm tide level = RL 14.43 m;
- 2050 100% AEP tide level, allowing for 0.3 m sea level rise = RL 14.73 m;
- 2050 100% AEP tide level, allowing for 0.5 m sea level rise = RL 14.93 m;
- 2100 100% AEP tide level, allowing for 0.8 m sea level rise = RL 15.23 m;
- 2100 100% AEP tide level, allowing for 1.0 m sea level rise = RL 15.43 m.

The flood hazard maps can be used to inform other decisions (e.g. number of properties flooded, building platform levels, flood management options etc.).

The flood hazard maps were created using a hydraulic model. The following sections provide details with regards to the model build and key hydraulic model inputs:

Section 3 River and floodplain hydraulics

The river and floodplain hydraulics determine the characteristics of the floods generated by design flows in the river (e.g. flood extent, flood depth, flow velocity). The section includes details regarding hydraulic model type, model build and boundary conditions.

Section 4 Hydrological assessment

The catchment hydrology determines the quantity and rate of runoff from the surrounding catchments. The section includes details regarding catchment and sub-catchment extents, catchment parameters and design rainfall.

Section 5 Hydrological calibration and hydraulic model validation

This section relates to the investigations that have been carried out to provide confidence in the model results. Details included in the section include calibration event selection, calibration parameters and model results.

Section 6 Model application to 1% AEP storm event

This section presents the results of the hydraulic model for the design storm using the parameters determined in the previous sections.

Section 7 Dambreak assessment

This section relates to the dam breach parameters and assessment of the flood extents caused by a hypothetical breach of the Maitai dam.

3 River and floodplain hydraulics

3.1 Overview

The approach to the hydraulic modelling involved utilising topographic data from LiDAR survey to build a representative model of the Maitai River and the floodplains within the study area. The LiDAR survey was supplemented by topographic surveys around bridge structures located in the watercourse.

The main urban area was modelled in detail using a combined 1 dimensional (1D) and 2 dimensional (2D) modelling approach. Upstream of Ch 11000 m (approx), the flood assessment is based on a 1D model. Refer to Figure A1 in Appendix A for a location plan showing these modelling elements.

3.2 Hydraulic model

The hydraulic modelling was carried out using the DHI Mike Flood modelling suite (v2011, SP7). The modelling approach combined a 1D representation (Mike 11) of the river channel (approximately 15.4 km channel length) with a 2D representation (Mike 21) of the floodplain. This ensures optimal representation of the channel geometry and floodplain topography.

Figure A1 shows the extents of the 1D and 2D models.

The 2D model was used to determine the flood areas within the urban area. It extends from about CH 11000 m to 15470 m. The 1D model extends from Maitai at Forks flow gauge (Ch 0 m) to the coast at Ch 15470 m (see Figure A1). The 1D and 2D models are linked dynamically within the Mike Flood package (i.e. flow can pass from one model to the other).

The stormwater reticulation network has not been included in the model, as the hydraulic capacity of this network is small compared with the inflows from the large upstream catchments.

3.3 Model build

Cross sections in the 1D model were created using LiDAR data flown on 1 July 2010. A limitation of LiDAR data is that it cannot pick up the channel bed profile below the water surface. Therefore, within the urban reach of the river, the LiDAR data has been supplemented with observed low flow depths to develop a channel bed profile. LiDAR was collected during low flows in the Maitai River, and flow depths are typically shallow relative to the bank to bank cross section. Thus any errors associated with not having a full survey of the river bed below low flow level are expected to be minimal. The grid was generated from the provided LiDAR data, cleaned of buildings and trees. The effects of these obstructions on the modelled flooding characteristics have been ignored in this assessment. In reality, we might expect floodplain obstructions such as buildings, fences and dense vegetation to affect flood flows across the floodplain, potentially resulting in localised differences between the model and reality in terms of flow velocities, flood extents and depths. Any such localised effects are accounted for by appropriate provision of freeboards in using the model outcomes.

The cross section locations are shown on Figures A2-A5. The topographic data was supplemented by ground survey of cross sections at the bridge structures in the Maitai River. Bridges are summarised in Table 3-1.

Table 3-1 Bridge locations

Name	Chainage	Type	Represented in model?
Queen Elizabeth II Bridge (SH6)	15368	Two lane road bridge	Yes
Trafalgar Park footbridge	15159	Foot bridge	No[1]
Trafalgar Street	14794	Two lane road bridge	Yes
Collingwood Street	14518	Two lane road bridge	Yes
Riverside footbridge	14272	Foot bridge	No[1]
Aratuna Normanby bridge	13955	Two lane road bridge	Yes
Hardy Street footbridge	13698	Foot bridge	No[1]
Nile Street	13450	Two lane road bridge	Yes
Clouston Bridge	12891	One lane road bridge	Yes
Gibbs Bridge	11983	Two lane road bridge	Yes
Jickells Bridge	11375	One lane road bridge	Yes
Ford	10462	Ford	No[2]
Golf Course	8901	Foot bridge	No[2]
Maitai Valley Motor Camp	7742	One lane road bridge	No[2]
Unnamed footbridge	6923	Foot bridge	No
Unnamed footbridge	6482	Foot bridge	No[2]
Poleford Bridge	5489	One lane road bridge	Yes
Smiths Ford Bridge	3959	One lane road bridge	Yes
Pipe bridge	3227	Pipe bridge	No[1]
Unnamed footbridge	127	Foot bridge	No[1]

[1] Bridge deck well above modelled flood flows

[2] Accurate flood levels are not required in this area for this study

The 2D model grid was created from the LiDAR data using a 2 m grid cell spacing.

Channel and floodplain roughness was part of the model calibration (see Section 5). The starting roughness values used for model calibration were taken from Worseldine & Wells (1994), and are shown in Table 3-2 below. The 1994 calibration indicated that estimates of Mannings “n” for the main channel generally increased upstream and ranged from 0.03 at the downstream end of the City reach to 0.065 in the upper reaches. Mannings “n” for the berm areas and floodplain was generally between 0.06 and 0.1. These values appeared reasonable based on our site walkover investigation and provided a good starting point for model calibration.

Table 3-2 Manning's n values from Worseldine and Wells, 1994 report

	Manning's n ($s/m^{1/3}$)	
Chainage (m)	Overbanks	Main channel
Dam to 8800	0.060	0.050
8800 to 9800	0.040 (left), 0.065 (right)	0.065
9800 to 10700	0.040 (left), 0.060 (right)	0.050
10700 to 11300	0.060	
11300 to 11450	0.060	
11450 to 12350	0.075	
12350 to 13030	0.065	
13030 to 13560	0.100	0.045
13560 to 14480	0.060	
14480 to 15120	0.035	0.035
15120 to end	0.030	0.030

This calibration process indicated that the Worseldine & Wells Manning's values were appropriate for the main river channel. A Manning's "n" value of 0.040 was selected for modelling floodplain flows in the 2D model of the urban area. A sensitivity check was carried out on this value (±50%). The parameter was found to have little impact on maximum flood levels and extents. This is due to the fact that urban floodplain flooding, particularly in the Wood area, is largely a ponding issue rather than an overland flowpath one.

3.4 Boundary conditions

All inflows to the Mike Flood model were generated within HEC-HMS v3.5, and imported into Mike11 boundary files.

3.4.1 Inflow boundary

Catchment inflows to the hydraulic model were determined from the hydrological model (see Section 4). Where a main tributary of the Matai River discharged into the main watercourse, a point source inflow was used to represent the flows. Where inflows were derived from smaller watercourses or directly from hill slopes, these were assumed to be distributed along the Maitai River, i.e. a distributed source along a range of river chainage values was applied. The inflow boundary conditions are shown in Table 3-3.

Table 3-3 Inflow boundary locations

Chainage (m)	Source type	Catchment
0	Point source	South Branch
0	Point source	North Branch
0	Point source	Forks
82-9425	Distributed source	North Bank
82-4945	Distributed source	Neds

Chainage (m)	Source type	Catchment
4945-13407	Distributed source	Groom
9425	Point source	Sharland
9425-13450	Distributed source	Kaka West
13407-15130	Distributed source	Nelson South
13588	Point source	Brook
13450-15350	Distributed source	Nelson East
15300-15350	Distributed source	York

3.4.2 Water level boundary

A water level was used to represent the downstream boundary in the hydraulic model. For the model application scenarios, NIWA advised adoption of the following water levels in combination with 1% AEP rainfall event modelling (levels reported in terms of NCC datum):

- Present day 100% AEP tide level = RL 14.43 m;
- 2050 100% AEP tide level, allowing for 0.3 m sea level rise = RL 14.73 m;
- 2050 100% AEP tide level, allowing for 0.5 m sea level rise = RL 14.93 m;
- 2100 100% AEP tide level, allowing for 0.8 m sea level rise = RL 15.23 m;
- 2100 100% AEP tide level, allowing for 1.0 m sea level rise = RL 15.43 m.

The tidal boundary was phased for all modelling scenarios to coincide the peak flows in the urban area with the peak level in the tidal cycle, as a worst case scenario. While being a "worst case", it is not overly conservative, since the tide level remains within 300 mm of high tide for about three hours. The effect of this conservative assumption is most evident at the downstream end of the Maitai River, downstream of the Collingwood Street bridge. The bottom of the Trafalgar Street Bridge deck is at approximately RL 15.9 m. At the above tides, this means that there is only 0.5 to 1.5 m of freeboard from the tide level to the bridge deck, through which to pass flood flows.

The above allowances for sea level rise have been adopted by NCC for future development and planning following consultation with NIWA and advice from the Ministry for the Environment (MfE). For details, refer to NIWA report titled "Review of Nelson City minimum ground level requirements in relations to coastal inundation and sea-level rise", dated August 2009, ref ELF10223.

4 Hydrological assessment

4.1 Overview

The catchment hydrology determines the quantity and rate of runoff from the surrounding catchments. This section includes details of catchment parameters and design rainfall.

4.2 Catchments

The locations of the sub-catchments of the Matai River were defined based on topography and the locations of flow monitoring stations. The sub-catchments were then represented using a hydrological model. The internationally accepted US Army Core of Engineers HEC-HMS model software (v3.5) was selected to represent the hydrological processes.

The hydrological sub-catchments of the Maitai River are shown on Figure A6. The catchment areas are summarised in Table 4-1.

Table 4-1 Hydrological sub-catchments for the Maitai River

Catchment	Area
South Branch	18.1 km^2
North Branch	13.4 km^2
Forks	1.6 km^2
North Bank	5.1 km^2
Neds	6.8 km^2
Groom	7.1 km^2
Sharland	15.7 km^2
Kaka West	3.9 km^2
Nelson South	1.8 km^2
Brook	17.1 km^2
Nelson East	1.2 km^2
York	7.4 km^2
TOTAL	99.2 km^2

4.3 Catchment parameters

The hydrological processes in the catchment were represented using the Soil Conservation Service (SCS) method for rainfall runoff processes. The method applies initial abstraction values to account for all the losses that occur before runoff begins, and a “Curve Number” to account for runoff variability due to soil type, ground cover type, soil treatment and hydrological condition. The initial abstraction, curve number, catchment area and time of concentration/lag time determines the distribution of excess rainfall that becomes runoff and the temporal pattern of that runoff. The time of concentration was initially determined for each of the sub-catchments using the empirical formulae shown in Table 4-2.

Table 4-2 Time of concentration formulae

Method	Formula	Parameter definitions
Ramser-Kirpich	$T_c = 0.0195\ L^{0.77} S_a^{-0.385}$	S_a = average channel slope (m/m) L = maximum flow length (m)
Bransby - Williams	$T_c = (0.953\ L^{1.2}) / (A^{0.1}\ H^{0.2})$	A = catchment area (km^2) L = maximum flow length (m) H = the difference in elevation between the highest and lowest points in the study area (m)
Auckland Regional Council TP108	$T_c = 0.14CL^{0.66}\{CN/(200\text{-}CN)\}^{-0.55}\ S_c^{-0.30}$	C = channelisation factor L = maximum flow length (km) CN = SCS Curve Number S_c = catchment slope (equal area method) (m/m)
U.S. Soil Conservation Service	$T_c = (0.87\ L^3 / H)^{0.385}$	L = maximum flow length (km) H = the difference in elevation between the highest and lowest points in the study area (m)

An assessment of the range of T_c results from the methods shown in Table 4-2 was made to determine a suitable value for the catchments. For Maitai sub-catchments, the Ramser-Kirpich and USSCS methods gave values in close agreement, while the Bransby-Williams method gave times of concentration that were consistently and significantly higher. The TP108 method gave results in the middle of this range. Thus, the starting point for the calibration process was to adopt times of concentration based on the TP108 estimate. Where necessary, these were adjusted to achieve a good match between modelled and observed hydrographs. The calibrated times of concentration are presented in Table 5-5. Estimates of times of concentration, and the parameters used in making these estimates, are included in Appendix F.

4.4 Rainfall

There are two rain gauges located in the Maitai catchment with records suitable for calibration purposes. The rain gauges are described in Table 4-3 and their locations can be seen in Figure A6.

Table 4-3 Rain gauge details

	Site start date	Elevation	Location (NZTM)
Brook at Third House	September 1991	RL 688 m	1627308m, 5425105m
Maitai South at Forks	November 1999	RL 120 m	1630638m, 5428925m

NIWA has developed a High Intensity Rainfall Distribution System (HIRDS v3) that gives extreme rainfall values throughout New Zealand, based on their extensive database of rainfall gauge data. HIRDS v3 rainfall data is presented in Table 4-4. Rainfall values are also included in Appendix F.

A study of the relationship between catchment locations and rainfall depths was achieved by comparing rainfall depths obtained from HIRDS version 3, shown in Appendix F. The location provided for each of the sub-catchments was selected as a location that is likely to be representative for the catchment, taking into consideration aspect, slope and elevation.

Table 4-4 HIRDS v3 24-hour rainfall depths for sub-catchments (adjusted for climate change to 2100)

	Catchment coordinates		HIRDS v3 24 hour Rainfall Depth (mm)			
	Easting	Northing	50% AEP	20% AEP	2% AEP	1% AEP
Brook Rain Gauge	1627308	5425105	177.1	220.3	350.0	400.3
Forks Rain Gauge	1630638	5428925	149.4	186.8	299.7	344.1
South Branch	1630632	5426187	168.5	210.0	334.0	382.2
North Branch	1633726	5427189	176.3	218.9	345.9	395.2
Forks	1630638	5428925	149.4	186.8	299.7	344.1
North Bank	1629409	5429427	141.3	176.9	284.9	327.1
Neds	1628163	5426740	173.5	216.0	343.6	393.1
Groom	1626288	5428795	140.0	174.9	280.4	321.7
Sharland	1629449	5432134	145.2	181.1	289.2	331.4
Kaka West	1626400	5432017	125.3	156.4	250.4	287.1
Nelson South	1623116	5430166	110.0	137.7	222.0	255.0
Brook	1624597	5425952	147.4	184.3	295.9	339.6
Nelson East	1624467	5431458	113.8	142.3	228.5	262.3
York	1622442	5428680	109.5	137.2	221.8	255.0

The following sub-sections explain how the differences in HIRDS v3 rainfall data for different sub-catchments were used to assist calibration of the model, and how they were used to generate design rainfall hyetographs for the model application scenarios.

4.4.1 Factors for estimating rainfall depths for each sub-catchment during calibration

The Brook rain gauge and the Forks rain gauge have captured point rainfall measurements during a number of historic storms. As can be seen in Table 4-4 above and Appendix B, the rainfall climate varies across the sub-catchments. In order to estimate the rainfall depths at sub-catchments located some distance away from the gauges, it was assumed that rainfall in some sub-catchments were proportional to the Brook gauge, and the rest were proportional to the Forks rain gauge. Catchments located on the west and south side of the Maitai River were based on the “Brook at Third House” rain gauge. Sub-catchments located on the north and east side of the Maitai River were based on the “Maitai at Forks” rain gauge. HIRDS data in Table 4-4 was used to determine the factor of proportionality between each of the sub-catchments and the relevant gauge.

The results of the analysis are shown in Table 4-5, and the factors can be applied to any of the storm events (e.g. 50% AEP, 5% AEP). For past storm events selected for model calibration, these factors were applied to the Brook and Forks rain gauge records to derive storm rainfall for each sub-catchment.

Table 4-5 Rainfall factors for calibration

	Rainfall factor	
	Brook Rain Gauge	Forks Rain Gauge
South Branch[1]	0.95	1.12
North Branch		1.17
Forks		1.00
North Bank		0.95
Neds	0.98	
Groom	0.79	
Sharland		0.97
Kaka West		0.84
Nelson South	0.63	
Brook	0.84	
Nelson East	0.66	
York	0.64	

[1]South Branch sub-catchment is midway between the Brook and Forks gauge, and therefore modelled rainfall is taken as the average of the two weighted gauges

4.4.2 Areal reduction factor

The rainfall depths presented in Table 4-4 above are point estimates for the depth of rainfall recorded at a particular coordinate. During any given storm event, there will be spatial as well as temporal variation in rainfall intensities. It is unlikely that peak intensities will be experienced at all points within a sub-catchment simultaneously. Thus, applying point rainfall data across a large area is likely to yield conservative (higher than actual) peak runoff flows and runoff volumes.

In order to compensate for this, it is best practice to apply an Areal Reduction Factor (ARF) to point rainfall depths before applying them across a large catchment. ARFs are a function of catchment area and storm duration. The shorter the storm duration and/or larger the catchment, the more significant (i.e. the lower) the ARF.

In previous modelling work, it was found that the critical storm duration in terms of flooding in the urban area is the 24 hour storm, with nested 2 hour duration storm intensity peaks. The total catchment of the Maitai River draining to the sea is 99.2 km² (refer Table 4-1).

A paper titled "The Frequency of High Intensity Rainfalls in New Zealand" in Part 1 of the Water and Soil Technical Publication No. 19, authored by A. I. Tomlinson in 1980 sets out recommended ARFs for a range of storm durations and catchment sizes. Given a storm duration of 24 hours and a total catchment size of 99.2 km², the appropriate ARF is given as 0.94. This factor has been applied to HIRDS v3 data to obtain 1% AEP design rainfall depths for each sub-catchment.

4.4.3 Design rainfall profiles

For the design scenarios it was assumed that the same return period event occurred across the catchment (e.g. when the 1% AEP event was occurring in the Groom sub-catchment, it was also occurring in the Sharland sub-catchment).

Design rainfall hyetographs were derived from HIRDS v3 data using the Chicago Storm method (Keifer and Chu, 1957). The method distributes the total storm depth into a series of nested events of shorter duration. A limit has been placed on the "peakiness" of the design hyetographs, to avoid modelling unrealistically peaky storm profiles. This has been achieved by ensuring that the peak intensity is no more than four times the average intensity. For the 24 hour event, this requires that the 2-hour intensity is the shortest-duration storm nested within the 24 hour hyetograph. The placement of this limit on peakiness is supported by:

- MOWD Civil Div. Publ. CDP705/B : Code of Practice for the Design of Bridge Waterways, which discusses the observation that "peak storm intensities can be expected to be about 3 times the average storm intensity". The rationale for not going to higher intensities is meteorological and that is the storm mechanism for producing long duration prolonged rainfalls is different to the weather systems causing short bursts of very high intensity rainfall, and so their inclusion could be inappropriate;
- Sensitivity modelling. The inclusion of nested ten minute peak intensities based on HIRDS v3 data produced flood extents similar to those modelled as above (no discernible difference in flood extents).

The design rainfall hyetographs for the present day, 2050 and 2090 1% AEP storms for the different catchments can be seen in Figures 4-1 to 4-3. Average temperatures are expected to rise by 0.9°C and 2.0°C by 2050 and 2090 respectively (Tables 2.2 and 2.3 in MfE, 2008). A corresponding rise in rainfall of 8% per degree Celsius is estimated (Table 5.2 in MfE, 2008). For the purposes of this study, rainfall estimates are calculated as being 8% and 16% higher than present day estimates for 2050 and 2100 respectively. The 1% AEP rainfall depths were varied across the catchment by the factors discussed in the previous section.

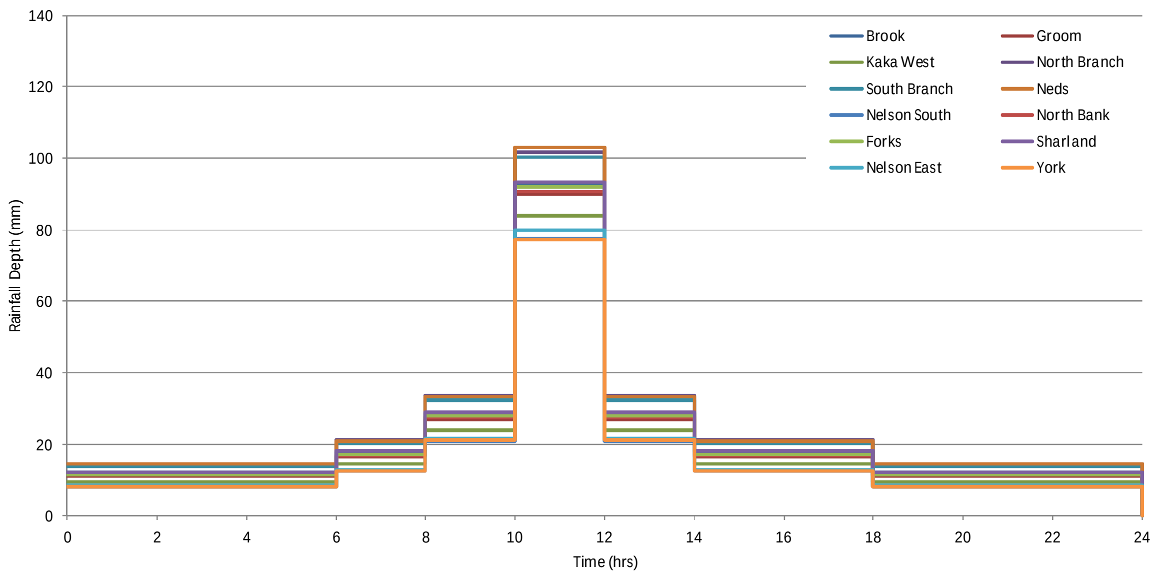

Figure 4-1 Design rainfall hyetograph – 1% AEP depths, present day

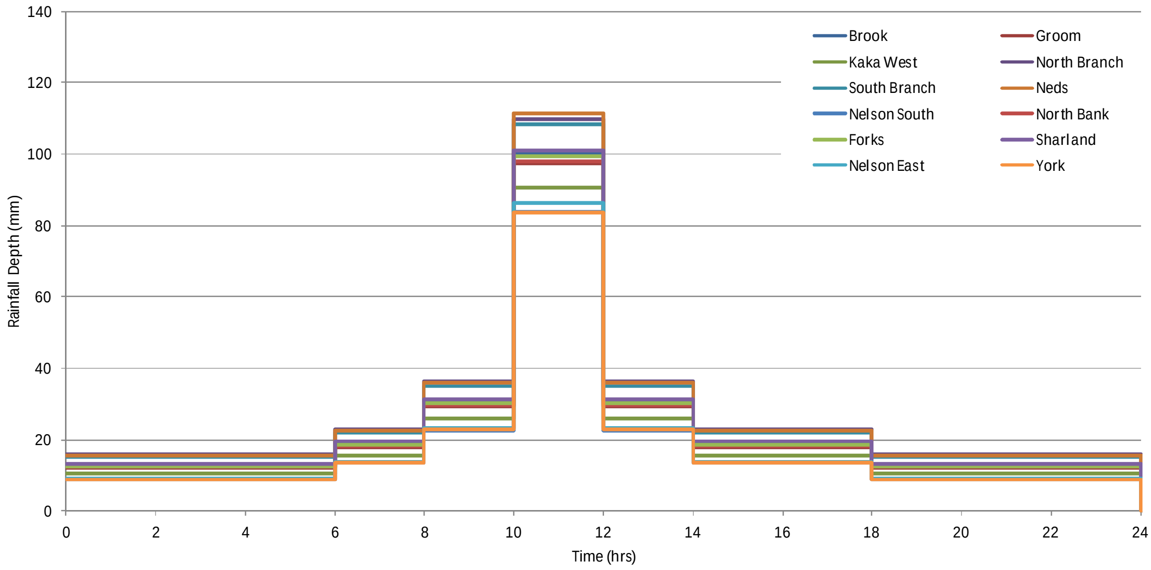

Figure 4-2 Design rainfall hyetograph – 1% AEP depths, 2050

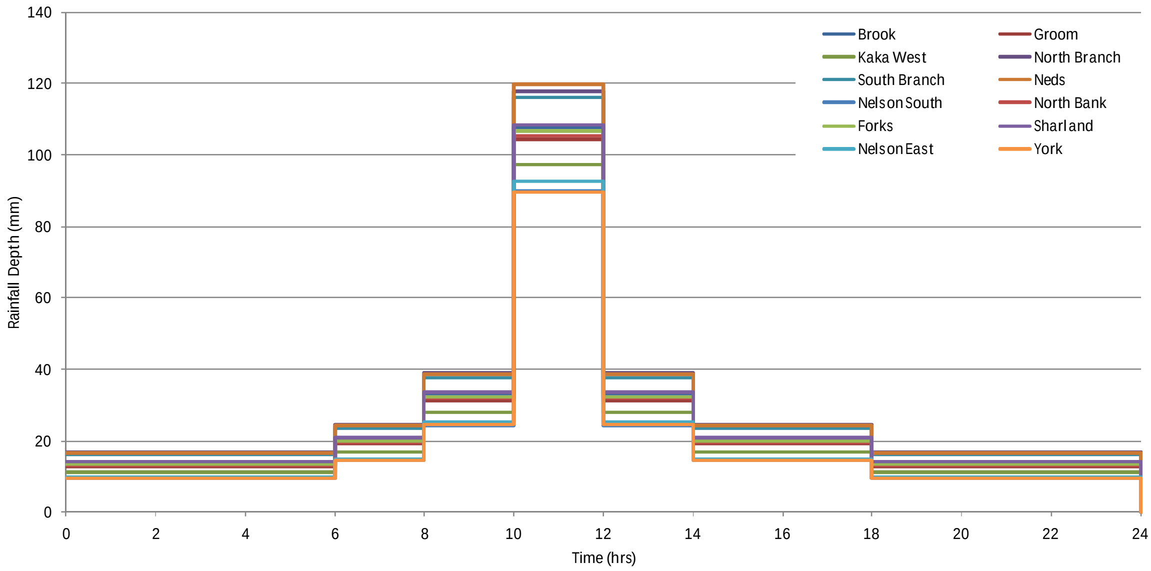

Figure 4-3 Design rainfall hyetograph – 1% AEP depths, 2100

5 Hydrological calibration and hydraulic validation

5.1 Overview

This section describes the model calibration and validation procedures that were carried out to ensure confidence in the model results. The calibration and validation analysis compare the results from the hydrological and hydraulic models with recorded flows and levels, where available. The only recorded storm for which there is flood level information available as well as stream flow and rainfall data was the recent December 2011 event. Therefore, this event has been used to calibrate the model with respect to flood levels within the urban area.

Where data is available, it is best practice to use one set of historic storms to calibrate a hydrological and hydraulic model, and a second set of (different) historic storms to validate the model. During the validation process, the sub-catchments would have their catchment parameters set to values determined during calibration. Observed rainfall and flow records would be run through the model, and resulting modelled flows checked against observed flow records.

5.2 Calibration methodology

The approach taken was to calibrate the hydrological and hydraulic models based on historical rainfall and flow records where available. The calibration process involved modifying hydrological and hydraulic parameters so that the flows predicted by the hydrological model reasonably simulate the flows recorded by gauges for a number of storm events. The catchment parameters required to achieve a good fit between modelled and recorded flows can vary from one historical event to the next, reflecting the variable nature of the catchment and storm event over time and space (e.g. ground cover changes at different times of the year, and temporal and spatial variability in rainfall, as well as antecedent moisture, are different for each storm event).

Flow gauges located in the Maitai catchment are listed in Table 5-1 and are shown in Figure A6.

Table 5-1 Flow gauge details

Flow gauge	Site start date	Elevation	Upstream catchment area	Location (NZTM)
Maitai South at Old Intake	May 1995	RL 160m	18.1 km^2	1630892, 5427697
Maitai at Forks	March 1997	RL 120m	33.1 km^2	1630618, 5428932
Maitai at Girlies	April 1990	RL 20m	71.8 km^2	1624420, 5430930
Maitai at Avon Terrace	November 2004	RL 20m	91.1km^2	1624740, 5430521

The level and method of calibration is dependent on location of the sub-catchment relative to the location of the flow gauge and availability of the rainfall and flow records. A summary of the hydrological sub-catchments and calibration details are provided in Table 5-2.

Table 5-2 Hydrological calibration details

Sub-catchment	Area (km^2)	Calibration	Comment
South Branch	18.1	Yes	Hydrological calibration based on flows recorded at "Maitai South at Old Intake" flow gauge.
North Branch	13.4	No	Flows from the Maitai Dam are affected by the reservoir level at the storm onset which depends on a range of factors including operational decisions on water supply in the period leading up to the storm.
Forks	1.6	No	No flow records available.
North Bank	5.1	Yes	Hydrological model and hydraulic model calibration based on "Avon Terrace" flow gauge. Recorded flows used to represent the North Branch, South Branch and Forks sub-catchments. Flood routing represented in the Mike11 hydraulic model. These catchments were calibrated conjunctively, i.e. individual calibration of these sub-catchments could not be carried out.
Neds	6.8	Yes	
Groom	7.1	Yes	
Sharland	15.7	Yes	
Kaka West	3.9	Yes	
Brook	17.1	Yes	
Nelson South	1.8	No	No flow records available.
Nelson East	1.2	No	No flow records available.
York	7.4	No	No flow records available.

Where there was insufficient data to calibrate the sub-catchments, an estimate of the hydrological parameters was made, based on the hydrological parameters from adjacent calibrated sub-catchments (see Section 5.5).

5.3 Calibration event selection

Flow gauge data was analysed to identify the largest recorded flow events. The hydrological gauging period (rainfall and flow data), and the results of the flood frequency analysis for the largest 14 storm events for each of the sites are provided in Appendix B.

A summary of the storm events considered for calibration is provided in Table 5-3. These storms were identified as the largest events in the region from an analysis of the flow gauge records. In order to produce reliable estimates for events with low Annual Exceedance Probabilities (AEPs), it is desirable to use gauge data collected over a long period of time.

Table 5-3 Hydrological calibration details

Storm Event date	Storm event rank			Indicative Annual Exceedance Probability	Used for calibration	Comment
	Matai South at Old Intake	Maitai at Forks	Maitai at Avon Terrace			
23 Feb 1995	No record	No record	No record	3% AEP flow at Girlies Hole[1]	No	No rainfall records at Maitai at Forks, and no reliable flow record.
23 February 1998	1	5	No record	3% AEP flow at Old Intake	No	Major flooding in South Branch only

Storm Event date	Storm event rank			Indicative Annual Exceedance Probability	Used for calibration	Comment
	Matai South at Old Intake	Maitai at Forks	Maitai at Avon Terrace			
1 July 1998	No record	1	No record	20-30% AEP flow at Girlies Hole[1]	No	Low return period flows only identified in upstream sub-catchments.
9 October 1998	2	3	No record	7% AEP flow at Girlies Hole[1]	Yes (South Branch only)	No rainfall records at Maitai at Forks
30 January 2000	5	6	No record	15-20% AEP flow at Forks and Old Intake	No	Modest return period flows identified in upstream sub-catchments only
29 June 2003	7	11	No record	15-20% AEP flow at Girlies Hole[1]	No	Large storm event over entire catchment. Avon Tce gauge not operating
24 November 2008	4	4	2	15-20% AEP flow at Avon Terrace	Yes	Large storm event over entire catchment
30 September 2010	11	8	3	30% AEP flow at Avon Terrace	Yes	Moderate storm event over entire catchment
28 December 2010	3	2	4	30-50% AEP flow at Avon Terrace	Yes	Moderate storm event over entire catchment
26 May 2011	12	9	5	30-50% AEP flow at Avon Terrace	Yes	Moderate storm event over entire catchment
14 December 2011	14	10	1	7-10% AEP flow at Avon Tce, 1% AEP 48hr rainfall in Brook catchment	Yes (flow and levels in urban area)	Large storm event over entire catchment, especially the Brook catchment. Only storm for which flood level data is available.

1 Note that the Girlies Hole flow gauge was discovered in 2012 to be over-estimating flows, and hence reported return periods are indicative only

Peak flows for the flow events selected for flow calibration are summarised below in Table 5-4.

Table 5-4 Calibration storm events

Event start date	Peak flow (m^3/s)		
	Maitai South at Old Intake	Maitai at Forks	Maitai at Avon Terrace
9/10/1998	51.8	120.8	No record
24/11/2008	48.5	116.0	185.1
30/09/2010	39.0	95.4	159.5
28/12/2010	50.4	121.9	149.3
26/05/2011	38.6	91.7	145.7
14/12/2011	36.8	90.0	235.0

5.4 Calibration parameters

Model calibration was carried out by adjusting hydrological and hydraulic parameters below:

- The SCS Curve Number (CN) is an empirical parameter used for modelling and predicting the proportion of direct runoff or infiltration from a pattern of rainfall. The curve number method was developed by the USDA Natural Resources Conservation Service, which was formerly called the Soil Conservation Service or SCS. The CN value controls the total volume of runoff during a storm event. For the purposes of calibration, the CN value was varied until modelled storm runoff volume matched observed runoff volume. An initial abstraction ratio of 0.2 was assumed, as per the SCS guidelines (SCS, 1986). i.e. Initial abstractions were assumed to be 20% of the Soil Storage parameter (S), which is a function of CN.
- Time of concentration was considered as a calibration parameter. As a starting point, the times of concentration were estimated based on the TP108 method outlined in Section 4.3. These values were found to represent the catchments adequately without adjustment.
- The Storage Coefficient in the Clark Unit Hydrograph Method for each catchment was then varied for each catchment to achieve an acceptable match between observed and modelled peak flows. A catchment's storage coefficient (units of time) is a measure of how "peaky" a catchment's runoff response is to a given rainfall event.
- Hydrological model calibration was carried out where possible using the two rainfall gauges identified in Table 4-4. However, due to spatial variation in rainfall in the Maitai Valley, we developed a methodology for varying rainfall across the catchment. The methodology is discussed in Section 4.4.
- Manning's "n" was used as a calibration parameter within the modelled cross sections during the calibration process. As a starting point, Manning's "n" values were adopted from the Worseldine & Wells, 1994 report. This report discretised the river into eleven reaches, and provided estimates for Manning's "n" in the main channel and overbank for each reach. The calibration process confirmed that these values provided a good match between modelled and observed flow levels and timings.
- Baseflow parameters were adjusted to achieve a similar flood recession curve in the calibration results to that observed during the December 2011 event. A recession constant of 0.1 and a threshold ratio to peak of 0.5 was found to represent the recession curve well for the December 2011 event, and reasonably well for other events. An initial discharge for each sub-catchment was found by apportioning the mean river flow at the Avon Terrace gauge by sub-catchment area.

5.5 Hydrological calibration results

In this section the results of the hydrological model calibration for the Maitai catchments are discussed, and the hydrological model parameters selected. The calibration results are discussed in three sections:

- Maitai sub-catchments upstream from "Maitai at Forks"
- Maitai sub-catchments upstream from "Maitai at Avon Tce"
- Maitai sub-catchments downstream from "Maitai at Avon Tce"

Results for all sub-catchments are summarised in Tables 5-5 and 5-6 below.

5.5.1 Upstream of "Maitai at Forks" flow gauge

There are three sub-catchments upstream of Maitai at Forks:

- Forks
- North Branch
- South Branch

The South Branch was calibrated against the "Maitai South at Old Intake" gauge. Calibration of the Forks and North Branch sub-catchment flows was then carried out using the "Maitai at Forks" flow gauge records.

The results of the model calibration for the South Branch are shown in Appendix C, Figures C1a to C1c. The results of the model calibration for the North Branch and Forks sub-catchments are shown in Appendix C, Figures C2a to C2c.

