Rangitawa Stream Modelling

Horizons Regional Council

Final

Document Control

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Contents

1. Introduction

Woods have been engaged by Horizons Regional Council (HRC) to undertake a stormwater model build for the Rangitawa Stream Catchment, located within the Manawatu District, for the purpose of mapping the extent of flooding within the catchment for the 1:200yr AEP event.

This report documents the process of building an integrated 1D/2D stormwater model of the catchment utilising Mike by DHI software.

Figure 1: Study location

2. Catchment description

The Rangitawa Stream catchment is a predominantly rural catchment and includes the village of Halcombe, which is located near the southern boundary of the catchment. The catchment extends from Waituna West in the west and ultimately discharges to the Rangitīkei River, located approximately 4km east of Halcombe.

2.1. Topography

The topography of the Rangitawa Stream catchment and surrounding Manawatu regions is generally characterised by flat to gently rolling terrain. Elevation ranges from approximately 90 mRL at the downstream end of the catchment draining to the Rangitīkei River, to approximately 300 mRL at the upstream boundary near Waituna West. The catchment is steepest in the upstream reaches and becomes flatter in the low-lying downstream portion of the catchment, including Halcombe Village area.

2.2. Soils and geology

Based on the New Zealand Soil Classification (NZSC)[1], the predominate soil type within the study area is Perch-Gley Pallic and Orthic Gley soil, with an area of Mafic Brown in the most upstream area of the catchment. Orthic Gley soils are affected by waterlogging and therefore have poor drainage and slow permeability, while Perch Glay Pallic and Mafic Brown are classified as imperfectly drained and moderately well drained respectively. Soil zones for the Rangitawa Stream catchment area are shown in Figure 2.

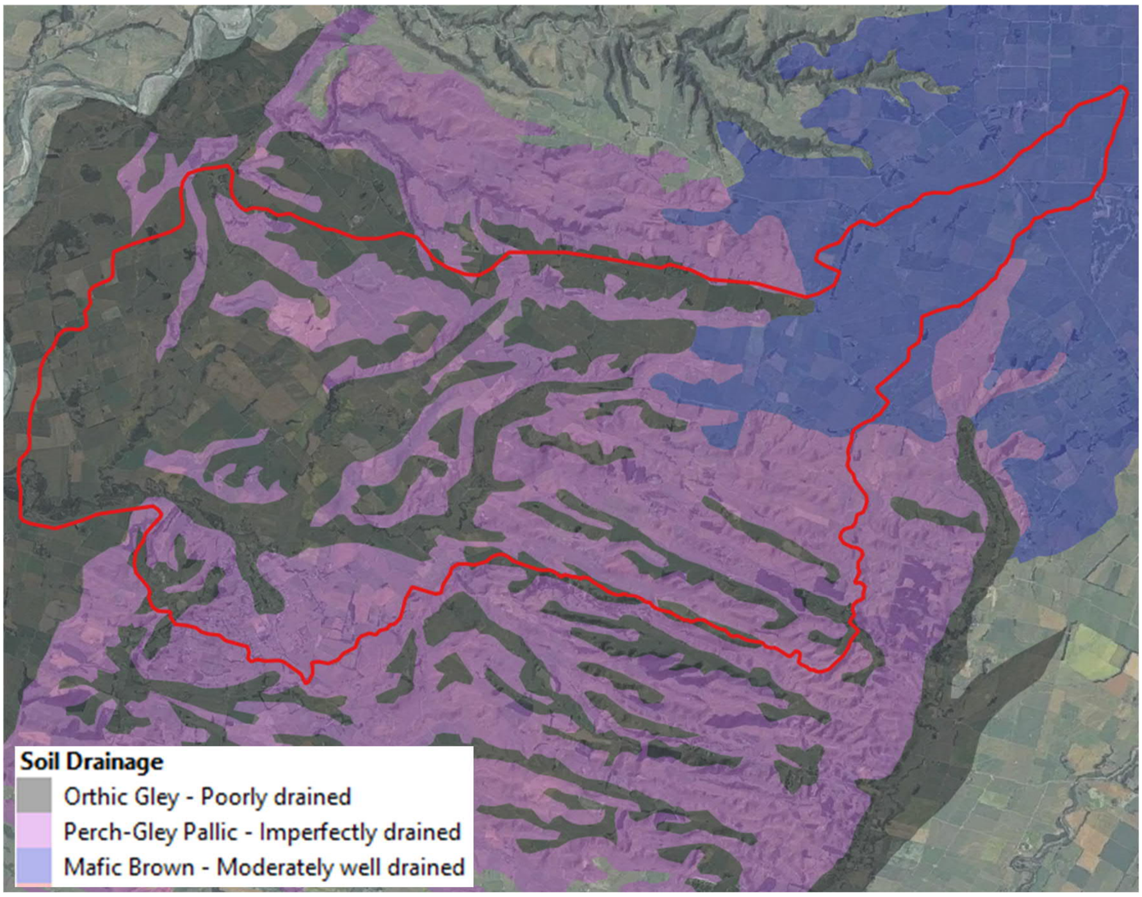


Figure 2: Soil type

3. Asset Survey

HRC have undertaken asset survey of the major bridges and culverts within the study are and provided the results of this survey to Woods for incorporation in the model build. Surveyed assets are shown in Appendix A.

[1] Manaaki Whenua – Landcare Research, SoilsPortal, accessed 16 August 2023 <http://soils.landcareresearch.co.nz>

4. Stormwater Model Build

4.1. Software

The Rangitawa Stream model has been developed using Mike by DHI Version 2020.1 Mike 11 has been used for to represent the 1D river extent and Mike 21 has been used to represent the 2D overland flow. The 1D/2D model have been coupled using Mike Flood. The existing pipe network within Halcombe township and surrounding areas has also been included in the model.

4.2. Model extent

A 1 m resolution LiDAR derived digital elevation model (DEM) was provided by HRC for use in this study and has been used to confirm the upstream contributing area and model extent, which are shown in Figure 3. The total model extent covers an area of 5,900 Ha.

The model consists of both 1D and 2D extent. Three main river reaches have been modelled in 1D using MIKE 11 and coupled to the 2D model via lateral linkages along the river extent. The 1D and 2D extents are shown in Figure 3.

