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Design Modelling

Northern Wairoa Catchment (M18)

Northland Regional Council

27 May 2021

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1 PROJECT OVERVIEW

Overview

Water Technology was commissioned by Northland Regional Council (NRC) to undertake a region-wide flood modelling study. The study area encompassed the entire Northland Regional Council area which covers an area of over 12,500 km^2, with the exclusion offshore islands. The aim of this project was to map riverine flood hazard zones across the entire Northland region and update existing flood intelligence.

Modelling approach

This project used a 2D Direct Rainfall (also known as Rain on Grid) approach for hydraulic modelling and has provided flood extents for a defined range of design storms. The hydraulic modelling software TUFLOW was used. TUFLOW is a widely used software package suitable for the analysis of flooding. TUFLOW routes overland flow across a topographic surface (2D domain) to create flood extent, depth, velocity and flood hazard outputs that can be used for planning, intelligence and emergency response. The latest release of TUFLOW offers several recent advanced modelling techniques to improve modelling accuracy which where practical, were tested and adopted in this project.

This study delineated and modelled 19 catchments, shown in Figure 1-1. To validate the adopted methodology and model parameters used in the design modelling, 9 catchments were calibrated against recent (and historic) flood events. The calibration/validation methodology is documented in a standalone report *NRC Riverine Flood Mapping - Calibration Report – R01* and is referred to throughout this document as the *Calibration Report*.

This report documents the design modelling methodology for Northern Wairoa Catchment (M18), noting that this catchment was not calibrated however, model parameters reflected regional parameters and assumptions relied upon for Catchments M01, M13, M14 and M15, located within close proximity to Catchment M16 and which were calibrated.

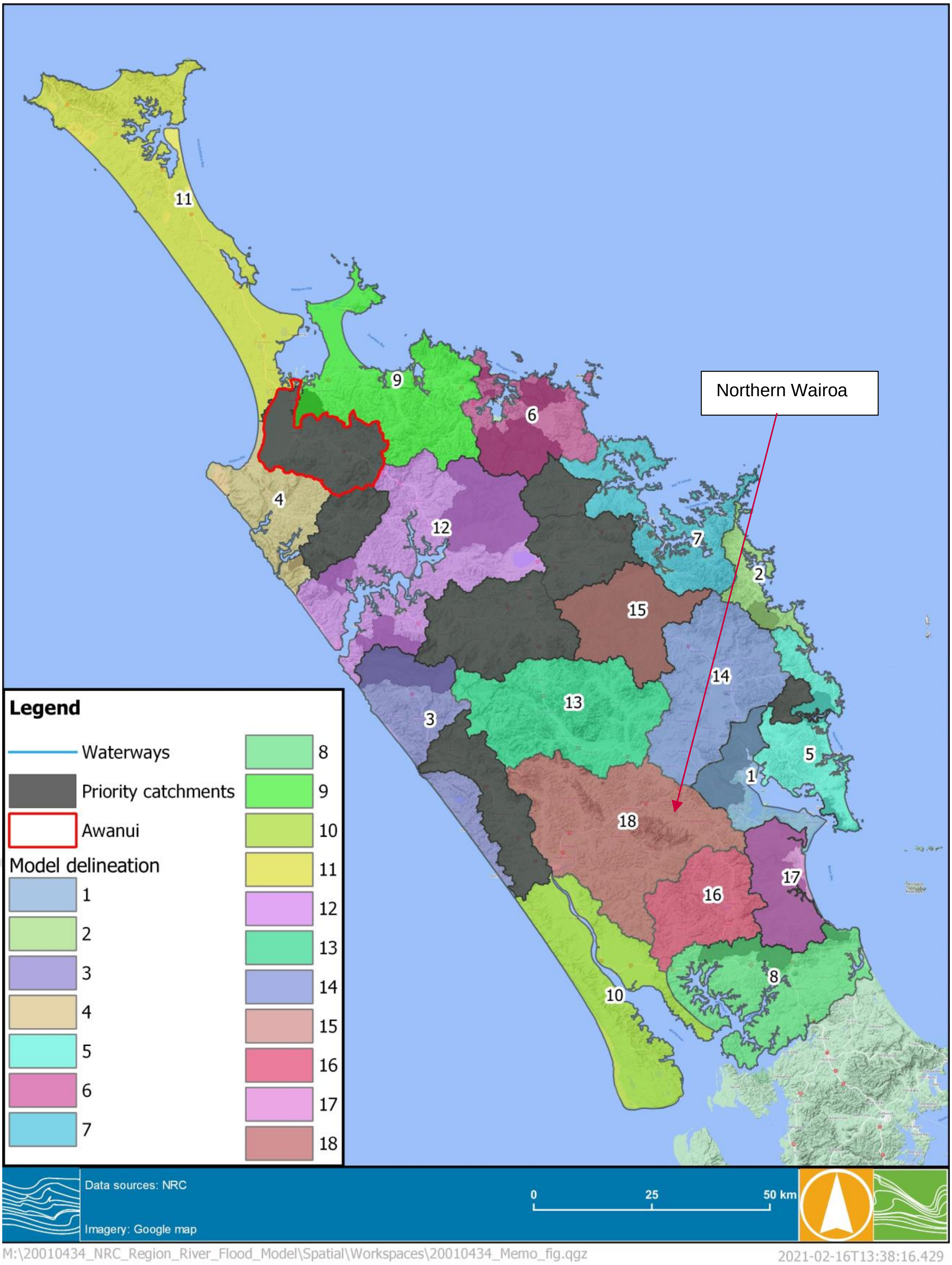

FIGURE 1-1 MODEL DELINEATION

2 STUDY AREA

The model 18 catchment is an inland mountainous catchment, covering a total area of approximately 1034 km^2 with Dargaville its largest township. The Wairoa River is the largest waterway flowing from east to west across the entire catchment towards Dargaville with numerous waterways/tributaries contributing to its flows, before heading south towards Whakaki River and the ocean. Figure 2-1 displays the study area of the catchment model 18 as well as the three upstream catchment modelss which feed flows into this study area.