There was significant variation in catchment parameters (especially CN) required to achieve calibration of these catchments to the calibration storms (refer Table 5-6). This is likely a result of the actual spatial distribution of rainfall across these sub-catchments being different to the assumed distribution as well as differences in antecedent catchment moisture. The modelled distribution is based on factored translations of the storm profile captured at the rain gauges (refer Section 4.4.1).

The effect of these differences is significant in terms of predicted flood characteristics in the upper reach of the river, but not as significant in the downstream reaches, including the Nelson urban area which is the focus of this study.

Final CN values for these sub-catchments have been derived by averaging calibrated CN values across the calibration storm events. The October 1998 and December 2011 CN storm events were excluded as as outliers for the upper catchments (refer Table 5-6).

5.5.2 Upstream of "Maitai at Avon Tce" flow gauge

There are six sub-catchments between the Maitai at Forks and Maitai at Avon Terrace gauges:

- North Bank
- Neds
- Groom
- Sharland
- Kaka West
- Brook

These catchments cannot be calibrated individually given the location of the existing flow gauges. However their combined flow contribution was calibrated based on the recorded flows at the Maitai at Avon Terrace gauge.

The relative rainfall for each catchment was related back to observed rainfall at the "Matai at Forks" and "Brook at Third House" rain gauges. The rainfall relationship for each catchment was established in Table 4-4.

Rainfall hyetographs for sub-catchments Neds and Groom were based on the "Brook at Third House" rain gauge. Similarly, rainfall hyetographs for sub-catchments North Bank, Sharland and Kaka West were based on "Maitai at Forks" rain gauge, as shown in Table 4-4.

The resulting calibration parameters are summarised in Tables 5-5 and 5-6 below.

Hydrographs of the model results using the calibrated parameters can be seen in Appendix C, Figures C3a to C3b. The modelled flows are compared with recorded flows at the Maitai at Avon Terrace flow gauge.

A final CN value of 62 has been adopted for these sub-catchments, after considering the average and range of the calibration CN values. More weight has been given to the calibration values derived from the largest storm on record at Avon Terrace (December 2011). The resulting modelled December 2011 flow at Avon Terrace (refer Figure C3b) shows a good match of peak flows and general hydrograph shape to observed data.

Storage coefficients equal to 2.5 times the time of concentration for these sub-catchments were generally found to produce peak flows at Girlies and Avon Terrace that matched the observed data. The exception to this was the Brook sub-catchment, for which a lower storage coefficient (i.e. higher peak flow) was considered appropriate. The basis for this was comparison of the modelled present day 1% AEP peak flow with values derived for recent development within the Brook sub-catchment. It was found that a storage coefficient 1.2 times the time of concentration fitted the peak flow estimates from recent developments, and this value was selected for the model. NCC and TDC are currently in the process of installing a flow gauge in the Brook sub-catchment. It is recommended that the catchment parameters for the Brook sub-catchment be re-assessed once the new gauge has recorded results from a significant storm event.

There is good agreement between the calibrated storage coefficients and those published in the relevant literature. For example, Russell, Kenning and Sunnell (1979) recommend adopting a linear relationship between time of concentration and storage coefficients, with a factor of proportionality between 1.5 and 2.8 for rural catchments.

5.5.3 Downstream of "Maitai at Avon Tce" flow gauge

There are no appropriately located flow gauges with which to calibrate the Nelson South, Nelson East and York catchments. Best-estimate parameters, including reference to other calibrated sub-catchment parameters, have been adopted for this sub-catchment. Storage coefficients of 2 times the time of concentration have been used for the Nelson East and Nelson South sub-catchments. A longer storage coefficient of 6 hrs has been selected for the York sub-catchment, to account for the effects of the York detention dam.

5.6 Calibration summary

Table 5-5 Calibrated catchment parameters (1 of 2)

	Rainfall method (Factor x gauge)	Transform method	Time of Concentration (hrs)	Storage coefficient (hrs)
South Branch	Average between 0.95 x Brook and 1.12 x Forks	Clark UH	1.5	3.0
North Branch	1.17 x Forks	Clark UH	1.23	0.5
Forks	1 x Forks	Clark UH	0.62	1.24
North Bank	0.95x Forks	Clark UH	0.62	1.55
Neds	0.98 x Brook	Clark UH	0.77	1.93
Groom	0.79 x Brook	Clark UH	1.03	2.58
Sharland	0.97 x Forks	Clark UH	1.88	4.70
Kaka West	0.84 x Forks	Clark UH	1.06	2.65
Nelson South	0.63 x Brook	Clark UH	0.56	1.12
Brook	0.84 x Brook	Clark UH	2.67	3.2
Nelson East	0.66 x Brook	Clark UH	0.43	0.86
York	0.64 x Brook	Clark UH	1.44	6[1]

[1]High storage coefficient estimate to represent effect of an un-modelled detention dam and the effects of known significant urban flooding issues within this sub-catchment. Actual attenuation characteristics of this sub-catchment should be refined during later stages of urban modelling.

Table 5-6 Calibrated catchment parameters (2 of 2)

Catchment	Oct-98	Nov-08	Sep-10	Dec-10	May-11	Dec-11	*Average*	*Selected*
South Branch	55	75	77	87	79	51	*71*	*77*[1]
North Branch (incl. dam)	No data available	74	72	90	68	97	*80*	*77*[1]
Forks		74	72	90	68	97	*80*	*77*[1]
North Bank	No data available	57	No data available	60	58	74	*62*	*62*
Neds		57		60	58	74	*62*	*62*
Groom		57		60	58	74	*62*	*62*
Sharland		57		60	58	74	*62*	*62*
Kaka West		57		60	58	74	*62*	*62*
Brook		57		60	58	74	*62*	*62*

[1]Oct 1998 and Dec 2011 values considered to be outliers and ignored in the selection process. The selected CN value of 77 is an average of the calibration CN values for the remaining 4 storms across the upper 3 sub-catchments.

Selected curve numbers were compared with tabulated values in the published literature. The United States Department of Agriculture Natural Resources Conservation Service (USDA NRCS) Technical Release 55 (TR-55) tabulates curve numbers for a range of land cover and soil types. Depending on soil classification, for forested catchments protected from grazing and adequate litter and brush cover, the published curve numbers range between 30 and 77 (refer Table 5-7 below). While there are no published local guidelines for estimating the CN values across the sub-catchments, the selected values fall within the expected range, and have therefore been considered appropriate for runoff modelling.

Table 5-7 Published curve numbers from TR-55, Table 2-2c

	Hydrological Soil Group			
Cover Type	A	B	C	D
Forested catchments with good hydrologic condition (protected from grazing, and litter and brush adequately cover the soil)	30	55	70	77

5.7 Hydraulic model validation

5.7.1 Methodology

In the absence of a flow record in the urban area with a gauging period long enough to capture the required number of significant storm events, this study has used the same set of storms for both hydrological calibration and hydraulic validation. We recommend that the model be validated against at least two significant future storm events once data becomes available.

5.7.2 Hydraulic validation of modelled peak flows

The flood hydrographs resulting from fixing calibration parameters to final selected values and re-running the historic storms through the model are shown in Appendix C. Validation hydrographs are shown in green for each storm event and gauge location.

The results show significant variation in the upper reaches, most likely from inaccurate representation of the spatial rainfall distribution across the larger and more mountainous sub-catchments and in the antecedent moisture. However, Figures C3a through C4b show a good match between modelled and observed flows in terms of peak values and hydrograph shape the urban area.

5.7.3 Hydraulic validation of modelled peak flood levels

During the 14 December 2011 rainfall event, as well as event data being captured by hydrological gauges, flood level observations were made manually at key locations throughout the city. The observations consisted of a series of photographs of flood waters against fixed benchmarks such as bridge abutments, park benches, footpaths and tree trunks. After the storm, various debris lines on either river bank were used to verify peak water level estimates. These were later surveyed to obtain point estimates of flood levels.

The photos were taken approximately 1 hour prior to the peak of the storm hydrograph, when flood levels were within approximately 100 mm of the storm peak along the assessed section of the river. Debris lines have been used where available as 'true' peak flood levels.

The rainfall data recorded at the Third House rainfall gauge during the rainfall event was applied in weighted form to the modelled sub-catchments, and the modelled urban flood levels compared with the observed levels. As a secondary check, the model was applied downstream of the Maitai @ Avon Tce flow gauge, using this gauge's December 2011 flow record as the input hydrograph to check peak flows and flood levels. The two approaches produced similar peak flows and flood levels.

The results are summarised in Figure 5-2 below, and show an excellent match between modelled and observed flood levels in the December 2011 event.

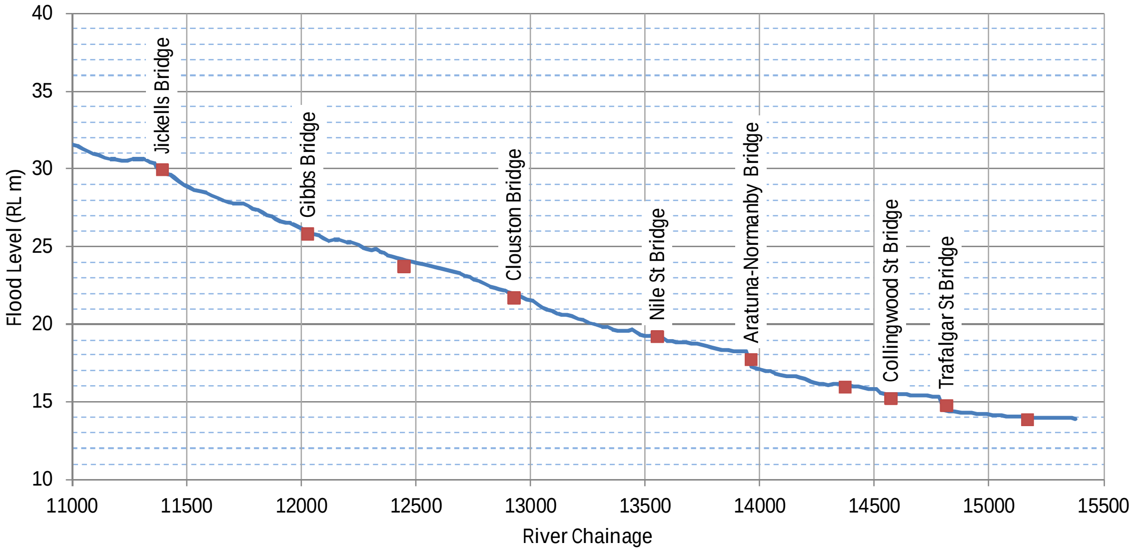

Figure 5-2 Modelled vs. observed flood levels during the December 2011 event

Table 5-8 Observed vs. modelled flood levels

Chainage	Flood Levels (RL m)		Difference (m)
	Observed	Modelled	
11390	29.98	29.82	-0.16
12025	25.85	25.99	0.14
12445	23.75	24.18	0.43
12925	21.74	21.96	0.22
13550	19.23	19.31	0.08
13960	17.75	17.60	-0.15
14370	15.98	16.09	0.10
14570	15.26	15.50	0.24
14812	14.81	14.47	-0.34
15166	13.90	14.03	-0.13

[1]Flood level observation taken at bridge structure, and may be affected by localised effects including debris accumulation and eddies.

The December 2011 event produced flood levels that were generally and approximately 300 mm from the top of the channel banks. If larger flows were modelled (e.g. the 1% AEP event), the majority of the extra flow would spill out of the main channel and discharge across the floodplain. Therefore, there is good basis for being confident that a Manning's "n" values adopted for the model is appropriate for full-channel flow.

6 1% AEP design flood extent

6.1 Overview

This section provides the results of the flood hazard mapping for the 1% AEP design storm. The inflows to the hydraulic model were determined from the hydrological model and the flood extents were determined using the hydraulic model.

A secondary but significant outcome of the modelling exercise has been to highlight the flooding issues that will arise purely as a result of anticipated sea level rise. Using existing LiDAR data and current sea level rise estimates, Nelson city can expect significant flooding across the lower portion of the urban area purely as a result of the estimated 100% AEP high tide in the year 2100. This flooding scenario is presented in Figure D6 in Appendix D.

6.2 1% AEP design flows

During previous modelling, storm event durations of 6 hours, 12 hours, 24 hours and 48 hours were assessed to determine the critical event duration that causes the worst case flood extents around Nelson. The 24-hour event with nested 2 hour rainfall depths was assessed to be the critical storm in terms of flooding in the urban area. Therefore, the 24-hour storm event (refer to Section 4.4.3 Figures 4-1 to 4-3) was used to determine design flows for the 1% AEP design storm event using the calibrated hydrological model.

The storm events were assessed for five different downstream water levels as described in Section 3.4.2.

The peak flows from the sub-catchments can be seen in Table 6-1 for the modelled design storm events.

Table 6-1 Summary of peak sub-catchment flows

Catchment	1% AEP peak flow (m^3/s)		
	Present day	2050	2100
South Branch	118.8	130.8	143.0
North Branch (via dam)	137.2	149.6	188.9
Forks	15.7	17.3	18.8
North Bank	29.5	33.5	37.4
Neds	44.7	50.3	55.9
Groom	30.3	34.4	38.7
Sharland	47.7	54.3	61.0
Kaka West	13.8	15.8	17.8
Brook	65.9	74.8	83.7
Nelson South	17.3	18.7	20.1
Nelson East	12.7	13.8	14.8
York	29.0	31.4	33.9

The results for each of the flood hazard mapping scenarios shown can be seen in Figures D1 to D5. Table 6-2 provides a summary of the scenario for each of the figures. It is important to note that these figures do not represent a snapshot in time during the storm, but a maximum flooding depth for each modelled grid cell from the duration of the modelled storm event.

Table 6-2 Summary of model application figures

Figure	Year	Rainfall	Tidal boundary
Figure D1	2013	1% AEP, present day	Present day 100% AEP sea level, RL 14.43 m
Figure D2	2050	1% AEP, present day +8%	100% AEP sea level + 0.3 m sea level rise, RL 14.73 m
Figure D3	2050	1% AEP, present day +8%	100% AEP sea level + 0.5 m sea level rise, RL 14.93 m
Figure D4	2100	1% AEP, present day +16%	100% AEP sea level + 0.8 m sea level rise, RL 15.23 m
Figure D5	2100	1% AEP, present day +16%	100% AEP sea level + 1.0 m sea level rise, RL 15.43 m
Figure D6	2100	Sunny day	100% AEP sea level + 1.0 m sea level rise, RL 15.43 m

7 Dambreak flood extent

7.1 Overview

Owners of large dams are required under the NZSOLD Guidelines and Building (Dam Safety) Regulations 2008 to carry out a potential impact assessment of their dams to determine the likely consequences in the event of a dam failure. Furthermore, a dambreak analysis can be construed as a requirement under the Resource Management Act to consider effects of low probability but high potential impact.

Dambreak analyses are undertaken within the dam industry primarily to assess downstream hazard potential, which in turn guides the setting of standards to adopt for dam design, construction and operation, and the development of an Emergency Action Plan. The analyses are hypothetical and entirely divorced from the chances of a dam failure ever occurring. The current study has not been instigated out of any particular concern for the integrity of the Maitai Dam.

7.2 Dambreak assessment

The dambreak assessment was carried out using a dambreak hydrograph to represent the uncontrolled flow from the dam in the event of a dambreak. The dambreak hydrograph was applied at the upstream boundary of the hydraulic model detailed in this report. The hydraulic model was used to assess the flood extents for the dam breach hydrographs.

7.2.1 Dambreak hydrograph

The T&T (2005) dam break investigation assessed the potential modes of failure, the speed at which a potential breach develops and the final size, shape and invert level of the breach through the dam embankment. Based on an assessment of these breach parameters, three dambreak hydrographs were developed to represent failure times of 0.5 hours, 1 hour and 2 hours. The dam breach hydrographs have been reproduced in Figure 7-1. Refer to the T&T 2005 report for more information on potential modes of failure.

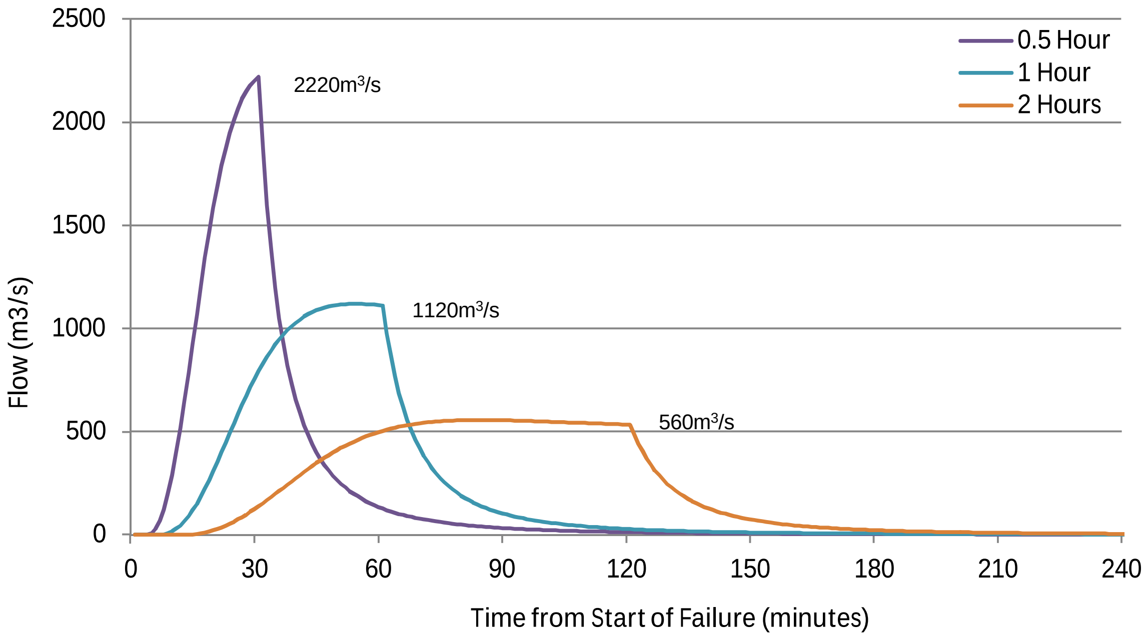

Figure 7-1 Dambreak hydrograph for Maitai dam for T_f=0.5, 1 and 2 hours (reproduced from T&T, 2005)

By way of comparison, it is noted that the peak present day 1% AEP flow into the city immediately below the confluence with Brook Stream is approximately 472m³/s. Note that this is a comparison of peak dambreak flows at the dam breach location with peak 1% AEP flows within the city. Peak dambreak flows in the Maitai River below the confluence with Brook Stream would be lower.

7.2.2 Flood extents

The flood extents for the dam break flow hydrographs shown in Figure 7-1 are presented in Figures E1 to E3.

As would be expected given the modelled peak flows, the flooding depths and extents for all dambreak scenarios are more severe than for the modelled 1% AEP event. Flooding extents for the 30 and 60 minute dambreak scenarios are very similar. The 120 minute dambreak scenario produces less flooding in the urban area, most notably in the vicinity of Neale Park which is inundated during the 30 and 60 minute events, but largely dry during the 120 minute event. There is also a section of the residential area in the Wood that is inundated during the 30 and 60 minute events but not in the 120 minute event. This section runs along the true right bank of the river, between the Brook Stream confluence and Halifax Street, and includes an island of relatively higher ground between Halifax Street and Cambria Street.

8 Recommended further assessment

8.1 Existing model

We note that NCC and TDC are currently working together to install an additional flow gauge in the city reach of the Brook Stream. Once this gauge has been installed, it will assist with developing calibrated catchment parameters for the Brook sub-catchment.

It is recommended that gauge data from the next two significant flow events are used as validation events for the current model, to confirm selected parameters.

8.2 Model extension

We understand that NCC is interested in extending the model to include modelling of the Brook and York watercourses within the urban environment. This can be achieved easily within the existing modelling framework, and would enable mapping of flooding extents to extend further upstream along both of these tributaries on the Maitai River.

In addition, the city's primary (reticulated) stormwater network could be added to the model. However, we note that this would require a significant survey brief to first identify and then fill gaps in NCC's existing GIS database with respect to the piped stormwater network.

9 References

1. T&T 2012; Maitai River Flood Hazard Mapping: Modelling Report
2. USDA (United States Department of Agriculture) 2007; National Engineering Handbook, Part 630 Hydrology. Chapter 16.
3. SCS, 1986; "Urban Hydrology for Small Watersheds", Technical Release No. 55, U.S. Department of Agriculture, Soil Conservation Service, 2nd ed., June 1986.
4. T&T, 2005; Maitai Water Supply Dam – Dam Break Study Review.
5. Worseldine & Wells Ltd., T&T and Sissons & Conway Ltd; July 1994. Maitai River Waterway Upgrading Investigation.
6. NIWA, August 2009; Review of Nelson City minimum ground level requirements in relation to coastal inundation and sea-level rise.
7. Keifer, C.J., and H. H. Chu, 1957; Vol. 83, (HY4) 1-25, ASCE Journal of the Hydraulics Division, Synthetic storm pattern for drainage design.
8. Tomlinson, A.I., 1980, Water and Soil Technical Publication No. 19, The Frequency of High Intensity Rainfalls in New Zealand, Part 1.
9. MfE, 2008: "Climate change effects and impacts assessment, a manual for local government in New Zealand, 2nd edition". Available from http://www.mfe.govt.nz/publications/climate/climate-change-effect-impacts-assessments-may08
10. Russell, Kenning and Sunnell, 1979, "Estimating Design Flows for Urban Drainage", Journal Hydraulics Division, American Society of Civil Engineers, Vol 105, No. HY1, pp 43-52.

10 Applicability

This report has been prepared for the benefit of Nelson City Council with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose without our prior review and agreement.

Tonkin & Taylor Ltd

Environmental and Engineering Consultants

Report prepared by:	Authorised for Tonkin & Taylor Ltd by:
....	....
Damian Velluppillai	Mark Foley
Water Resources Engineer	Project Director

Reviewed by:

pp ....

Jon Rix

Senior Water Resources Engineer

DNV

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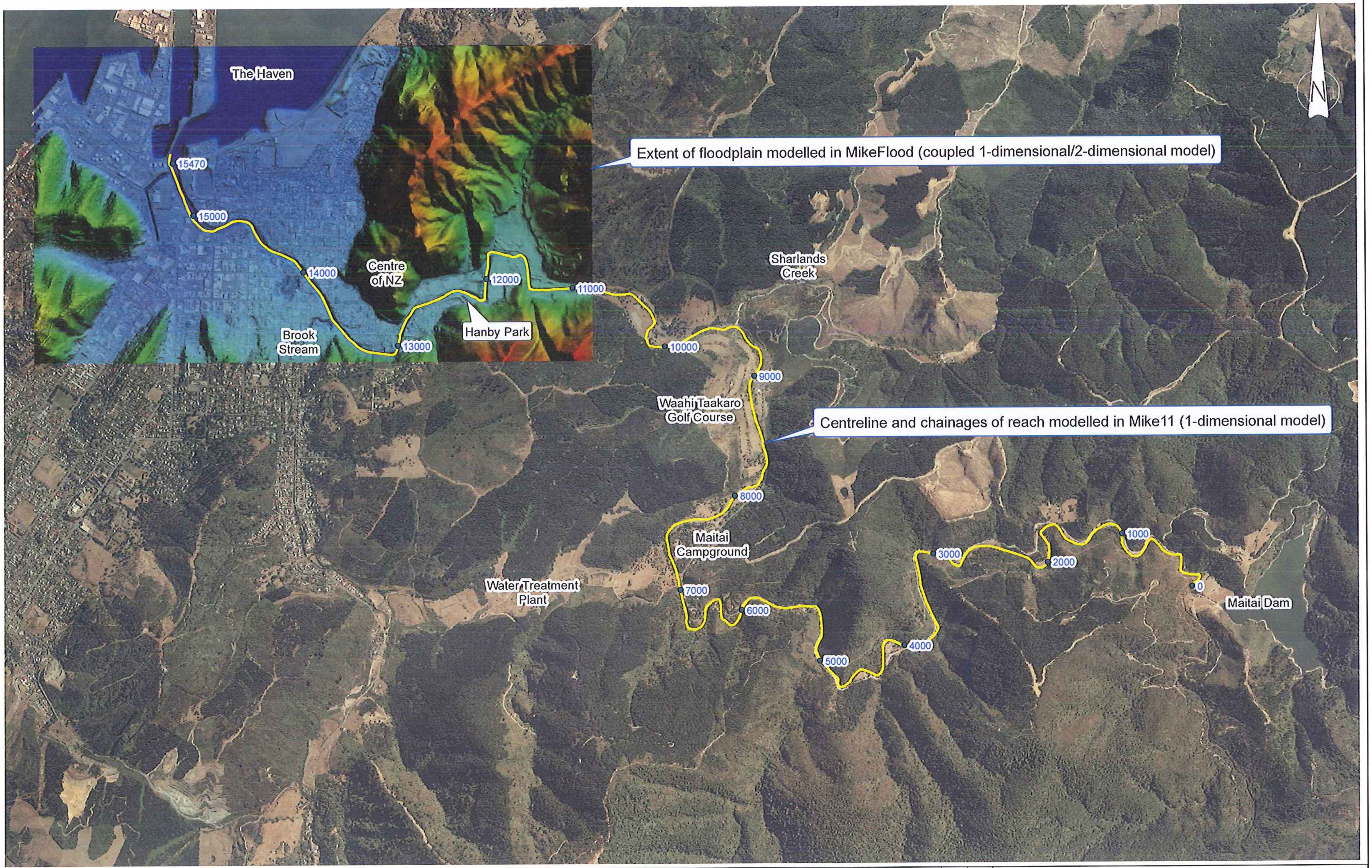
Appendix A: Figures – Model Build

- Figure A1 Modelled area overview
- Figure A2 Modelled cross sections – Sheet 1 of 4
- Figure A3 Modelled cross sections – Sheet 2 of 4
- Figure A4 Modelled cross sections – Sheet 3 of 4
- Figure A5 Modelled cross sections – Sheet 4 of 4
- Figure A6 Catchments and recording gauges



Notes:

A3 SCALE 1:25,000

0 0.3 0.6 0.9 1.2 1.5 (km)

Nelson City Council
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APPROVED		6/8/13
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PROJECT No.	870888	

NELSON CITY COUNCIL
MAITAI RIVER FLOOD MODELLING
Hydraulic Modelling
Modelled area overview

FIGURE No. Figure A1 — Rev. 1

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Notes:

A3 SCALE 1:7,500

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Location Plan

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DRAWN	DNV	Feb.11
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APPROVED	J	6.8.13

ARCFILE Figure A2.mxd

SCALE (AT A3 SIZE) 1:7,500

PROJECT No. 870888

NELSON CITY COUNCIL
MAITAI RIVER FLOOD MODELLING
Hydraulic Modelling
Modelled Cross Sections - Sheet 1 of 4

FIGURE No. Figure A2

Rev. 1

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Notes:

A3 SCALE 1:7,500

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PROJECT No. 870888		

NELSON CITY COUNCIL
MAITAI RIVER FLOOD MODELLING
Hydraulic Modelling
Modelled Cross Sections - Sheet 2 of 4

FIGURE No. Figure A3

Rev. 1

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Notes:

A3 SCALE 1:7,500

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PROJECT No. 870888		

NELSON CITY COUNCIL
MAITAI RIVER FLOOD MODELLING
Hydraulic Modelling
Modelled Cross Sections - Sheet 3 of 4

FIGURE No. Figure A4 Rev. 1

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P:\870888\WorkingMaterial\Report Figures\Figure A5.mxd

Notes:

A3 SCALE 1:7,500

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Location Plan

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DRAWN	DNV	Feb.11
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APPROVED	JJ	6.8.13
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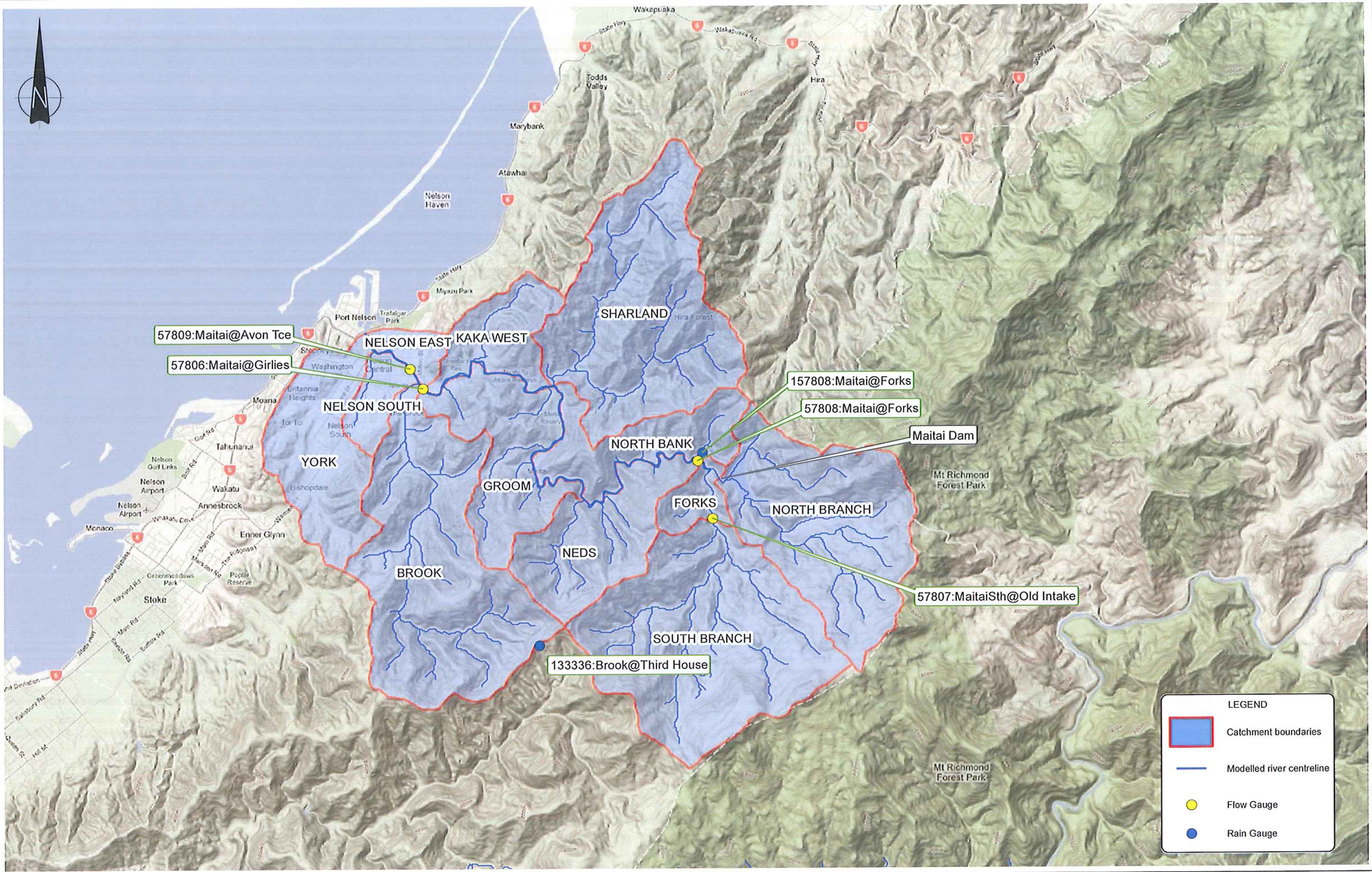
SCALE (AT A3 SIZE)	1:7,500	
PROJECT No.	870888	

NELSON CITY COUNCIL
MAITAI RIVER FLOOD MODELLING
Hydraulic Modelling
Modelled Cross Sections - Sheet 4 of 4

FIGURE No. Figure A5

Rev. 1



Notes:

A3 SCALE 1:75,000

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DRAWN	DNV	Feb.11
CHECKED	DCL	6.8.13
APPROVED	Y	6.8.13

ARCFILE Figure A6.mxd

SCALE (AT A3 SIZE) 1:75,000

PROJECT No. 870888

NELSON CITY COUNCIL
MAITAI RIVER FLOOD MODELLING
Hydrological Analysis
Catchments and recording gauges

FIGURE No. Figure A6

Rev. 1

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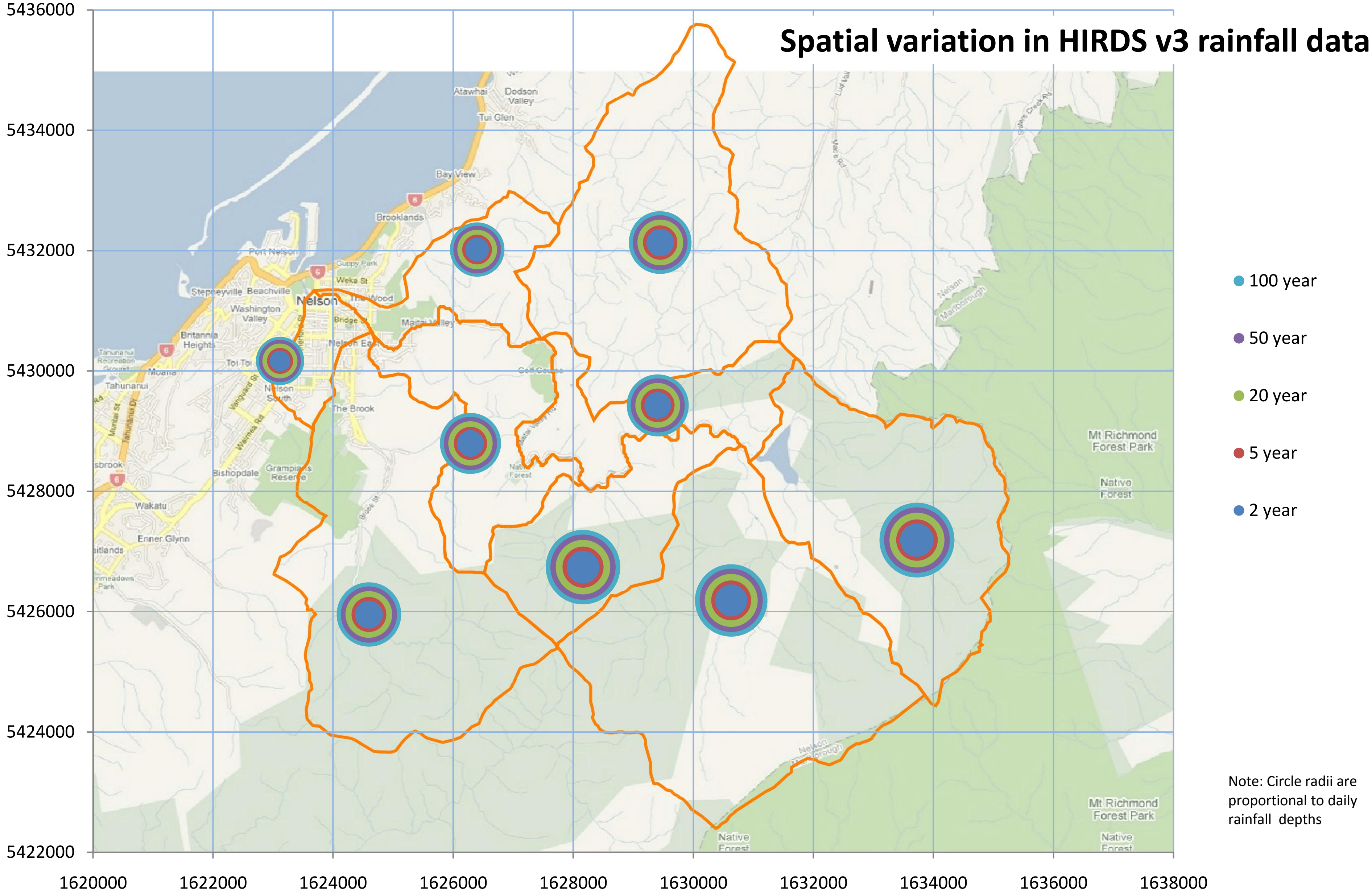
Appendix B: Flood frequency analysis