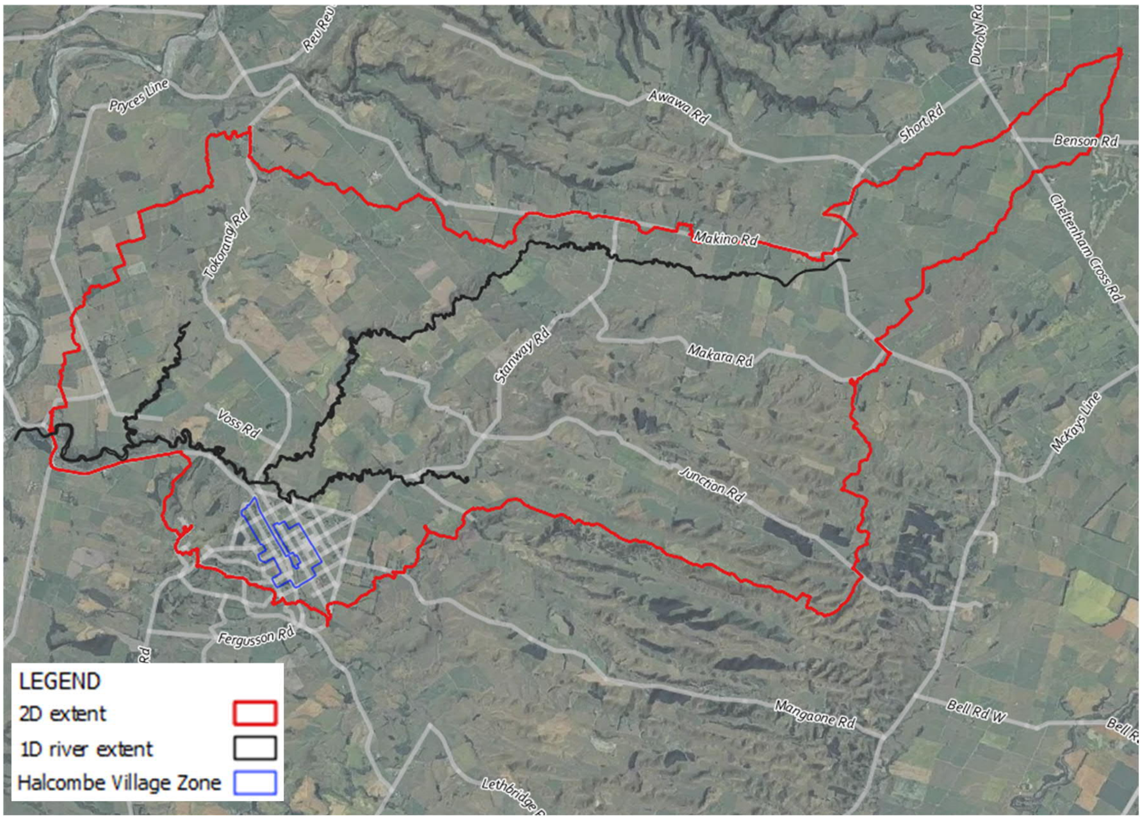


Figure 3: Model extent

4.3. Methodology

Woods have undertaken a 1D/2D model build of the catchment utilising Mike by DHI software. The model build process included the following steps:

1. Create a 2D surface based on LiDAR data provided by HRC.
2. Set up model hydrology for 0.5% AEP (current climate) and 1% AEP (RCP 6.0)
3. Define the 1D river reaches and banks for the main river reaches based on available LiDAR and aerial imagery.

4. Create 1D cross sections based on LiDAR.
5. Incorporation of structures (culverts and bridges) within the 1D network.
6. Incorporate Halcombe piped stormwater network.
7. Set up of linkages between 1D and 2D model components.
8. Set up model boundary conditions.

4.4. Model hydrology

4.4.1. Methodology

The Soil Conservation Service Curve Number (SCS-CN) methodology has been used to calculate the effective rainfall using the parameters provided in Table 1.

Table 1: Model hydrological parameters summary

Parameter	Value
SCS curve number impervious areas	98
SCS curve number pervious areas, Orthic Gley soil type (poorly drained)	86
SCS curve number pervious areas, Perch-Gley Palic and Mafic Brown (imperfectly drained – moderately well drained)	74
Initial loss for Impervious areas (mm)	0
Initial loss pervious areas (mm)	5

4.4.2. Land use

Existing landuse if predominantly rural, with aerial imagery showing minimal existing development within the study area. The exception is the small rural settlement of Halcombe, which is located towards the southern boundary of the catchment and consists of lower density housing and lifestyle sections.

The Manawatu District Plan provides guidance on future land use and maximum allowable developable area within the Manawatu district. The majority of the study area is zoned as Rural, with the exception of the village of Halcombe which is zoned as Village. Within the Village zone the maximum allowable impervious coverage is 35%, with the exception of sites designated 'identified frontage', which are able to have a maximum impervious coverage of 75%.

For sites zoned as Rural there is no maximum allowable impervious coverage, although the district plan lays out a number of rules governing subdivision of rural zoned land, two of which are summarised below.

- A minimum lot size following subdivision of 5000m^2 applies if not serviced by wastewater, and 800m^2 for serviced sites. In addition,
- When subdividing, an area comprising one half of the existing lot area or an area comprising 20 Ha, whichever is a smaller area of land, must be wholly retained within one of the new allotments being created.

An assumption of 5% maximum impervious coverage has been used to estimate the future runoff for rural zoned land. A future impervious assumption of 10% has been applied to rural zoned lots within the Halcombe Village catchment that have an existing development. These assumptions were presented during a meeting with HRC on 06/09/2022. Percentage impervious assumptions for the future infill scenario by land use is summarised in Table 2. Based on the above methodology, the overall impervious percentage of the Rangitawa Stream catchment is approximately 7%.

Table 2: Impervious area by land-use, future infill development

Land-use	Percentage impervious
Halcombe village zone (35%)	35%
Halcombe village zone (75%)	75%
Railway	25%
Road	70%
Existing building	100%
Rest of parcel (with existing development)	10%
Rural and Recreational	5%

4.4.3. Boundary conditions

4.4.3.1. Rainfall

Rainfall intensities have been taken from NIWA's High Intensity Rainfall Design System (HIRDS) version 4, for the annual exceedance probabilities (AEPs) of 1% (with climate change based on RCP 6.0) and 0.5% (no climate change). The 24-hour design storm curves in the Auckland Regional Council stormwater modelling guidelines TP108 (ARC, 1999) have been used to develop the rainfall hyetographs. The 1% and 0.5% 24-hr rainfall depths and associated hyetographs developed based on the above methodology are shown in Table 3 and Figure 4 respectively. The rainfall has been applied to the 2D surface using the rain on grid module within Mike 21. Rainfall has been adjusted to allow for losses associated with land use and soil type.