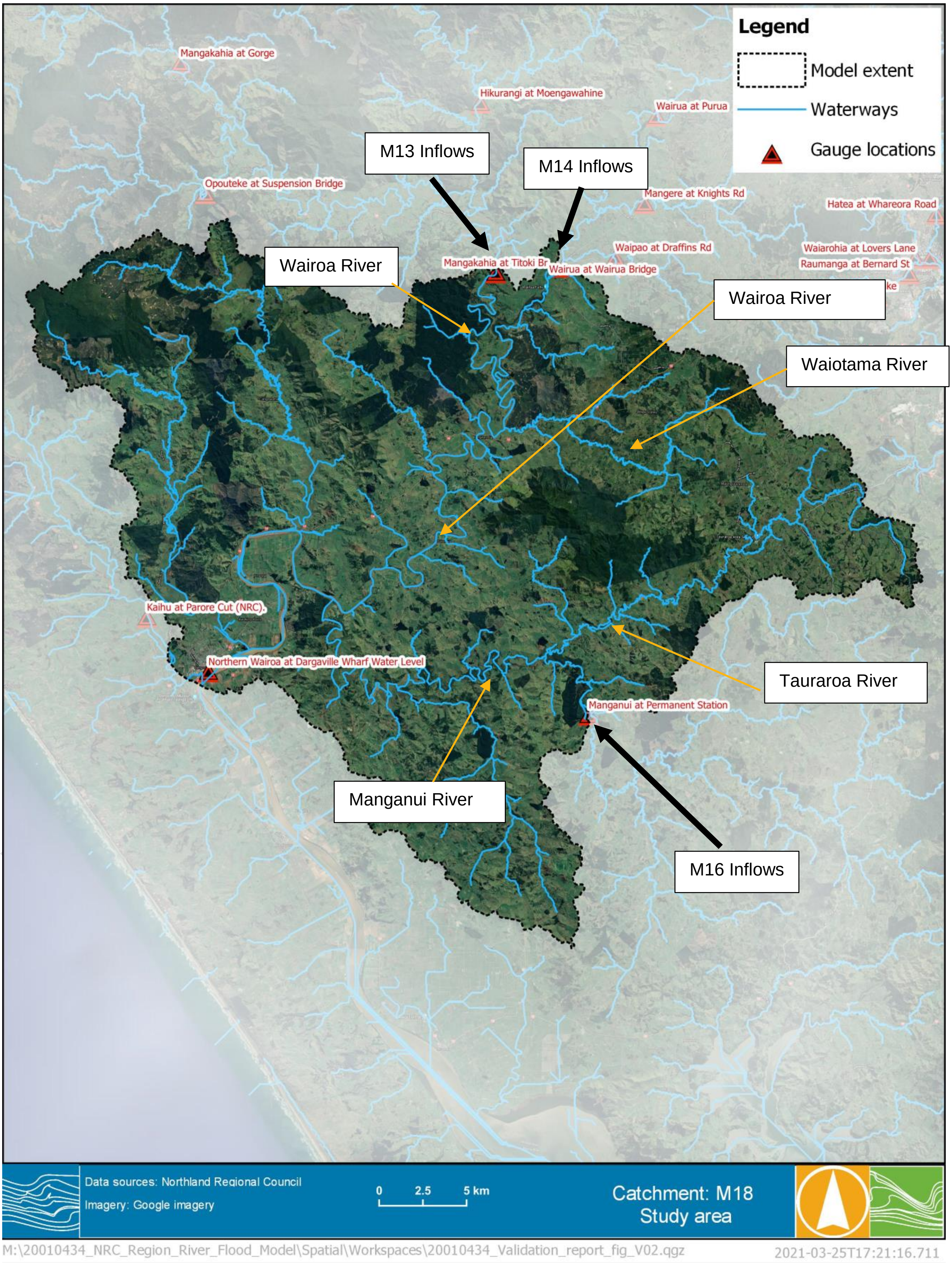

FIGURE 2-1 STUDY AREA

3 DESIGN MODELLING

3.1 Overview

A hydraulic model (TUFLOW) of the Northern Wairoa catchment (M18) was constructed to model overland flooding. A range of storm durations were run and results for each Annual Exceedance Probability (AEP) event were enveloped to ensure the critical duration was well represented across each part of the study area. The merged results captured the maximum flood level and depth of the range of design event durations modelled.

Table 3-1 and the following sections detail the key modelling information used in the development of the hydraulic model.

TABLE 3-1 KEY MODELLING INFORMATION

Terrain data	NRC 1m LiDAR without filling of sinks but includes the “burning of creek alignments’ through embankments
Model type	Direct rainfall model
Model build	Build: 2020-10-AA-iSP-w64
Rainfall	See Sections 3.2.1 and 3.2.4
Losses	See Section 3.2.3
Boundaries	See Section 3.2.4
Modelling solution scheme	TUFLOW HPC (adaptive timestep)
Modelling hardware	GPU
Modelling technique	Sub-grid-sampling (SGS)
Model grid size	10m with 1m SGS

3.2 Model Parameters

A range of model parameters were adopted, based on the calibration of catchments (i.e. M01, M13, M14 and M15) in the Whangarei District. Details of these are outlined below.

3.2.1 Rainfall Intensity-Duration-Frequency

Intensity-Duration-Frequency (IDF) tables were developed by NIWA through the High Intensity Rainfall Design System (HIRDSV4)[1]. Design rainfall totals for durations from 10 minute up to 120 hours were developed for design modelling and were developed at 179 rainfall gauge sites across the wider study area. The IDF tables cover a range of magnitude events from 1 in 1.58 ARI through to 1 in 250 ARI along with climate change predictions (Representative Concentration Pathway 4.6, 6 & 8.5) up to the year 2100. For this catchment, 11 rainfall gauges were used with a spatially weighted grid of rainfall totals created for design modelling. Figure 3-1 shows the 12-hour cumulative rainfall grid for the 1% AEP event along with the rainfall gauge locations used to create the grid.