Spatial variation in HIRDS v3 rainfall data
5436000
5434000
5432000
5430000
5428000
5426000
5424000
5422000
1620000
1622000
1624000
1626000
1628000
1630000
1632000
1634000
1636000
1638000
100 year
50 year
20 year
5 year
2 year
Note: Circle radii are proportional to daily rainfall depths
Nelson
Port Nelson
Atawhai
Dodson Valley
Tui Glen
Bay View
Brooklands
Stepneyville
Beachville
Washington Valley
Britannia Heights
Toi Toi
Moana
Tahunanui
Nelson South
The Brook
Bishopdale
Grampians Reserve
Wakatu
Enner Glynn
Maitai Valley
The Wood
Golf Course
Mt Richmond Forest Park
Native Forest

Stream flow gauge #57806: Maitai @ Girlies Hole

Data received from TDC January 2013 Computed DNV 22/07/2013 P:\870888\WorkingMaterial\Hydrology\[Frequency Analysis v4 (updated Girles Hole).dcl-edited.xlsx]57806 Maitai at Girlies Hole

Raw Data from Tideda

Rank	Year	Mean	Coeff of Var	Maximum	Date
1	1986	No mean		325	25/01/1986 12:00
8	1990	5.1172		128.25	12/11/1990 7:35
11	1991	2.7979		100.43	24/01/1991 16:06
12	1992	3.9196		96.238	14/11/1992 21:39
16	1993	3.4111		79.582	15/05/1993 21:30
18	1994	3.8452		70.275	17/07/1994 16:42
2	1995	4.6299		294.28	23/02/1995 8:20
14	1996	1.9647		91.766	1/10/1996 22:53
22	1997	0.27808		26.359	26/08/1997 22:27
3	1998	4.3699		230.68	9/10/1998 4:35
10	2001	3.0423		118.11	3/12/2001 4:15
20	2002	2.9991		45.346	15/01/2002 6:15
7	2003	2.753		144.01	29/06/2003 17:52
13	2004	3.8954		94.108	1/02/2004 20:59
21	2005	1.6186		32.134	11/02/2005 20:30
17	2006	2.2287		75.852	18/11/2006 5:30
19	2007	2.6529		47.544	18/12/2007 15:30
5	2008	5.1303		176.68	24/11/2008 19:15
15	2009	2.5507		88.231	11/09/2009 16:30
6	2010	3.6363		156.36	30/09/2010 9:30
4	2011	4.3239		200	14/12/2011 20:00
9	2012	3.5		126.67	15/07/2012 8:15

Ranked Data

Rank	Year	Mean	Coeff of Var	Maximum	Date
1	1986	No mean		325	25/01/1986 12:00
2	1995	4.6299		294.28	23/02/1995 8:20
3	1998	4.3699		230.68	9/10/1998 4:35
4	2011	4.3239		200	14/12/2011 20:00
5	2008	5.1303		176.68	24/11/2008 19:15
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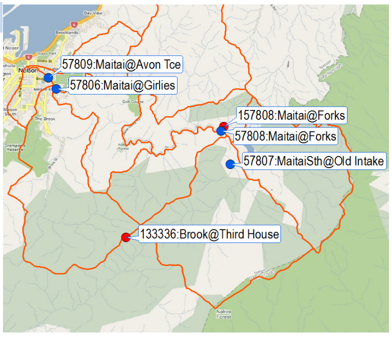
7	2003	2.753		144.01	29/06/2003 17:52
8	1990	5.1172		128.25	12/11/1990 7:35
9	2012	3.5		126.67	15/07/2012 8:15
10	2001	3.0423		118.11	3/12/2001 4:15
11	1991	2.7979		100.43	24/01/1991 16:06
12	1992	3.9196		96.238	14/11/1992 21:39
13	2004	3.8954		94.108	1/02/2004 20:59
14	1996	1.9647		91.766	1/10/1996 22:53
15	2009	2.5507		88.231	11/09/2009 16:30
16	1993	3.4111		79.582	15/05/1993 21:30
17	2006	2.2287		75.852	18/11/2006 5:30
18	1994	3.8452		70.275	17/07/1994 16:42
19	2007	2.6529		47.544	18/12/2007 15:30
20	2002	2.9991		45.346	15/01/2002 6:15
21	2005	1.6186		32.134	11/02/2005 20:30
22	1997	0.27808		26.359	26/08/1997 22:27



Frequency Analysis

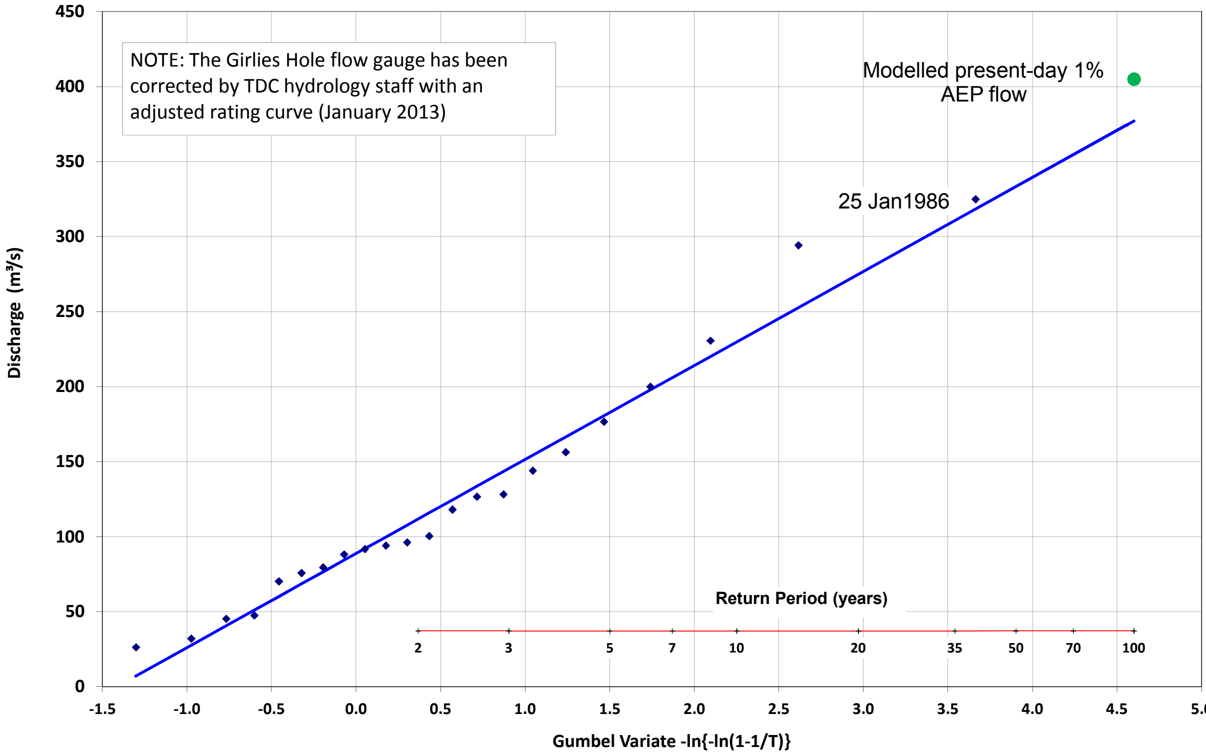
Confidence Interval % = 0.68
S.D. = 1.00

Year	annual max discharge m³/s	Date	Rank	Weibull Plotting Position (years)	Gringorten Plotting Position (years)	y = -ln(ln(1 - 1/T))	PWM1	PWM2	GEV Fit PWM	EV1 Fit PWM	Normal	LogNormal	Standard Error (EV1)	EV1 Upper Bound (m3/s)	EV1 Lower Bound (m3/s)
				100	100	4.6001			439	377	310	387	55	365	255
				80	97	4.5695			435	375	309	385	54	363	254
				70	96	4.5591			434	374	308	384	54	363	254
				60	95	4.5486			433	374	308	383	54	362	254
1986	325.00	25-Jan-86	1	23.00	39.50	3.6635	6825	136500	346	318	280	316	44	324	236
1995	294.28	23-Feb-95	2	11.50	14.18	2.6155	5886	111826	256	253	242	243	32	274	210
1998	230.68	9-Oct-98	3	7.67	8.64	2.0956	4383	78893	216	220	220	209	26	246	194
2011	200.00	14-Dec-11	4	5.75	6.21	1.7403	3600	61200	191	198	204	186	23	226	181
2008	176.68	24-Nov-08	5	4.60	4.85	1.4659	3004	48057	173	181	190	170	20	210	170
2010	156.36	30-Sep-10	6	3.83	3.98	1.2396	2502	37526	158	166	178	156	18	196	160
2003	144.01	29-Jun-03	7	3.29	3.37	1.0448	2160	30242	145	154	167	145	17	184	150
1990	128.25	12-Nov-90	8	2.88	2.93	0.8718	1796	23342	135	143	157	136	16	173	142
2012	126.67	15-Jul-12	9	2.56	2.58	0.7147	1647	19761	125	134	148	127	15	163	133
2001	118.11	3-Dec-01	10	2.30	2.31	0.5692	1417	15591	117	124	138	119	14	153	124
1991	100.43	24-Jan-91	11	2.09	2.09	0.4324	1105	11047	109	116	129	112	14	143	115
1992	96.24	14-Nov-92	12	1.92	1.91	0.3019	962	8661	101	108	120	105	14	134	107
2004	94.11	1-Feb-04	13	1.77	1.76	0.1757	847	6776	94	100	111	99	14	125	97
1996	91.77	1-Oct-96	14	1.64	1.63	0.0519	734	5139	88	92	102	93	14	116	88
2009	88.23	11-Sep-09	15	1.53	1.52	-0.0710	618	3706	81	84	93	87	14	107	78
1993	79.58	15-May-93	16	1.44	1.42	-0.1951	477	2387	75	77	82	81	15	97	68
2006	75.85	18-Nov-06	17	1.35	1.34	-0.3227	379	1517	68	69	72	75	16	87	56
1994	70.28	17-Jul-94	18	1.28	1.26	-0.4569	281	843	61	60	60	69	16	76	43
2007	47.54	18-Dec-07	19	1.21	1.19	-0.6025	143	285	54	51	46	63	17	64	29
2002	45.35	15-Jan-02	20	1.15	1.13	-0.7685	91	91	46	41	30	56	19	48	11
2005	32.13	11-Feb-05	21	1.10	1.08	-0.9752	32	0	36	28	8	48	20	28	-12
1997	26.36	26-Aug-97	22	1.05	1.03	-1.3019	0	0	22	7	-30	37	23	-7	-54
				10	**10**	2.2504			228	230	227	219	28	255	199
				20	**20**	2.9702			285	275	256	267	36	292	220
				35	**35**	3.5409			334	311	276	307	42	318	234
	ln_s.d. =	0.547164397		**66**	**66**	4.1820			395	351	297	355	50	347	247
	ln_mean =	4.686041827		**100**	**100**	4.6001			439	377	310	387	55	365	255

n =	22	PWM0 =	125	Alpha =	63
x bar =	124.90	PWM1 =	84	U =	89
s.d. =	79.4440345	PWM2 =	65		
alpha =	61.94225958	C =	-0.0191	Alpha =	54
u =	89.1517005	K =	-0.1491	U =	85
		Z =	-0.1194		
Q5 =	182.0650899	Gamma(1+k) =	1.1116		
Q100 =	374.0860945				

Standard Errors For EV1

var(Qt) = (alpha2/n)[(1.1128n - 0.9066) - (0.4574n - 1.1722)yt + (0.8046n - 0.1855)yt2] / (n - 1)



Stream flow gauge #57807: Maitai South at Old Intake

Data received from NCC 18 October 2012 — Computed DNV 22/07/2013 — P:\870888\WorkingMaterial\Hydrology\[Frequency Analysis v4 (updated Girles Hole).dcl-edited.xlsx]57807 Maitai Sth at Old Intake

Raw Data from Tideda

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13	1995	1.2305	2	27.875	29/09/1995 1:00
6	1996	0.81998	1.9	41.617	1/10/1996 22:15
16	1997	0.46737	2.13	21.217	4/10/1997 14:15
1	1998	1.1487	2.19	57.038	23/02/1998 13:45
11	1999	1.1715	1.61	30.492	31/01/1999 7:30
4	2000	0.86298	1.88	45.11	30/01/2000 2:00
9	2001	0.92743	2.4	38.374	3/12/2001 3:15
17	2002	0.80072	1.64	20.816	14/06/2002 19:00
5	2003	0.63473	2.46	43.422	29/06/2003 16:30
7	2004	0.96087	1.72	40.785	1/02/2004 19:00
18	2005	0.46206	1.78	15.949	11/02/2005 19:00
15	2006	0.64412	2.15	25.804	18/11/2006 2:30
14	2007	0.58086	2.07	25.878	18/12/2007 14:15
3	2008	1.1645	1.97	48.53	24/11/2008 17:45
12	2009	0.74944	1.81	29.714	26/08/2009 0:45
2	2010	0.90325	2.38	50.37	28/12/2010 5:15
8	2011	1.2311	2.22	38.638	25/05/2011 23:00
10	2012	0.84647	2.58	36.138	15/07/2012 7:15

Ranked Data

Rank	Year	Mean	Coeff of Var	Maximum	Date
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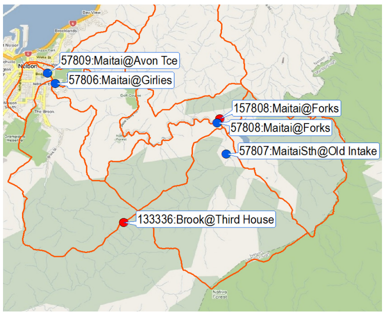
2	2010	0.90325	2.38	50.37	28/12/2010 5:15
3	2008	1.1645	1.97	48.53	24/11/2008 17:45
4	2000	0.86298	1.88	45.11	30/01/2000 2:00
5	2003	0.63473	2.46	43.422	29/06/2003 16:30
6	1996	0.81998	1.9	41.617	1/10/1996 22:15
7	2004	0.96087	1.72	40.785	1/02/2004 19:00
8	2011	1.2311	2.22	38.638	25/05/2011 23:00
9	2001	0.92743	2.4	38.374	3/12/2001 3:15
10	2012	0.84647	2.58	36.138	15/07/2012 7:15
11	1999	1.1715	1.61	30.492	31/01/1999 7:30
12	2009	0.74944	1.81	29.714	26/08/2009 0:45
13	1995	1.2305	2	27.875	29/09/1995 1:00
14	2007	0.58086	2.07	25.878	18/12/2007 14:15
15	2006	0.64412	2.15	25.804	18/11/2006 2:30
16	1997	0.46737	2.13	21.217	4/10/1997 14:15
17	2002	0.80072	1.64	20.816	14/06/2002 19:00
18	2005	0.46206	1.78	15.949	11/02/2005 19:00



Frequency Analysis

Confidence Interval % = 0.68
S.D. = 1.00

Year	annual max discharge m³/s	Date	Rank	Weibull Plotting Position (years)	Gringorten Plotting Position (years)	y = -ln(ln(1 - 1/T))	PWM1	PWM2	GEV Fit PWM	EV1 Fit PWM	Normal	LogNormal	Standard Error (EV1)	EV1 Upper Bound (m3/s)	EV1 Lower Bound (m3/s)
				100	100	4.6001			62	74	62	70	9	71	53
				80	97	4.5695			62	74	62	70	9	71	52
				70	96	4.5591			62	74	62	70	9	71	52
				60	95	4.5486			62	74	62	69	9	71	52
1998	57.04	23-Feb-98	1	19.00	32.36	3.4612	970	15514	58	63	57	61	7	64	50
2010	50.37	28-Dec-10	2	9.50	11.62	2.4077	806	12089	52	53	51	52	5	56	46
2008	48.53	24-Nov-08	3	6.33	7.08	1.8818	728	10191	48	48	48	47	4	52	44
2000	45.11	30-Jan-00	4	4.75	5.09	1.5199	632	8210	46	45	45	44	4	49	42
2003	43.42	29-Jun-03	5	3.80	3.97	1.2382	564	6774	43	42	43	42	3	46	40
1996	41.62	1-Oct-96	6	3.17	3.26	1.0038	499	5493	41	40	41	40	3	44	38
2004	40.79	1-Feb-04	7	2.71	2.76	0.7997	449	4486	40	38	39	38	3	42	37
2011	38.64	25-May-11	8	2.38	2.40	0.6163	386	3477	38	36	38	36	2	40	35
2001	38.37	3-Dec-01	9	2.11	2.12	0.4472	345	2763	36	34	36	34	2	39	34
2012	36.14	15-Jul-12	10	1.90	1.90	0.2878	289	2024	34	33	35	33	2	37	32
1999	30.49	31-Jan-99	11	1.73	1.72	0.1345	213	1281	33	31	33	32	2	35	31
2009	29.71	26-Aug-09	12	1.58	1.57	-0.0159	178	891	31	30	31	30	2	34	29
1995	27.88	29-Sep-95	13	1.46	1.44	-0.1667	139	558	29	28	30	29	3	32	27
2007	25.88	18-Dec-07	14	1.36	1.34	-0.3219	104	311	27	27	28	27	3	30	25
2006	25.80	18-Nov-06	15	1.27	1.24	-0.4869	77	155	25	25	26	26	3	29	23
1997	21.22	4-Oct-97	16	1.19	1.16	-0.6714	42	42	23	23	23	24	3	26	20
2002	20.82	14-Jun-02	17	1.12	1.09	-0.8970	21	0	19	21	20	22	3	23	17
2005	15.95	11-Feb-05	18	1.06	1.03	-1.2461	0	0	14	18	14	19	4	18	10
				10	**10**	2.2504			51	52	50	50	5	55	45
				20	**20**	2.9702			55	59	54	56	6	60	48
				35	**35**	3.5409			58	64	57	61	7	64	50
ln_s.d. =	0.313146896			**66**	**66**	4.1820			61	70	60	66	9	69	52
ln_mean =	3.518570766			**100**	**100**	4.6001			62	74	62	70	9	71	53

n = 18
x bar = 35.43
s.d. = 11.37290686

alpha = 8.867419097
u = 30.3132257

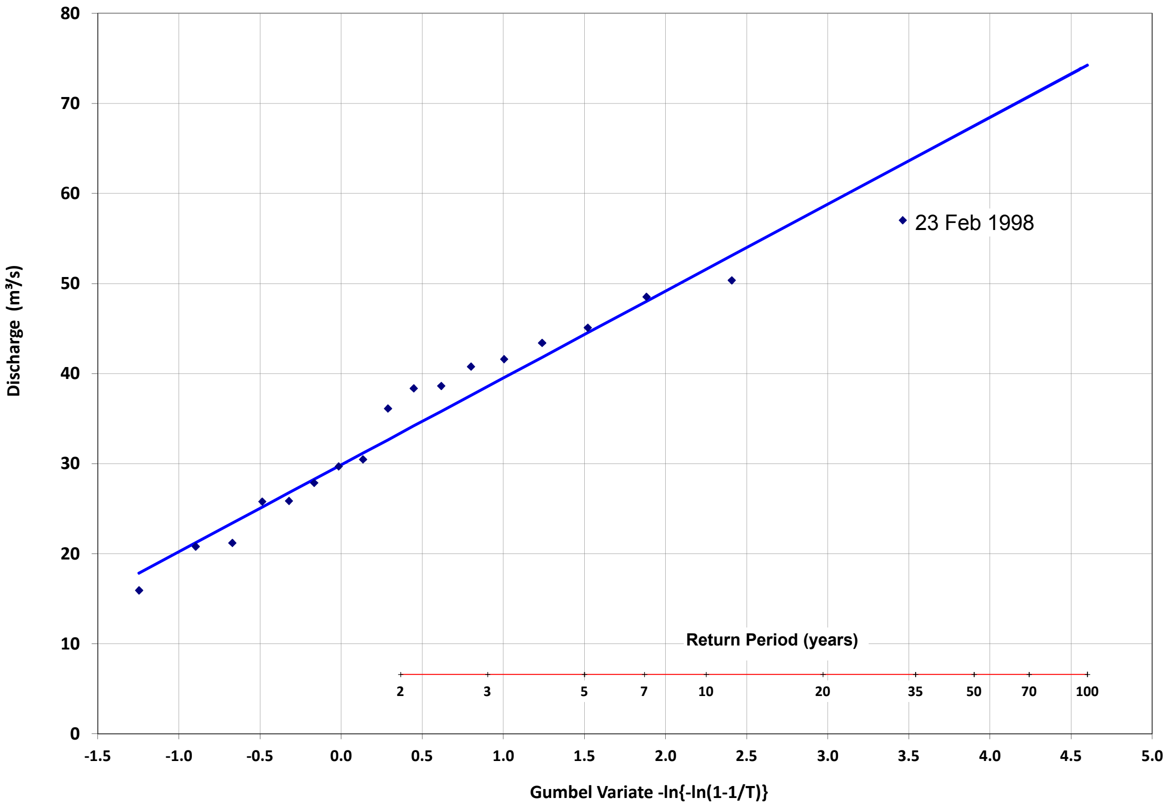
Q5 = 43.61435434
Q100 = 71.10335354

PWM0 = 35 — Alpha = 10
PWM1 = 21 — U = 30
PWM2 = 15

C = 0.0328 — Alpha = 12
K = 0.2610 — U = 31
Z = 0.1854
Gamma(1+k) = 0.9042

Standard Errors For EV1

var(Qt) = (alpha2/n)[(1.1128n - 0.9066) - (0.4574n - 1.1722)yt + (0.8046n - 0.1855)yt2] / (n - 1)



Stream flow gauge #57808: Maitai at Forks

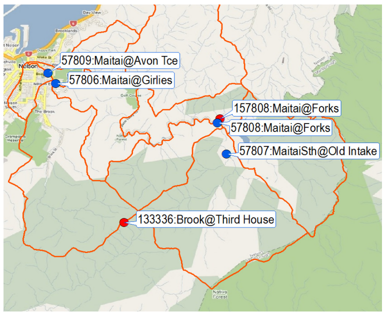
Data received from NCC 18 October 2012 Computed DNV 22/07/2013 P:\870888\WorkingMaterial\Hydrology\[Frequency Analysis v4 (updated Girles Hole).dcl-edited.xlsx]57808 Maitai at Forks

Raw Data from Tideda

Rank	Year	Mean	Coeff of Var	Maximum	Date
13	1997	0.91675	2.93	49.832	17/06/1997 18:00
1	1998	2.4018	3.06	167.81	1/07/1998 15:30
12	1999	1.6715	1.93	51.731	12/11/1999 11:15
4	2000	1.3316	2.4	98.158	30/01/2000 2:15
8	2001	1.5746	3.05	74.608	3/12/2001 3:30
15	2002	1.1286	1.9	30.93	17/06/2002 19:15
7	2003	1.0313	3.07	89.859	29/06/2003 16:45
9	2004	1.5389	2.1	72.089	1/02/2004 19:15
16	2005	0.98686	1.55	24.872	11/02/2005 19:15
11	2006	1.2594	2.71	57.552	18/11/2006 4:30
14	2007	0.7968	2.22	47.21	23/05/2007 10:00
3	2008	1.9342	2.43	116.04	24/11/2008 18:00
10	2009	1.1625	2.15	62.925	11/09/2009 15:15
2	2010	1.4921	3.16	121.86	28/12/2010 5:30
6	2011	2.2486	2.91	91.711	25/05/2011 23:15
5	2012	1.4781	3.9	97.53	15/07/2012 7:30

Ranked Data

Rank	Year	Mean	Coeff of Var	Maximum	Date
1	1998	2.4018	3.06	167.81	1/07/1998 15:30
2	2010	1.4921	3.16	121.86	28/12/2010 5:30
3	2008	1.9342	2.43	116.04	24/11/2008 18:00
4	2000	1.3316	2.4	98.158	30/01/2000 2:15
5	2012	1.4781	3.9	97.53	15/07/2012 7:30
6	2011	2.2486	2.91	91.711	25/05/2011 23:15
7	2003	1.0313	3.07	89.859	29/06/2003 16:45
8	2001	1.5746	3.05	74.608	3/12/2001 3:30
9	2004	1.5389	2.1	72.089	1/02/2004 19:15
10	2009	1.1625	2.15	62.925	11/09/2009 15:15
11	2006	1.2594	2.71	57.552	18/11/2006 4:30
12	1999	1.6715	1.93	51.731	12/11/1999 11:15
13	1997	0.91675	2.93	49.832	17/06/1997 18:00
14	2007	0.7968	2.22	47.21	23/05/2007 10:00
15	2002	1.1286	1.9	30.93	17/06/2002 19:15
16	2005	0.98686	1.55	24.872	11/02/2005 19:15



Frequency Analysis

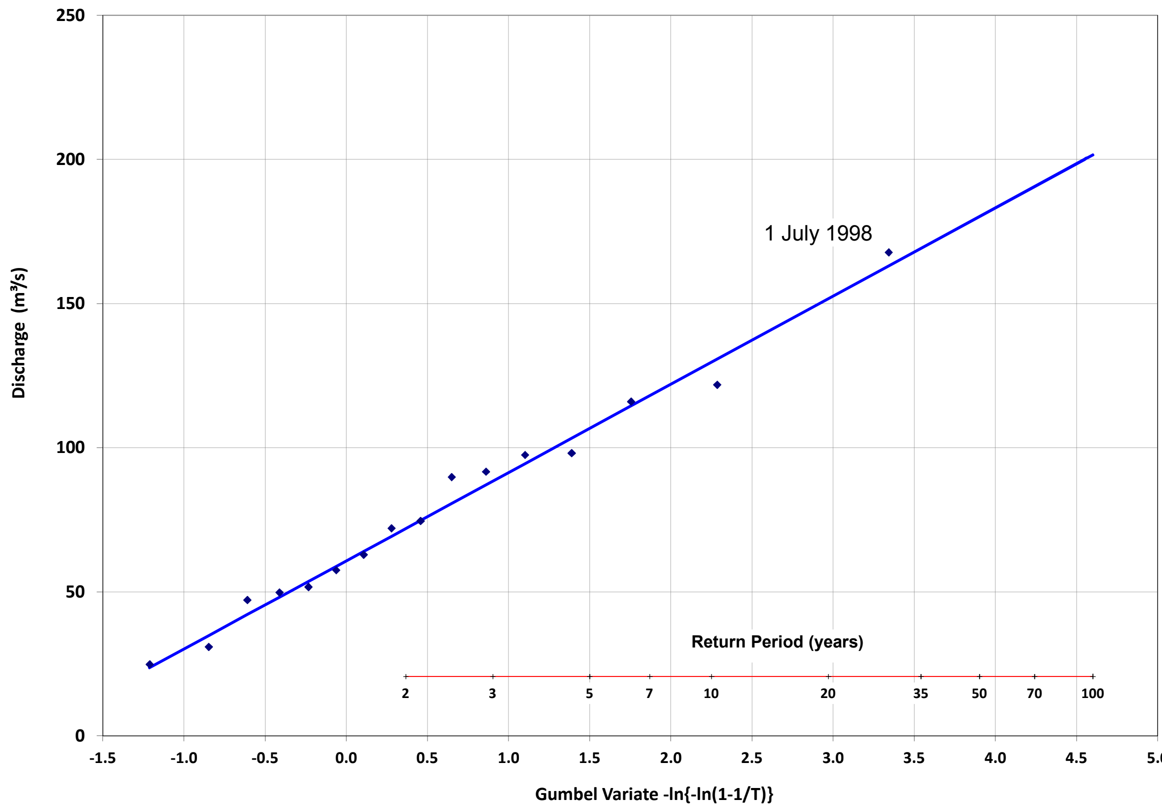
Confidence Interval % = 0.68
S.D. = 1.00

Year	annual max discharge m³/s	Date	Rank	Weibull Plotting Position (years)	Gringorten Plotting Position (years)	y = -ln(ln(1 - 1/T))	PWM1	PWM2	GEV Fit PWM	EV1 Fit PWM	Normal	LogNormal	Standard Error (EV1)	EV1 Upper Bound (m3/s)	EV1 Lower Bound (m3/s)
				100	100	4.6001			194	202	165	202	32	197	133
				80	97	4.5695			194	201	164	201	31	196	133
				70	96	4.5591			193	200	164	201	31	196	133
				60	95	4.5486			193	200	164	200	31	196	133
1998	167.81	1-Jul-98	1	17.00	28.79	3.3423	2517	35240	160	163	146	160	23	169	123
2010	121.86	28-Dec-10	2	8.50	10.33	2.2849	1706	22179	131	131	127	127	16	143	110
2008	116.04	24-Nov-08	3	5.67	6.30	1.7548	1509	18102	115	114	116	111	13	129	102
2000	98.16	30-Jan-00	4	4.25	4.53	1.3881	1178	12957	104	103	107	100	11	118	96
2012	97.53	15-Jul-12	5	3.40	3.54	1.1011	1073	10728	96	94	100	92	10	110	90
2011	91.71	25-May-11	6	2.83	2.90	0.8604	917	8254	88	87	93	85	9	102	84
2003	89.86	29-Jun-03	7	2.43	2.46	0.6492	809	6470	82	81	87	79	8	96	79
2001	74.61	3-Dec-01	8	2.13	2.13	0.4573	597	4178	76	75	81	73	8	89	73
2004	72.09	1-Feb-04	9	1.89	1.88	0.2781	505	3028	70	69	76	68	8	83	68
2009	62.93	11-Sep-09	10	1.70	1.69	0.1064	378	1888	65	64	70	64	8	78	62
2006	57.55	18-Nov-06	11	1.55	1.53	-0.0625	288	1151	59	59	64	59	8	72	55
1999	51.73	12-Nov-99	12	1.42	1.39	-0.2333	207	621	54	54	57	55	9	66	48
1997	49.83	17-Jun-97	13	1.31	1.28	-0.4123	149	299	48	48	50	50	9	59	41
2007	47.21	23-May-07	14	1.21	1.19	-0.6098	94	94	42	42	41	45	10	51	31
2002	30.93	17-Jun-02	15	1.13	1.11	-0.8482	31	0	34	35	30	39	11	41	19
2005	24.87	11-Feb-05	16	1.06	1.04	-1.2119	0	0	22	24	11	31	13	24	-2
				10	**10**	2.2504			130	130	126	126	16	142	110
				20	**20**	2.9702			150	152	140	149	21	160	119
				35	**35**	3.5409			166	169	149	167	25	174	125
ln_s.d. =	0.450062371			**66**	**66**	4.1820			183	189	159	188	29	188	130
ln_mean =	4.260798537			**100**	**100**	4.6001			194	202	165	202	32	197	133

n =	16	PWM0 =	78	Alpha =	31
x bar =	78.4198125	PWM1 =	50	U =	61
s.d. =	37.15881463	PWM2 =	37		
alpha =	28.9726089	C =	0.0053	Alpha =	32
u =	61.69682264	K =	0.0414	U =	61
		Z =	0.0280		
Q5 =	105.155736	Gamma(1+k) =	0.9777		
Q100 =	194.9708236				

Standard Errors For EV1

var(Qt) = (alpha2/n)[(1.1128n - 0.9066) - (0.4574n - 1.1722)yt + (0.8046n - 0.1855)yt2] / (n - 1)



Stream flow gauge #57809: Maitai at Avon Tce

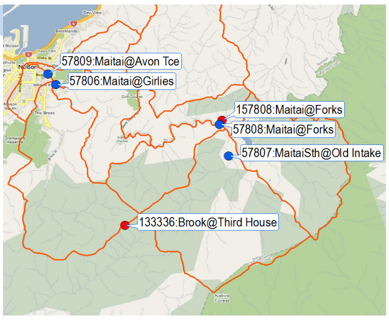
Data received from NCC 18 October 2012 | Computed DNV 22/07/2013 | P:\870888\WorkingMaterial\Hydrology\[Frequency Analysis v4 (updated Girles Hole).dcl-edited.xlsx]57809 Maitai at Avon Tce

Raw Data from Tideda

Rank	Year	Mean	Coeff of Var	Maximum	Date
9	2004	2.4759	1.5	25.691	30/12/2004 9:45
8	2005	1.1052	1.67	28.621	11/02/2005 20:45
6	2006	1.5972	2.61	82.224	18/11/2006 5:45
7	2007	1.4441	2.47	76.611	18/12/2007 15:45
2	2008	3.7349	2.19	185.1	24/11/2008 20:00
5	2009	1.9319	2.14	91.03	11/09/2009 16:45
3	2010	2.6904	2.83	159.53	30/09/2010 9:30
1	2011	4.3316	3.1	235.03	14/12/2011 21:00
4	2012	3.2912	2.42	144.05	15/07/2012 8:45

Ranked Data

Rank	Year	Mean	Coeff of Var	Maximum	Date
1	2011	4.3316	3.1	235.03	14/12/2011 21:00
2	2008	3.7349	2.19	185.1	24/11/2008 20:00
3	2010	2.6904	2.83	159.53	30/09/2010 9:30
4	2012	3.2912	2.42	144.05	15/07/2012 8:45
5	2009	1.9319	2.14	91.03	11/09/2009 16:45
6	2006	1.5972	2.61	82.224	18/11/2006 5:45
7	2007	1.4441	2.47	76.611	18/12/2007 15:45
8	2005	1.1052	1.67	28.621	11/02/2005 20:45
9	2004	2.4759	1.5	25.691	30/12/2004 9:45



Frequency Analysis

Confidence Interval % = **0.68**
S.D. = **1.00**

Year	annual max discharge m³/s	Date	Rank	Weibull Plotting Position (years)	Gringorten Plotting Position (years)	y = -ln(ln(1 - 1/T))	PWM1	PWM2	GEV Fit PWM	EV1 Fit PWM	Normal	LogNormal	Standard Error (EV1)	EV1 Upper Bound (m3/s)	EV1 Lower Bound (m3/s)
				100	100	4.6001			332	362	280	368	87	367	193
				80	97	4.5695			331	360	279	366	87	366	193
				70	96	4.5591			331	359	279	365	86	366	193
				60	95	4.5486			330	358	279	364	86	365	192
2011	235.03	14-Dec-11	1	10.00	16.29	2.7588	1880	13162	244	248	224	235	54	278	171
2008	185.10	24-Nov-08	2	5.00	5.85	1.6735	1296	7774	184	182	182	167	35	217	146
2010	159.53	30-Sep-10	3	3.33	3.56	1.1102	957	4786	151	147	156	135	28	183	128
2012	144.05	15-Jul-12	4	2.50	2.56	0.7035	720	2881	126	122	134	114	24	158	111
2009	91.03	11-Sep-09	5	2.00	2.00	0.3665	364	1092	105	101	114	97	22	136	92
2006	82.22	18-Nov-06	6	1.67	1.64	0.0611	247	493	85	82	94	83	22	116	73
2007	76.61	18-Dec-07	7	1.43	1.39	-0.2394	153	153	65	64	73	69	23	96	50
2005	28.62	11-Feb-05	8	1.25	1.21	-0.5686	29	0	43	44	46	56	26	73	20
2004	25.69	30-Dec-04	9	1.11	1.07	-1.0261	0	0	10	16	4	40	32	36	-28