Table 3: 24 hr rainfall depths

AEP	24-hr rainfall depth
1% (RCP 6.0)	139
0.5% (no climate change)	134

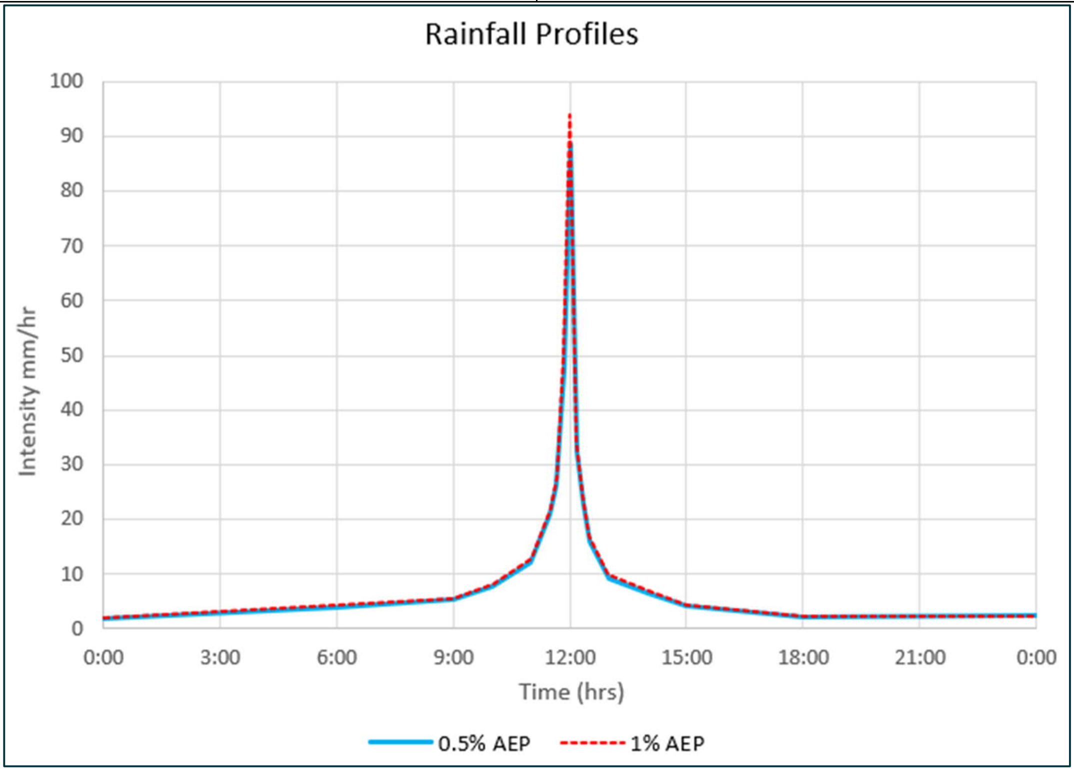


Figure 4: Rainfall profiles

4.4.3.2. Mike 11 boundary conditions

A constant inflow of 0.01 m^3/s has been applied at the upstream chainage of the three Mike 11 branches. A downstream water level boundary where the Rangitawa discharges to the Rangitikei River has been set equal to the invert of the downstream chainage (i.e. no initial downstream water depth).

4.5. Hydraulic model

4.5.1. 1D river network

Three river branches have been modelled in Mike 11 representing the main river reaches within the catchment. A total of 33.25km has been modelled in Mike 11. The 1D river extent captures the low flow channel, and the left and right banks for the low flow channel have been estimated based on the DEM and initial results obtained from a Rapid Flood (rain of grid) Infoworks ICM model. No cross-section survey has been undertaken as part of this study and all cross sections have been interpolated based on the DEM. The Mike 11 1D river extent is summarised in Figure 4.

Table 4: Mike 11 1D river extent

Branch name	Length (m)	Number of cross sections
Branch 1	3,640.85	309
Branch 2	17,402.89	1392
Branch 3	12,205	941

Structures have been modelled using the survey data undertaken by HRC as part of this study. All bridges have been modelled using the Federal Highway Administration (FHWA) WSPRO method. Refer to Appendix A for survey locations.

4.5.2. 1D piped stormwater network

The 1D pipe network has been modelled in Mike Urban utilising GIS data and the results of asset survey carried out by HRC as part of this study. Culverts make up the majority of the Halcombe stormwater network. Private stormwater assets and assets with a diameter <450mm have been excluded from the model extent. Stormwater pipes and culverts included in the Mike Urban model extent are shown in Figure 5. Culvert inlets and outlets have been coupled to the 2D surface.

Figure 5: Modelled pipes

4.5.3. 2D surface flow

A 1 m resolution LiDAR derived digital elevation model (DEM) was provided by HRC for use in this study. The ground surface within the 2D zone was represented using a triangular mesh, generated in Mike Zero. A mesh size of 2 to 8 m^2 was used for the main 2D zone with a refined mesh zone used for areas where the ICM model predicts flooding and the Halcombe village zone.

The different mesh zones applied to the model are shown in Table 5 and Figure 6.