[1] Accessed via https://hirds.niwa.co.nz/

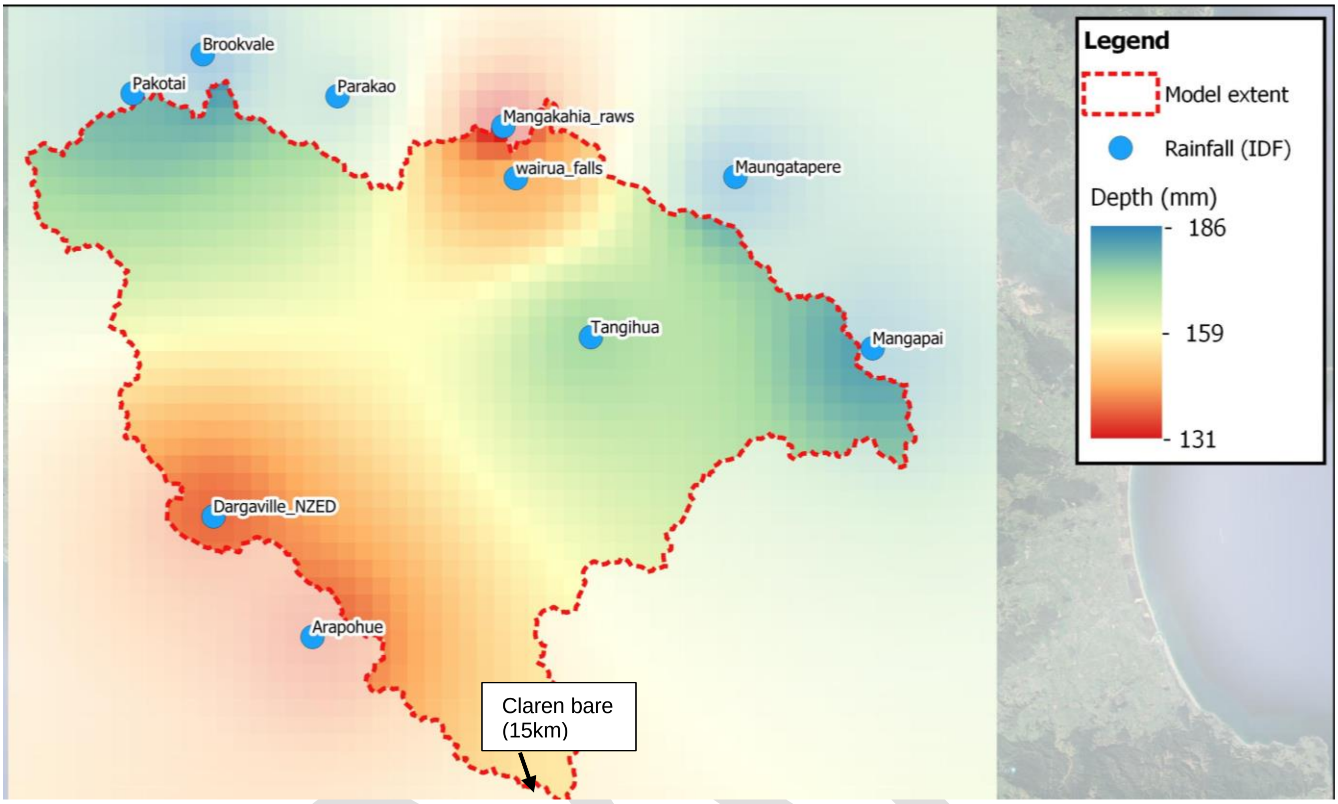

FIGURE 3-1 EXAMPLE OF DESIGN RAINFALL GRID (12-HOUR, 1% AEP RAINFALL) FOR M18

3.2.2 Design Rainfall Temporal Patterns

Design temporal patterns (rainfall hyetographs) were provided by NRC for design modelling. These were developed as part of a previous project undertaken by Macky & Shamseldin (2020)[2]. The project aimed to provide multiple design hyetographs and a better representation of rainfall variability across the Northland region, replacing the single set of design hyetographs previously developed.

The HIRDS design temporal pattern is recommended for design modelling of Northland catchments[2]. Hence, the design hyetographs for the rainfall gauges were developed using the rainfall IDF data at available rainfall gauges for the catchment. Although a 12-hour hyetograph is suitable for design modelling for most Northland catchments as suggested[2], a range of durations were selected; including 1-hour, 6-hour, 12-hour and 24-hour for each design event, including 10%, 2% and 1% AEP events to ensure that the event critical duration was identified across the catchment. The shorter durations were critical in the upper parts of the catchment, while the longer 24-hour durations were critical in the lower catchment, where flood volumes are generally the predominant factor in generating peak flood levels.

Table 3-2 summarises the 1% AEP rainfall depth (based on IDF from HIRDSV4) for different event durations at each rainfall gauge and Figure 3-2 shows the design rainfall temporal patterns across different gauges for the 12-hour duration event. Considering a single temporal pattern is assigned (i.e. HIRDS hyetograph), the proportional amount of rainfall applied through time for a given duration (e.g., 6-hour) is generally consistent (as shown in Figure 3-2) across the catchment area.

[2] Macky & Shamseldin (2020) - Northland Region-wide Hyetograph review

TABLE 3-2 1% AEP DESIGN RAINFALL DEPTH

Gauge location	1% AEP (mm)			
	1-hour	6-hour	12-hour	24-hour
Arapohue_A63091	49	106	138	174
DARGAVILLE N.Z.E.D._A53983	47	106	139	178
Glenmont_Pakotai_A53781	57	133	178	231
Mangakahia_raws_O00891	52	103	131	163
Mangapai_A54821	62	140	181	228
Maungatapere_A54721	63	140	184	237
Opouteke at Brookvale_536812	60	141	186	238
Parakao_A53791	57	133	176	226
RUAWAI_Claren_bare_A64112	55	121	155	192
TANGIHUA_A54811	61	134	173	216
Wairua_falls_A54701	53	113	148	187

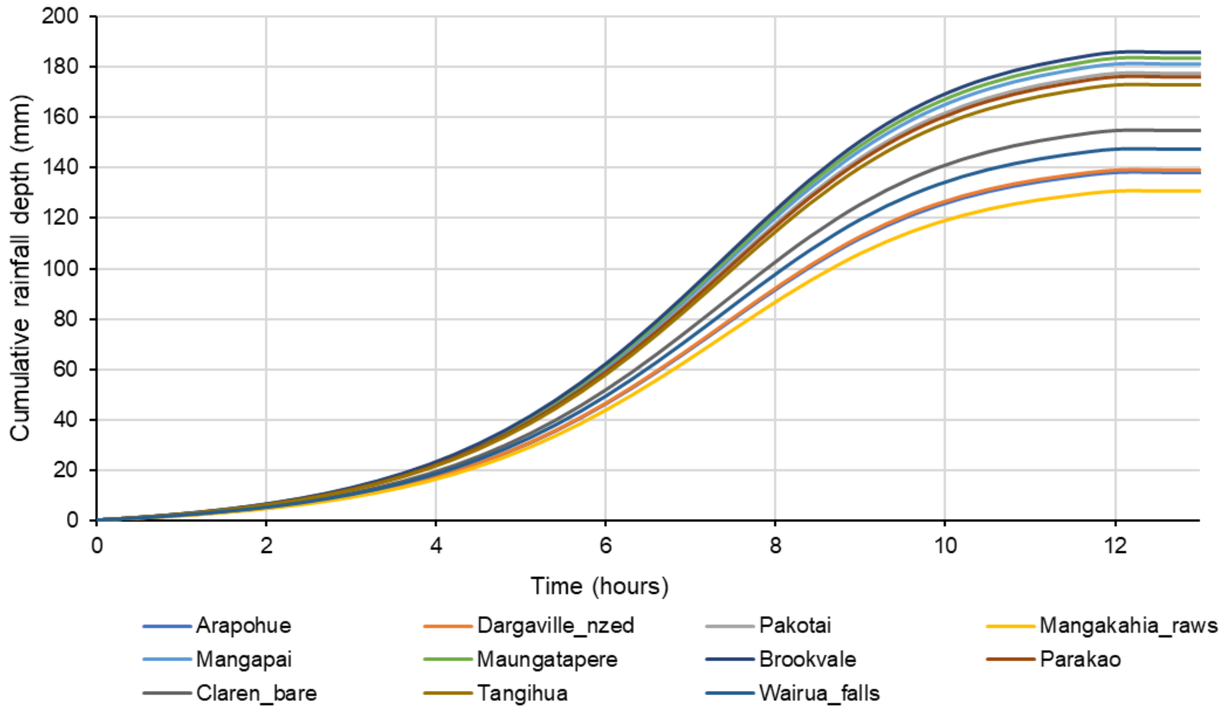

FIGURE 3-2 TEMPORAL PATTERN FOR DESIGN RAINFALL OF 12-HOUR, 1% AEP EVENT

A climate change scenario (for the 1% AEP events) was modelled for the 2081-2100 timeframe, for the RCP 8.5. This is based on the increases in rainfall intensity of 35%, 30%, 26% and 22% respectively for 1-hour, 6-hour, 12-hour and 24-hour duration events.