				10	**10**	2.2504			217	217	206	202	45	250	161
				20	**20**	2.9702			255	261	232	249	57	289	174
				35	**35**	3.5409			283	296	250	289	68	318	182
ln_s.d. =	0.573883443			**66**	**66**	4.1820			313	336	269	336	79	348	189
ln_mean =	4.573364837			**100**	**100**	4.6001			332	362	280	368	87	367	193

n = 9
x bar = 114.2096667
s.d. = 71.32880219

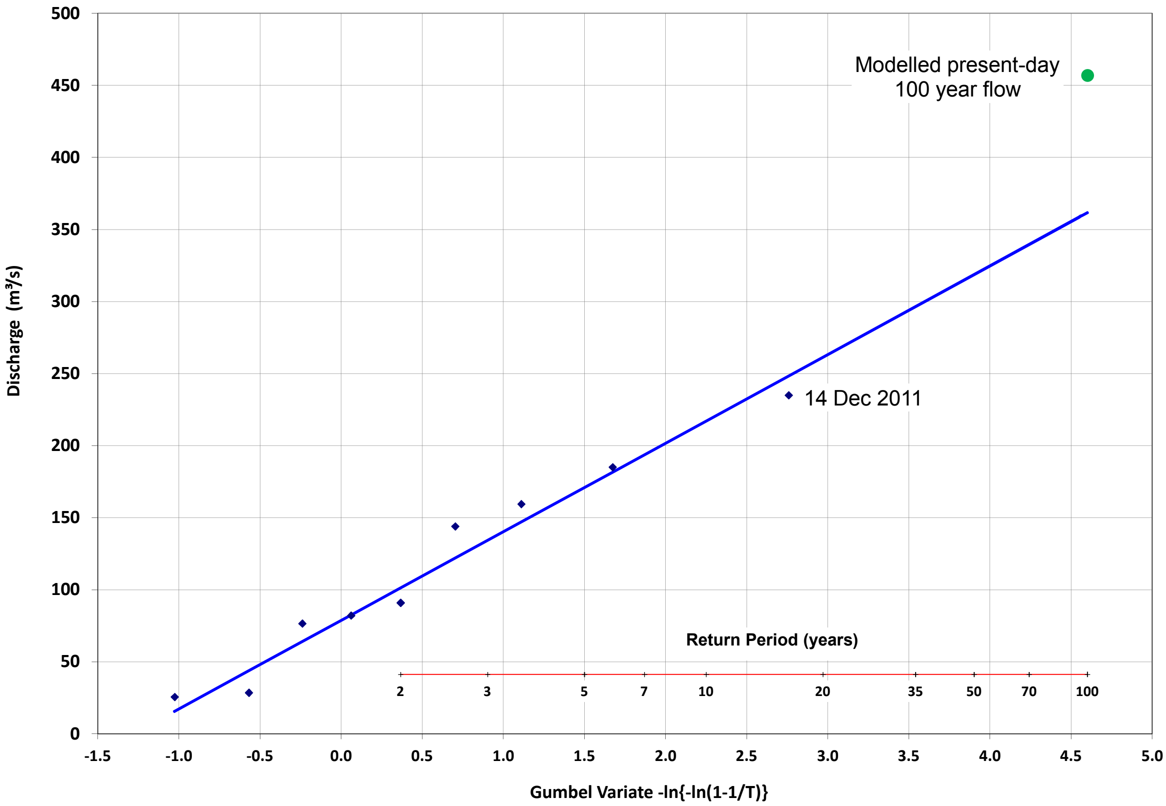
alpha = 55.61483891
u = 82.10878165

Q5 = 165.53104
Q100 = 337.9370406

PWM0 = 114 | Alpha = 61
PWM1 = 78 | U = 79
PWM2 = 60

C = 0.0110 | Alpha = 66
K = 0.0871 | U = 81
Z = 0.0441
Gamma(1+k) = 0.9567

Standard Errors For EV1
var(Qt) = (alpha2/n)[(1.1128n - 0.9066) - (0.4574n - 1.1722)yt + (0.8046n - 0.1855)yt2] / (n - 1)



Rainfall gauge #133336: Brook at Third House

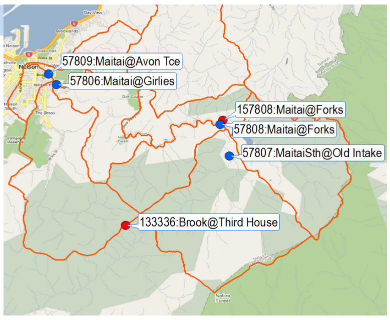
Data received from NCC 18 October 2012 Computed DNV 22/07/2013 P:\870888\WorkingMaterial\Hydrology\[Frequency Analysis v4 (updated Girles Hole).dcl-edited.xlsx]133336 Brook at Third House24hr

Raw Data from Tideda

Rank	Year	Maximum	Date
4	1992	230	14/11/1992 4:30
17	1993	115	21/09/1993 21:45
15	1994	118	10/06/1994 13:30
7	1995	175	26/01/1995 7:45
10	1996	141	12/01/1996 23:00
11	1997	137	17/06/1997 5:45
2	1998	273	1/07/1998 7:00
8	1999	148	14/01/1999 3:30
13	2000	130	29/01/2000 6:00
5	2001	207	2/12/2001 4:30
21	2002	76	10/02/2002 12:15
6	2003	182	28/06/2003 16:30
14	2004	129	1/02/2004 3:15
20	2005	97	17/06/2005 17:45
18	2006	112	23/04/2006 16:00
19	2007	111	18/12/2007 12:00
9	2008	147	23/11/2008 19:15
16	2009	117	10/09/2009 17:04
12	2010	136	29/09/2010 13:30
1	2011	335	13/12/2011 21:01
3	2012	239	14/07/2012 11:28

Ranked Data

Rank	Year	Maximum	Date
1	2011	335	13/12/2011 21:01
2	1998	273	1/07/1998 7:00
3	2012	239	14/07/2012 11:28
4	1992	230	14/11/1992 4:30
5	2001	207	2/12/2001 4:30
6	2003	182	28/06/2003 16:30
7	1995	175	26/01/1995 7:45
8	1999	148	14/01/1999 3:30
9	2008	147	23/11/2008 19:15
10	1996	141	12/01/1996 23:00
11	1997	137	17/06/1997 5:45
12	2010	136	29/09/2010 13:30
13	2000	130	29/01/2000 6:00
14	2004	129	1/02/2004 3:15
15	1994	118	10/06/1994 13:30
16	2009	117	10/09/2009 17:04
17	1993	115	21/09/1993 21:45
18	2006	112	23/04/2006 16:00
19	2007	111	18/12/2007 12:00
20	2005	97	17/06/2005 17:45
21	2002	76	10/02/2002 12:15



Frequency Analysis

Confidence Interval % = 0.68
S.D. = 1.00

Year	annual max rainfall mm	Date	Rank	Weibull Plotting Position (years)	Gringorten Plotting Position (years)	y = -ln(ln(1 - 1/T))	PWM1	PWM2	GEV Fit PWM	EV1 Fit PWM	Normal	LogNormal	Standard Error (EV1)	EV1 Upper Bound (m3/s)	EV1 Lower Bound (m3/s)
				100	100	4.6001			438	359	309	365	44	354	265
				80	97	4.5695			435	358	308	363	44	353	264
				70	96	4.5591			433	357	308	363	44	352	264
				60	95	4.5486			432	357	308	362	44	352	264
2011	335.00	13-Dec-11	1	22.00	37.71	3.6166	6700	127300	342	311	284	313	35	319	249
1998	273.00	1-Jul-98	2	11.00	13.54	2.5674	5187	93366	260	259	253	260	26	278	227
2012	239.00	14-Jul-12	3	7.33	8.25	2.0463	4302	73134	226	233	235	233	21	256	214
1992	230.00	14-Nov-92	4	5.50	5.93	1.6896	3910	62560	206	215	221	215	18	240	203
2001	207.00	2-Dec-01	5	4.40	4.63	1.4137	3312	49680	191	201	210	201	16	226	194
2003	182.00	28-Jun-03	6	3.67	3.80	1.1858	2730	38220	179	190	200	189	15	215	186
1995	175.00	26-Jan-95	7	3.14	3.22	0.9890	2450	31850	169	180	191	179	13	205	178
1999	148.00	14-Jan-99	8	2.75	2.79	0.8140	1924	23088	161	172	183	171	13	196	171
2008	147.00	23-Nov-08	9	2.44	2.47	0.6545	1764	19404	154	164	175	163	12	187	163
1996	141.00	12-Jan-96	10	2.20	2.21	0.5064	1551	15510	147	156	167	155	11	179	156
1997	137.00	17-Jun-97	11	2.00	2.00	0.3665	1370	12330	141	149	160	148	11	171	148
2010	136.00	29-Sep-10	12	1.83	1.83	0.2324	1224	9792	136	143	152	142	11	163	141
2000	130.00	29-Jan-00	13	1.69	1.68	0.1019	1040	7280	131	136	144	135	11	156	133
2004	129.00	1-Feb-04	14	1.57	1.56	-0.0270	903	5418	126	130	136	129	12	148	125
1994	118.00	10-Jun-94	15	1.47	1.45	-0.1563	708	3540	121	123	128	122	12	140	116
2009	117.00	10-Sep-09	16	1.38	1.36	-0.2886	585	2340	116	117	119	116	12	132	107
1993	115.00	21-Sep-93	17	1.29	1.28	-0.4272	460	1380	111	110	109	109	13	122	96
2006	112.00	23-Apr-06	18	1.22	1.20	-0.5769	336	672	106	102	98	102	14	112	84
2007	111.00	18-Dec-07	19	1.16	1.14	-0.7468	222	222	100	94	85	94	15	100	70
2005	97.00	17-Jun-05	20	1.10	1.08	-0.9576	97	0	94	84	67	85	16	83	50
2002	76.00	10-Feb-02	21	1.05	1.03	-1.2892	0	0	84	67	36	70	19	54	17
				10	**10**	2.2504			239	243	242	243	23	265	219
				20	**20**	2.9702			289	279	265	280	29	295	236
				35	**35**	3.5409			335	307	282	309	34	316	247
ln_s.d. =		0.386965323		**66**	**66**	4.1820			394	339	299	343	40	339	258
ln_mean =		4.998813531		**100**	**100**	4.6001			438	359	309	365	44	354	265

n = 21
x bar = 159.76
s.d. = 64.21051687

alpha = 50.06473461
u = 130.8645399

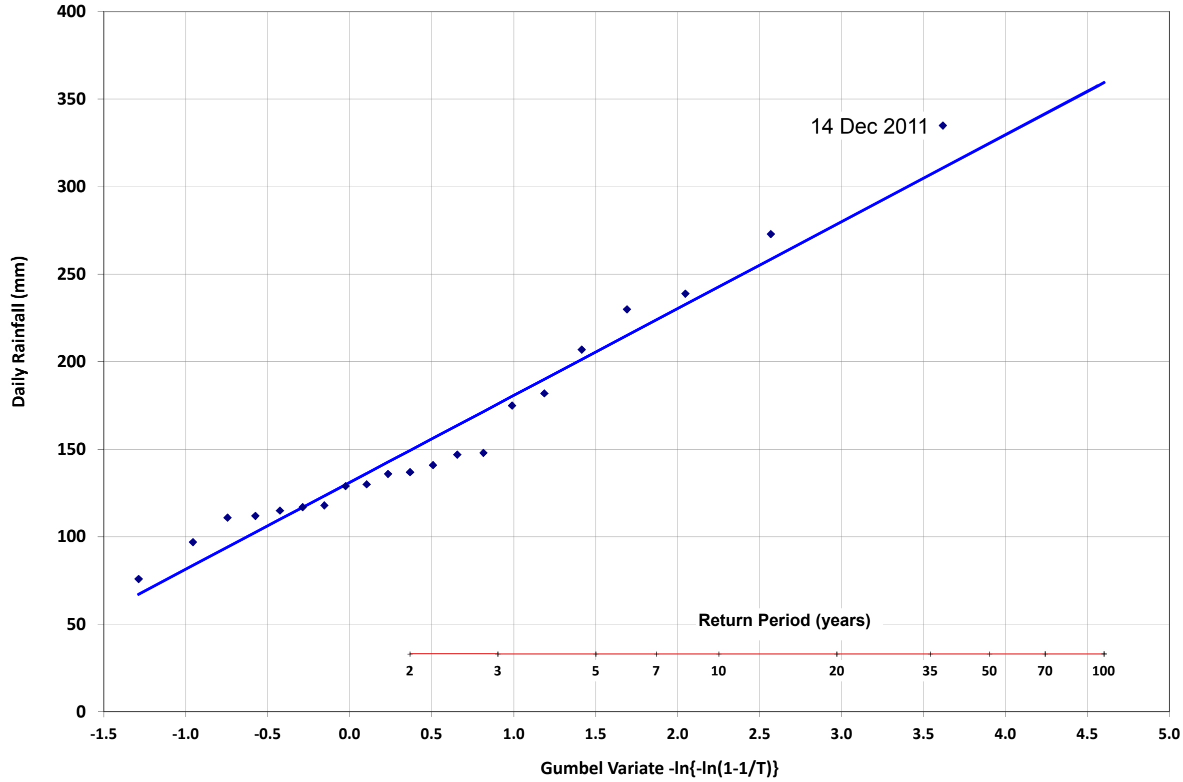
Q5 = 205.9616419
Q100 = 361.1623191

PWM0 = 160 Alpha = 50
PWM1 = 97 U = 131
PWM2 = 72

C = -0.0293 Alpha = 38
K = -0.2279 U = 127
Z = -0.1790
Gamma(1+k) = 1.1971

Standard Errors For EV1

var(Qt) = (alpha2/n)[(1.1128n - 0.9066) - (0.4574n - 1.1722)yt + (0.8046n - 0.1855)yt2] / (n - 1)



Rainfall gauge #157808 Maitai at Forks

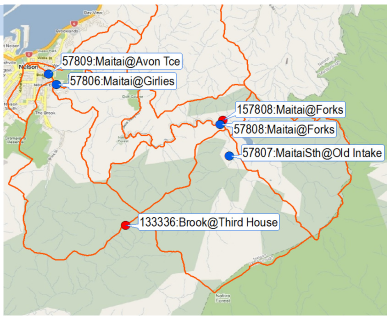
Data received from NCC 18 October 2012 Computed DNV 22/07/2013 P:\870888\WorkingMaterial\Hydrology\[Frequency Analysis v4 (updated Girles Hole).dcl-edited.xlsx]157808 Maitai at Forks

Raw Data from Tideda

Rank	Year	Maximum	Date
7	2000	106	25/12/1999 13:00
5	2001	131	30/01/2000 13:00
11	2002	73	7/10/2001 13:00
3	2003	151	15/01/2002 13:00
9	2004	92	29/06/2003 13:00
12	2005	57	13/09/2004 13:00
	2006	no valid values	
8	2007	94	22/05/2007 9:45
2	2008	165	24/11/2008 13:00
10	2009	82	9/10/2009 13:00
4	2010	144	11/06/2010 13:00
1	2011	235	13/12/2011 22:44
6	2012	127	22/02/2012 3:17

Ranked Data

Rank	Year	Maximum	Date
1	2011	235	13/12/2011 22:44
2	2008	165	24/11/2008 13:00
3	2003	151	15/01/2002 13:00
4	2010	144	11/06/2010 13:00
5	2001	131	30/01/2000 13:00
6	2012	127	22/02/2012 3:17
7	2000	106	25/12/1999 13:00
8	2007	94	22/05/2007 9:45
9	2004	92	29/06/2003 13:00
10	2009	82	9/10/2009 13:00
11	2002	73	7/10/2001 13:00
12	2005	57	13/09/2004 13:00



Frequency Analysis

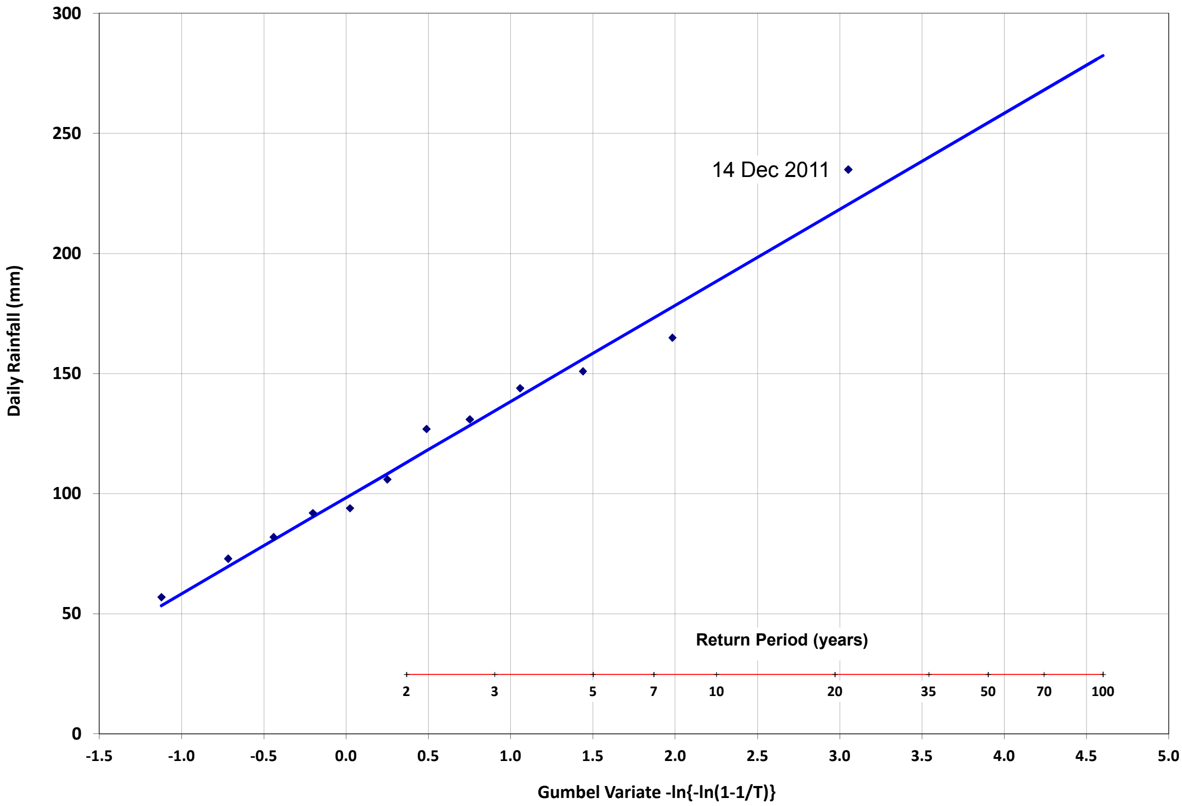
Confidence Interval % = 0.68
S.D. = 1.00

Year	annual max rainfall mm	Date	Rank	Weibull Plotting Position (years)	Gringorten Plotting Position (years)	y = -ln(ln(1 - 1/T))	PWM1	PWM2	GEV Fit PWM	EV1 Fit PWM	Normal	LogNormal	Standard Error (EV1)	EV1 Upper Bound (m3/s)	EV1 Lower Bound (m3/s)
				100	100	4.6001			291	282	235	277	48	283	187
				80	97	4.5695			290	281	234	276	48	283	186
				70	96	4.5591			290	281	234	276	48	282	186
				60	95	4.5486			289	280	234	275	48	282	186
2011	235.00	13-Dec-11	1	13.00	21.64	3.0511	2585	25850	222	220	204	216	33	236	171
2008	165.00	24-Nov-08	2	6.50	7.77	1.9821	1650	14850	177	178	177	175	22	199	154
2003	151.00	15-Jan-02	3	4.33	4.73	1.4386	1359	10872	155	156	161	154	18	178	143
2010	144.00	11-Jun-10	4	3.25	3.40	1.0563	1152	8064	139	141	148	139	15	163	133
2001	131.00	30-Jan-00	5	2.60	2.66	0.7508	917	5502	127	128	137	127	13	150	124
2012	127.00	22-Feb-12	6	2.17	2.18	0.4880	762	3810	117	118	126	117	12	139	114
2000	106.00	25-Dec-99	7	1.86	1.85	0.2494	530	2120	107	108	116	108	12	128	104
2007	94.00	22-May-07	8	1.63	1.60	0.0227	376	1128	99	99	106	100	12	118	94
2004	92.00	29-Jun-03	9	1.44	1.42	-0.2030	276	552	90	90	95	91	13	108	82
2009	82.00	9-Oct-09	10	1.30	1.27	-0.4414	164	164	81	81	82	83	14	96	68
2002	73.00	7-Oct-01	11	1.18	1.15	-0.7179	73	0	70	70	66	73	16	82	50
2005	57.00	13-Sep-04	12	1.08	1.05	-1.1232	0	0	55	53	39	59	19	58	20
				10	**10**	2.2504			188	188	184	185	25	209	159
				20	**20**	2.9702			219	217	202	213	32	234	170
				35	**35**	3.5409			244	240	214	235	37	252	177
	ln_s.d. =	0.387075828		**66**	**66**	4.1820			272	266	227	261	44	271	183
	ln_mean =	4.724314308		**100**	**100**	4.6001			291	282	235	277	48	283	187

n =	12	PWM0 =	121	Alpha =	40
x bar =	121.4166667	PWM1 =	75	U =	98
s.d. =	48.81404107	PWM2 =	55		
alpha =	38.06015168	C =	-0.0048	Alpha =	39
u =	99.44834712	K =	-0.0373	U =	98
		Z =	-0.0219		
Q5 =	156.5385746	Gamma(1+k) =	1.0230		
Q100 =	274.5250449				

Standard Errors For EV1

var(Qt) = (alpha2/n)[(1.1128n - 0.9066) - (0.4574n - 1.1722)yt + (0.8046n - 0.1855)yt2] / (n - 1)



Rainfall gauge #133336: Brook at Third House

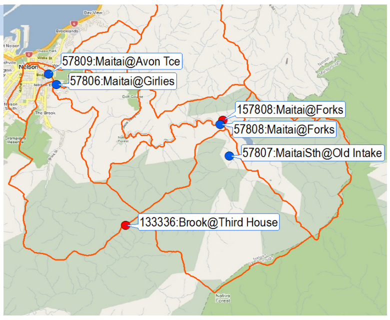
Data received from NCC 7 March 2012 | Computed DNV | 4/11/2010 | P:\870888\WorkingMaterial\Hydrology\[Frequency Analysis v4 (updated Girles Hole).dcl-edited.xlsx]133336 Brook at Third House48hr

Raw Data from Tideda

Rank	Year	Maximum	Date
4	1992	252	13/11/1992 4:15
14	1993	139	15/05/1993 3:15
10	1994	160	10/06/1994 7:30
5	1995	216	21/12/1995 21:30
8	1996	167	12/01/1996 11:00
12	1997	144	16/06/1997 9:00
2	1998	376	30/06/1998 17:45
9	1999	161	13/01/1999 10:00
16	2000	131	29/01/2000 1:15
3	2001	296	1/12/2001 5:00
18	2002	103	6/12/2002 0:00
6	2003	194	28/06/2003 14:45
14	2004	139	11/09/2004 13:30
20	2005	98	16/06/2005 17:45
11	2006	152	23/04/2006 14:00
19	2007	100	29/06/2007 20:00
7	2008	176	22/11/2008 20:15
17	2009	111	10/09/2009 12:43
13	2010	141	28/09/2010 22:16
1	2011	501	13/12/2011 15:49

Ranked Data

Rank	Year	Maximum	Date
1	2011	501	13/12/2011 15:49
2	1998	376	30/06/1998 17:45
3	2001	296	1/12/2001 5:00
4	1992	252	13/11/1992 4:15
5	1995	216	21/12/1995 21:30
6	2003	194	28/06/2003 14:45
7	2008	176	22/11/2008 20:15
8	1996	167	12/01/1996 11:00
9	1999	161	13/01/1999 10:00
10	1994	160	10/06/1994 7:30
11	2006	152	23/04/2006 14:00
12	1997	144	16/06/1997 9:00
13	2010	141	28/09/2010 22:16
14	1993	139	15/05/1993 3:15
15	2004	139	11/09/2004 13:30
16	2000	131	29/01/2000 1:15
17	2009	111	10/09/2009 12:43
18	2002	103	6/12/2002 0:00
19	2007	100	29/06/2007 20:00
20	2005	98	16/06/2005 17:45



Frequency Analysis

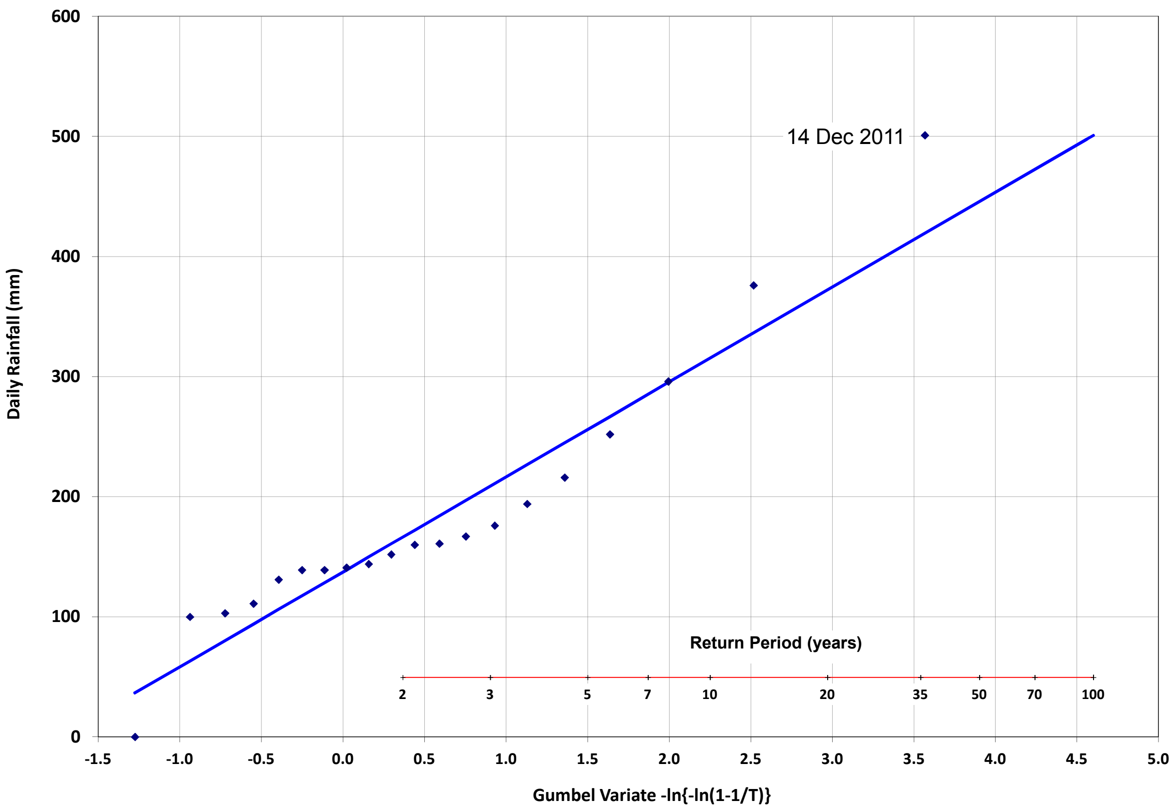
Confidence Interval % = 0.68
S.D. = 1.00

Year	annual max rainfall mm	Date	Rank	Weibull Plotting Position (years)	Gringorten Plotting Position (years)	y = -ln(ln(1 - 1/T))	PWM1	PWM2	GEV Fit PWM	EV1 Fit PWM	Normal	LogNormal	Standard Error (EV1)	EV1 Upper Bound (m3/s)	EV1 Lower Bound (m3/s)
				100	100	4.6001			615	501	434	562	73	507	361
				80	97	4.5695			610	498	433	558	72	505	360
				70	96	4.5591			609	498	432	557	72	504	360
				60	95	4.5486			607	497	432	556	72	504	360
40544	501.00	13-Dec-11	1	21.00	35.93	3.5675	9519	171342	463	419	389	448	57	446	333
35796	376.00	30-Jun-98	2	10.50	12.90	2.5169	6768	115056	338	336	336	343	41	377	295
36892	296.00	1-Dec-01	3	7.00	7.86	1.9944	5032	80512	285	295	306	294	34	340	272
33604	252.00	13-Nov-92	4	5.25	5.65	1.6362	4032	60480	253	267	283	262	29	312	254
34700	216.00	21-Dec-95	5	4.20	4.41	1.3586	3240	45360	229	245	264	237	26	289	238
37622	194.00	28-Jun-03	6	3.50	3.62	1.1288	2716	35308	210	227	247	218	23	270	224
39448	176.00	22-Nov-08	7	3.00	3.07	0.9299	2288	27456	195	211	232	202	21	253	210
35065	167.00	12-Jan-96	8	2.63	2.66	0.7525	2004	22044	182	197	217	187	20	237	197
36161	161.00	13-Jan-99	9	2.33	2.35	0.5903	1771	17710	170	184	203	175	19	222	184
34335	160.00	10-Jun-94	10	2.10	2.10	0.4391	1600	14400	159	172	190	163	19	208	171
38718	152.00	23-Apr-06	11	1.91	1.91	0.2955	1368	10944	150	161	176	152	18	195	158
35431	144.00	16-Jun-97	12	1.75	1.74	0.1571	1152	8064	141	150	163	142	18	181	144
40179	141.00	28-Sep-10	13	1.62	1.60	0.0214	987	5922	132	139	149	133	19	167	130
33970	139.00	15-May-93	14	1.50	1.48	-0.1140	834	4170	124	128	134	123	19	154	115
37987	139.00	11-Sep-04	15	1.40	1.38	-0.2516	695	2780	115	117	119	114	20	139	99
36526	131.00	29-Jan-00	16	1.31	1.29	-0.3950	524	1572	107	106	102	105	21	123	81
39814	111.00	10-Sep-09	17	1.24	1.21	-0.5493	333	666	98	94	83	95	22	105	60
37257	103.00	6-Dec-02	18	1.17	1.15	-0.7235	206	206	89	80	60	85	24	84	36
39083	100.00	29-Jun-07	19	1.11	1.08	-0.9388	100	0	78	63	30	72	27	56	3
38353	0.00	0-Jan-00	20	1.05	1.03	-1.2758	0	0	61	37	-24	55	31	7	-54
				10	**10**	2.2504			310	315	321	317	37	358	284
				20	**20**	2.9702			388	372	360	387	48	408	313
				35	**35**	3.5409			459	417	388	446	56	445	332
ln_s.d. =	0.546363551			**66**	**66**	4.1820			550	468	417	515	66	483	350
ln_mean =	5.059956327			**100**	**100**	4.6001			615	501	434	562	73	507	361

n =	20		PWM0 =	183	Alpha =	79
x bar =	182.95		PWM1 =	119	U =	137
s.d. =	107.902234		PWM2 =	91		
alpha =	84.13102671		C =	-0.0271	Alpha =	62
u =	134.3895714		K =	-0.2112	U =	131
			Z =	-0.1618		
Q5 =	260.5861114	Gamma(1+k) =		1.1770		
Q100 =	521.3922942					

Standard Errors For EV1

var(Qt) = (alpha2/n)[(1.1128n - 0.9066) - (0.4574n - 1.1722)yt + (0.8046n - 0.1855)yt2] / (n - 1)