Table 5: 2D zone mesh elements

2D Area	Maximum mesh size (m2)
Refined mesh zone	3
Remaining 2D extent	20

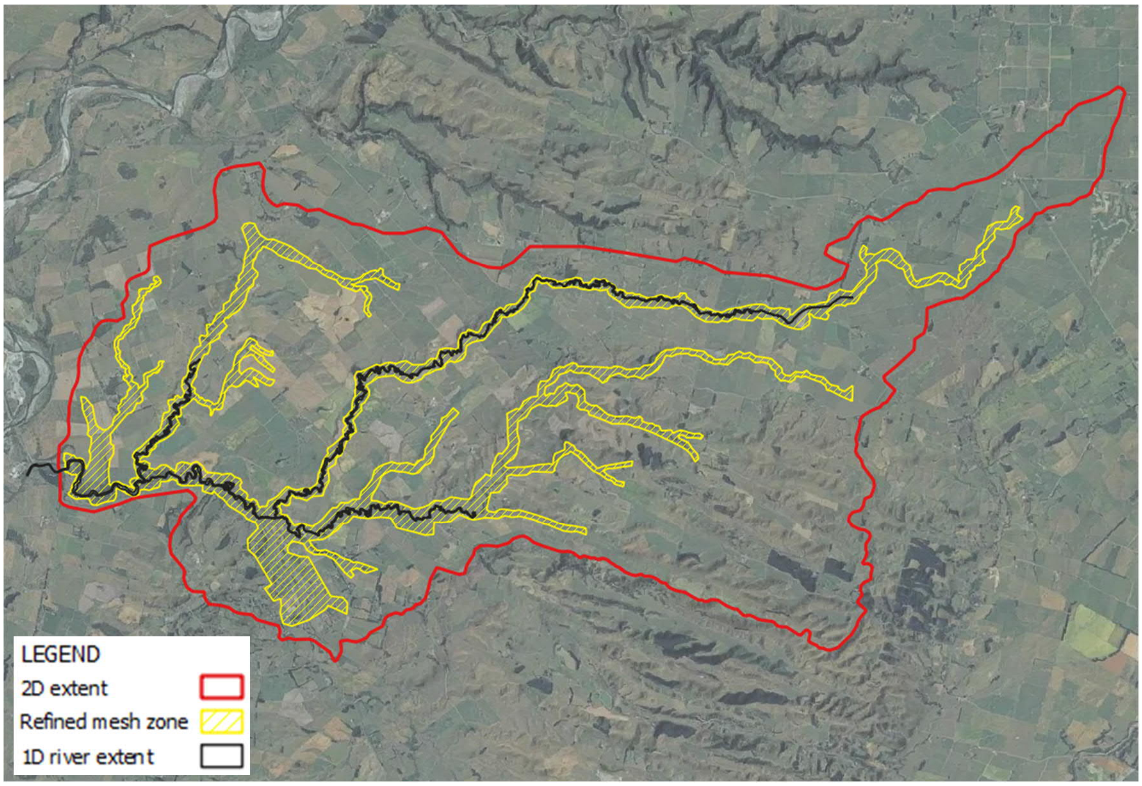


Figure 6: Model mesh zones

4.5.4. Roughness

Values applied to the 1D river model and 2D surface model are shown in Table 6.

Table 6: Manning's roughness

Surface	Manning's n
Village zone	0.035
Roads	0.02
Rest of parcel	0.045
Watercourse – 1D network	0.025
Conduits	0.013

5. Model Validation

5.1. Flood extent

Woods recently undertook a 1D-2D model build Infoworks ICM for the rural settlement of Halcombe, which sits within the Rangitawa Stream model extent. This model has been used to validate the results of the Rangitawa Stream 1% AEP event.

Both the Rangitawa Stream model and the Halcombe ICM model utilise the 24-hour design storm curves in the Auckland Regional Council stormwater modelling guidelines (ARC, 1999) for the modelled rainfall hyetographs. Rainfall intensities for both models have been taken from NIWA's High Intensity Rainfall Design System (HIRDS) version 4 under RCP 6.0 for the period 2081-2100. The 24-hour rainfall depths used for the two models are shown in Table 7.

Table 7: 24 hr rainfall depths, Rangitawa Stream model vs Horizons ICM model

Model	1% AEP 24-hour rainfall depth*
Rangitawa Stream Model	139
Halcombe ICM Model	135

*HIRDS version 4 under RCP 6.0 for the period 2081-2100

A comparison of the flood extent for the 1% AEP event shows a good correlation between the Rangitawa Stream model and the Halcombe ICM model. Figure 7 shows the flood extents for the Halcombe Village area. Flood depths <0.05m have been excluded from the comparison extent.

Figure 7: Comparison of Rangitawa Stream and Halcombe ICM model results for the 1% AEP event

5.2. Rangitawa Stream flow comparisons

Flows downstream of Halcombe Village have been compared against the 1% AEP event (with climate change based on RCP 6.0) and a validation storm event using rain gauge data from Makino rainfall gauge at Halcombe Road. The location point used for the flow comparisons is shown in Figure 8.

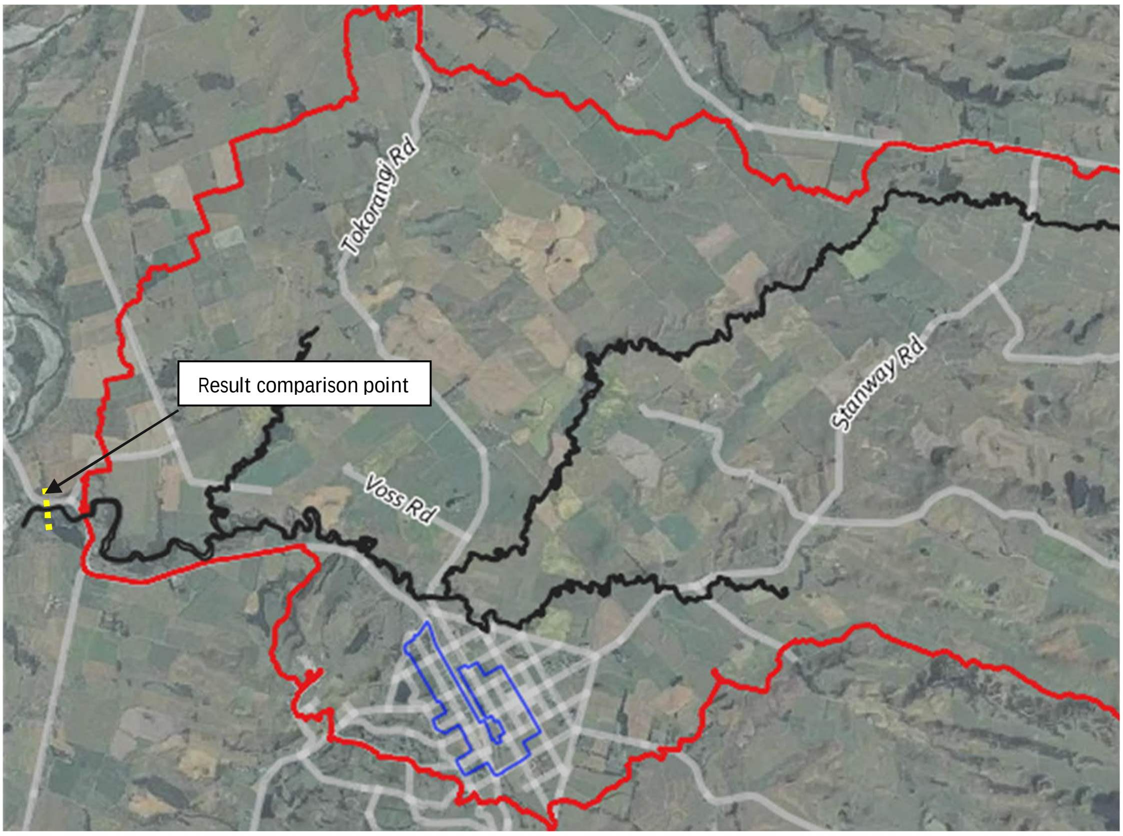


Figure 8: Location used for model result comparison.

A comparison of the flow profiles for the 1% AEP event (with climate change based on RCP 6.0) between the Halcombe ICM and Horizons DHI model is shown in Figure 10. Note there is a difference is flow profile and peak flow due to the different modelling approaches; as this location is outside the area of interest for the Halcombe model study, the Halcombe ICM model represents the stream in this location as 2D only and is based on a maximum mesh triangle size of 5m2. The ICM model also does not have bridges represented.