3.2.3 Losses

Model cells were assigned a Manning's "*n*" (surface roughness), initial loss and a continuing loss based on land use types and hydrologically important characteristics. Table 3-3 summarises the adopted roughness and loss parameters. It should be noted these parameters were adopted based on the calibration to a historic event where streamflow gauges were present in other Whangarei District catchments (i.e. M01, M13, M14 and M15). Figure 3-3 displays the roughness layer based on the land use type, showing most land use is forest and grassland.

TABLE 3-3 DESIGN MODEL PARAMETERS

Hydrological areas	Land use types	Manning's n	Initial loss (IL) – mm	Continuing loss (CL) – mm/hr
Entire M18 catchment	Forest	0.08	34	5.3
	Grassland	0.06	34	5.3
	Cropland – perennial	0.04	20	2
	Cropland – annual	0.04	20	2
	Wetland – open water	0.04	0	0
	Wetland – vegetated	0.05	10	1
	Urban areas	0.10	5	1.5
	Waterways	0.06	0	0
	Other	0.06	15	1.5

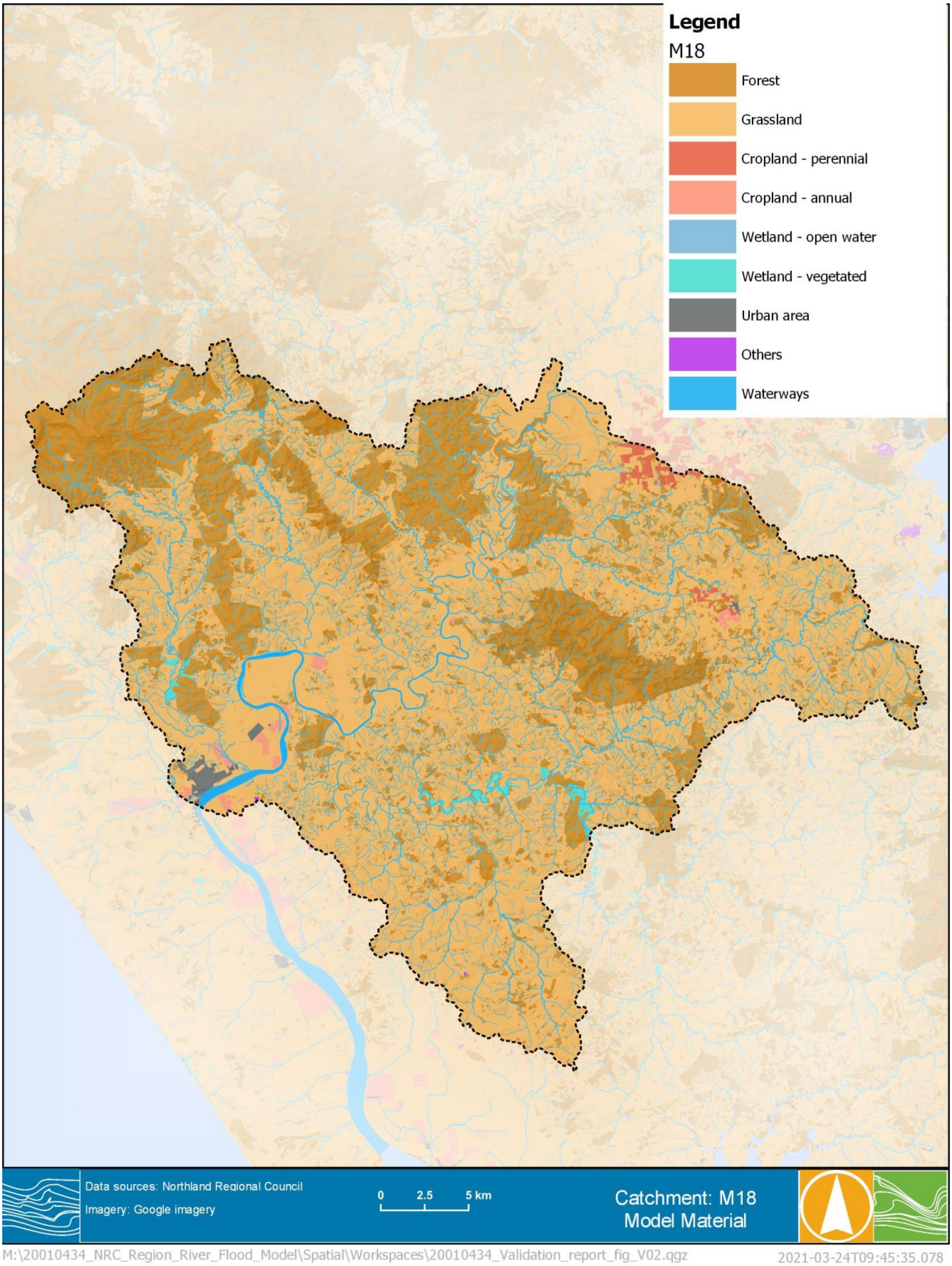

FIGURE 3-3 HYDRAULIC MODEL MATERIAL LAYER

3.2.4 Boundaries

As the Northern Wairoa catchment is an inland catchment, a stage and discharge (i.e. HQ) outflow boundary was used at downstream of Dargaville Wharf in the design modelling.

Upstream inflows coming from upstream catchments were applied in this catchment model, including inflows from catchment M16 in Manganui River, catchment M14 in Wairua River and catchment M13 in Mangakahia River.

4 MODELLING RESULTS

4.1 Modelled Result Processing/Filtering

Design modelling consisted of running the model for four storm durations (1-hour, 6-hour, 12-hour and 24-hour) with the results enveloped for each design event (i.e. 1%, 2% and 10% AEP) to ensure the critical duration was well represented across each part of the catchment. Each model run produced gridded results, including depth, water surface elevation (WSE), hazard (Z0) and velocity. Several post-processing steps were required to produce the final design modelling outputs. These are described as follows:

Step 1:

- The modelling results are firstly merged to produce the maximum outputs of the range of storm durations modelled. For example, the flood depth output is produced by merging the depth results of the four different durations within each AEP. This allows for the critical storm duration across each part of the catchment to be represented (i.e. the short intense storms in upper reaches and longer duration storms in the lower parts of the catchment). Effectively, a map of the worst-case scenario at each location (based on the modelled scenarios) is generated across the whole area.

Step 2:

- The maximum gridded results are then remapped to a finer DEM grid using the 5-m LiDAR data. This allows the flood extent to be more accurately displayed on the map and the higher resolution gridded results (i.e. same resolution as the 5-m DEM) to be produced.

Step 3:

- Finally, the remapped results are post-processed by filtering out depths below 100mm and puddle areas less than 2000m^2 as agreed with NRC.