Appendix C: Figures – Calibration Modelling

Figure C1a - Maitai South at Old Intake

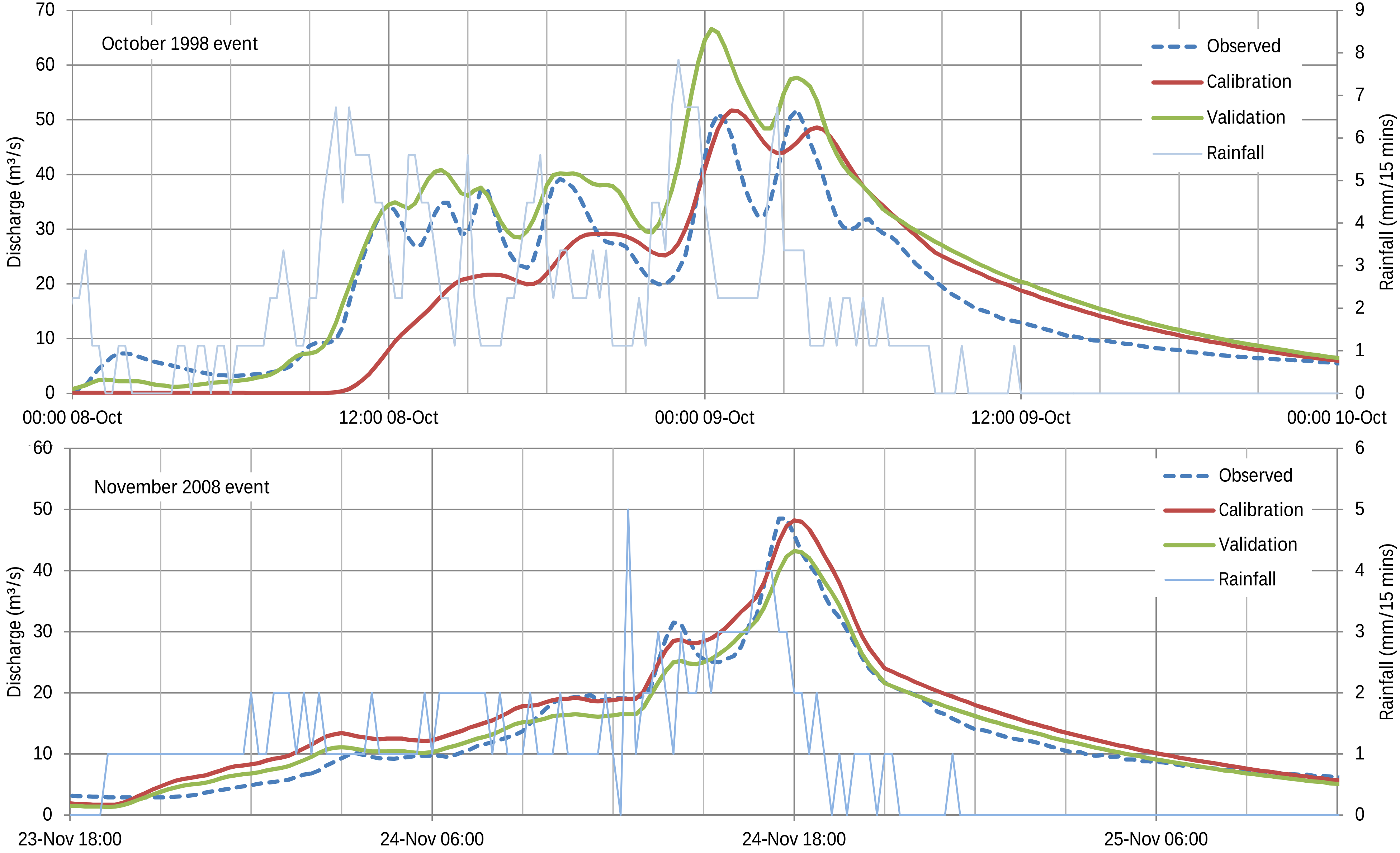


Figure C1b - Maitai South at Old Intake

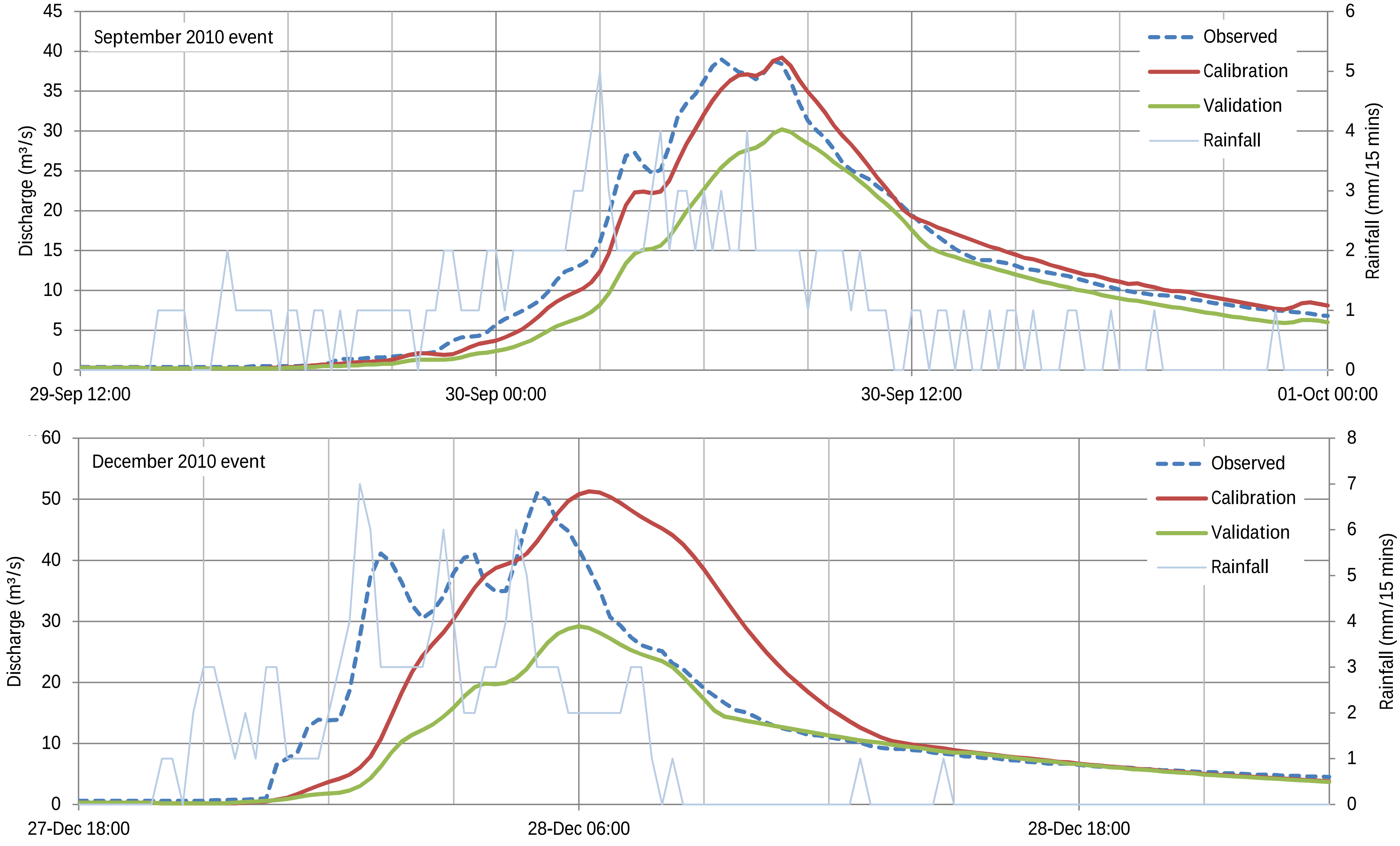


Figure C1c - Maitai South at Old Intake

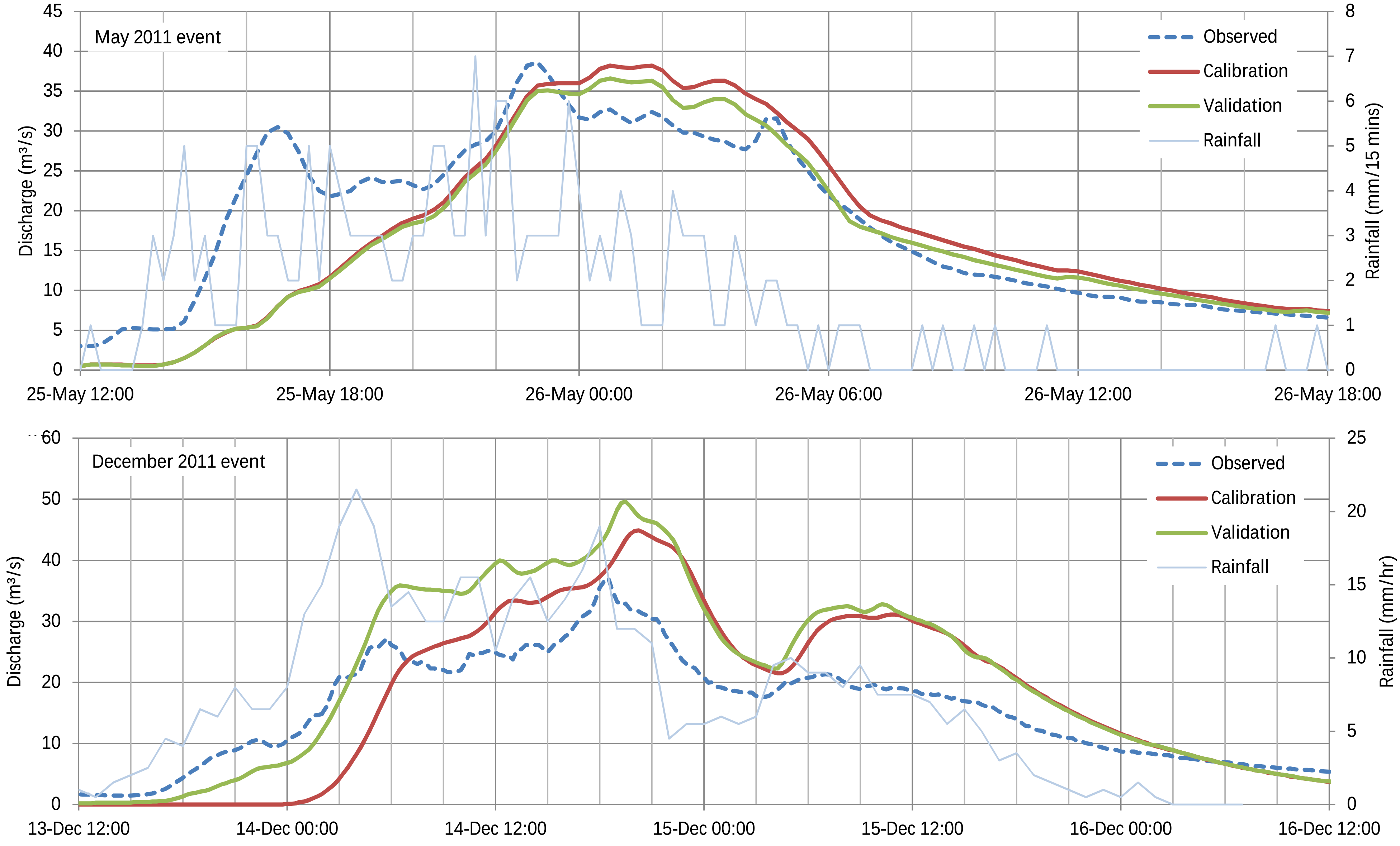


Figure C2a - Maitai at Forks

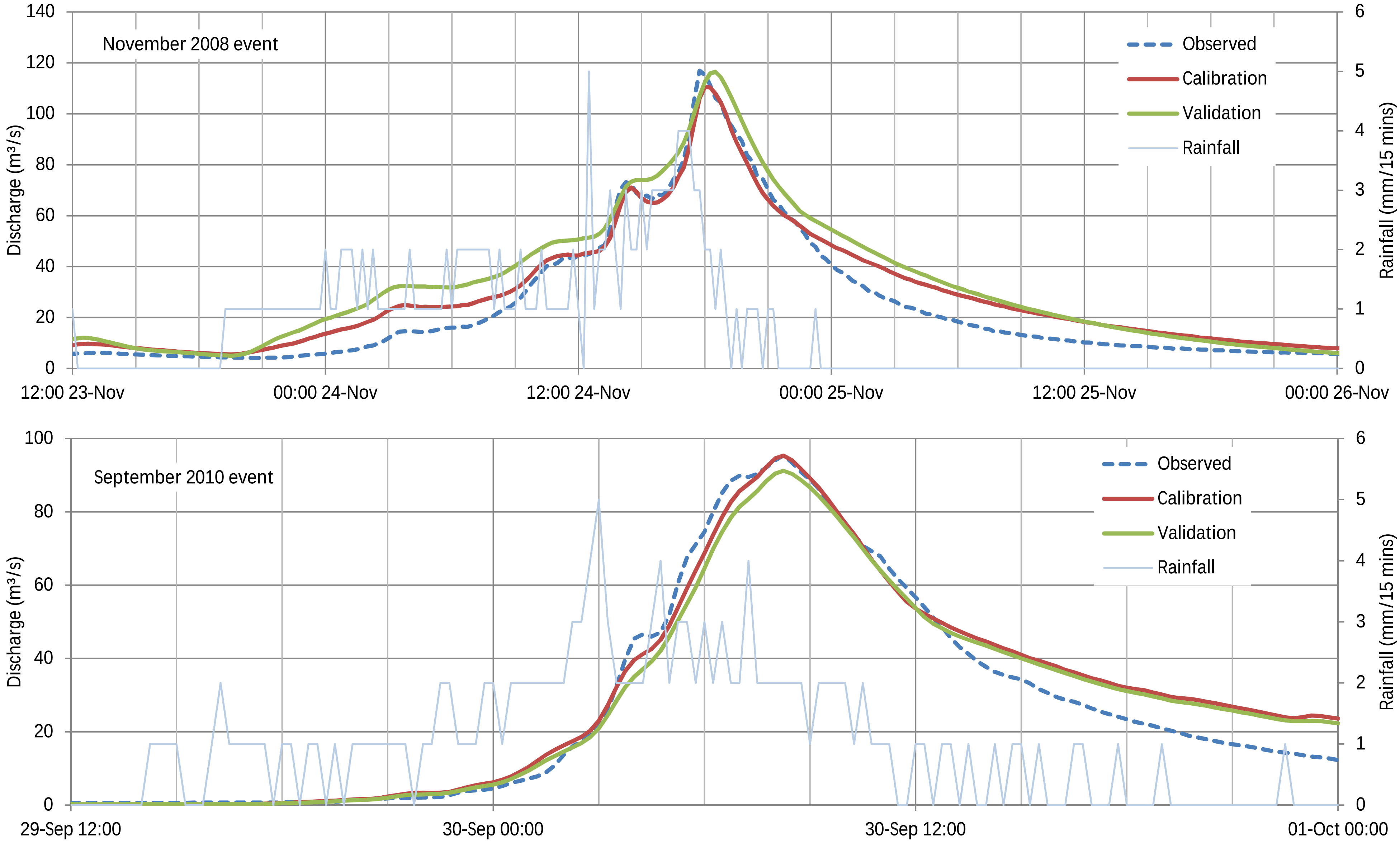
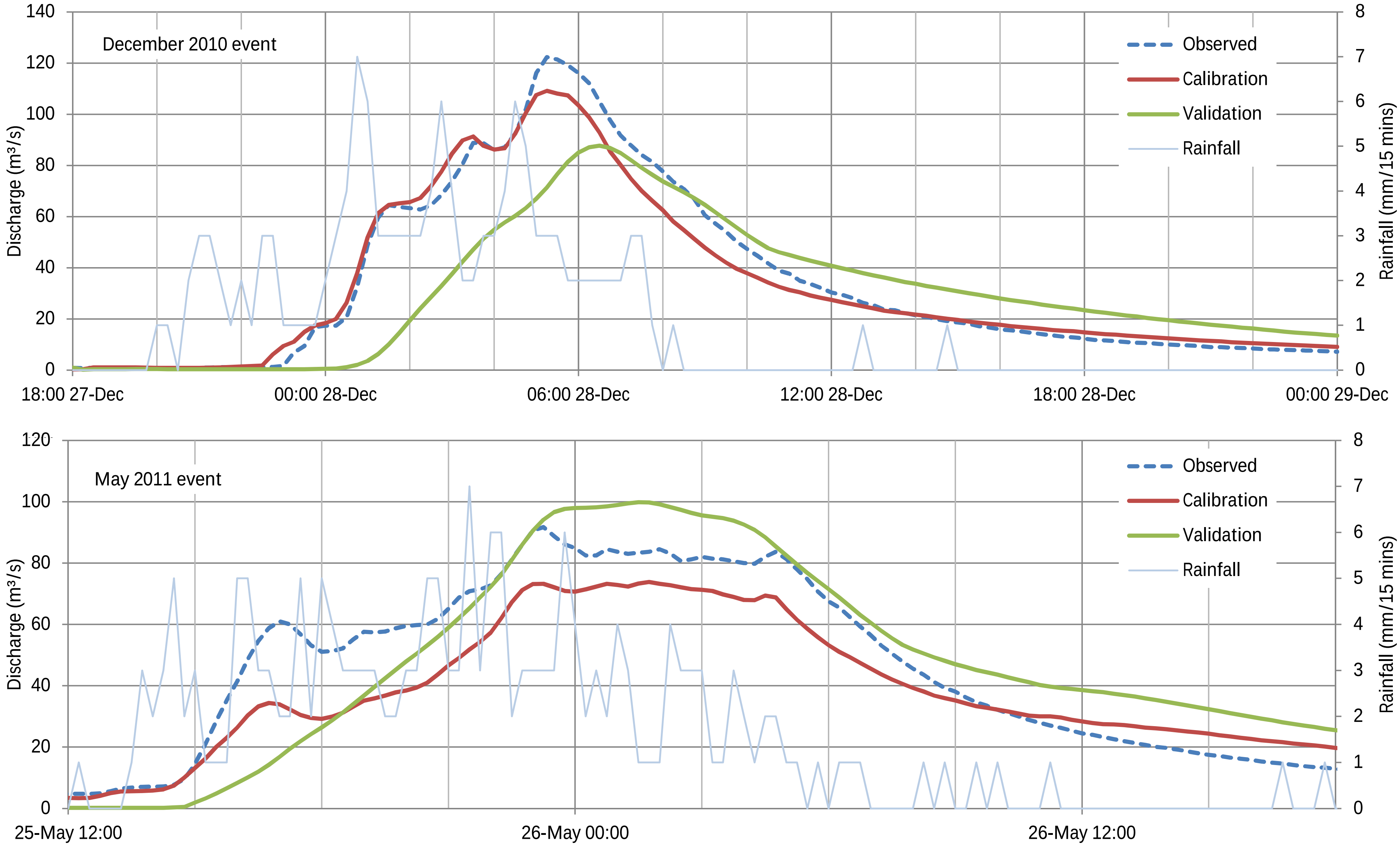


Figure C2b - Maitai at Forks



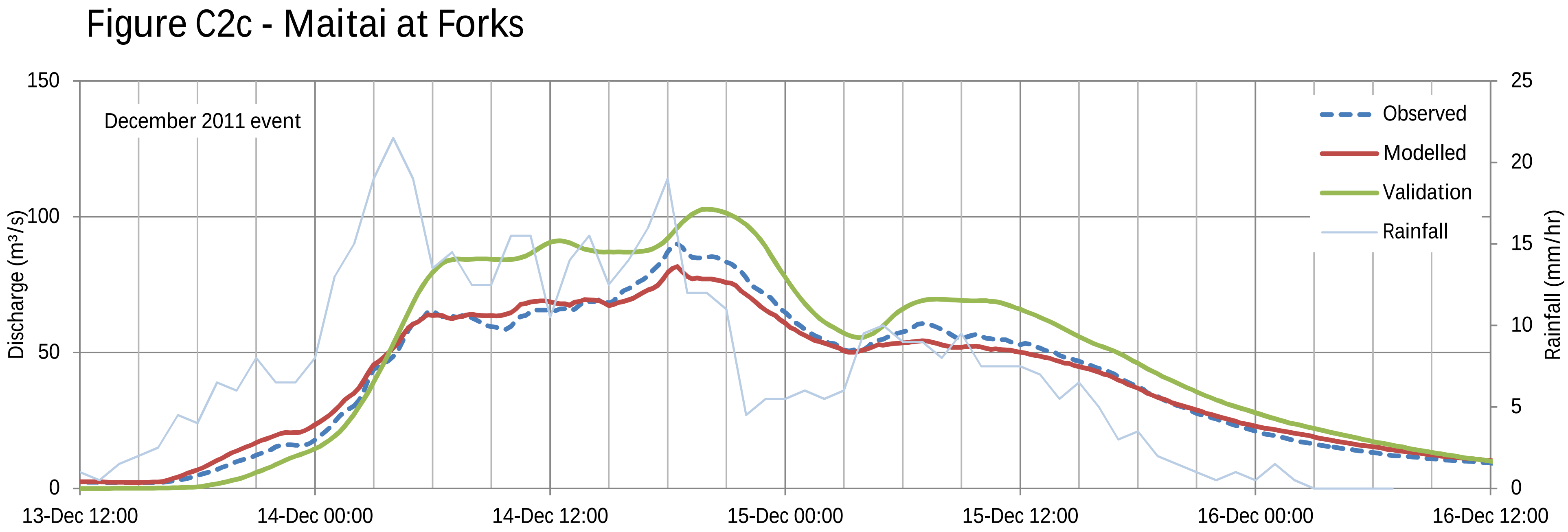


Figure C2c - Maitai at Forks
December 2011 event
Discharge (m³/s)
Rainfall (mm/hr)
150
100
50
0
25
20
15
10
5
0
13-Dec 12:00
14-Dec 00:00
14-Dec 12:00
15-Dec 00:00
15-Dec 12:00
16-Dec 00:00
16-Dec 12:00
Observed
Modelled
Validation
Rainfall

Figure C3a - Maitai at Girlies Hole

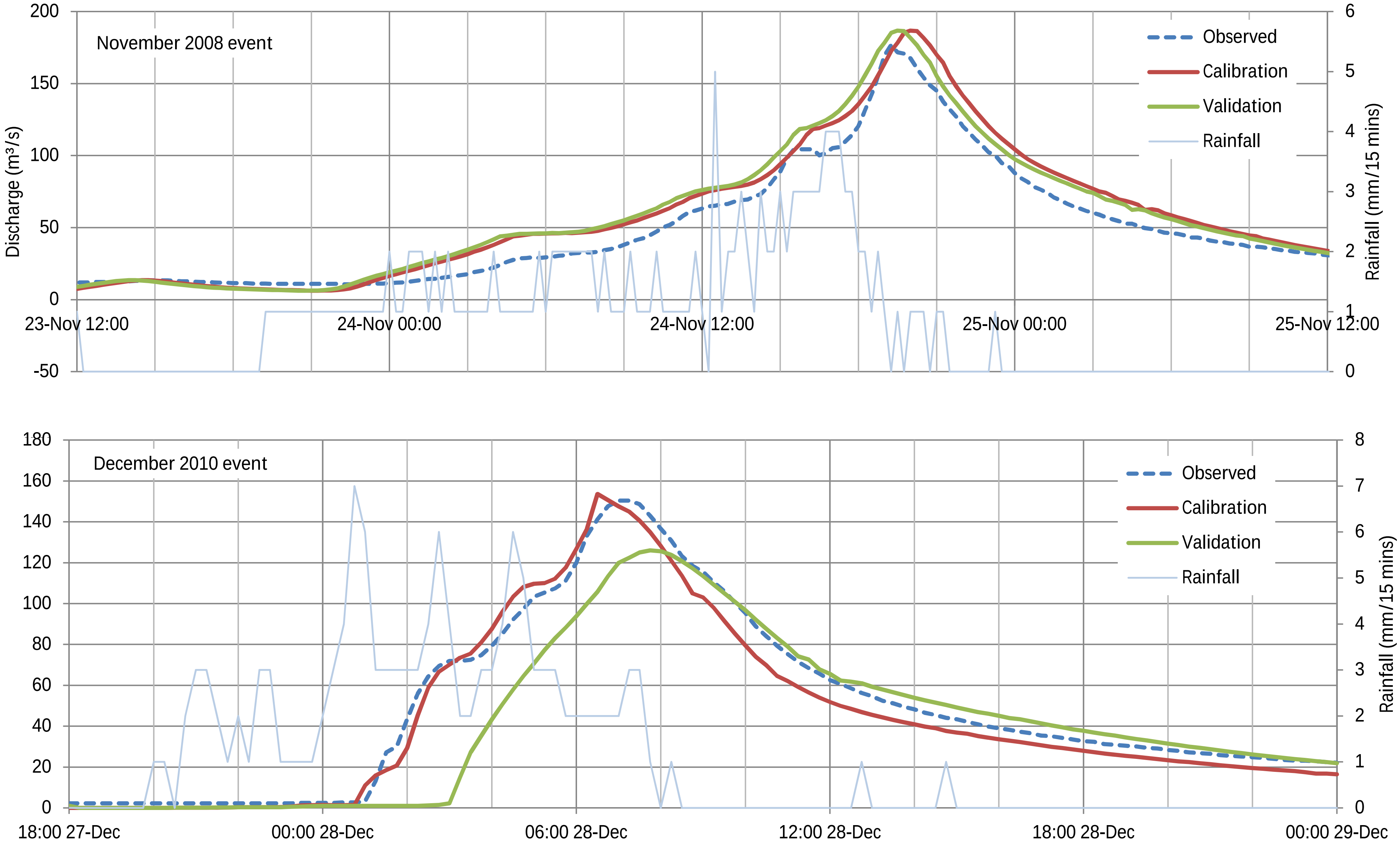


Figure C3b - Maitai at Girlies Hole

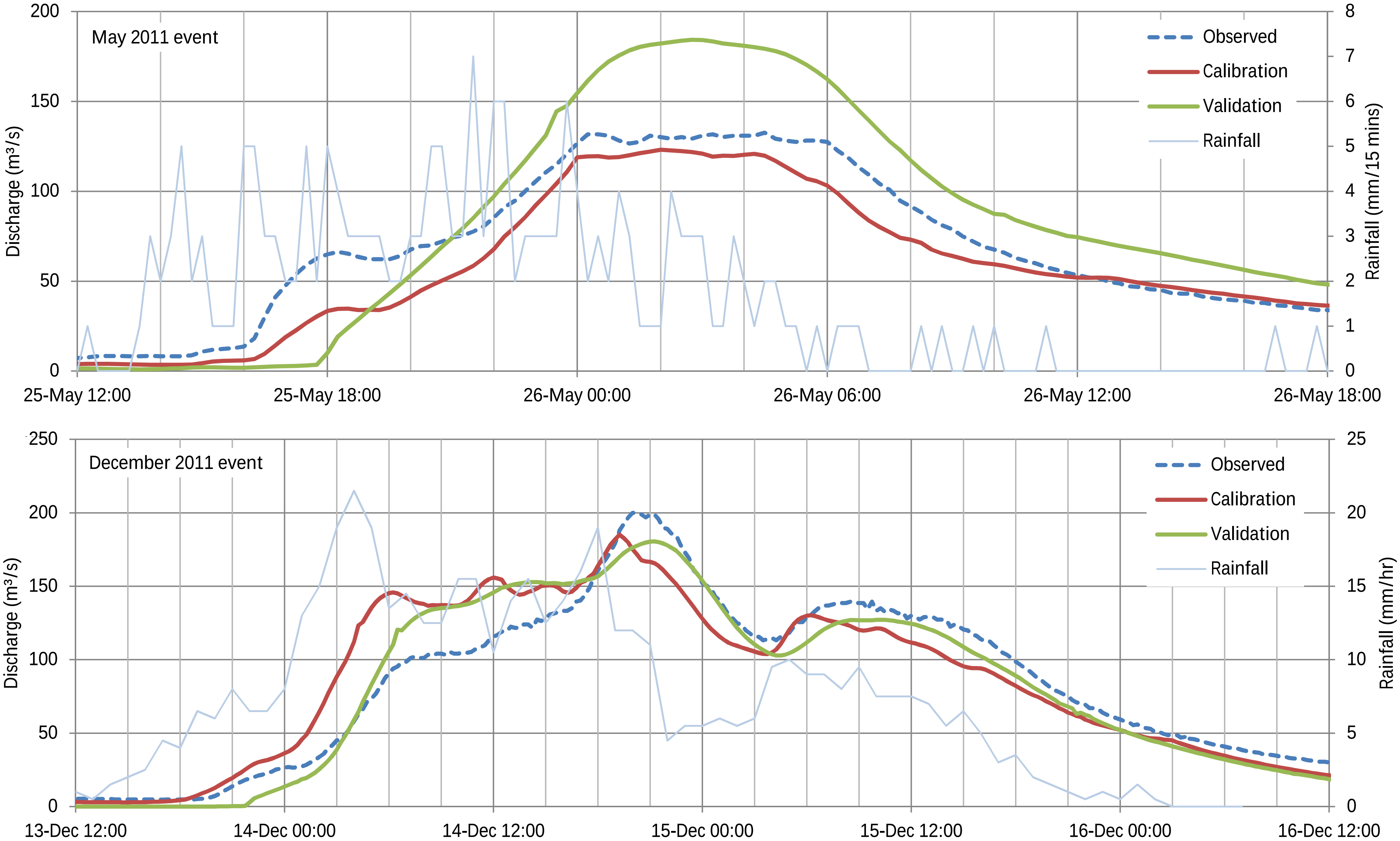


Figure C4a - Maitai at Avon Terrace

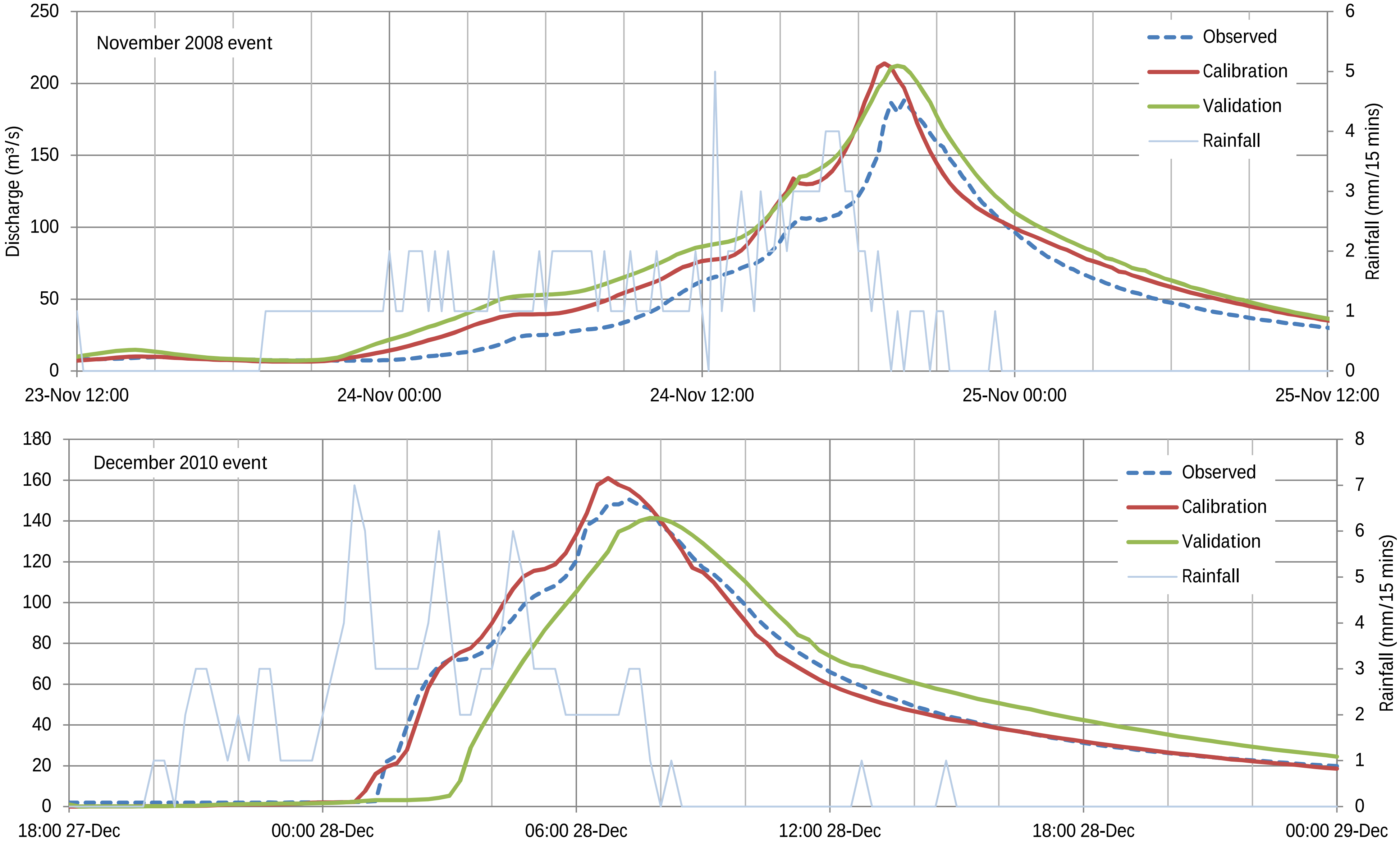
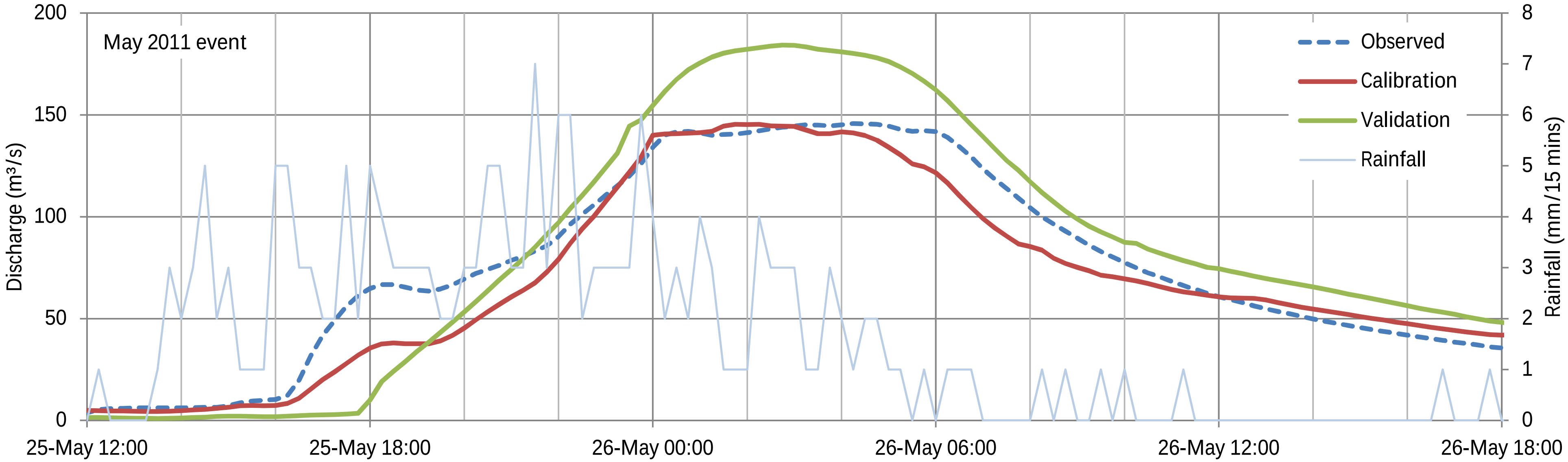
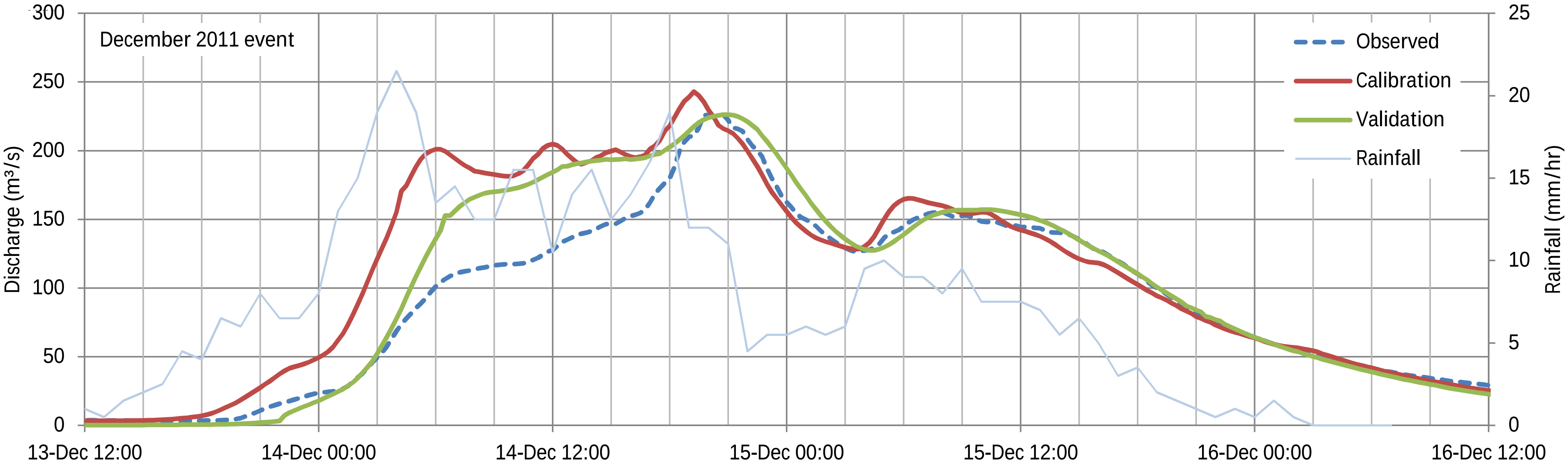


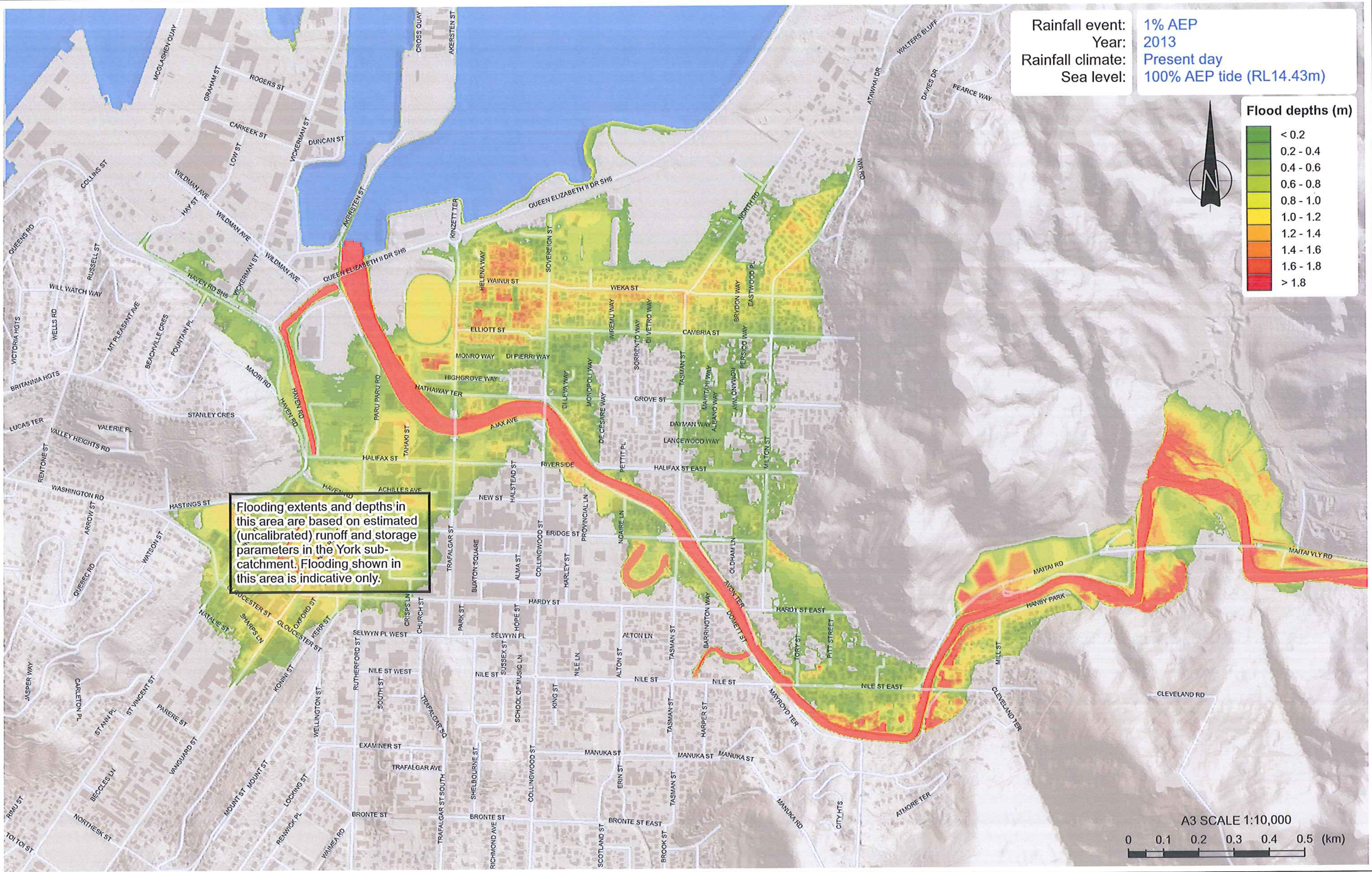
Figure C4b - Maitai at Avon Terrace





Appendix D: Figures – 1% AEP Modelled Floodplain

- Figure D1 1% AEP rainfall, 2013 rainfall climate, 100% AEP sea level
- Figure D2 1% AEP rainfall, 2050 rainfall, 100% AEP sea level +0.3 m SLR
- Figure D3 1% AEP rainfall, 2050 rainfall, 100% AEP sea level +0.5 m SLR
- Figure D4 1% AEP rainfall, 2100 rainfall, 100% AEP sea level +0.8 m SLR
- Figure D5 1% AEP rainfall, 2100 rainfall, 100% AEP sea level +1.0 m SLR
- Figure D6 Sunny day, 100% AEP sea level +1.0 m SLR



Notes:

1. Modelling is based on NCC LiDAR data collected 2007 and 2010
2. Modelling assumes existing land cover/use patterns.
3. Stormwater pipe network and any associated localised flooding due to surcharging has not been modelled.