The ICM model has also been run using rainfall gauge data from the Makino rainfall gauge at Halcombe Road for a significant rainfall event which occurred on 13/12/2021 – 16/12/2021. The rainfall profile for this event is shown in comparison to the 1% and 0.5% design storm rainfall profiles in Figure 9.

The modelled peak flow for this event is approximately 206 l/s at the point indicated in Figure 8. Figure 10 compares the peak flows for the 1% AEP for the DHI and ICM model with the ICM validation event peak flows. The DHI model has not been run for the validation event due to the model run times, but based on the difference in peak flows between the ICM and DHI model observed for the 1% AEP event, it is expected the DHI model would result in peak flows approximately 5% higher than the peak flows observed in the ICM model, in the range of 210 – 220 l/s. It is considered that this flow range is in reasonable agreement with Horizon's Regional Council's slope/area calculation for the flow associated with the December 2021 flood event (250m3/s), as that flow estimate is likely to be +/- 15%-25%.

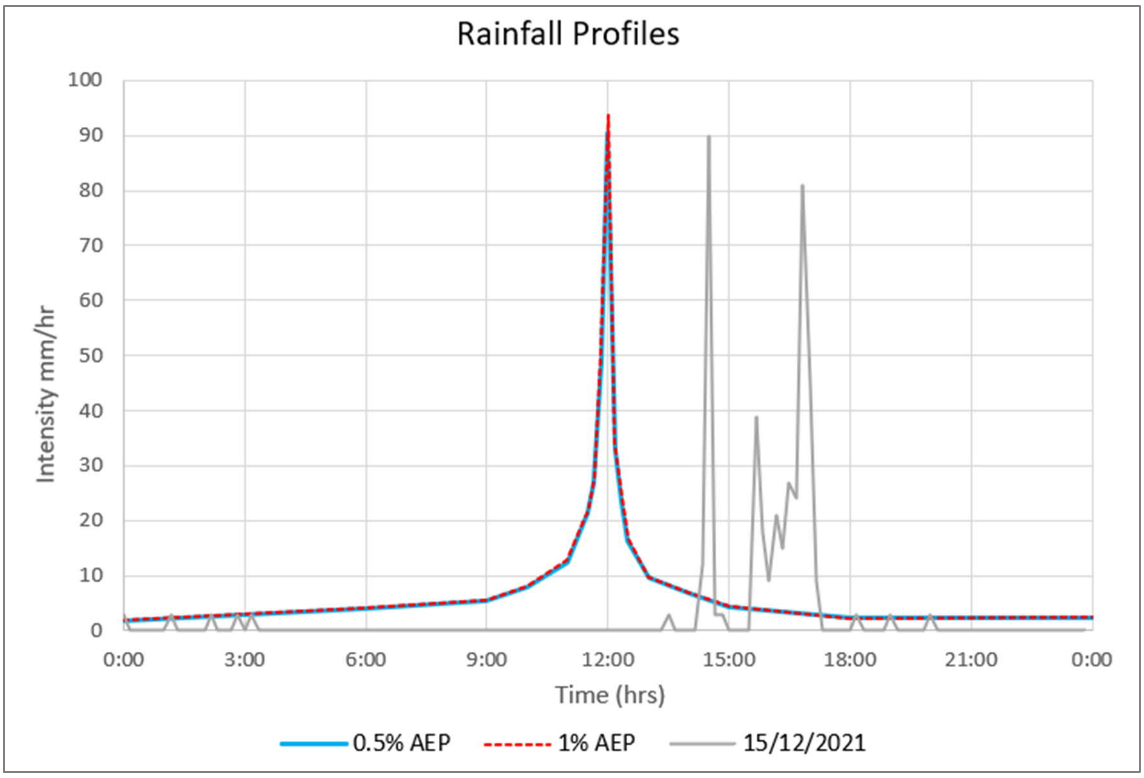


Figure 9: Rainfall intensity (mm/hr) for the design storms and the storm event on 15/12/2021

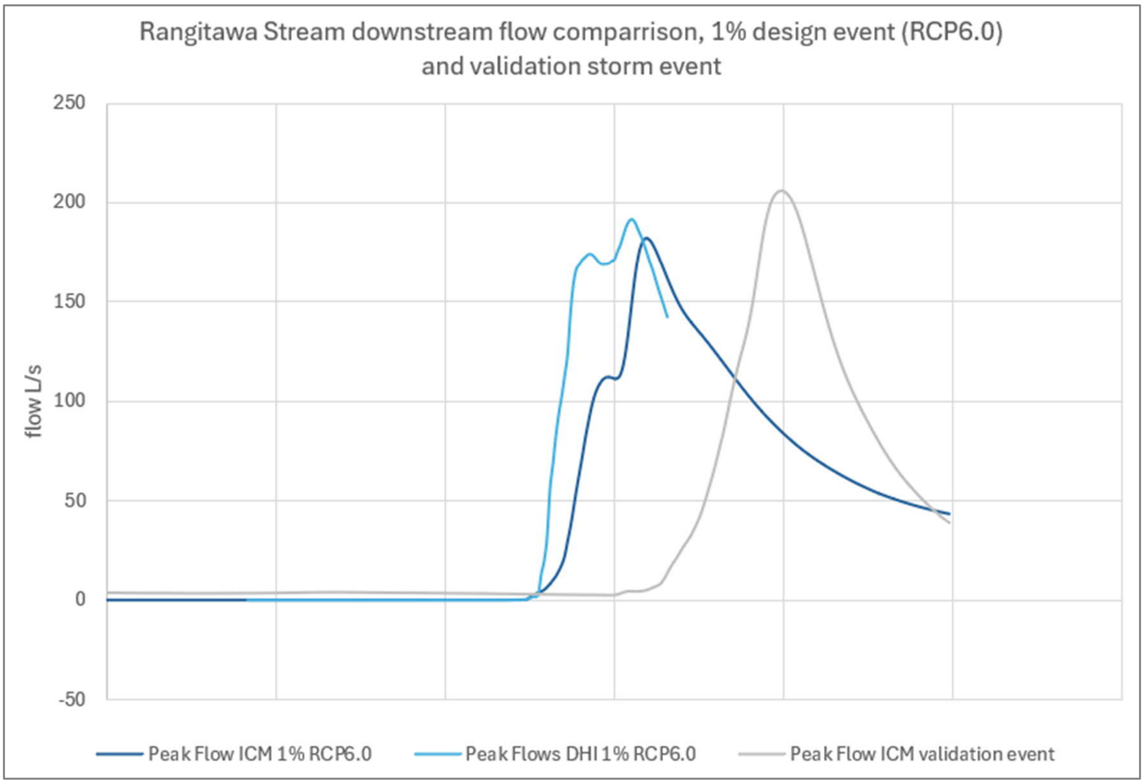


Figure 10: Model result comparison, peak downstream flows 1% design evet (RCP 6.0) vs. validation event

5.2.1. TP108 comparison, 1% AEP event

The modelled 1D peak flow rates for the Rangitawa Stream at the downstream model extent have been compared with peak flow rates calculated using the stormwater modelling guidelines TP108 (ARC, 1999).