Figure 4-1, Figure 4-2 and Figure 4-3 respectively show the final post-processed flood depths, velocity and hazard of the 1% AEP design event modelled for M13. Figure 4-4 shows the flood depth map zoomed in at a township as an example. It is noted that the hazard classification is based on the following criteria:

TABLE 4-1 FLOOD HAZARD CLASSIFICATION

Hazard classification	Hazard – VxD (m^2/s)
Low	< 0.2
Low to Moderate	0.2 to 0.4
Moderate	0.4 to 0.6
Moderate to High	0.6 to 0.84
High	> 0.84

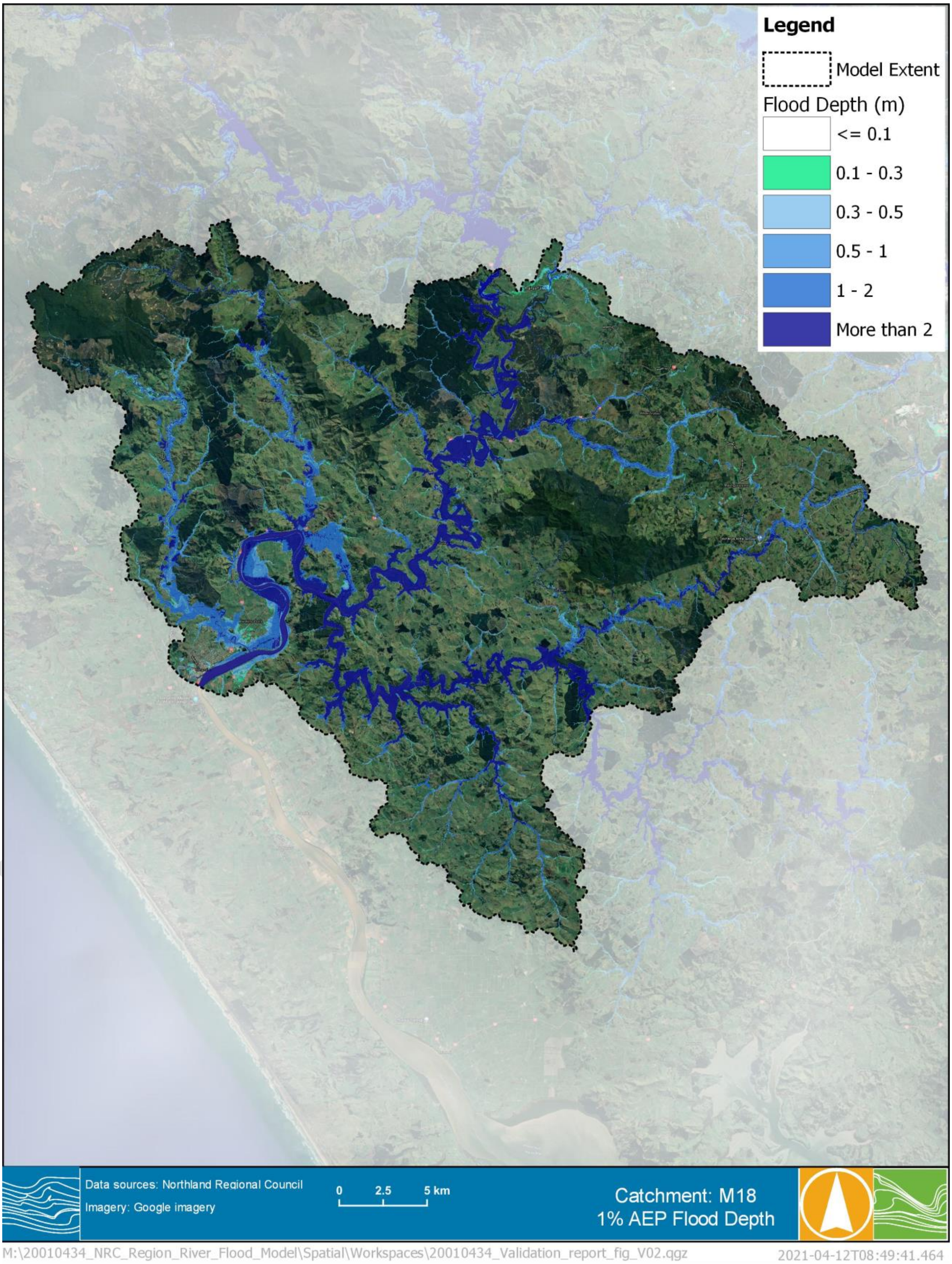

FIGURE 4-1 DESIGN MODELLING OF 1% FLOOD DEPTH

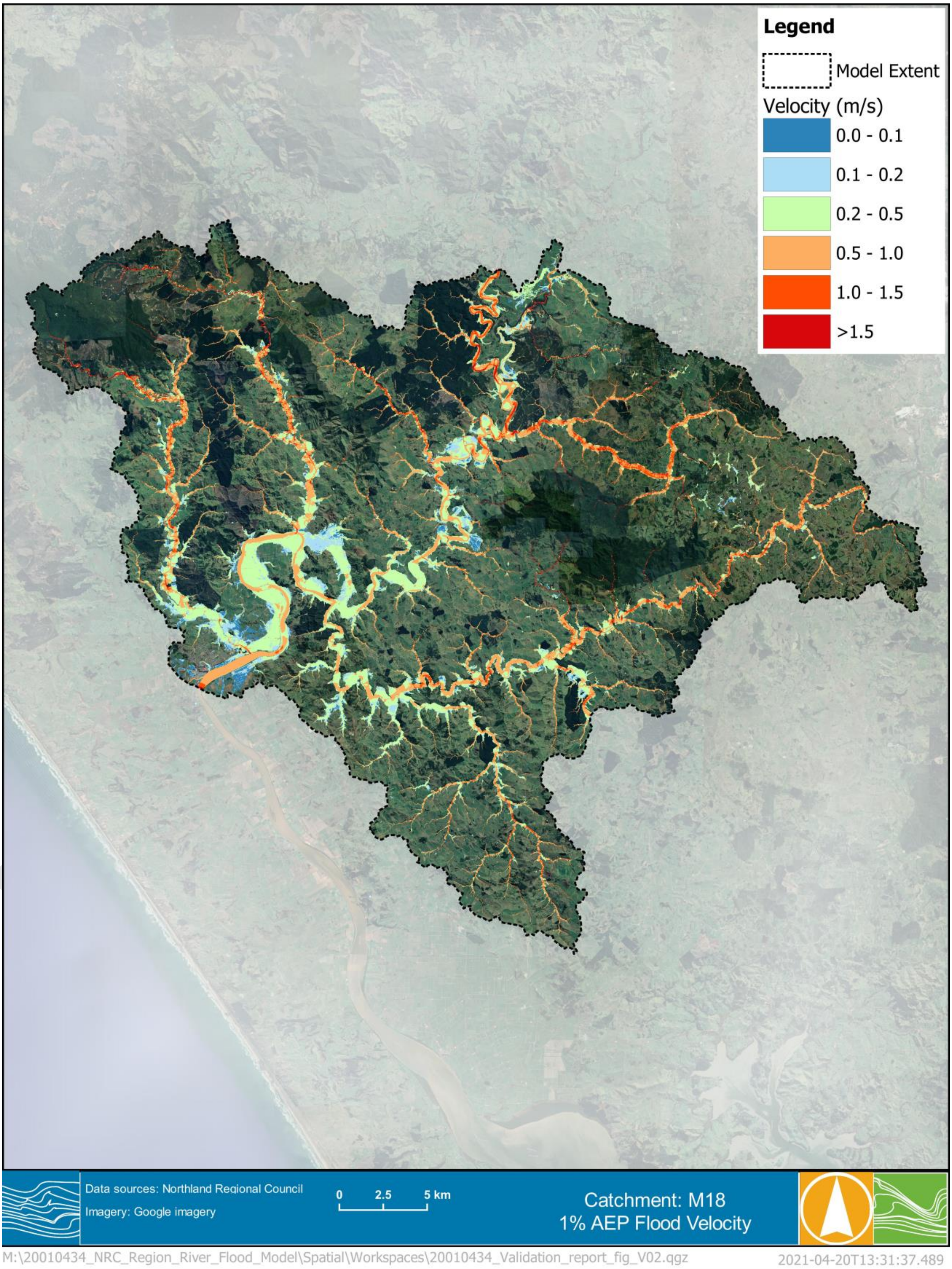

FIGURE 4-2 DESIGN MODELLING OF 1% AEP FLOOD VELOCITY

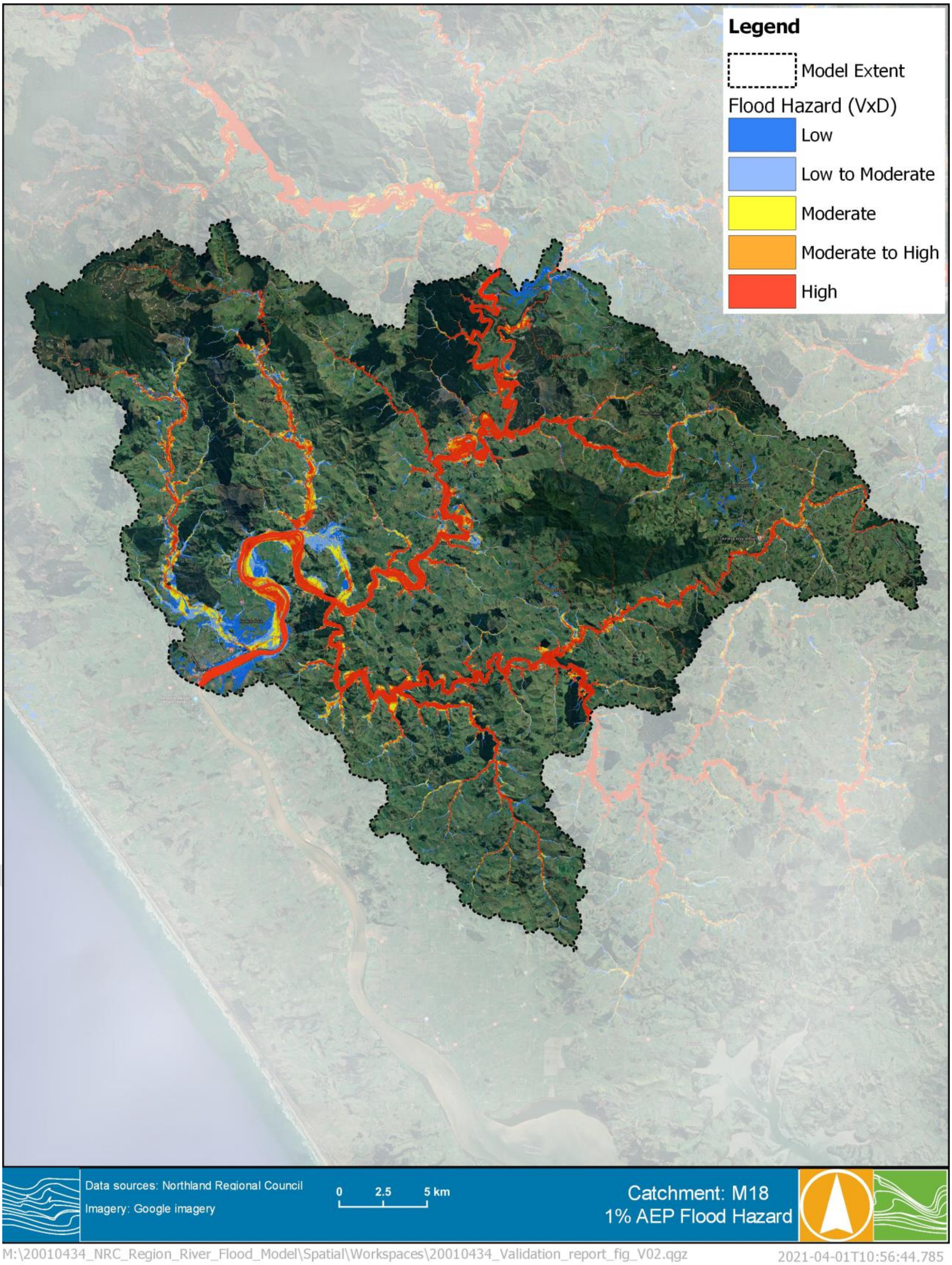

FIGURE 4-3 DESIGN MODELLING OF 1% AEP FLOOD HAZARD

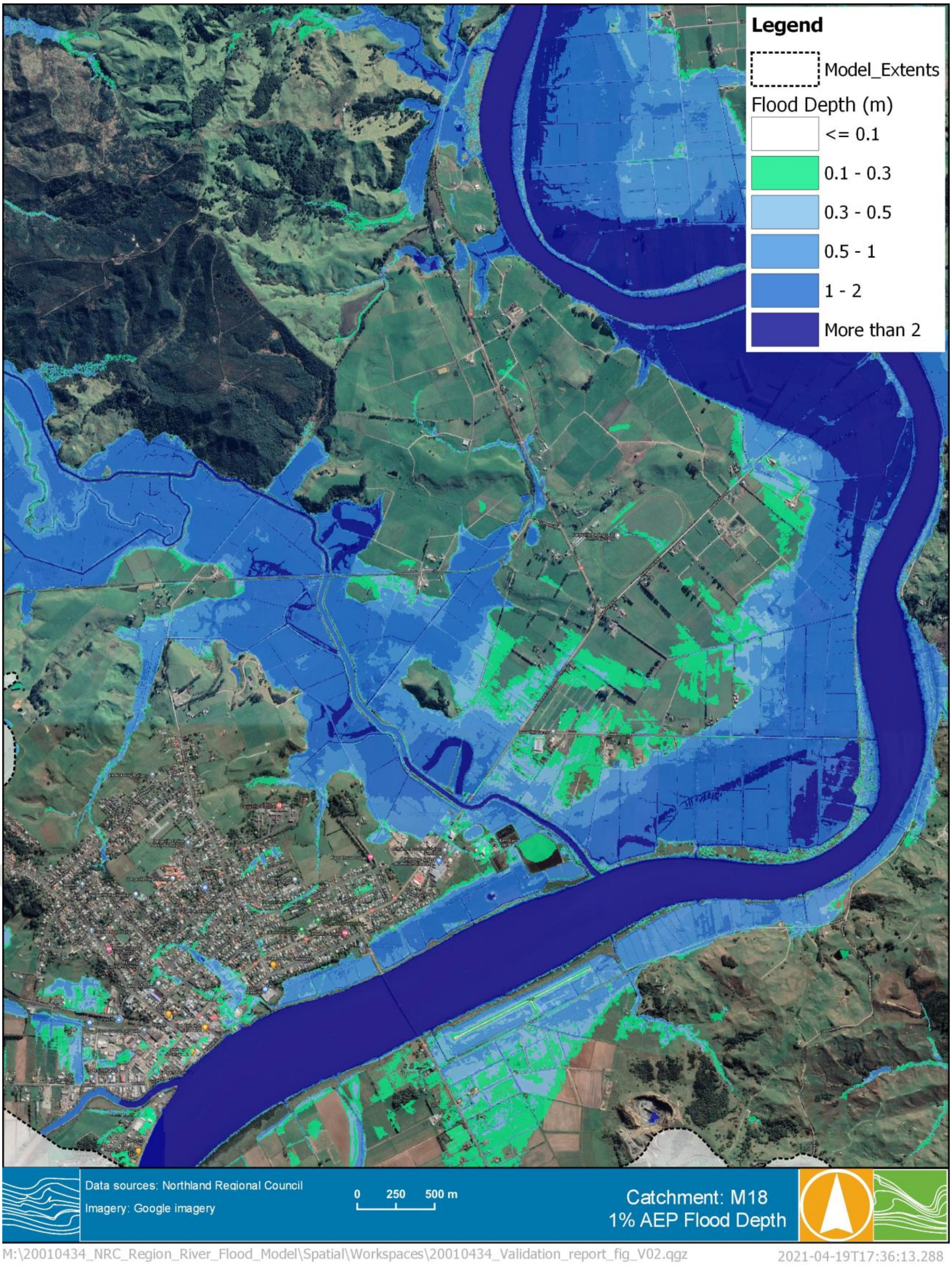

FIGURE 4-4 DESIGN MODELLING OF 1% AEP FLOOD DEPTH ZOOMED AT A TOWNSHIP

5 VERIFICATION OF DESIGN FLOWS