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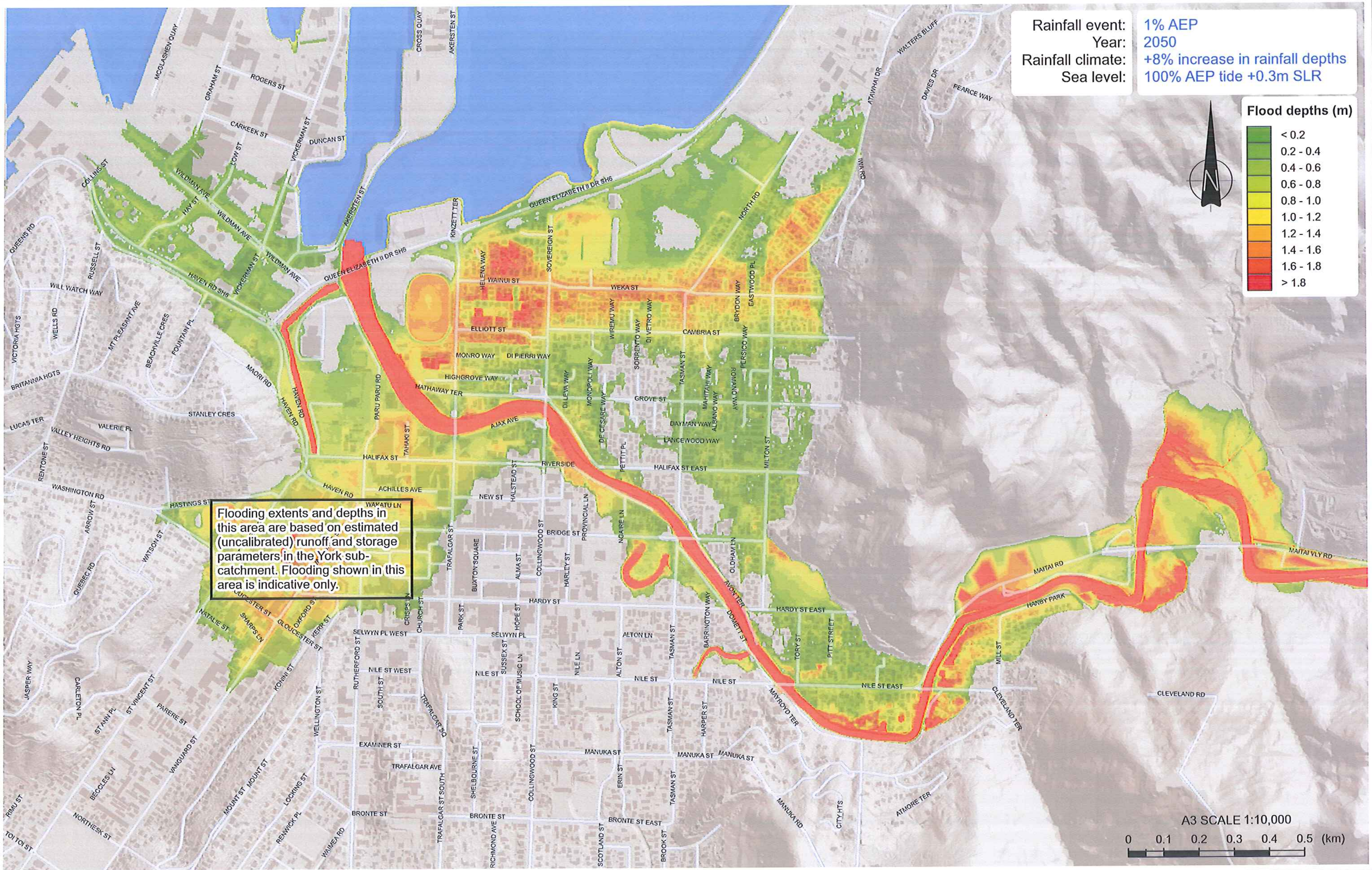
DRAWN	DNV	Feb.13
CHECKED	DCL	6.8.13
APPROVED	Y	6.8.13
ARCFILE	Figure D1.mxd	
SCALE (AT A3 SIZE)	1:10,000	
PROJECT No.	870888	

NELSON CITY COUNCIL
MAITAI RIVER FLOOD HAZARD MAPPING
Modelled floodplain depths
2013: 1% AEP rainfall, 100% AEP tide

FIGURE No. Figure D1 Rev. 1

P:\870888\WorkingMaterial\Report Figures\Figure D1.mxd



Notes:
1. Modelling is based on NCC LiDAR data collected 2007 and 2010
2. Modelling assumes existing land cover/use patterns.
3. Stormwater pipe network and any associated localised flooding due to surcharging has not been modelled.

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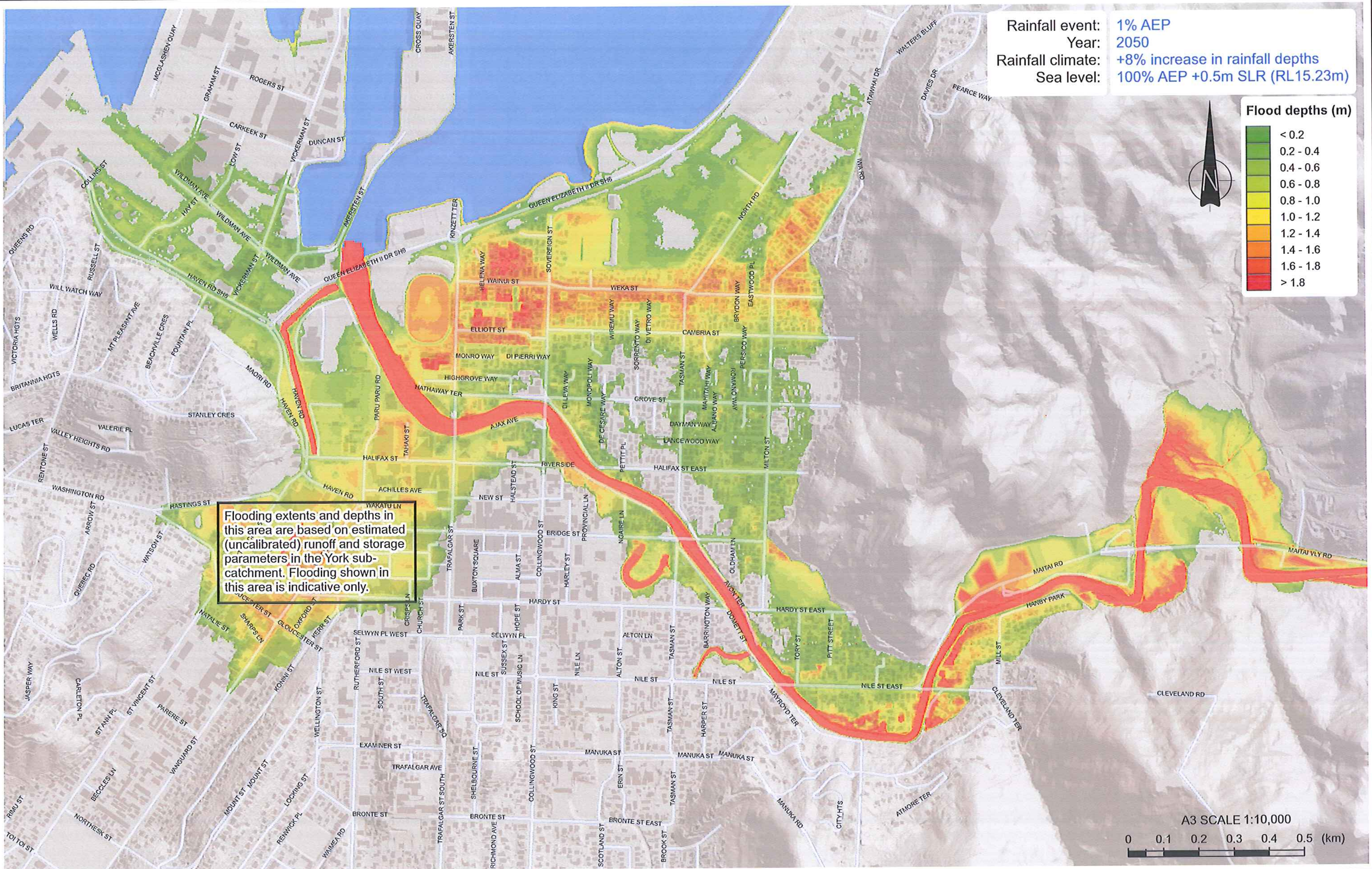
DRAWN	DNV	Feb.13
CHECKED	DCL	6.8.13
APPROVED	T	6.8.13
ARCFILE	Figure D2.mxd	
SCALE (AT A3 SIZE)	1:10,000	
PROJECT No.	870888	

NELSON CITY COUNCIL
MAITAI RIVER FLOOD HAZARD MAPPING
Modelled floodplain depths
2050: 1% AEP rainfall, 100% AEP tide +0.3m SLR

FIGURE No. Figure D2

Rev. 1

P:\870888\WorkingMaterial\Report Figures\Figure D2.mxd



Notes:
1. Modelling is based on NCC LiDAR data collected 2007 and 2010
2. Modelling assumes existing land cover/use patterns.
3. Stormwater pipe network and any associated localised flooding due to surcharging has not been modelled.

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Location Plan

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DRAWN	DNV	Feb.13
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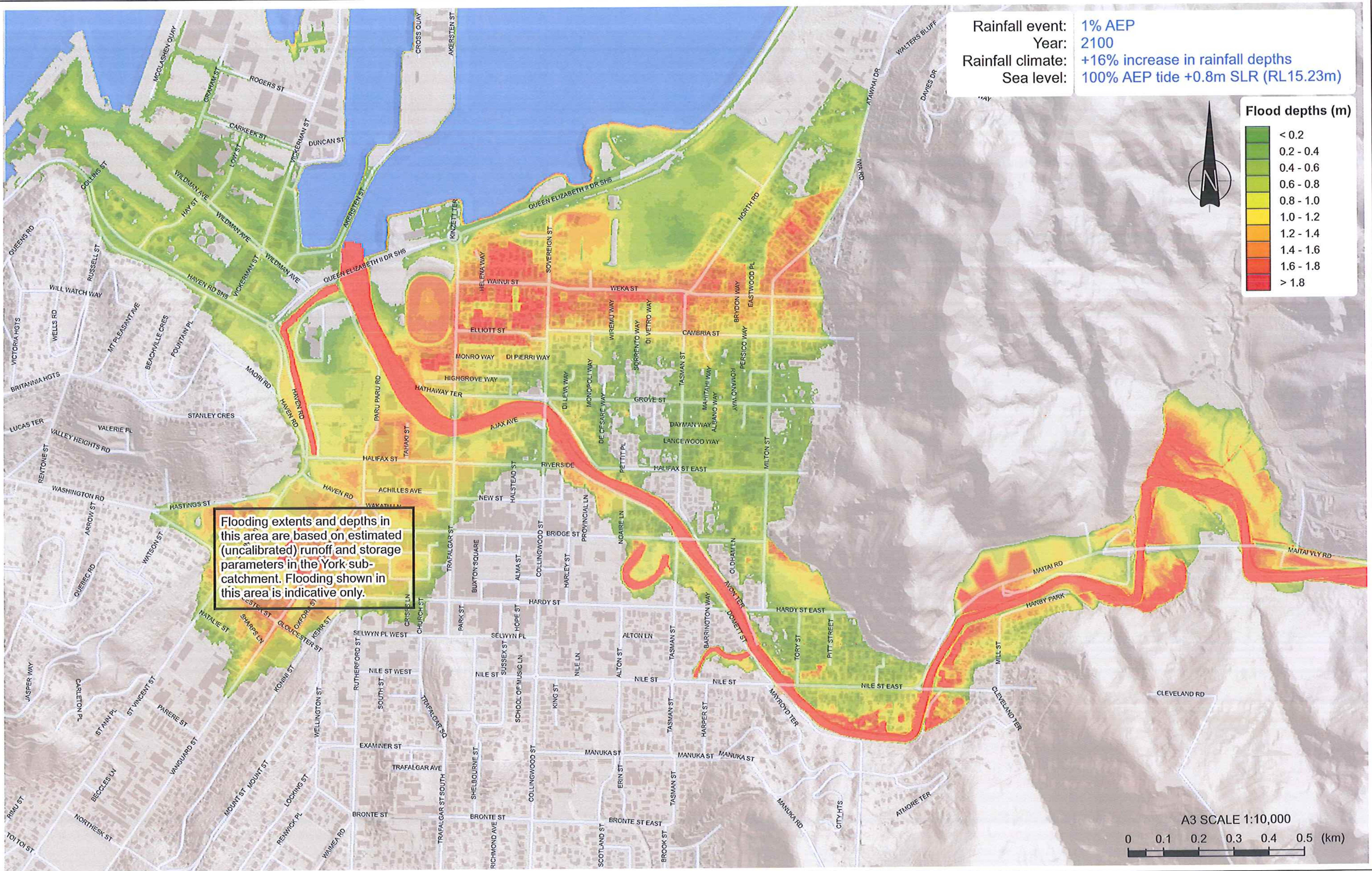
APPROVED	T	6.8.13
ARCFILE Figure D3.mxd		
SCALE (AT A3 SIZE) 1:10,000		
PROJECT No. 870888		

NELSON CITY COUNCIL
MAITAI RIVER FLOOD HAZARD MAPPING
Modelled floodplain depths
2050: 1% AEP rainfall, 100% AEP tide +0.5m SLR

FIGURE No. Figure D3 | Rev. 1

P:\870888\WorkingMaterial\Report Figures\Figure D3.mxd



Notes:
1. Modelling is based on NCC LiDAR data collected 2007 and 2010
2. Modelling assumes existing land cover/use patterns.
3. Stormwater pipe network and any associated localised flooding due to surcharging has not been modelled.

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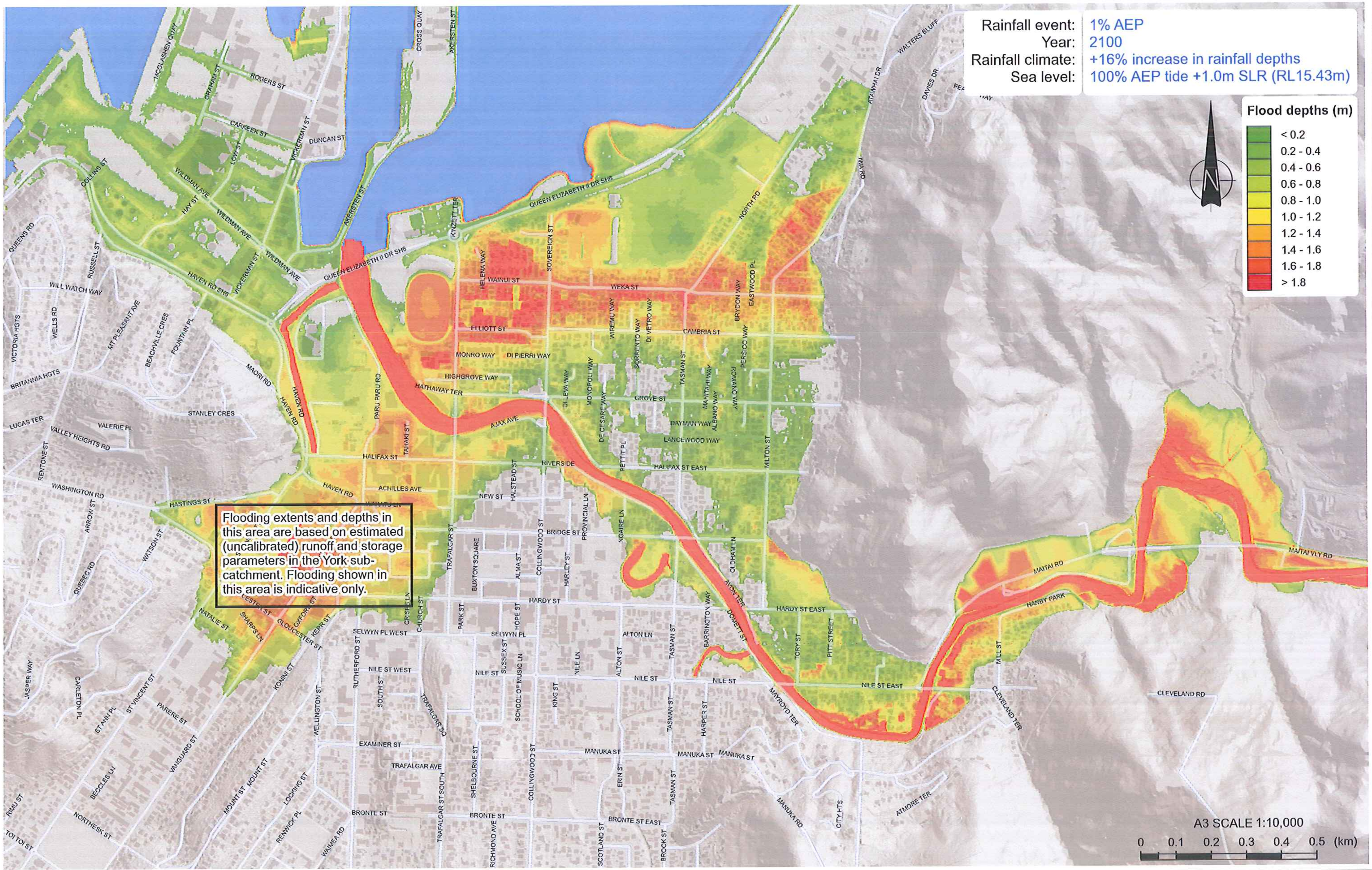
DRAWN	DNV	Feb.13
CHECKED	PCL	6.8.13
APPROVED	F	6.8.13
ARCFILE Figure D4.mxd		
SCALE (AT A3 SIZE) 1:10,000		
PROJECT No. 870888		

NELSON CITY COUNCIL
MAITAI RIVER FLOOD HAZARD MAPPING
Modelled floodplain depths
2100: 1% AEP rainfall, 100% AEP tide +0.8m SLR

FIGURE No. Figure D4

Rev. 1

P:\870888\WorkingMaterial\Report Figures\Figure D4.mxd



Notes:

1. Modelling is based on NCC LiDAR data collected 2007 and 2010
2. Modelling assumes existing land cover/use patterns.
3. Stormwater pipe network and any associated localised flooding due to surcharging has not been modelled.

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DRAWN	DNV	Feb.13
CHECKED	DCL	6.8.13
APPROVED	T	6.8.13
ARCFILE Figure D5.mxd		
SCALE (AT A3 SIZE) 1:10,000		
PROJECT No. 870888		

NELSON CITY COUNCIL
MAITAI RIVER FLOOD HAZARD MAPPING
Modelled floodplain depths
2100: 1% AEP rainfall, 100% AEP tide +1.0m SLR

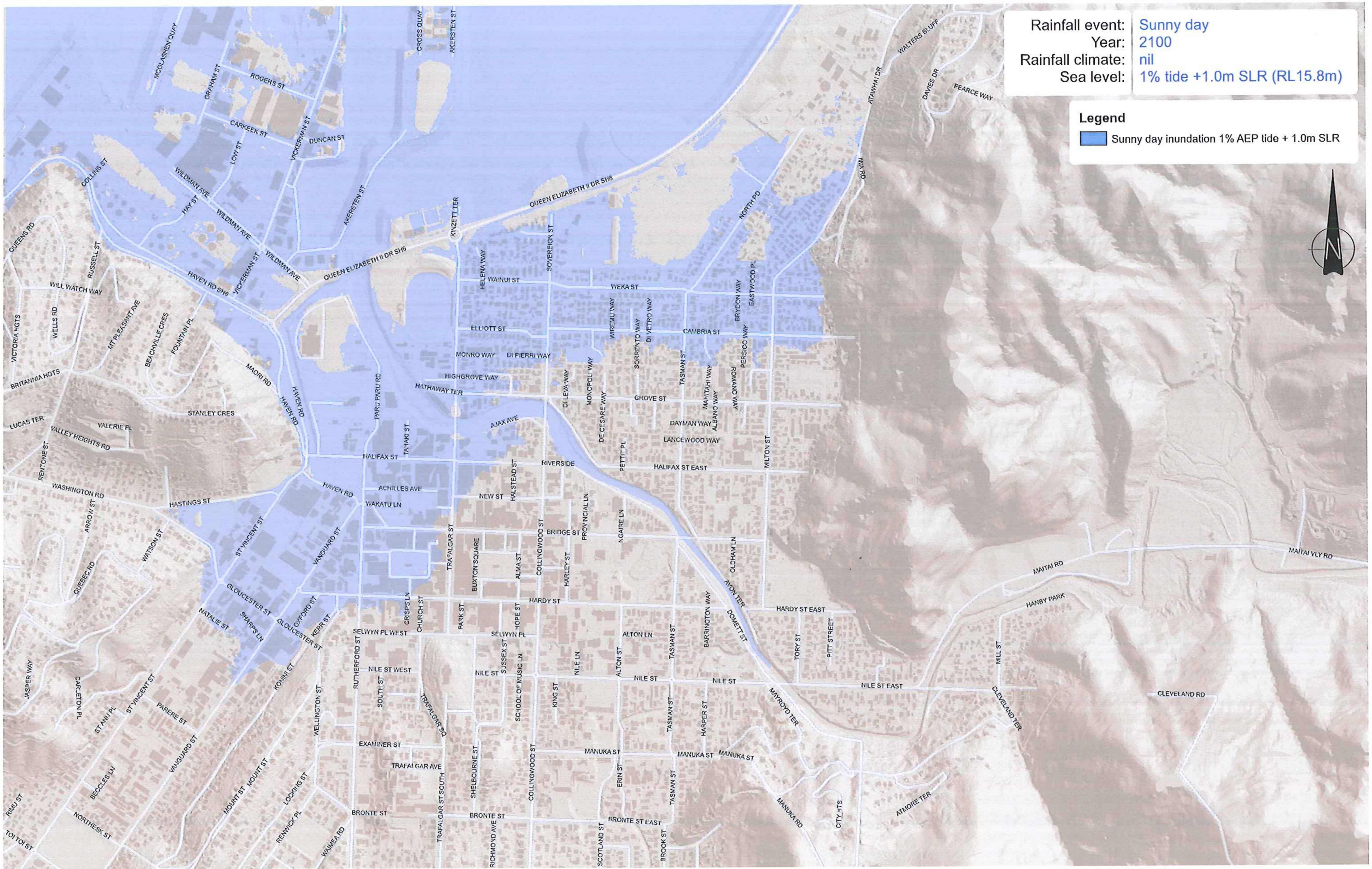
FIGURE No. Figure D5 Rev. 0

P:\870888\WorkingMaterial\Report Figures\Figure D5.mxd

Rainfall event:	Sunny day
Year:	2100
Rainfall climate:	nil
Sea level:	1% tide +1.0m SLR (RL15.8m)

Legend

Sunny day inundation 1% AEP tide + 1.0m SLR



P:\870888\WorkingMaterial\Report Figures\Figure D6.mxd

Notes: Based on NCC LiDAR data collected 2007 and 2010

A3 SCALE 1:10,000

0 0.1 0.2 0.3 0.4 0.5 (km)

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DRAWN	DNV	Feb.13
CHECKED	DCL	6.8.13
APPROVED	Y	6.8.13
ARCFILE Figure D6.mxd		
SCALE (AT A3 SIZE) 1:10,000		
PROJECT No. 870888		

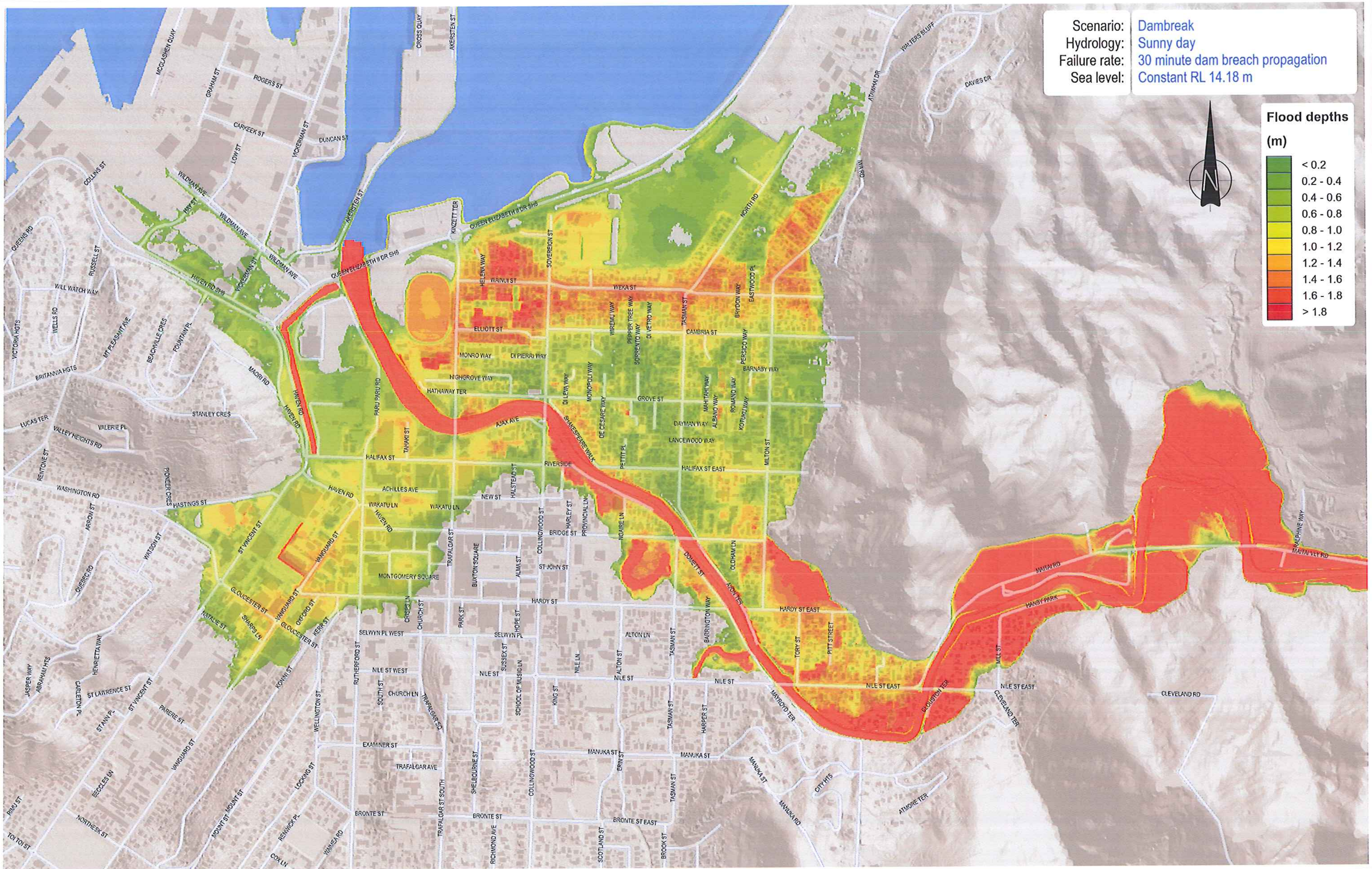
NELSON CITY COUNCIL
MAITAI RIVER FLOOD HAZARD MAPPING
Modelled floodplain
2100: Sunny day, 1% AEP sea level +1.0m SLR

FIGURE No. Figure D6

Rev. 0

Appendix E: Figures – Modelled Dambreak Floodplain

- Figure E1 Modelled dambreak floodplain (Tf = 0.5 hrs)
- Figure E2 Modelled dambreak floodplain (Tf = 1.0 hrs)
- Figure E3 Modelled dambreak floodplain (Tf = 2.0 hrs)



Notes: Based on NCC LiDAR data collected 2007 and 2010

A3 SCALE 1:10,000

0 0.1 0.2 0.3 0.4 0.5 (km)

Nelson City Council
te kaunihera ō whakatū

Tonkin & Taylor
Environmental and Engineering Consultants
43 Halifax Street, Nelson
www.tonkin.co.nz

DRAWN	DNV	Feb.13
CHECKED	PCL	6.8.13
APPROVED		6.8.13
ARCFILE Figure E1.mxd		
SCALE (AT A3 SIZE) 1:10,000		
PROJECT No. 870888		

NELSON CITY COUNCIL
MAITAI RIVER FLOOD HAZARD MAPPING
Modelled floodplain depths
Sunny day dambreak, 30 min breach

FIGURE No. Figure E1 | Rev. 0

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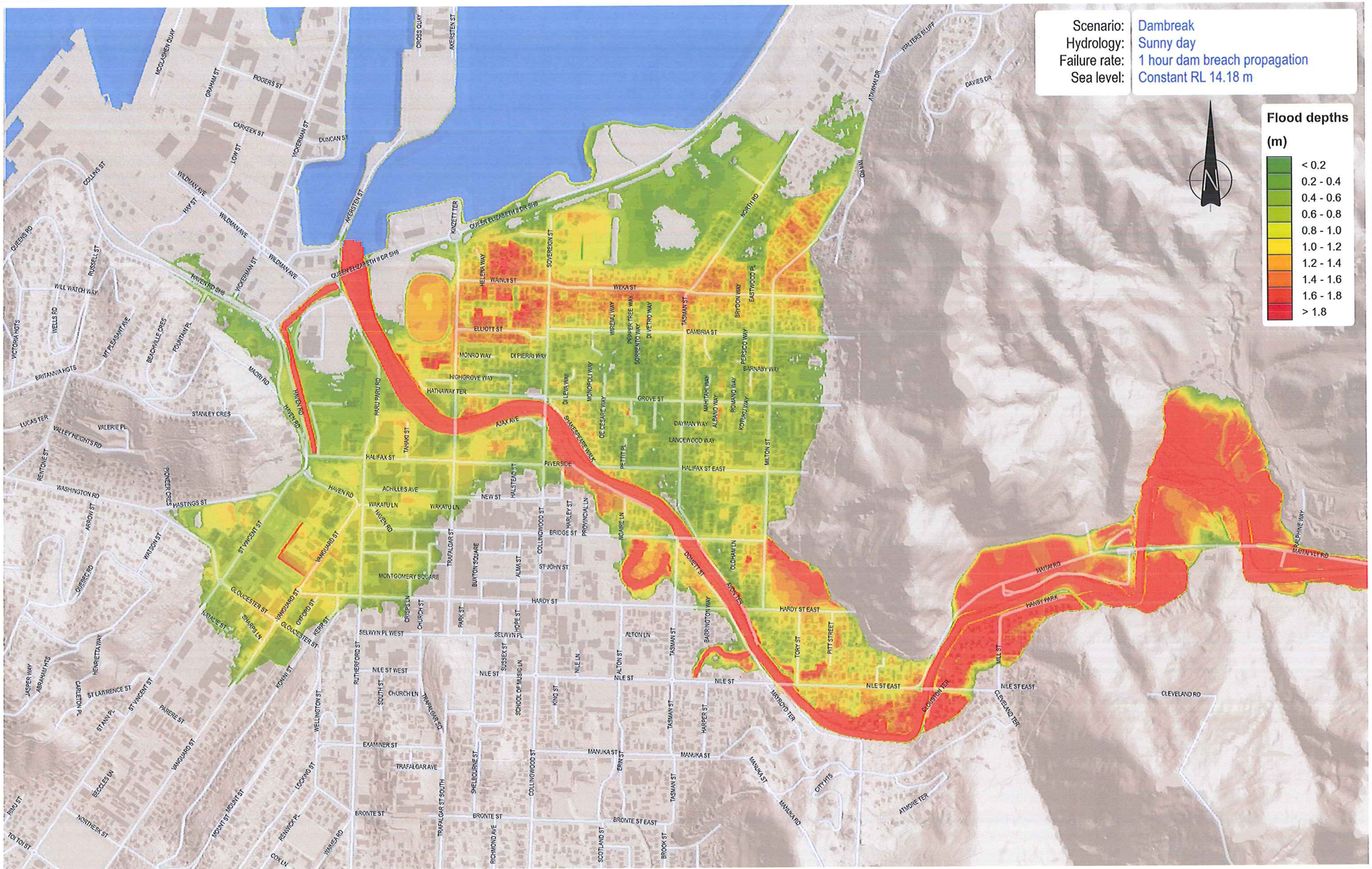

Notes: Based on NCC LiDAR data collected 2007 and 2010

A3 SCALE 1:10,000

0 0.1 0.2 0.3 0.4 0.5 (km)

Nelson City Council
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Tonkin & Taylor
Environmental and Engineering Consultants
43 Halifax Street, Nelson
www.tonkin.co.nz

DRAWN	DNV	Feb.13
CHECKED	DCL	6.3.13
APPROVED	7	6.3.13

ARCFILE: Figure E2.mxd

SCALE (AT A3 SIZE): 1:10,000

PROJECT No. 870888

NELSON CITY COUNCIL
MAITAI RIVER FLOOD HAZARD MAPPING
Modelled floodplain depths
Sunny day dambreak, 1 hour breach

FIGURE No. Figure E2

Rev. 0

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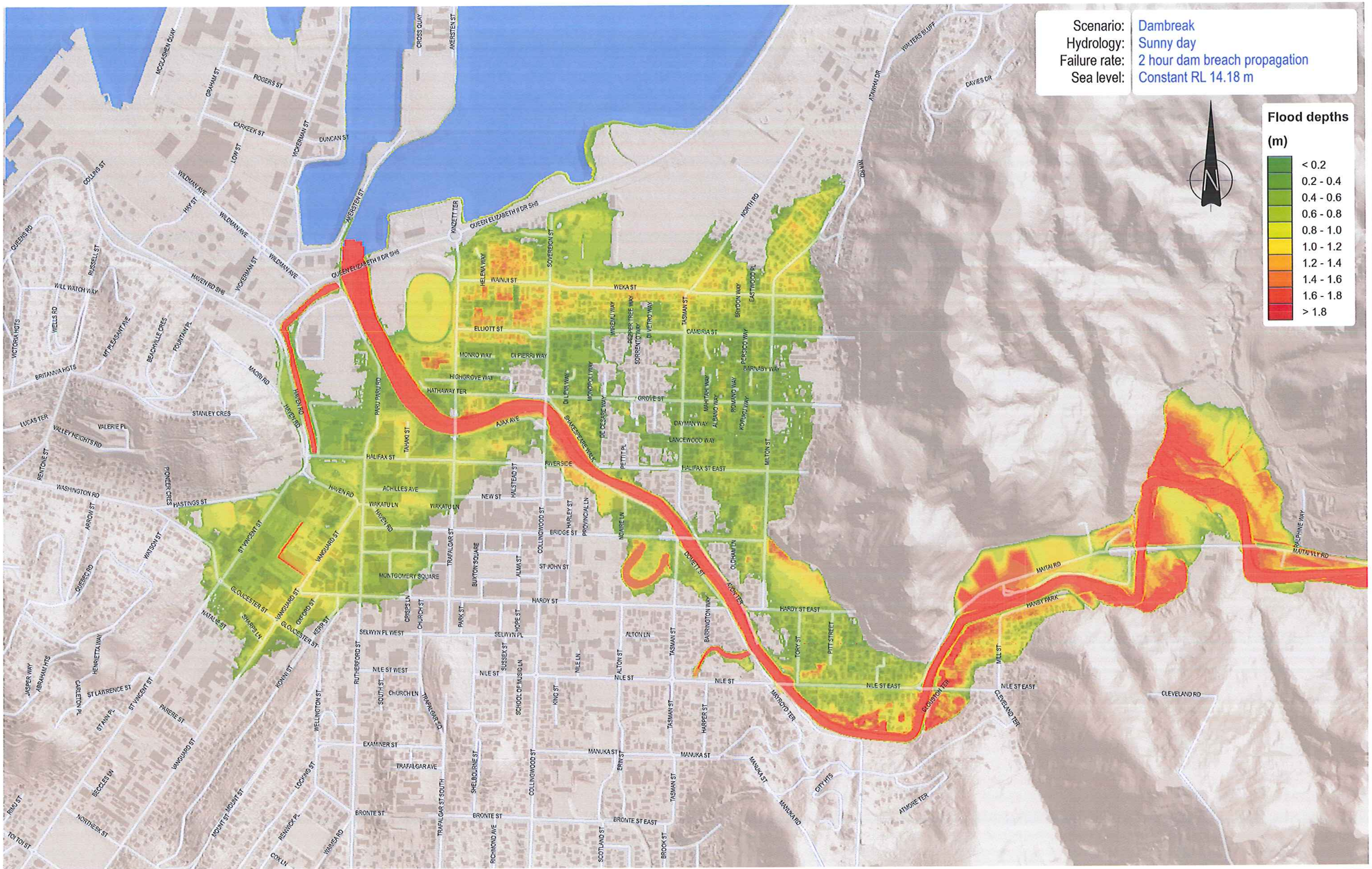

Notes: Based on NCC LiDAR data collected 2007 and 2010

A3 SCALE 1:10,000

0 0.1 0.2 0.3 0.4 0.5 (km)

Nelson City Council
te kaunihera ō whakatū

Location Plan

Tonkin & Taylor
Environmental and Engineering Consultants
43 Halifax Street, Nelson
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DRAWN	DNV	Feb.13
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ARCFILE Figure E3.mxd		
SCALE (AT A3 SIZE) 1:10,000		
PROJECT No. 870888		

NELSON CITY COUNCIL
MAITAI RIVER FLOOD HAZARD MAPPING
Modelled floodplain depths
Sunny day dambreak, 2 hour breach

FIGURE No. Figure E3

Rev. 0

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Appendix F: Hydrological parameters

- HIRDS v3 Rainfall Data
- Times of concentration

Maitai River subcatchments - Times of Concentration estimation

Sub-catchment	Length (m)	Area (m²)	Max elev (RL m)	Min elev (RL m)	Hgt Diff (m)	Slope (m/m)	Curve number	Channel. factor	Ramser-Kirpich (mins)	Bransby-Williams (mins)	TP108 (mins)	USSCS (mins)	Average (mins)	Selected (mins)
SOUTH-BRANCH	7267	18,099,000	960	140	820	0.094	77	1.0	46	121	82	42	73	90
NORTH-BRANCH	6241	13,421,000	940	140	800	0.095	77	1.0	40	104	74	36	64	74
FORKS	1488	1,585,000	160	120	40	0.039	77	1.0	19	42	37	22	30	37
NORTH-BANK	1946	5,138,000	480	120	360	0.131	62	1.0	15	33	37	13	24	37
NEDS	3226	6,802,000	800	80	720	0.197	62	1.0	18	52	46	17	33	46
GROOM	4012	7,116,000	780	40	740	0.119	62	1.0	26	66	62	22	44	62
SHARLAND	6703	15,744,000	500	30	470	0.049	62	1.0	55	124	113	48	85	113
KOKA-WEST	3351	3,888,000	420	15	405	0.072	62	1.0	28	64	64	23	45	64
NELSON-SOUTH	2456	1,828,000	260	10	250	0.023	85	0.6	34	52	34	19	35	34
BROOK	9785	17,069,000	800	15	785	0.035	62	1.0	84	175	160	61	120	160
NELSON-EAST	1750	1,230,000	180	10	170	0.025	85	0.6	25	39	26	15	26	26
YORK	5836	7,414,000	295	10	285	0.017	85	0.8	74	125	86	50	84	86

Note: catchment shape parameters derived from LINZ 20m contour data. Catchment slope calculated using Equal Areas method as described in ARC TP108 publication.