TP108. Results are shown in Table 8. TP108 peak flow calculations for the Rangitawa Stream catchment are included in Appendix B.

Table 8: Rangitawa Stream peak flow comparison

Model	Rangitawa Stream peak flow for the 1% AEP event (l/s)
Rangitawa Stream Model	190
TP108 calculated	189

6. Model Limitations and Assumptions

The following key assumptions and limitations apply to the model:

- A downstream boundary condition has not been applied based on Woods understanding that the water level in the Rangitīkei River does not influence the levels of the watercourses within the study area.
- No sedimentation or blockage has been allowed for in any existing watercourses or culverts in the base model scenarios.
- The stormwater model for this catchment has been prepared using latest LiDAR DEM supplied by HRC. This includes all stream cross sections. It is understood the supplied DEM is in draft format and therefore may be altered at a future data following the QA/QC process followed.

7. Conclusions and next steps

An integrated 1D-2D stormwater model of the Rangitawa Stream catchment has been built using Mike by DHI software.

Following completion of the model build exercise, next steps include:

- For the 1% AEP (RCP 6.0) and 0.5% AEP (current climate) scenarios, system performance maps will be produced showing the following results:
  - Depth
  - Velocity and direction
  - Flood extent
  - Flood level contours
  - Flood Hazard

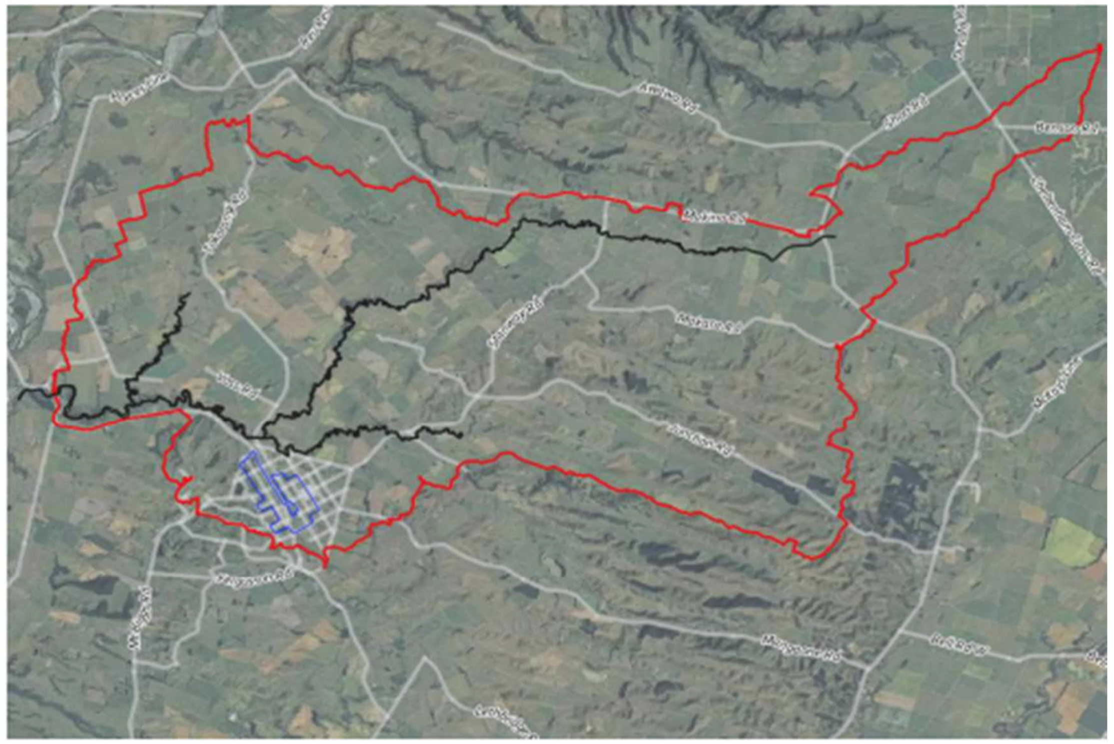
APPENDIX A: Asset Survey


Voss Rd
Tokorangi Rd
Junction Rd W
Junction Rd
Stanway Rd
Halcombe Rd
Pearce St
Godley St
Cassan St
Pleasants Rd
Shenwill St
Clive St
Hastings St
Gillett St
Levin St
Stewart St
King St
Ingham St
Mt Biggs Rd
Monteith St
Vogel St
Gilbert St
Kimber St
Barton St
Beattie St
Knorp St
Carruthers St
James Rd
Mangaone Rd
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
21
22
23
01 - 450 culvert under Halcombe Road
02 - 600 culvert under Halcombe Road
03 - 600 culvert under Halcombe Road
04 - Twin 600 culverts under railway
05 - 600 culvert under railway
06 - 600 culvert under Halcombe Road
07 - 900 culvert under railway
08 - 1950 culvert under Willoughby St
09 - XS 5m upstream of Godley St bridge
10 - Upstream side of Godely St bridge
11 - 600 culvert under Cassan St
12 - rivate farm bridge
13 - Private farm bridge
14 - Private farm bridge
15 - 600 culvert under Stanway St
16 - Private farm bridge
17 - XS 9m upstream of farm bridge
18 - Private farm bridge with concrete bed
19 - 211 Stanway Road
20 - Current road bridge on Tokorangi Road
21 - Old road bridge by Tokorangi Road
22 - Bridge on Pleasants Road
223 - Bridge on Junction Road
24 - Railway Bridge
25 - Bridge on Halcombe Road, between Mingaroa Road and Pryces Line
LEGEND
SURVEYED CULVERTS
SURVEY XS-LINES
0
1,000
2,000 m
P23-238 Rangitawa Stream Modelling - Horizons Regional Council
HRC surveyed assets
23/01/2024
WOODS.CO.NZ

APPENDIX B: TP108 Peak Flow Calculation

WOODS
Engineers. Surveyors. Planners.