Flow lines were included at several waterways in the hydraulic model as 2D Plot Output (2D PO) for design events. This allows flow hydrographs and peak flows to be extracted at these locations. Figure 5-1 displays the Northern Wairoa at Dargaville Wharf gauge found within the Northern Wairoa catchment. It is noted that this gauge has water level record available only.

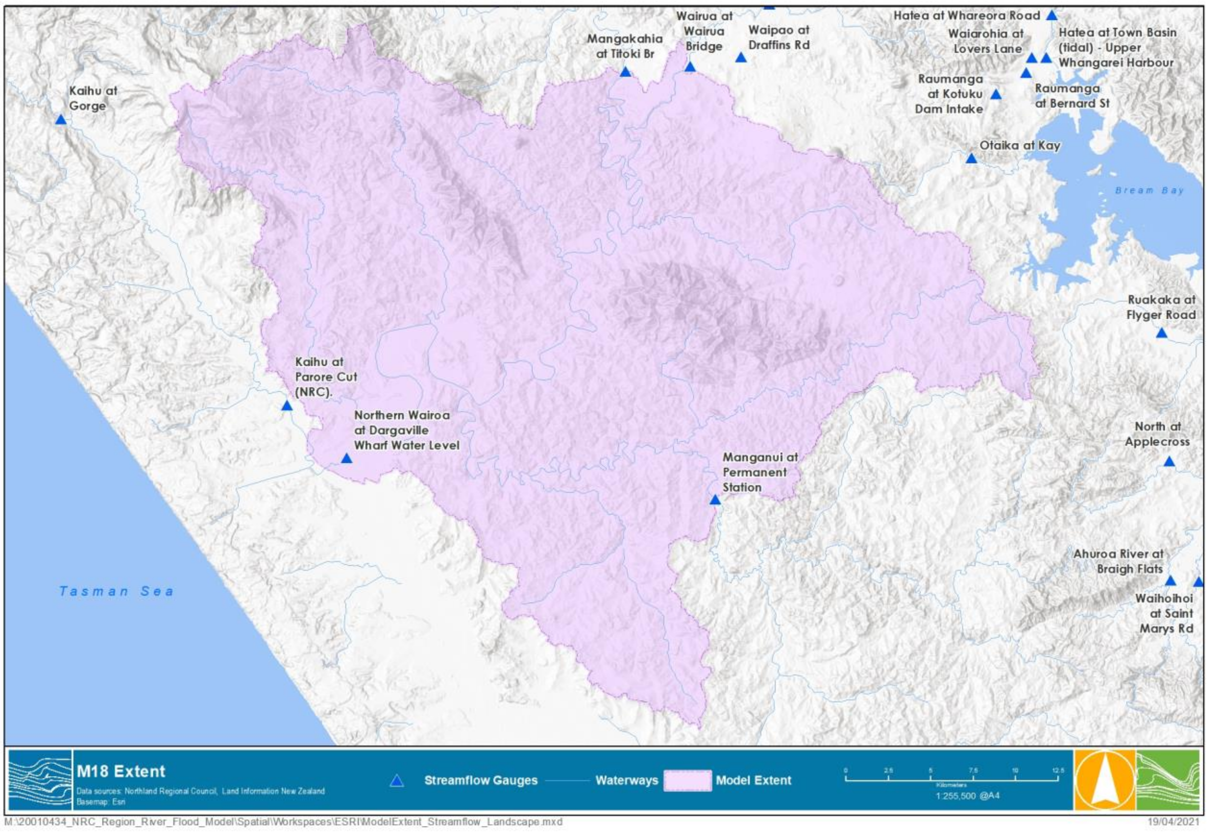

FIGURE 5-1 AVAILABLE STREAMFLOW GAUGES WITHIN NORTHERN WAIROA CATCHMENT

The modelled peak flow for the 1% AEP design flood was compared with hydrological estimates, including rational method and SCS method.

5.1 Regional Estimation Methods

For catchments where a suitable streamflow gauge record was not available, additional estimation methods were used to provide design flow verification. These methods are based on empirical estimations using catchment area and design rainfall totals to verify design flows. These methods were checked for each streamflow gauge location within the study area and are described below.

5.1.1 NIWA New Zealand River Flood Statistics Portal

The New Zealand River Flood Statistics portal[3] provides peak flood estimation at streamflow gauging stations and the entire river system in New Zealand completed in 2018. The design estimates can be extracted from the portal are:

- Flood Frequency estimates (at flow gauge).
- Flood Frequency estimates, noted as Henderson & Collins 2018 (at river reach).
- Rational Method HIRDS V3 (at river reach).

The flood frequency estimates given by the portal are determined using the Mean Annual Flow method developed by Henderson & Collins (2018)[4].

SCS method

The Soil Conservation Service (SCS) method, first developed by the U.S. Department of Agriculture's Soil Conservation Service, calculates peak flood flow based on rainfall and land-cover-related parameters. It is the recommended method for stormwater design in the Auckland region, providing a useful comparison. The peak flow equation is:

$$Q = (P - Ia)^2 / (P - Ia + S)$$

where:

- Q is run-off depth (millimetres)..
- P is rainfall depth (millimetres)
- S is the potential maximum retention after run-off begins (millimetres).
- Ia is initial abstraction (millimetres), which is 5 millimetres for permeable areas and zero otherwise.