Method	Formula	Parameter definitions
Ramser-Kirpich	$T_c = 0.0195\, L^{0.77} S_a^{-0.385}$	S_a = average channel slope (m/m) L = flow length from the study location to the farthest point in the catchment (m)
Bransby - Williams	$T_c = (0.953\, L^{1.2}) / (A^{0.1} H^{0.2})$	A = catchment area (km^2) L = maximum flow length (m) H = the difference in elevation between the highest and lowest points in the study area (m)
TP108	$T_c = 0.14\, C\, L^{0.66} \{CN/(200-CN)\}^{-0.55} S_c^{-0.30}$	C = Channelisation Factor L = maximum flow length (km) CN = SCS Curve Number S_c = catchment slope by equal area method
U.S. Soil Conservation Service	$T_c = (0.87\, L^3 / H)^{0.385}$	L = maximum flow length (km) H = the difference in elevation between the highest and lowest points in the study area (m)

High Intensity Rainfall System V3
Depth-Duration-Frequency results (produced on Friday 5th of November 2010)
Sitename: Brook
Coordinate system: NZTM2000
Easting: 1624597
Northing: 5425952

Rainfall depths (mm)

					Duration						
ARI (y)	aep	10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
1.58	0.633	7.2	11.1	14.3	22	31.7	56.8	81.9	118.2	138.2	151.5
2	0.5	7.9	12.2	15.7	24.2	34.8	61.7	88.5	127.1	148.7	162.9
5	0.2	10.6	16.4	21.1	32.5	46	79.5	112.4	158.9	185.9	203.7
10	0.1	12.9	19.9	25.6	39.5	55.3	94.1	131.7	184.2	215.5	236.2
20	0.05	15.5	24	30.9	47.7	66	110.7	153.3	212.3	248.4	272.2
30	0.033	17.3	26.7	34.4	53.1	73.1	121.5	167.3	230.4	269.5	295.4
40	0.025	18.7	28.8	37.1	57.3	78.6	129.7	177.9	244	285.4	312.9
50	0.02	19.8	30.6	39.4	60.7	83.1	136.4	186.6	255.1	298.4	327.1
60	0.017	20.8	32.1	41.3	63.7	86.9	142.2	194	264.6	309.5	339.2
80	0.012	22.4	34.6	44.5	68.7	93.4	151.8	206.2	280.1	327.7	359.1
100	0.01	23.8	36.6	47.2	72.8	98.7	159.6	216.2	292.8	342.5	375.4

Coefficients

c1	c2	c3	d1	d2	d3	e	f
-0.0001	-0.0198	0	0.6256	0.529	0.2261	0.2602	3.0916

Standard errors (mm)

					Duration						
ARI (y)	aep	10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
1.58	0.633	0.8	0.8	0.8	0.9	0.9	1.3	1.7	1.7	2	2.1
2	0.5	0.8	0.8	0.9	0.9	1	1.4	1.9	1.9	2.2	2.4
5	0.2	0.8	0.9	1	1.2	1.3	2.1	2.9	2.9	3.4	3.7
10	0.1	0.9	1.1	1.3	1.7	1.8	3.1	4.3	4.3	5	5.5
20	0.05	1.1	1.5	1.8	2.5	2.5	4.6	6.6	6.4	7.5	8.2
30	0.033	1.2	1.8	2.2	3.1	3.1	5.8	8.3	8	9.5	10.2
40	0.025	1.4	2	2.6	3.6	3.7	6.8	9.7	9.4	11	12
50	0.02	1.5	2.3	2.9	4.1	4.1	7.7	10.9	10.5	12.4	13.4
60	0.017	1.6	2.5	3.2	4.5	4.5	8.5	12	11.5	13.6	14.7
80	0.012	1.9	2.8	3.7	5.2	5.2	9.8	13.9	13.3	15.6	17
100	0.01	2	3.1	4.1	5.8	5.8	10.9	15.5	14.8	17.4	18.8

2050 (assuming 1°C temp rise, and corresponding 8% increase in rainfall)
Rainfall depths (mm)

					Duration						
ARI (y)	aep	10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
1.58	0.633	7.8	12.0	15.4	23.8	34.2	61.3	88.5	127.7	149.3	163.6
2	0.5	8.5	13.2	17.0	26.1	37.6	66.6	95.6	137.3	160.6	175.9
5	0.2	11.4	17.7	22.8	35.1	49.7	85.9	121.4	171.6	200.8	220.0
10	0.1	13.9	21.5	27.6	42.7	59.7	101.6	142.2	198.9	232.7	255.1
20	0.05	16.7	25.9	33.4	51.5	71.3	119.6	165.6	229.3	268.3	294.0
30	0.033	18.7	28.8	37.2	57.3	78.9	131.2	180.7	248.8	291.1	319.0
40	0.025	20.2	31.1	40.1	61.9	84.9	140.1	192.1	263.5	308.2	337.9
50	0.02	21.4	33.0	42.6	65.6	89.7	147.3	201.5	275.5	322.3	353.3
60	0.017	22.5	34.7	44.6	68.8	93.9	153.6	209.5	285.8	334.3	366.3
80	0.012	24.2	37.4	48.1	74.2	100.9	163.9	222.7	302.5	353.9	387.8
100	0.01	25.7	39.5	51.0	78.6	106.6	172.4	233.5	316.2	369.9	405.4

2100 (assuming 2°C temp rise, and corresponding 16% increase in rainfall)
Rainfall depths (mm)

					Duration						
ARI (y)	aep	10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
1.58	0.633	8.4	12.9	16.6	25.5	36.8	65.9	95.0	137.1	160.3	175.7
2	0.5	9.2	14.2	18.2	28.1	40.4	71.6	102.7	147.4	172.5	189.0
5	0.2	12.3	19.0	24.5	37.7	53.4	92.2	130.4	184.3	215.6	236.3
10	0.1	15.0	23.1	29.7	45.8	64.1	109.2	152.8	213.7	250.0	274.0
20	0.05	18.0	27.8	35.8	55.3	76.6	128.4	177.8	246.3	288.1	315.8
30	0.033	20.1	31.0	39.9	61.6	84.8	140.9	194.1	267.3	312.6	342.7
40	0.025	21.7	33.4	43.0	66.5	91.2	150.5	206.4	283.0	331.1	363.0
50	0.02	23.0	35.5	45.7	70.4	96.4	158.2	216.5	295.9	346.1	379.4
60	0.017	24.1	37.2	47.9	73.9	100.8	165.0	225.0	306.9	359.0	393.5
80	0.012	26.0	40.1	51.6	79.7	108.3	176.1	239.2	324.9	380.1	416.6
100	0.01	27.6	42.5	54.8	84.4	114.5	185.1	250.8	339.6	397.3	435.5

High Intensity Rainfall System V3
Depth-Duration-Frequency results (produced on Friday 5th of November 2010)
Sitename: Kaka West
Coordinate system: NZTM2000
Easting: 1626400
Northing: 5432017

Rainfall depths (mm)

		Duration									
ARI (y)	aep	10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
1.58	0.633	7.1	10.8	13.7	20.6	29.1	50.3	71.1	100.4	114.3	123.2
2	0.5	7.9	11.8	15	22.6	31.8	54.6	76.8	108	122.8	132.4
5	0.2	10.5	15.8	20.1	30.3	42	70.3	97.3	134.8	153.4	165.4
10	0.1	12.8	19.2	24.4	36.8	50.4	83.1	113.9	156.2	177.7	191.6
20	0.05	15.4	23.1	29.4	44.2	60.1	97.5	132.4	179.8	204.6	220.6
30	0.033	17.1	25.7	32.7	49.2	66.5	107	144.4	195	221.9	239.2
40	0.025	18.4	27.8	35.3	53.1	71.4	114.2	153.5	206.5	234.9	253.3
50	0.02	19.5	29.4	37.4	56.2	75.4	120	161	215.9	245.5	264.8
60	0.017	20.5	30.8	39.2	59	78.9	125.1	167.3	223.8	254.6	274.5
80	0.012	22.1	33.2	42.2	63.5	84.6	133.4	177.8	236.9	269.4	290.5
100	0.01	23.4	35.2	44.7	67.3	89.4	140.3	186.3	247.5	281.5	303.6

Coefficients

c1	c2	c3	d1	d2	d3	e	f
-0.0002	-0.0193	-0.0001	0.5905	0.4987	0.1861	0.2574	3.025

Standard errors (mm)

		Duration									
ARI (y)	aep	10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
1.58	0.633	1	1	1.1	1.1	1.1	1.4	1.6	1.6	1.8	1.9
2	0.5	1	1.1	1.1	1.1	1.2	1.5	1.8	1.8	1.9	2.1
5	0.2	1.1	1.1	1.2	1.3	1.4	2	2.6	2.5	2.8	3
10	0.1	1.1	1.3	1.4	1.7	1.8	2.9	3.8	3.5	4	4.3
20	0.05	1.3	1.6	1.8	2.4	2.5	4.2	5.7	5.1	5.8	6.2
30	0.033	1.4	1.8	2.2	2.9	3.1	5.3	7.2	6.3	7.2	7.7
40	0.025	1.5	2.1	2.5	3.4	3.6	6.2	8.5	7.3	8.3	8.9
50	0.02	1.6	2.3	2.8	3.8	4	6.9	9.5	8.2	9.3	10
60	0.017	1.7	2.5	3.1	4.2	4.4	7.6	10.5	8.9	10.2	10.9
80	0.012	1.9	2.8	3.5	4.8	5.1	8.8	12.1	10.2	11.6	12.5
100	0.01	2.1	3.1	3.9	5.3	5.6	9.8	13.5	11.3	12.9	13.9

2050 (assuming 1°C temp rise, and corresponding 8% increase in rainfall)
Rainfall depths (mm)

		Duration									
ARI (y)	aep	10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
1.58	0.633	7.7	11.7	14.8	22.2	31.4	54.3	76.8	108.4	123.4	133.1
2	0.5	8.5	12.7	16.2	24.4	34.3	59.0	82.9	116.6	132.6	143.0
5	0.2	11.3	17.1	21.7	32.7	45.4	75.9	105.1	145.6	165.7	178.6
10	0.1	13.8	20.7	26.4	39.7	54.4	89.7	123.0	168.7	191.9	206.9
20	0.05	16.6	24.9	31.8	47.7	64.9	105.3	143.0	194.2	221.0	238.2
30	0.033	18.5	27.8	35.3	53.1	71.8	115.6	156.0	210.6	239.7	258.3
40	0.025	19.9	30.0	38.1	57.3	77.1	123.3	165.8	223.0	253.7	273.6
50	0.02	21.1	31.8	40.4	60.7	81.4	129.6	173.9	233.2	265.1	286.0
60	0.017	22.1	33.3	42.3	63.7	85.2	135.1	180.7	241.7	275.0	296.5
80	0.012	23.9	35.9	45.6	68.6	91.4	144.1	192.0	255.9	291.0	313.7
100	0.01	25.3	38.0	48.3	72.7	96.6	151.5	201.2	267.3	304.0	327.9

2100 (assuming 2°C temp rise, and corresponding 16% increase in rainfall)
Rainfall depths (mm)

		Duration									
ARI (y)	aep	10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
1.58	0.633	8.2	12.5	15.9	23.9	33.8	58.3	82.5	116.5	132.6	142.9
2	0.5	9.2	13.7	17.4	26.2	36.9	63.3	89.1	125.3	142.4	153.6
5	0.2	12.2	18.3	23.3	35.1	48.7	81.5	112.9	156.4	177.9	191.9
10	0.1	14.8	22.3	28.3	42.7	58.5	96.4	132.1	181.2	206.1	222.3
20	0.05	17.9	26.8	34.1	51.3	69.7	113.1	153.6	208.6	237.3	255.9
30	0.033	19.8	29.8	37.9	57.1	77.1	124.1	167.5	226.2	257.4	277.5
40	0.025	21.3	32.2	40.9	61.6	82.8	132.5	178.1	239.5	272.5	293.8
50	0.02	22.6	34.1	43.4	65.2	87.5	139.2	186.8	250.4	284.8	307.2
60	0.017	23.8	35.7	45.5	68.4	91.5	145.1	194.1	259.6	295.3	318.4
80	0.012	25.6	38.5	49.0	73.7	98.1	154.7	206.2	274.8	312.5	337.0
100	0.01	27.1	40.8	51.9	78.1	103.7	162.7	216.1	287.1	326.5	352.2

High Intensity Rainfall System V3
Depth-Duration-Frequency results (produced on Monday 15th of July 2013)
Sitename: Forks
Coordinate system: NZTM2000
Easting: 1630638
Northing: 5428925

Rainfall depths (mm)

					Duration						
ARI (y)	aep	10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
1.58	0.633	7	10.7	13.7	20.9	30.6	55.9	81.9	119.8	138.7	151.1
2	0.5	7.7	11.8	15.1	23.1	33.6	60.9	88.6	128.8	149.1	162.5
5	0.2	10.5	16.1	20.6	31.5	44.9	79	112.8	161	186.5	203.2
10	0.1	12.9	19.8	25.3	38.6	54.4	93.9	132.4	186.7	216.2	235.5
20	0.05	15.8	24	30.8	47	65.5	110.8	154.4	215.1	249.1	271.4
30	0.033	17.6	26.9	34.5	52.6	72.8	121.8	168.6	233.4	270.3	294.5
40	0.025	19.1	29.1	37.3	56.9	78.4	130.3	179.5	247.2	286.3	311.9
50	0.02	20.3	31	39.7	60.5	83.1	137.2	188.3	258.4	299.3	326.1
60	0.017	21.4	32.6	41.7	63.7	87.1	143.2	195.9	268	310.4	338.2
80	0.012	23.1	35.3	45.2	68.9	93.8	153	208.4	283.7	328.6	358
100	0.01	24.6	37.5	48	73.2	99.4	161.1	218.6	296.6	343.4	374.2

Coefficients

c1	c2	c3	d1	d2	d3	e	f
-0.0003	-0.0237	0.0001	0.6107	0.5492	0.2115	0.2724	3.0406

Standard errors (mm)

					Duration						
ARI (y)	aep	10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
1.58	0.633	0.9	0.9	1	1	1.1	1.4	1.7	1.8	2	2.1
2	0.5	0.9	0.9	1	1	1.1	1.5	1.9	2	2.2	2.4
5	0.2	1	1	1.1	1.3	1.4	2.2	2.9	3	3.4	3.7
10	0.1	1	1.2	1.4	1.8	1.9	3.1	4.3	4.4	5.1	5.6
20	0.05	1.2	1.6	2	2.6	2.6	4.7	6.5	6.6	7.6	8.4
30	0.033	1.4	2	2.4	3.3	3.3	5.9	8.2	8.4	9.6	10.5
40	0.025	1.6	2.2	2.8	3.9	3.8	6.9	9.7	9.8	11.3	12.3
50	0.02	1.7	2.5	3.2	4.4	4.3	7.8	10.9	11	12.7	13.9
60	0.017	1.8	2.8	3.5	4.9	4.7	8.5	12	12.1	13.9	15.3
80	0.012	2.1	3.2	4.1	5.7	5.4	9.8	13.8	13.9	16.1	17.6
100	0.01	2.3	3.6	4.6	6.4	6	11	15.4	15.5	17.9	19.6

2050 (assuming 1°C temp rise, and corresponding 8% increase in rainfall)
Rainfall depths (mm)

					Duration						
ARI (y)	aep	10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
1.58	0.633	7.6	11.6	14.8	22.6	33.0	60.4	88.5	129.4	149.8	163.2
2	0.5	8.3	12.7	16.3	24.9	36.3	65.8	95.7	139.1	161.0	175.5
5	0.2	11.3	17.4	22.2	34.0	48.5	85.3	121.8	173.9	201.4	219.5
10	0.1	13.9	21.4	27.3	41.7	58.8	101.4	143.0	201.6	233.5	254.3
20	0.05	17.1	25.9	33.3	50.8	70.7	119.7	166.8	232.3	269.0	293.1
30	0.033	19.0	29.1	37.3	56.8	78.6	131.5	182.1	252.1	291.9	318.1
40	0.025	20.6	31.4	40.3	61.5	84.7	140.7	193.9	267.0	309.2	336.9
50	0.02	21.9	33.5	42.9	65.3	89.7	148.2	203.4	279.1	323.2	352.2
60	0.017	23.1	35.2	45.0	68.8	94.1	154.7	211.6	289.4	335.2	365.3
80	0.012	24.9	38.1	48.8	74.4	101.3	165.2	225.1	306.4	354.9	386.6
100	0.01	26.6	40.5	51.8	79.1	107.4	174.0	236.1	320.3	370.9	404.1

2100 (assuming 2°C temp rise, and corresponding 16% increase in rainfall)
Rainfall depths (mm)

					Duration						
ARI (y)	aep	10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
1.58	0.633	8.1	12.4	15.9	24.2	35.5	64.8	95.0	139.0	160.9	175.3
2	0.5	8.9	13.7	17.5	26.8	39.0	70.6	102.8	149.4	173.0	188.5
5	0.2	12.2	18.7	23.9	36.5	52.1	91.6	130.8	186.8	216.3	235.7
10	0.1	15.0	23.0	29.3	44.8	63.1	108.9	153.6	216.6	250.8	273.2
20	0.05	18.3	27.8	35.7	54.5	76.0	128.5	179.1	249.5	289.0	314.8
30	0.033	20.4	31.2	40.0	61.0	84.4	141.3	195.6	270.7	313.5	341.6
40	0.025	22.2	33.8	43.3	66.0	90.9	151.1	208.2	286.8	332.1	361.8
50	0.02	23.5	36.0	46.1	70.2	96.4	159.2	218.4	299.7	347.2	378.3
60	0.017	24.8	37.8	48.4	73.9	101.0	166.1	227.2	310.9	360.1	392.3
80	0.012	26.8	40.9	52.4	79.9	108.8	177.5	241.7	329.1	381.2	415.3
100	0.01	28.5	43.5	55.7	84.9	115.3	186.9	253.6	344.1	398.3	434.1

High Intensity Rainfall System V3
Depth-Duration-Frequency results (produced on Friday 5th of November 2010)
Sitename: Groom
Coordinate system: NZTM2000
Easting: 1626288
Northing: 5428795

Rainfall depths (mm)

ARI (y)	aep	Duration 10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
1.58	0.633	6.9	10.7	13.7	21.1	30.4	54.2	78	112.2	128.2	138.5
2	0.5	7.6	11.8	15.1	23.3	33.4	58.9	84.3	120.7	137.8	148.9
5	0.2	10.3	15.9	20.4	31.4	44.2	76.1	107.1	150.8	172.2	186.1
10	0.1	12.6	19.3	24.9	38.3	53.3	90.1	125.5	174.7	199.6	215.7
20	0.05	15.2	23.4	30.1	46.3	63.8	106	146.1	201.3	229.9	248.5
30	0.033	17	26.1	33.6	51.6	70.7	116.4	159.4	218.4	249.4	269.5
40	0.025	18.3	28.2	36.3	55.8	76.1	124.4	169.6	231.3	264.1	285.5
50	0.02	19.4	29.9	38.5	59.2	80.5	130.9	177.9	241.7	276.1	298.4
60	0.017	20.4	31.4	40.4	62.2	84.2	136.4	184.9	250.6	286.3	309.4
80	0.012	22	33.9	43.6	67.1	90.5	145.6	196.6	265.3	303	327.5
100	0.01	23.4	36	46.3	71.2	95.8	153.2	206.1	277.3	316.7	342.3

Coefficients

c1	c2	c3	d1	d2	d3	e	f
-0.0002	-0.0212	0	0.6222	0.5253	0.1915	0.2638	3.0517

Standard errors (mm)

ARI (y)	aep	Duration 10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
1.58	0.633	0.9	0.9	0.9	1	1	1.3	1.6	1.7	1.9	2
2	0.5	0.9	0.9	0.9	1	1.1	1.4	1.8	1.9	2.1	2.2
5	0.2	0.9	1	1.1	1.3	1.3	2.1	2.8	2.8	3.2	3.4
10	0.1	1	1.2	1.3	1.7	1.8	3	4.1	4	4.6	4.9
20	0.05	1.1	1.5	1.8	2.5	2.5	4.5	6.2	6	6.8	7.3
30	0.033	1.3	1.8	2.3	3.1	3.1	5.6	7.8	7.5	8.5	9.2
40	0.025	1.4	2.1	2.6	3.6	3.6	6.6	9.2	8.7	9.9	10.7
50	0.02	1.6	2.3	2.9	4.1	4.1	7.4	10.4	9.8	11.2	12
60	0.017	1.7	2.5	3.2	4.5	4.5	8.2	11.4	10.7	12.2	13.2
80	0.012	1.9	2.9	3.7	5.2	5.2	9.4	13.2	12.3	14.1	15.1
100	0.01	2.1	3.2	4.2	5.8	5.7	10.5	14.7	13.6	15.6	16.8

2050 (assuming 1°C temp rise, and corresponding 8% increase in rainfall)
Rainfall depths (mm)

ARI (y)	aep	Duration 10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
1.58	0.633	7.5	11.6	14.8	22.8	32.8	58.5	84.2	121.2	138.5	149.6
2	0.5	8.2	12.7	16.3	25.2	36.1	63.6	91.0	130.4	148.8	160.8
5	0.2	11.1	17.2	22.0	33.9	47.7	82.2	115.7	162.9	186.0	201.0
10	0.1	13.6	20.8	26.9	41.4	57.6	97.3	135.5	188.7	215.6	233.0
20	0.05	16.4	25.3	32.5	50.0	68.9	114.5	157.8	217.4	248.3	268.4
30	0.033	18.4	28.2	36.3	55.7	76.4	125.7	172.2	235.9	269.4	291.1
40	0.025	19.8	30.5	39.2	60.3	82.2	134.4	183.2	249.8	285.2	308.3
50	0.02	21.0	32.3	41.6	63.9	86.9	141.4	192.1	261.0	298.2	322.3
60	0.017	22.0	33.9	43.6	67.2	90.9	147.3	199.7	270.6	309.2	334.2
80	0.012	23.8	36.6	47.1	72.5	97.7	157.2	212.3	286.5	327.2	353.7
100	0.01	25.3	38.9	50.0	76.9	103.5	165.5	222.6	299.5	342.0	369.7

2100 (assuming 2°C temp rise, and corresponding 16% increase in rainfall)
Rainfall depths (mm)

ARI (y)	aep	Duration 10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
1.58	0.633	8.0	12.4	15.9	24.5	35.3	62.9	90.5	130.2	148.7	160.7
2	0.5	8.8	13.7	17.5	27.0	38.7	68.3	97.8	140.0	159.8	172.7
5	0.2	11.9	18.4	23.7	36.4	51.3	88.3	124.2	174.9	199.8	215.9
10	0.1	14.6	22.4	28.9	44.4	61.8	104.5	145.6	202.7	231.5	250.2
20	0.05	17.6	27.1	34.9	53.7	74.0	123.0	169.5	233.5	266.7	288.3
30	0.033	19.7	30.3	39.0	59.9	82.0	135.0	184.9	253.3	289.3	312.6
40	0.025	21.2	32.7	42.1	64.7	88.3	144.3	196.7	268.3	306.4	331.2
50	0.02	22.5	34.7	44.7	68.7	93.4	151.8	206.4	280.4	320.3	346.1
60	0.017	23.7	36.4	46.9	72.2	97.7	158.2	214.5	290.7	332.1	358.9
80	0.012	25.5	39.3	50.6	77.8	105.0	168.9	228.1	307.7	351.5	379.9
100	0.01	27.1	41.8	53.7	82.6	111.1	177.7	239.1	321.7	367.4	397.1

High Intensity Rainfall System V3
Depth-Duration-Frequency results (produced on Friday 5th of November 2010)
Sitename: Sharland
Coordinate system: NZTM2000
Easting: 1629449
Northing: 5432134

Rainfall depths (mm)

					Duration						
ARI (y)	aep	10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
1.58	0.633	7.2	11	14.1	21.4	31	55.7	80.6	116.5	135	147.1
2	0.5	7.9	12.1	15.5	23.6	34	60.5	87	125.2	145	158
5	0.2	10.7	16.4	20.9	31.9	45.1	78.1	110.4	156.1	180.8	197.1
10	0.1	13.1	20	25.5	38.9	54.4	92.5	129.3	180.7	209.3	228.1
20	0.05	15.8	24.1	30.9	47.1	65.1	108.8	150.4	207.9	240.8	262.4
30	0.033	17.7	26.9	34.5	52.6	72.2	119.4	164.1	225.4	261.1	284.5
40	0.025	19.1	29.1	37.3	56.8	77.7	127.6	174.5	238.6	276.3	301.1
50	0.02	20.3	30.9	39.5	60.3	82.1	134.2	182.9	249.3	288.8	314.7
60	0.017	21.3	32.5	41.5	63.3	86	139.9	190.1	258.4	299.3	326.2
80	0.012	23	35	44.8	68.3	92.5	149.3	202.1	273.4	316.7	345.1
100	0.01	24.4	37.2	47.6	72.5	97.8	157.1	211.8	285.7	330.8	360.5

Coefficients

c1	c2	c3	d1	d2	d3	e	f
-0.0002	-0.022	0	0.6086	0.5325	0.2118	0.2646	3.0663

Standard errors (mm)

					Duration						
ARI (y)	aep	10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
1.58	0.633	1.1	1.1	1.1	1.2	1.2	1.5	1.8	1.8	2	2.1
2	0.5	1.1	1.1	1.1	1.2	1.2	1.6	2	2	2.2	2.4
5	0.2	1.1	1.2	1.3	1.4	1.5	2.2	2.9	2.9	3.3	3.6
10	0.1	1.2	1.3	1.5	1.8	1.9	3.1	4.3	4.1	4.8	5.2
20	0.05	1.3	1.7	2	2.6	2.7	4.6	6.4	6.1	7	7.7
30	0.033	1.5	2	2.4	3.2	3.3	5.8	8.1	7.6	8.8	9.6
40	0.025	1.6	2.2	2.8	3.8	3.8	6.8	9.4	8.8	10.2	11.1
50	0.02	1.7	2.5	3.1	4.2	4.3	7.6	10.6	9.9	11.4	12.5
60	0.017	1.9	2.7	3.4	4.7	4.7	8.4	11.7	10.8	12.5	13.7
80	0.012	2.1	3.1	3.9	5.4	5.4	9.7	13.5	12.4	14.4	15.7
100	0.01	2.3	3.4	4.4	6	6	10.8	15	13.8	16	17.4

2050 (assuming 1°C temp rise, and corresponding 8% increase in rainfall)
Rainfall depths (mm)

					Duration						
ARI (y)	aep	10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
1.58	0.633	7.8	11.9	15.2	23.1	33.5	60.2	87.0	125.8	145.8	158.9
2	0.5	8.5	13.1	16.7	25.5	36.7	65.3	94.0	135.2	156.6	170.6
5	0.2	11.6	17.7	22.6	34.5	48.7	84.3	119.2	168.6	195.3	212.9
10	0.1	14.1	21.6	27.5	42.0	58.8	99.9	139.6	195.2	226.0	246.3
20	0.05	17.1	26.0	33.4	50.9	70.3	117.5	162.4	224.5	260.1	283.4
30	0.033	19.1	29.1	37.3	56.8	78.0	129.0	177.2	243.4	282.0	307.3
40	0.025	20.6	31.4	40.3	61.3	83.9	137.8	188.5	257.7	298.4	325.2
50	0.02	21.9	33.4	42.7	65.1	88.7	144.9	197.5	269.2	311.9	339.9
60	0.017	23.0	35.1	44.8	68.4	92.9	151.1	205.3	279.1	323.2	352.3
80	0.012	24.8	37.8	48.4	73.8	99.9	161.2	218.3	295.3	342.0	372.7
100	0.01	26.4	40.2	51.4	78.3	105.6	169.7	228.7	308.6	357.3	389.3

2100 (assuming 2°C temp rise, and corresponding 16% increase in rainfall)
Rainfall depths (mm)

					Duration						
ARI (y)	aep	10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
1.58	0.633	8.4	12.8	16.4	24.8	36.0	64.6	93.5	135.1	156.6	170.6
2	0.5	9.2	14.0	18.0	27.4	39.4	70.2	100.9	145.2	168.2	183.3
5	0.2	12.4	19.0	24.2	37.0	52.3	90.6	128.1	181.1	209.7	228.6
10	0.1	15.2	23.2	29.6	45.1	63.1	107.3	150.0	209.6	242.8	264.6
20	0.05	18.3	28.0	35.8	54.6	75.5	126.2	174.5	241.2	279.3	304.4
30	0.033	20.5	31.2	40.0	61.0	83.8	138.5	190.4	261.5	302.9	330.0
40	0.025	22.2	33.8	43.3	65.9	90.1	148.0	202.4	276.8	320.5	349.3
50	0.02	23.5	35.8	45.8	69.9	95.2	155.7	212.2	289.2	335.0	365.1
60	0.017	24.7	37.7	48.1	73.4	99.8	162.3	220.5	299.7	347.2	378.4
80	0.012	26.7	40.6	52.0	79.2	107.3	173.2	234.4	317.1	367.4	400.3
100	0.01	28.3	43.2	55.2	84.1	113.4	182.2	245.7	331.4	383.7	418.2

High Intensity Rainfall System V3
Depth-Duration-Frequency results (produced on Friday 5th of November 2010)
Sitename: Neds
Coordinate system: NZTM2000
Easting: 1628163
Northing: 5426740

Rainfall depths (mm)

		Duration									
ARI (y)	aep	10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
1.58	0.633	7	11	14.3	22.3	33.3	62.7	93.5	139.3	161.1	175.4
2	0.5	7.8	12.1	15.8	24.7	36.6	68.2	101	149.6	173	188.4
5	0.2	10.6	16.6	21.6	33.9	49.1	88.5	128.4	186.2	215.4	234.5
10	0.1	13.1	20.5	26.6	41.7	59.7	105.2	150.5	215.3	249	271.1
20	0.05	16	25	32.5	50.9	71.9	124.2	175.3	247.4	286.1	311.5
30	0.033	17.9	28	36.5	57.1	80	136.6	191.3	268	309.9	337.5
40	0.025	19.4	30.4	39.5	62	86.3	146	203.5	283.5	327.9	357.1
50	0.02	20.7	32.4	42.1	66	91.5	153.8	213.4	296.2	342.5	373
60	0.017	21.7	34.1	44.3	69.4	96	160.5	221.9	306.9	354.9	386.5
80	0.012	23.6	36.9	48	75.2	103.5	171.5	235.9	324.6	375.4	408.7
100	0.01	25.1	39.3	51.1	80.1	109.7	180.6	247.4	338.9	392	426.8

Coefficients

c1	c2	c3	d1	d2	d3	e	f
0.0002	-0.0265	0	0.6472	0.5761	0.2098	0.2774	3.1064

Standard errors (mm)

		Duration									
ARI (y)	aep	10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
1.58	0.633	0.9	0.9	0.9	1	1	1.4	1.9	2	2.2	2.4
2	0.5	0.9	0.9	1	1	1.1	1.6	2.1	2.2	2.5	2.7
5	0.2	0.9	1	1.1	1.4	1.4	2.3	3.3	3.4	4	4.3
10	0.1	1	1.2	1.5	1.9	1.9	3.4	4.8	5.1	5.9	6.3
20	0.05	1.2	1.7	2.1	2.8	2.7	5.1	7.3	7.6	8.8	9.5
30	0.033	1.4	2	2.6	3.6	3.4	6.5	9.3	9.6	11.1	12
40	0.025	1.6	2.4	3	4.3	3.9	7.6	10.9	11.2	13	14
50	0.02	1.7	2.6	3.4	4.8	4.4	8.5	12.2	12.6	14.6	15.8
60	0.017	1.9	2.9	3.8	5.4	4.8	9.4	13.4	13.8	16	17.3
80	0.012	2.1	3.4	4.4	6.3	5.5	10.8	15.6	15.9	18.5	20
100	0.01	2.4	3.8	5	7.1	6.2	12.1	17.3	17.7	20.6	22.3

2050 (assuming 1°C temp rise, and corresponding 8% increase in rainfall)
Rainfall depths (mm)