PROJECT NUMBER:	**P23-238**
ADDRESS:	**Rangitawa Stream - Horizons Regional Council**
BY:	**GN**
DATE:	**15/02/2024**



Catchment Details

Total Area (ha)	Atotal =	5900.000
Pervious Area (ha)	Aper =	5487.000
Impervious Area (ha)	Aimp=	413.000
Channelisation facor	C =	1.00
Catchment Length (km)	L =	23.000
Catchment Slope	Sc =	0.012

RUNOFF CURVE NUMBER (CN) AND INITIAL ABSTRACTION (Ia)

Soil Name &Classification	Cover Description (cover type, treatment and hydrological condition)	Curve Number CN	Area (ha)	Product CN x Area
Orthic Brown Soil	Pervious	79	5487.00	433,473.0
Orthic Brown Soil	Impervious	98	413.00	40,474.0
		Total	**5900.00**	**473,947.0**

CN (weighted) = $\frac{\text{total product}}{\text{total area}} = \frac{473{,}947.0}{5{,}900.00}$ = **80.3**

Ia (weighted) = $\frac{4.5 \times \text{pervious area}}{\text{total area}} = \frac{24{,}691.5}{5{,}900.00}$ = **4.2**

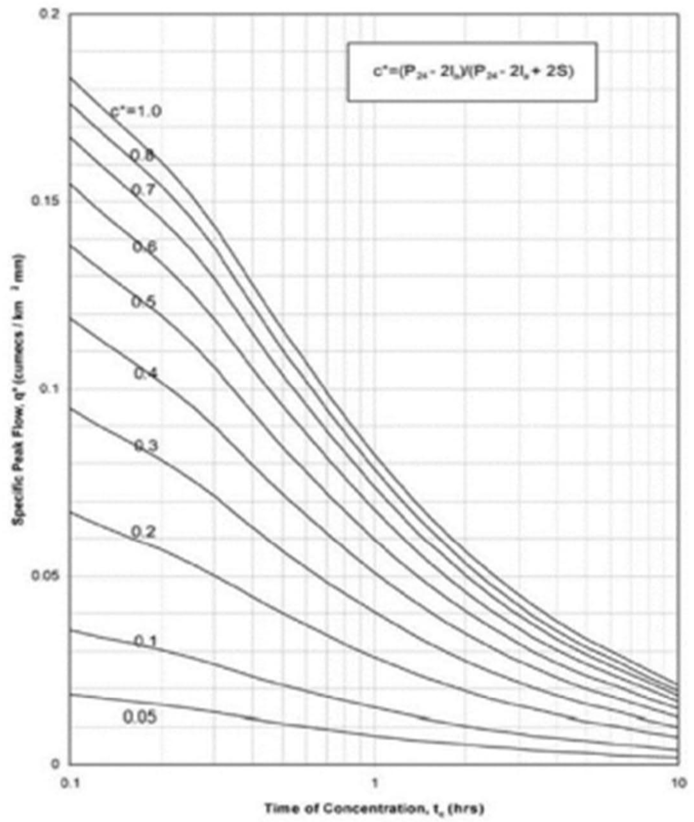
TIME OF CONCENTRATION

Runoff Factor = $\frac{CN}{200 - CN}$ = 0.671

Note: tc = 10 min = 0.17hrs

tc = 0.14C x L0.66 x [CN/(200-CN)]-.55 x Sc-0.30 = **5.238** hrs = **314.3** mins