The retention parameter S (measured in millimetres) is related to catchment characteristics through:

$$S = (1000/CN - 10)\ 25.4.$$

The value of the curve number (CN) represents the run-off from 0 (no run-off) to 100 (full run-off) and it is influenced by soil group and land use. A CN value of 50 was used for the SCS estimation of this catchment.

The run-off depth (Q) is then converted to a peak flow rate using the SCS unit hydrograph.

Rational Method

The Rational Method is widely used across both New Zealand and Australia. The equation is based on catchment area and design rainfall. The equation is:

$$Q = C\ i\ A\ /3.6$$

where:

- Q is the estimate of the peak design discharge in cubic meters per second
- C is the run-off coefficient

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[3] NIWA Flood Frequency tool, accessed via: https://niwa.co.nz/natural-hazards/hazards/floods
[4]Henderson, R.D., Collins, D.B.G., Doyle, M., Watson, J. (2018) *Regional Flood Estimation Tool for New Zealand Final Report Part 2*. NIWA Client Report

- i is rainfall intensity in mm/hr hour, for the time of concentration
- A is the catchment area in km^2.

5.2 Verification Results

Table 5-1 summarises the comparison of 1% AEP peak flow estimates with the modelled value at Northern Wairoa at Dargaville Wharf gauge in the Northern Wairoa catchment and the differences between the estimation methods and modelled results can be visualised in Figure 5-2.

The Rational Method and the SCS are only applicable for relatively small catchment with SGS method limited to 12km^2. The catchment size of the streamflow gauge is 866 km^2 so these two methods are subject to great uncertainty in summarising catchment characteristics.

It is noted that the Dargaville Wharf gauge has no flow record available for empirical estimates such as FFA to verify the modelled design flow. Without any other design flow estimates applicable, the modelled design flow at the streamflow gauge has a reasonably good match to the SCS and Rational methods

The use of empirical method estimations provides an additional degree of verification for streamflow gauges with no flow record. Limited design flow estimates constrain the reliability of this modelled design flow verification.

TABLE 5-1 SUMMARY OF 1% AEP PEAK FLOW COMPARISON

PO line location	Hydraulic model (m^3/s)				Empirical estimates (m^3/s)					
	Critical duration	Modelled peak				SCS	Rational method			
Northern Wairoa at Dargaville Wharf	24 hr	1113.1				1004.8	713.01			

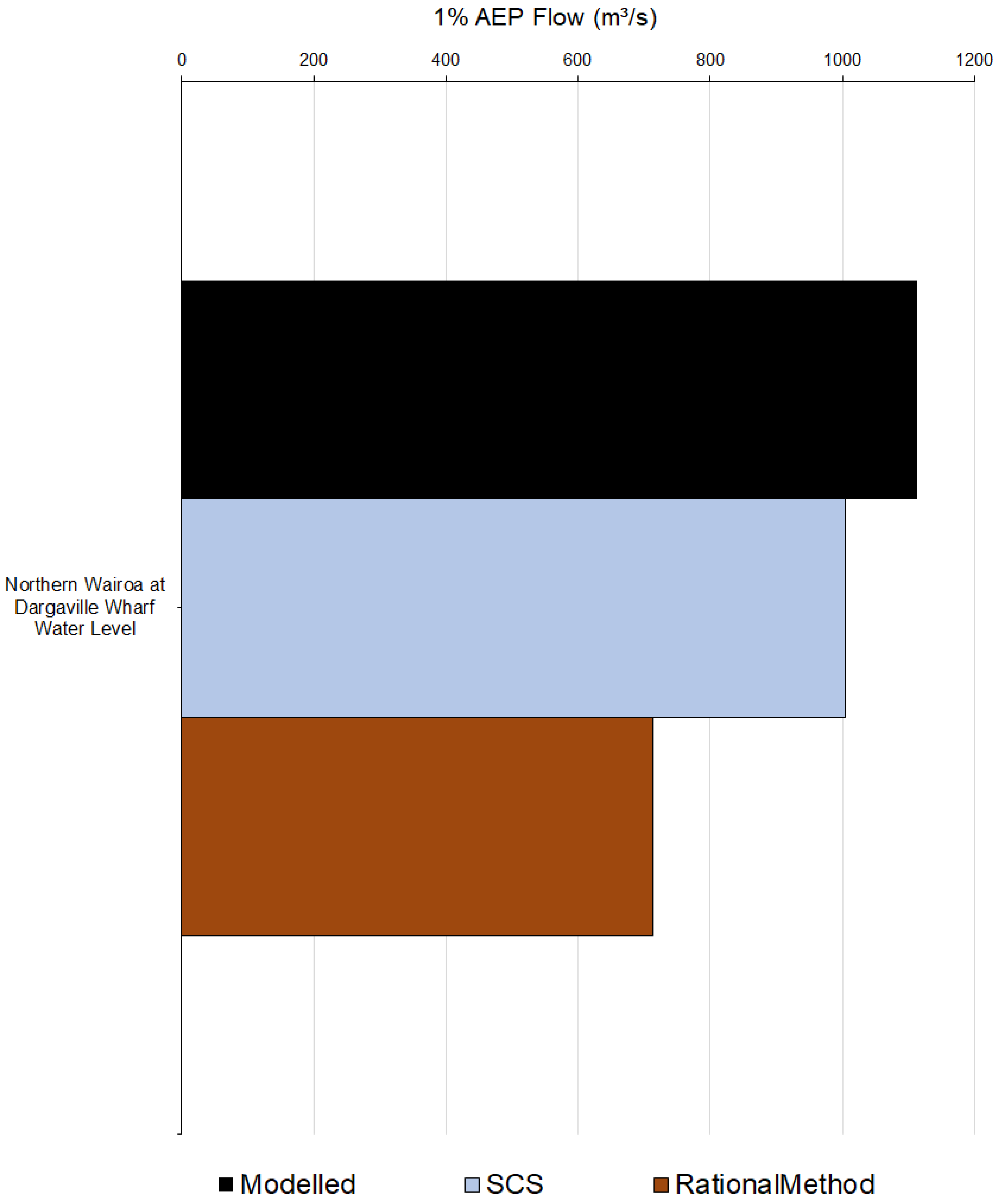

FIGURE 5-2 VERIFICATION OF DESIGN MODELLING RESULTS AGAINST HYDROLOGICAL ESTIMATES

6 SUMMARY

The Northern Wairoa catchment model (M18) was not calibrated and its model parameters were adopted based on calibrated catchments (i.e. M01, M13, M14 and M15) in the Whangarei District. The design modelling of this catchment consisted of four storm durations (1-hour, 6-hour, 12-hour and 24-hour) for each design AEP (i.e. 1%, 2% and 10% AEP). Design flood extents and gridded results, including depth, water surface elevation, velocity and hazard were produced and delivered to NRC.

The modelled 1% AEP design flow at the Dargaville Wharf gauge was verified against estimates derived by SGS and Rational methods only. But the modelled design flow sits within a reasonable range of these design flow estimates.

When considering the scope and the scale of this project, the current modelling results are considered fit for use. Modelling outputs can be used to identify flood hazard and potential flood risk. It can also inform planning decisions, infill flood mapping between detailed flood studies and provide a basis for broad emergency management exercises.