		Duration									
ARI (y)	aep	10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
1.58	0.633	7.6	11.9	15.4	24.1	36.0	67.7	101.0	150.4	174.0	189.4
2	0.5	8.4	13.1	17.1	26.7	39.5	73.7	109.1	161.6	186.8	203.5
5	0.2	11.4	17.9	23.3	36.6	53.0	95.6	138.7	201.1	232.6	253.3
10	0.1	14.1	22.1	28.7	45.0	64.5	113.6	162.5	232.5	268.9	292.8
20	0.05	17.3	27.0	35.1	55.0	77.7	134.1	189.3	267.2	309.0	336.4
30	0.033	19.3	30.2	39.4	61.7	86.4	147.5	206.6	289.4	334.7	364.5
40	0.025	21.0	32.8	42.7	67.0	93.2	157.7	219.8	306.2	354.1	385.7
50	0.02	22.4	35.0	45.5	71.3	98.8	166.1	230.5	319.9	369.9	402.8
60	0.017	23.4	36.8	47.8	75.0	103.7	173.3	239.7	331.5	383.3	417.4
80	0.012	25.5	39.9	51.8	81.2	111.8	185.2	254.8	350.6	405.4	441.4
100	0.01	27.1	42.4	55.2	86.5	118.5	195.0	267.2	366.0	423.4	460.9

2100 (assuming 2°C temp rise, and corresponding 16% increase in rainfall)
Rainfall depths (mm)

		Duration									
ARI (y)	aep	10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
1.58	0.633	8.1	12.8	16.6	25.9	38.6	72.7	108.5	161.6	186.9	203.5
2	0.5	9.0	14.0	18.3	28.7	42.5	79.1	117.2	173.5	200.7	218.5
5	0.2	12.3	19.3	25.1	39.3	57.0	102.7	148.9	216.0	249.9	272.0
10	0.1	15.2	23.8	30.9	48.4	69.3	122.0	174.6	249.7	288.8	314.5
20	0.05	18.6	29.0	37.7	59.0	83.4	144.1	203.3	287.0	331.9	361.3
30	0.033	20.8	32.5	42.3	66.2	92.8	158.5	221.9	310.9	359.5	391.5
40	0.025	22.5	35.3	45.8	71.9	100.1	169.4	236.1	328.9	380.4	414.2
50	0.02	24.0	37.6	48.8	76.6	106.1	178.4	247.5	343.6	397.3	432.7
60	0.017	25.2	39.6	51.4	80.5	111.4	186.2	257.4	356.0	411.7	448.3
80	0.012	27.4	42.8	55.7	87.2	120.1	198.9	273.6	376.5	435.5	474.1
100	0.01	29.1	45.6	59.3	92.9	127.3	209.5	287.0	393.1	454.7	495.1

High Intensity Rainfall System V3
Depth-Duration-Frequency results (produced on Friday 5th of November 2010)
Sitename: Maitai North Branch
Coordinate system: NZTM2000
Easting: 1633726
Northing: 5427189

Rainfall depths (mm)

					Duration						
ARI (y)	aep	10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
1.58	0.633	7.1	11	14.3	22.3	33.4	63.2	94.7	141.7	167.9	185.5
2	0.5	7.8	12.2	15.8	24.6	36.7	68.8	102.2	152	180.1	198.9
5	0.2	10.7	16.6	21.6	33.6	49	88.9	129.5	188.7	223.6	246.9
10	0.1	13.1	20.4	26.5	41.3	59.3	105.4	151.5	217.7	257.9	284.9
20	0.05	16	24.9	32.2	50.2	71.3	124.1	176	249.7	295.9	326.7
30	0.033	17.9	27.9	36.1	56.2	79.2	136.3	191.9	270.2	320.2	353.6
40	0.025	19.4	30.2	39.1	60.9	85.3	145.6	203.9	285.7	338.5	373.8
50	0.02	20.6	32.1	41.6	64.8	90.4	153.2	213.8	298.2	353.3	390.2
60	0.017	21.7	33.8	43.8	68.1	94.7	159.8	222.1	308.9	366	404.1
80	0.012	23.5	36.6	47.4	73.8	102	170.6	236	326.4	386.7	427.1
100	0.01	25	38.9	50.4	78.4	108	179.5	247.3	340.7	403.6	445.7

Coefficients

c1	c2	c3	d1	d2	d3	e	f
-0.0003	-0.0261	0	0.6404	0.582	0.2448	0.2734	3.1045

Standard errors (mm)

					Duration						
ARI (y)	aep	10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
1.58	0.633	1.3	1.3	1.3	1.3	1.4	1.7	2.1	2.2	2.5	2.6
2	0.5	1.3	1.3	1.3	1.4	1.4	1.8	2.3	2.4	2.7	2.9
5	0.2	1.3	1.4	1.4	1.6	1.7	2.5	3.4	3.5	4.1	4.5
10	0.1	1.4	1.5	1.7	2.1	2.1	3.6	5	5	5.9	6.5
20	0.05	1.5	1.9	2.2	2.9	2.9	5.3	7.5	7.4	8.8	9.6
30	0.033	1.7	2.2	2.7	3.7	3.6	6.6	9.4	9.3	11	12
40	0.025	1.8	2.5	3.1	4.3	4.1	7.7	11	10.8	12.8	14
50	0.02	1.9	2.8	3.4	4.9	4.6	8.6	12.4	12.1	14.3	15.7
60	0.017	2.1	3	3.8	5.4	5	9.5	13.7	13.2	15.7	17.2
80	0.012	2.3	3.5	4.4	6.3	5.8	10.9	15.8	15.2	18	19.8
100	0.01	2.5	3.9	4.9	7	6.4	12.1	17.6	16.9	20	22

2050 (assuming 1°C temp rise, and corresponding 8% increase in rainfall)
Rainfall depths (mm)

					Duration						
ARI (y)	aep	10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
1.58	0.633	7.7	11.9	15.4	24.1	36.1	68.3	102.3	153.0	181.3	200.3
2	0.5	8.4	13.2	17.1	26.6	39.6	74.3	110.4	164.2	194.5	214.8
5	0.2	11.6	17.9	23.3	36.3	52.9	96.0	139.9	203.8	241.5	266.7
10	0.1	14.1	22.0	28.6	44.6	64.0	113.8	163.6	235.1	278.5	307.7
20	0.05	17.3	26.9	34.8	54.2	77.0	134.0	190.1	269.7	319.6	352.8
30	0.033	19.3	30.1	39.0	60.7	85.5	147.2	207.3	291.8	345.8	381.9
40	0.025	21.0	32.6	42.2	65.8	92.1	157.2	220.2	308.6	365.6	403.7
50	0.02	22.2	34.7	44.9	70.0	97.6	165.5	230.9	322.1	381.6	421.4
60	0.017	23.4	36.5	47.3	73.5	102.3	172.6	239.9	333.6	395.3	436.4
80	0.012	25.4	39.5	51.2	79.7	110.2	184.2	254.9	352.5	417.6	461.3
100	0.01	27.0	42.0	54.4	84.7	116.6	193.9	267.1	368.0	435.9	481.4

2100 (assuming 2°C temp rise, and corresponding 16% increase in rainfall)
Rainfall depths (mm)

					Duration						
ARI (y)	aep	10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
1.58	0.633	8.2	12.8	16.6	25.9	38.7	73.3	109.9	164.4	194.8	215.2
2	0.5	9.0	14.2	18.3	28.5	42.6	79.8	118.6	176.3	208.9	230.7
5	0.2	12.4	19.3	25.1	39.0	56.8	103.1	150.2	218.9	259.4	286.4
10	0.1	15.2	23.7	30.7	47.9	68.8	122.3	175.7	252.5	299.2	330.5
20	0.05	18.6	28.9	37.4	58.2	82.7	144.0	204.2	289.7	343.2	379.0
30	0.033	20.8	32.4	41.9	65.2	91.9	158.1	222.6	313.4	371.4	410.2
40	0.025	22.5	35.0	45.4	70.6	98.9	168.9	236.5	331.4	392.7	433.6
50	0.02	23.9	37.2	48.3	75.2	104.9	177.7	248.0	345.9	409.8	452.6
60	0.017	25.2	39.2	50.8	79.0	109.9	185.4	257.6	358.3	424.6	468.8
80	0.012	27.3	42.5	55.0	85.6	118.3	197.9	273.8	378.6	448.6	495.4
100	0.01	29.0	45.1	58.5	90.9	125.3	208.2	286.9	395.2	468.2	517.0

High Intensity Rainfall System V3
Depth-Duration-Frequency results (produced on Friday 5th of November 2010)
Sitename: Maitai South Branch
Coordinate system: NZTM2000
Easting: 1630632
Northing: 5426187

Rainfall depths (mm)

		Duration									
ARI (y)	aep	10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
1.58	0.633	7	10.8	14	21.8	32.4	61	90.9	135.3	158.1	173.2
2	0.5	7.7	12	15.5	24.1	35.7	66.4	98.2	145.3	169.8	186
5	0.2	10.6	16.4	21.3	33	47.8	86.1	124.8	181	211.4	231.5
10	0.1	13	20.2	26.2	40.6	58.1	102.3	146.3	209.2	244.4	267.7
20	0.05	15.9	24.7	31.9	49.6	70	120.7	170.4	240.4	280.9	307.6
30	0.033	17.8	27.7	35.8	55.6	77.9	132.8	186	260.5	304.3	333.3
40	0.025	19.3	30	38.8	60.3	84	142	197.8	275.6	322	352.6
50	0.02	20.6	32	41.3	64.2	89	149.6	207.5	287.9	336.3	368.3
60	0.017	21.7	33.6	43.5	67.5	93.4	156	215.8	298.3	348.5	381.7
80	0.012	23.5	36.4	47.1	73.2	100.6	166.8	229.4	315.5	368.6	403.7
100	0.01	25	38.8	50.2	77.9	106.6	175.6	240.5	329.5	384.9	421.6

Coefficients

c1	c2	c3	d1	d2	d3	e	f
0	-0.0263	0	0.6345	0.575	0.2245	0.2769	3.0809

Standard errors (mm)

		Duration									
ARI (y)	aep	10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
1.58	0.633	1	1	1.1	1.1	1.2	1.5	1.9	2	2.3	2.4
2	0.5	1	1	1.1	1.2	1.2	1.6	2.1	2.2	2.5	2.7
5	0.2	1.1	1.1	1.2	1.4	1.5	2.4	3.2	3.4	3.9	4.2
10	0.1	1.1	1.3	1.5	1.9	2	3.4	4.8	4.9	5.8	6.2
20	0.05	1.3	1.7	2.1	2.8	2.7	5.1	7.2	7.4	8.6	9.4
30	0.033	1.5	2.1	2.6	3.6	3.4	6.4	9.1	9.2	10.8	11.8
40	0.025	1.7	2.4	3	4.2	3.9	7.4	10.7	10.8	12.7	13.7
50	0.02	1.8	2.7	3.4	4.8	4.4	8.4	12	12.1	14.3	15.5
60	0.017	1.9	2.9	3.8	5.3	4.8	9.2	13.2	13.3	15.7	17
80	0.012	2.2	3.4	4.4	6.2	5.6	10.6	15.3	15.4	18	19.6
100	0.01	2.4	3.8	4.9	7	6.2	11.8	17	17.1	20.1	21.8

2050 (assuming 1°C temp rise, and corresponding 8% increase in rainfall)
Rainfall depths (mm)

		Duration									
ARI (y)	aep	10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
1.58	0.633	7.6	11.7	15.1	23.5	35.0	65.9	98.2	146.1	170.7	187.1
2	0.5	8.3	13.0	16.7	26.0	38.6	71.7	106.1	156.9	183.4	200.9
5	0.2	11.4	17.7	23.0	35.6	51.6	93.0	134.8	195.5	228.3	250.0
10	0.1	14.0	21.8	28.3	43.8	62.7	110.5	158.0	225.9	264.0	289.1
20	0.05	17.2	26.7	34.5	53.6	75.6	130.4	184.0	259.6	303.4	332.2
30	0.033	19.2	29.9	38.7	60.0	84.1	143.4	200.9	281.3	328.6	360.0
40	0.025	20.8	32.4	41.9	65.1	90.7	153.4	213.6	297.6	347.8	380.8
50	0.02	22.2	34.6	44.6	69.3	96.1	161.6	224.1	310.9	363.2	397.8
60	0.017	23.4	36.3	47.0	72.9	100.9	168.5	233.1	322.2	376.4	412.2
80	0.012	25.4	39.3	50.9	79.1	108.6	180.1	247.8	340.7	398.1	436.0
100	0.01	27.0	41.9	54.2	84.1	115.1	189.6	259.7	355.9	415.7	455.3

2100 (assuming 2°C temp rise, and corresponding 16% increase in rainfall)
Rainfall depths (mm)

		Duration									
ARI (y)	aep	10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
1.58	0.633	8.1	12.5	16.2	25.3	37.6	70.8	105.4	156.9	183.4	200.9
2	0.5	8.9	13.9	18.0	28.0	41.4	77.0	113.9	168.5	197.0	215.8
5	0.2	12.3	19.0	24.7	38.3	55.4	99.9	144.8	210.0	245.2	268.5
10	0.1	15.1	23.4	30.4	47.1	67.4	118.7	169.7	242.7	283.5	310.5
20	0.05	18.4	28.7	37.0	57.5	81.2	140.0	197.7	278.9	325.8	356.8
30	0.033	20.6	32.1	41.5	64.5	90.4	154.0	215.8	302.2	353.0	386.6
40	0.025	22.4	34.8	45.0	69.9	97.4	164.7	229.4	319.7	373.5	409.0
50	0.02	23.9	37.1	47.9	74.5	103.2	173.5	240.7	334.0	390.1	427.2
60	0.017	25.2	39.0	50.5	78.3	108.3	181.0	250.3	346.0	404.3	442.8
80	0.012	27.3	42.2	54.6	84.9	116.7	193.5	266.1	366.0	427.6	468.3
100	0.01	29.0	45.0	58.2	90.4	123.7	203.7	279.0	382.2	446.5	489.1

High Intensity Rainfall System V3
Depth-Duration-Frequency results (produced on Friday 5th of November 2010)
Sitename: North Bank
Coordinate system: NZTM2000
Easting: 1629409
Northing: 5429427

Rainfall depths (mm)

					Duration						
ARI (y)	aep	10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
1.58	0.633	7	10.6	13.6	20.6	29.9	53.9	78.1	113.2	129.3	139.7
2	0.5	7.7	11.8	15	22.8	32.9	58.6	84.5	121.8	139.1	150.3
5	0.2	10.5	16	20.4	31	43.8	76.1	107.7	152.5	174.2	188.2
10	0.1	12.9	19.5	25	37.9	53.1	90.4	126.5	177	202.1	218.5
20	0.05	15.6	23.7	30.3	46.1	63.7	106.6	147.5	204.1	233.1	252
30	0.033	17.5	26.5	33.9	51.5	70.8	117.2	161.2	221.6	253.1	273.6
40	0.025	18.9	28.7	36.7	55.7	76.3	125.4	171.6	234.8	268.2	289.9
50	0.02	20.1	30.5	39	59.2	80.8	132	180.1	245.6	280.5	303.2
60	0.017	21.1	32.1	41	62.2	84.6	137.7	187.3	254.7	290.9	314.4
80	0.012	22.8	34.7	44.3	67.3	91.1	147.2	199.3	269.8	308.1	333.1
100	0.01	24.3	36.9	47.1	71.5	96.5	155	209.1	282	322.1	348.2

Coefficients

c1	c2	c3	d1	d2	d3	e	f
-0.0001	-0.0225	0	0.6035	0.5354	0.1918	0.2699	3.028

Standard errors (mm)

					Duration						
ARI (y)	aep	10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
1.58	0.633	0.8	0.8	0.8	0.9	0.9	1.2	1.6	1.6	1.8	2
2	0.5	0.8	0.8	0.8	0.9	1	1.4	1.8	1.8	2	2.2
5	0.2	0.8	0.9	1	1.2	1.3	2.1	2.8	2.8	3.2	3.5
10	0.1	0.9	1.1	1.3	1.7	1.8	3	4.1	4.2	4.7	5.2
20	0.05	1.1	1.5	1.9	2.5	2.6	4.5	6.2	6.3	7.1	7.8
30	0.033	1.3	1.8	2.3	3.2	3.2	5.6	7.9	8	9	9.9
40	0.025	1.4	2.1	2.7	3.7	3.7	6.6	9.2	9.3	10.5	11.5
50	0.02	1.6	2.4	3.1	4.2	4.2	7.5	10.4	10.5	11.9	13
60	0.017	1.7	2.6	3.4	4.7	4.6	8.2	11.4	11.5	13	14.3
80	0.012	2	3	3.9	5.4	5.3	9.5	13.2	13.3	15	16.5
100	0.01	2.2	3.4	4.4	6.1	5.9	10.6	14.8	14.8	16.7	18.3

2050 (assuming 1°C temp rise, and corresponding 8% increase in rainfall)
Rainfall depths (mm)

					Duration						
ARI (y)	aep	10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
1.58	0.633	7.6	11.4	14.7	22.2	32.3	58.2	84.3	122.3	139.6	150.9
2	0.5	8.3	12.7	16.2	24.6	35.5	63.3	91.3	131.5	150.2	162.3
5	0.2	11.3	17.3	22.0	33.5	47.3	82.2	116.3	164.7	188.1	203.3
10	0.1	13.9	21.1	27.0	40.9	57.3	97.6	136.6	191.2	218.3	236.0
20	0.05	16.8	25.6	32.7	49.8	68.8	115.1	159.3	220.4	251.7	272.2
30	0.033	18.9	28.6	36.6	55.6	76.5	126.6	174.1	239.3	273.3	295.5
40	0.025	20.4	31.0	39.6	60.2	82.4	135.4	185.3	253.6	289.7	313.1
50	0.02	21.7	32.9	42.1	63.9	87.3	142.6	194.5	265.2	302.9	327.5
60	0.017	22.8	34.7	44.3	67.2	91.4	148.7	202.3	275.1	314.2	339.6
80	0.012	24.6	37.5	47.8	72.7	98.4	159.0	215.2	291.4	332.7	359.7
100	0.01	26.2	39.9	50.9	77.2	104.2	167.4	225.8	304.6	347.9	376.1

2100 (assuming 2°C temp rise, and corresponding 16% increase in rainfall)
Rainfall depths (mm)

					Duration						
ARI (y)	aep	10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
1.58	0.633	8.1	12.3	15.8	23.9	34.7	62.5	90.6	131.3	150.0	162.1
2	0.5	8.9	13.7	17.4	26.4	38.2	68.0	98.0	141.3	161.4	174.3
5	0.2	12.2	18.6	23.7	36.0	50.8	88.3	124.9	176.9	202.1	218.3
10	0.1	15.0	22.6	29.0	44.0	61.6	104.9	146.7	205.3	234.4	253.5
20	0.05	18.1	27.5	35.1	53.5	73.9	123.7	171.1	236.8	270.4	292.3
30	0.033	20.3	30.7	39.3	59.7	82.1	136.0	187.0	257.1	293.6	317.4
40	0.025	21.9	33.3	42.6	64.6	88.5	145.5	199.1	272.4	311.1	336.3
50	0.02	23.3	35.4	45.2	68.7	93.7	153.1	208.9	284.9	325.4	351.7
60	0.017	24.5	37.2	47.6	72.2	98.1	159.7	217.3	295.5	337.4	364.7
80	0.012	26.4	40.3	51.4	78.1	105.7	170.8	231.2	313.0	357.4	386.4
100	0.01	28.2	42.8	54.6	82.9	111.9	179.8	242.6	327.1	373.6	403.9

High Intensity Rainfall System V3
Depth-Duration-Frequency results (produced on Tuesday 9th of July 2013)
Sitename: Nelson East
Coordinate system: NZTM2000
Easting: 1624467
Northing: 5431458

Rainfall depths (mm)

		Duration									
ARI (y)	aep	10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
1.58	0.633	7	10.5	13.4	20.2	28.1	47.3	65.7	91.2	103.7	111.8
2	0.5	7.7	11.6	14.7	22.2	30.7	51.3	70.9	98.1	111.5	120.2
5	0.2	10.2	15.4	19.6	29.5	40.3	65.9	89.9	122.7	139.5	150.4
10	0.1	12.3	18.6	23.6	35.7	48.2	77.8	105.2	142.2	161.7	174.4
20	0.05	14.8	22.3	28.3	42.8	57.3	91.2	122.3	163.9	186.4	201
30	0.033	16.4	24.7	31.5	47.5	63.3	100	133.3	177.9	202.3	218.1
40	0.025	17.6	26.6	33.9	51.1	67.9	106.6	141.7	188.4	214.3	231
50	0.02	18.7	28.2	35.8	54.1	71.7	112.1	148.6	197	224	241.5
60	0.017	19.6	29.5	37.5	56.6	74.9	116.7	154.4	204.3	232.3	250.4
80	0.012	21.1	31.8	40.4	60.9	80.3	124.4	164.1	216.3	246	265.2
100	0.01	22.3	33.6	42.7	64.5	84.8	130.8	171.9	226.1	257.1	277.2

Coefficients

c1	c2	c3	d1	d2	d3	e	f
-0.0003	-0.0171	0	0.5942	0.4737	0.1854	0.2517	3.008

Standard errors (mm)

		Duration									
ARI (y)	aep	10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
1.58	0.633	1	1	1	1.1	1.1	1.3	1.5	1.5	1.6	1.7
2	0.5	1	1	1	1.1	1.1	1.4	1.7	1.6	1.8	1.9
5	0.2	1	1.1	1.1	1.3	1.4	1.9	2.5	2.3	2.5	2.7
10	0.1	1.1	1.2	1.3	1.6	1.8	2.7	3.6	3.2	3.5	3.8
20	0.05	1.2	1.5	1.7	2.2	2.4	4	5.4	4.5	5.1	5.5
30	0.033	1.3	1.7	2.1	2.7	3	5	6.8	5.6	6.3	6.9
40	0.025	1.4	1.9	2.4	3.2	3.5	5.8	7.9	6.5	7.3	7.9
50	0.02	1.5	2.1	2.6	3.5	3.9	6.5	8.9	7.2	8.2	8.9
60	0.017	1.6	2.3	2.8	3.9	4.2	7.2	9.8	7.9	8.9	9.7
80	0.012	1.8	2.6	3.2	4.4	4.9	8.3	11.3	9	10.2	11.1
100	0.01	1.9	2.9	3.6	4.9	5.4	9.2	12.6	10	11.3	12.2

2050 (assuming 1°C temp rise, and corresponding 8% increase in rainfall)
Rainfall depths (mm)

		Duration									
ARI (y)	aep	10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
1.58	0.633	7.6	11.3	14.5	21.8	30.3	51.1	71.0	98.5	112.0	120.7
2	0.5	8.3	12.5	15.9	24.0	33.2	55.4	76.6	105.9	120.4	129.8
5	0.2	11.0	16.6	21.2	31.9	43.5	71.2	97.1	132.5	150.7	162.4
10	0.1	13.3	20.1	25.5	38.6	52.1	84.0	113.6	153.6	174.6	188.4
20	0.05	16.0	24.1	30.6	46.2	61.9	98.5	132.1	177.0	201.3	217.1
30	0.033	17.7	26.7	34.0	51.3	68.4	108.0	144.0	192.1	218.5	235.5
40	0.025	19.0	28.7	36.6	55.2	73.3	115.1	153.0	203.5	231.4	249.5
50	0.02	20.2	30.5	38.7	58.4	77.4	121.1	160.5	212.8	241.9	260.8
60	0.017	21.2	31.9	40.5	61.1	80.9	126.0	166.8	220.6	250.9	270.4
80	0.012	22.8	34.3	43.6	65.8	86.7	134.4	177.2	233.6	265.7	286.4
100	0.01	24.1	36.3	46.1	69.7	91.6	141.3	185.7	244.2	277.7	299.4

2100 (assuming 2°C temp rise, and corresponding 16% increase in rainfall)
Rainfall depths (mm)

		Duration									
ARI (y)	aep	10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
1.58	0.633	8.1	12.2	15.5	23.4	32.6	54.9	76.2	105.8	120.3	129.7
2	0.5	8.9	13.5	17.1	25.8	35.6	59.5	82.2	113.8	129.3	139.4
5	0.2	11.8	17.9	22.7	34.2	46.7	76.4	104.3	142.3	161.8	174.5
10	0.1	14.3	21.6	27.4	41.4	55.9	90.2	122.0	165.0	187.6	202.3
20	0.05	17.2	25.9	32.8	49.6	66.5	105.8	141.9	190.1	216.2	233.2
30	0.033	19.0	28.7	36.5	55.1	73.4	116.0	154.6	206.4	234.7	253.0
40	0.025	20.4	30.9	39.3	59.3	78.8	123.7	164.4	218.5	248.6	268.0
50	0.02	21.7	32.7	41.5	62.8	83.2	130.0	172.4	228.5	259.8	280.1
60	0.017	22.7	34.2	43.5	65.7	86.9	135.4	179.1	237.0	269.5	290.5
80	0.012	24.5	36.9	46.9	70.6	93.1	144.3	190.4	250.9	285.4	307.6
100	0.01	25.9	39.0	49.5	74.8	98.4	151.7	199.4	262.3	298.2	321.6

High Intensity Rainfall System V3
Depth-Duration-Frequency results (produced on Friday 5th of November 2010)
Sitename: Nelson South
Coordinate system: NZTM2000
Easting: 1623116
Northing: 5430166

Rainfall depths (mm)

					Duration						
ARI (y)	aep	10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
1.58	0.633	7	10.5	13.3	20.1	27.7	46.2	63.8	88.1	101.1	109.6
2	0.5	7.6	11.5	14.6	22	30.3	50.1	68.9	94.8	108.8	118
5	0.2	10.1	15.2	19.4	29.1	39.6	64.3	87.4	118.7	136.3	147.8
10	0.1	12.2	18.3	23.3	35.1	47.3	75.9	102.3	137.8	158.2	171.5
20	0.05	14.6	21.9	27.9	42	56.1	88.9	118.9	159	182.6	197.9
30	0.033	16.1	24.3	30.9	46.5	61.9	97.4	129.7	172.7	198.2	214.9
40	0.025	17.4	26.1	33.2	50	66.3	103.9	137.9	183	210	227.7
50	0.02	18.4	27.6	35.1	52.9	70	109.2	144.5	191.4	219.7	238.2
60	0.017	19.2	28.9	36.8	55.3	73.1	113.7	150.2	198.5	227.9	247
80	0.012	20.7	31.1	39.5	59.4	78.3	121.2	159.6	210.2	241.4	261.7
100	0.01	21.8	32.9	41.8	62.8	82.6	127.3	167.3	219.8	252.4	273.6

Coefficients

c1	c2	c3	d1	d2	d3	e	f
-0.0003	-0.0155	0.0001	0.5912	0.4653	0.1988	0.2479	3.0004

Standard errors (mm)

					Duration						
ARI (y)	aep	10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
1.58	0.633	1	1	1	1	1.1	1.3	1.5	1.5	1.6	1.7
2	0.5	1	1	1	1.1	1.1	1.4	1.6	1.6	1.7	1.9
5	0.2	1	1	1.1	1.3	1.3	1.9	2.4	2.2	2.5	2.7
10	0.1	1	1.2	1.3	1.6	1.7	2.7	3.5	3.1	3.5	3.8
20	0.05	1.2	1.4	1.7	2.2	2.4	3.9	5.3	4.4	5	5.5
30	0.033	1.3	1.7	2	2.6	2.9	4.9	6.6	5.5	6.3	6.8
40	0.025	1.4	1.9	2.2	3	3.4	5.7	7.8	6.3	7.2	7.9
50	0.02	1.5	2	2.5	3.4	3.8	6.4	8.7	7.1	8.1	8.8
60	0.017	1.6	2.2	2.7	3.7	4.2	7.1	9.6	7.7	8.8	9.6
80	0.012	1.7	2.5	3.1	4.2	4.8	8.2	11.1	8.8	10.1	11
100	0.01	1.9	2.7	3.4	4.7	5.3	9.1	12.4	9.8	11.2	12.2

2050 (assuming 1°C temp rise, and corresponding 8% increase in rainfall)
Rainfall depths (mm)

					Duration						
ARI (y)	aep	10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
1.58	0.633	7.6	11.3	14.4	21.7	29.9	49.9	68.9	95.1	109.2	118.4
2	0.5	8.2	12.4	15.8	23.8	32.7	54.1	74.4	102.4	117.5	127.4
5	0.2	10.9	16.4	21.0	31.4	42.8	69.4	94.4	128.2	147.2	159.6
10	0.1	13.2	19.8	25.2	37.9	51.1	82.0	110.5	148.8	170.9	185.2
20	0.05	15.8	23.7	30.1	45.4	60.6	96.0	128.4	171.7	197.2	213.7
30	0.033	17.4	26.2	33.4	50.2	66.9	105.2	140.1	186.5	214.1	232.1
40	0.025	18.8	28.2	35.9	54.0	71.6	112.2	148.9	197.6	226.8	245.9
50	0.02	19.9	29.8	37.9	57.1	75.6	117.9	156.1	206.7	237.3	257.3
60	0.017	20.7	31.2	39.7	59.7	78.9	122.8	162.2	214.4	246.1	266.8
80	0.012	22.4	33.6	42.7	64.2	84.6	130.9	172.4	227.0	260.7	282.6
100	0.01	23.5	35.5	45.1	67.8	89.2	137.5	180.7	237.4	272.6	295.5

2100 (assuming 2°C temp rise, and corresponding 16% increase in rainfall)
Rainfall depths (mm)

					Duration						
ARI (y)	aep	10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
1.58	0.633	8.1	12.2	15.4	23.3	32.1	53.6	74.0	102.2	117.3	127.1
2	0.5	8.8	13.3	16.9	25.5	35.1	58.1	79.9	110.0	126.2	136.9
5	0.2	11.7	17.6	22.5	33.8	45.9	74.6	101.4	137.7	158.1	171.4
10	0.1	14.2	21.2	27.0	40.7	54.9	88.0	118.7	159.8	183.5	198.9
20	0.05	16.9	25.4	32.4	48.7	65.1	103.1	137.9	184.4	211.8	229.6
30	0.033	18.7	28.2	35.8	53.9	71.8	113.0	150.5	200.3	229.9	249.3
40	0.025	20.2	30.3	38.5	58.0	76.9	120.5	160.0	212.3	243.6	264.1
50	0.02	21.3	32.0	40.7	61.4	81.2	126.7	167.6	222.0	254.9	276.3
60	0.017	22.3	33.5	42.7	64.1	84.8	131.9	174.2	230.3	264.4	286.5
80	0.012	24.0	36.1	45.8	68.9	90.8	140.6	185.1	243.8	280.0	303.6
100	0.01	25.3	38.2	48.5	72.8	95.8	147.7	194.1	255.0	292.8	317.4

High Intensity Rainfall System V3
Depth-Duration-Frequency results (produced on Tuesday 9th of July 2013)
Sitename: York
Coordinate system: NZTM2000
Easting: 1622442
Northing: 5428680

Rainfall depths (mm)

		Duration									
ARI (y)	aep	10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
1.58	0.633	7	10.6	13.4	20.2	27.8	46.2	63.7	87.7	101.5	110.6
2	0.5	7.7	11.6	14.7	22.1	30.3	50.1	68.8	94.4	109.2	119
5	0.2	10.2	15.3	19.4	29.2	39.6	64.3	87.2	118.3	137	149.3
10	0.1	12.2	18.4	23.3	35.1	47.3	75.8	102.1	137.5	159.2	173.4
20	0.05	14.6	21.9	27.8	41.9	56	88.8	118.7	158.7	183.8	200.2
30	0.033	16.1	24.3	30.8	46.4	61.7	97.2	129.5	172.4	199.6	217.5
40	0.025	17.3	26.1	33.1	49.8	66.1	103.7	137.6	182.8	211.6	230.5
50	0.02	18.3	27.6	35	52.6	69.7	108.9	144.3	191.2	221.4	241.2
60	0.017	19.2	28.8	36.6	55.1	72.8	113.4	150	198.4	229.7	250.2
80	0.012	20.6	31	39.3	59.1	77.9	120.9	159.4	210.2	243.4	265.1
100	0.01	21.8	32.7	41.5	62.4	82.2	127	167.1	219.8	254.5	277.3

Coefficients

c1	c2	c3	d1	d2	d3	e	f
-0.0002	-0.0143	0	0.5893	0.4618	0.2112	0.2452	3.0065

Standard errors (mm)

		Duration									
ARI (y)	aep	10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
1.58	0.633	0.9	0.9	0.9	1	1	1.2	1.4	1.4	1.6	1.7
2	0.5	0.9	0.9	0.9	1	1	1.3	1.6	1.6	1.7	1.8
5	0.2	0.9	1	1	1.2	1.3	1.8	2.4	2.2	2.5	2.7
10	0.1	1	1.1	1.2	1.5	1.7	2.6	3.5	3.1	3.5	3.9
20	0.05	1.1	1.4	1.6	2.1	2.3	3.9	5.3	4.5	5.2	5.6
30	0.033	1.2	1.6	1.9	2.6	2.9	4.9	6.6	5.6	6.4	7
40	0.025	1.3	1.8	2.2	3	3.4	5.7	7.8	6.5	7.5	8.1
50	0.02	1.4	2	2.4	3.3	3.8	6.4	8.8	7.2	8.3	9.1
60	0.017	1.5	2.1	2.6	3.6	4.1	7	9.6	7.9	9.1	10
80	0.012	1.7	2.4	3	4.2	4.7	8.1	11.1	9.1	10.5	11.4
100	0.01	1.8	2.7	3.3	4.6	5.3	9.1	12.4	10	11.6	12.6

2050 (assuming 1°C temp rise, and corresponding 8% increase in rainfall)
Rainfall depths (mm)

		Duration									
ARI (y)	aep	10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
1.58	0.633	7.6	11.4	14.5	21.8	30.0	49.9	68.8	94.7	109.6	119.4
2	0.5	8.3	12.5	15.9	23.9	32.7	54.1	74.3	102.0	117.9	128.5
5	0.2	11.0	16.5	21.0	31.5	42.8	69.4	94.2	127.8	148.0	161.2
10	0.1	13.2	19.9	25.2	37.9	51.1	81.9	110.3	148.5	171.9	187.3
20	0.05	15.8	23.7	30.0	45.3	60.5	95.9	128.2	171.4	198.5	216.2
30	0.033	17.4	26.2	33.3	50.1	66.6	105.0	139.9	186.2	215.6	234.9
40	0.025	18.7	28.2	35.7	53.8	71.4	112.0	148.6	197.4	228.5	248.9
50	0.02	19.8	29.8	37.8	56.8	75.3	117.6	155.8	206.5	239.1	260.5
60	0.017	20.7	31.1	39.5	59.5	78.6	122.5	162.0	214.3	248.1	270.2
80	0.012	22.2	33.5	42.4	63.8	84.1	130.6	172.2	227.0	262.9	286.3
100	0.01	23.5	35.3	44.8	67.4	88.8	137.2	180.5	237.4	274.9	299.5

2100 (assuming 2°C temp rise, and corresponding 16% increase in rainfall)
Rainfall depths (mm)

		Duration									
ARI (y)	aep	10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
1.58	0.633	8.1	12.3	15.5	23.4	32.2	53.6	73.9	101.7	117.7	128.3
2	0.5	8.9	13.5	17.1	25.6	35.1	58.1	79.8	109.5	126.7	138.0
5	0.2	11.8	17.7	22.5	33.9	45.9	74.6	101.2	137.2	158.9	173.2
10	0.1	14.2	21.3	27.0	40.7	54.9	87.9	118.4	159.5	184.7	201.1
20	0.05	16.9	25.4	32.2	48.6	65.0	103.0	137.7	184.1	213.2	232.2
30	0.033	18.7	28.2	35.7	53.8	71.6	112.8	150.2	200.0	231.5	252.3
40	0.025	20.1	30.3	38.4	57.8	76.7	120.3	159.6	212.0	245.5	267.4
50	0.02	21.2	32.0	40.6	61.0	80.9	126.3	167.4	221.8	256.8	279.8
60	0.017	22.3	33.4	42.5	63.9	84.4	131.5	174.0	230.1	266.5	290.2
80	0.012	23.9	36.0	45.6	68.6	90.4	140.2	184.9	243.8	282.3	307.5
100	0.01	25.3	37.9	48.1	72.4	95.4	147.3	193.8	255.0	295.2	321.7