SCS Lag for HEC-HMS "tp" = 2/3 x tc = 3.492 hrs = 209.5 mins



Peak Flow Rate

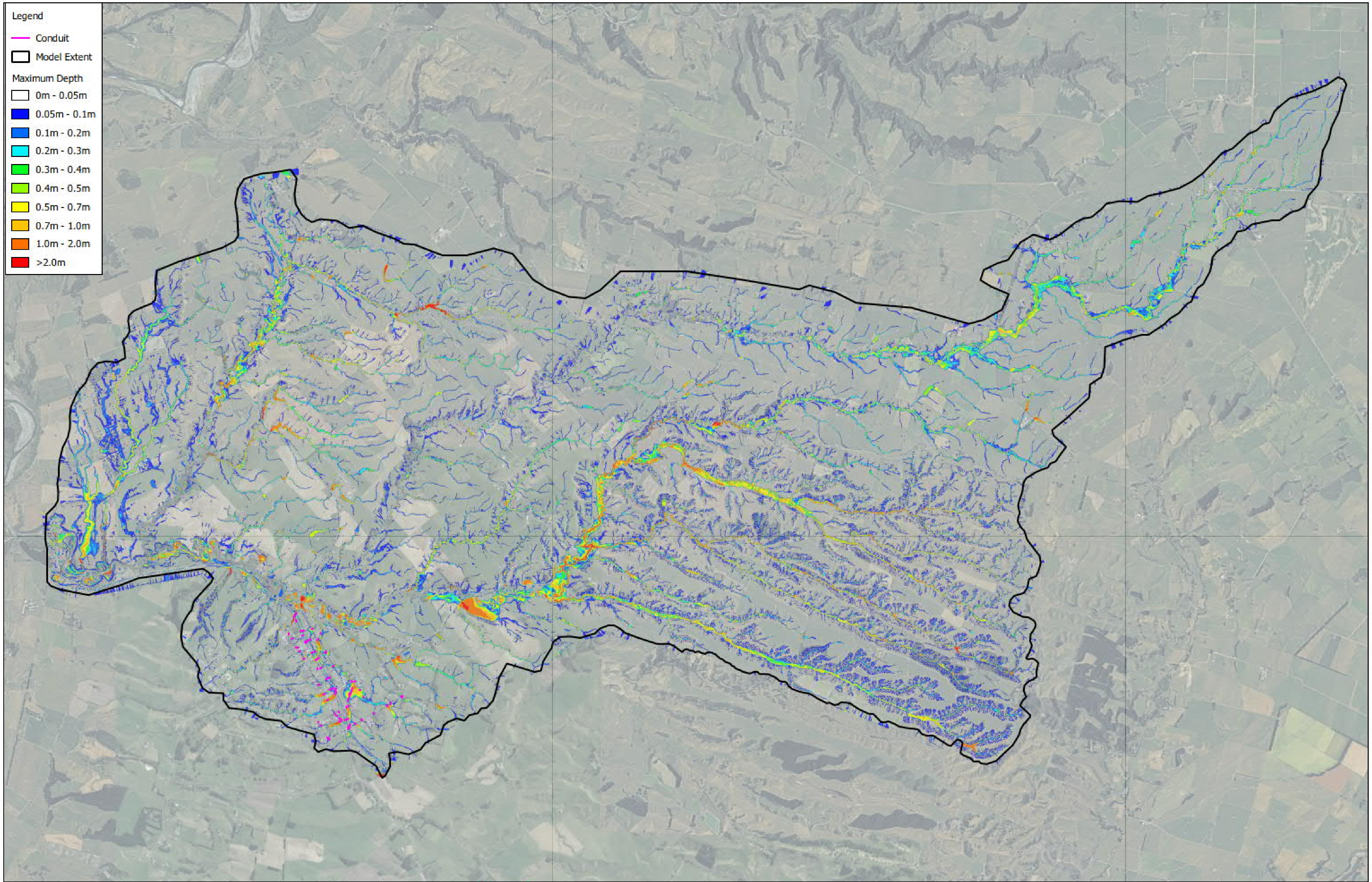
1. Catchment Area (km^2) = 59.0000

2. Storage, $S = 25.4 \times [(1000/CN) - 10]$ = 62.2

		Calculated	Model
3. Annual Recurrence Interval (ARI)			
4. 24 hour rainfall depth, P_{24} (mm)		139.00	
5. Compute c* =	$\frac{P_{24} - 2Ia}{P_{24} - 2Ia + 2S}$ (mm)	0.512	
6. Specific flow rate q*		0.023	
7. Peak flow rate, $q_p = q^* A P_{24}$ (m^3/sec)		188.62300	
8. Runoff depth, Q_{24} =	$\frac{(P_{24} - Ia)^2}{(P_{24} - Ia) + S}$ (mm)	92.3	
9. Runoff Volume, $V_{24} = 1000 \times Q_{24}A$ (m^3)		5,443,004	

APPENDIX C: Model Result

- 0.5% AEP Flood Depth map
- 0.5% AEP Flood Hazard map



REVISION DETAILS		INT	DATE	SURVEYED	-
1.0	For Information	-	08/03/2024	DESIGNED	-
-	-	-	-	DRAWN	GN
-	-	-	-	CHECKED	AD
				APPROVED	-

8 Nugent Street
Grafton 1023
Auckland

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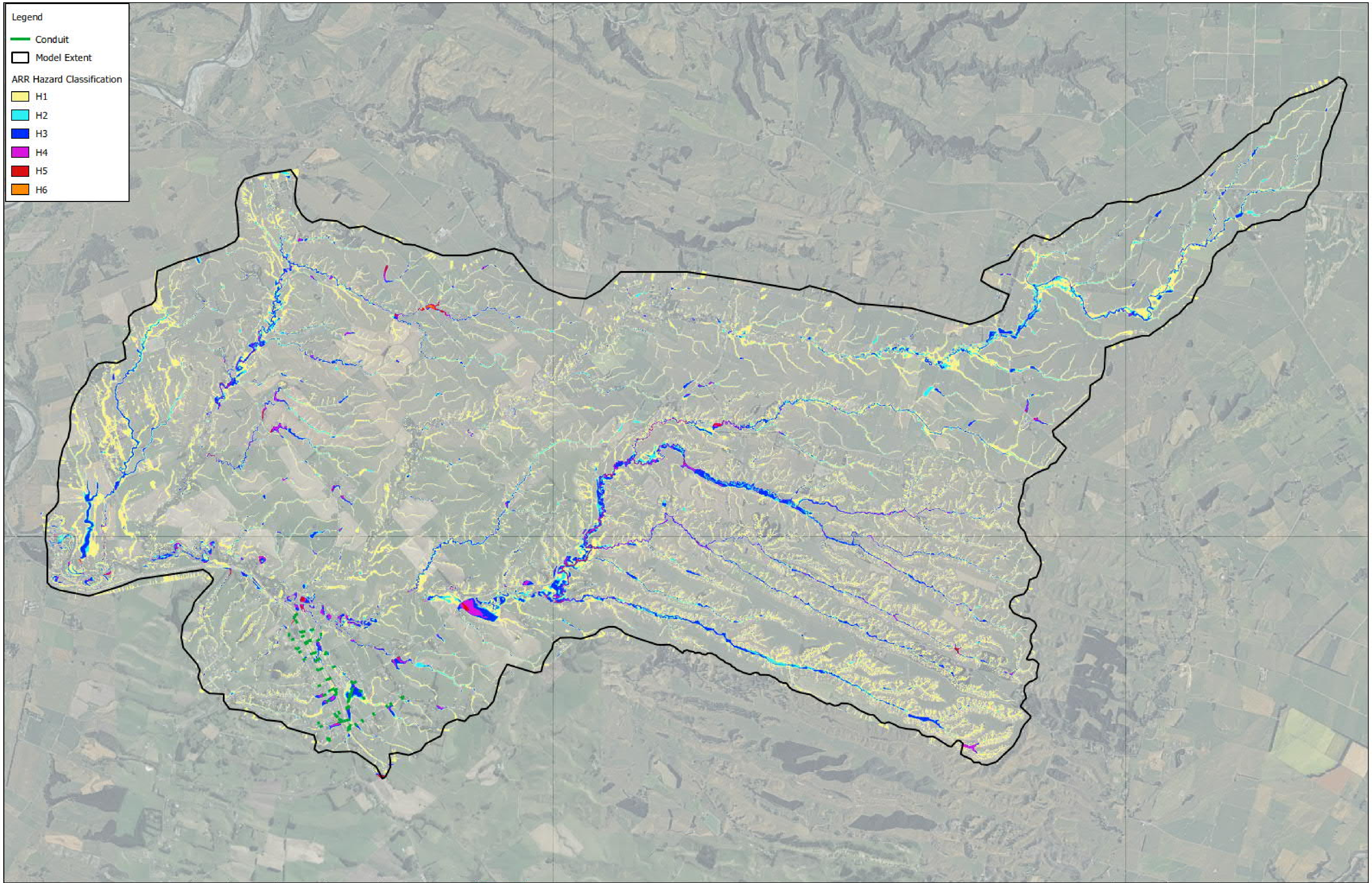
WOODS
Est.1970

P23-238 Rangitawa Stream Stormwater Modelling
Horizons Regional Council
Maximum Depth
MPD 0.5% event without CC

STATUS	DRAFT	REV
SCALE	NTS	1.0
COUNCIL	Horizons Regional Council	
SHEET NO	SHEET 1	



REVISION DETAILS		INT	DATE	SURVEYED	-	8 Nugent Street Grafton 1023 Auckland	WOODS	P23-238 Rangitawa Stream Stormwater Modelling	STATUS	DRAFT	REV
1.0	For Information	-	08/03/2024	DESIGNED	-			Horizons Regional Council	SCALE	NTS	1.0
-	-	-	-	DRAWN	GN			ARR Hazard	COUNCIL	Horizons Regional Council	
-	-	-	-	CHECKED	AD			MPD 0.5% event without CC	SHEET NO	SHEET 1	
				APPROVED	-	WOODS.CO.NZ					