Design Modelling

Pouto Peninsula Catchment (M10)

Northland Regional Council

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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 Pouto Peninsula Catchment (M10), noting that this catchment was not calibrated however, model parameters reflected regional parameters and assumptions relied upon for Catchment M08 which was calibrated and is located within close proximity to Catchment M10.

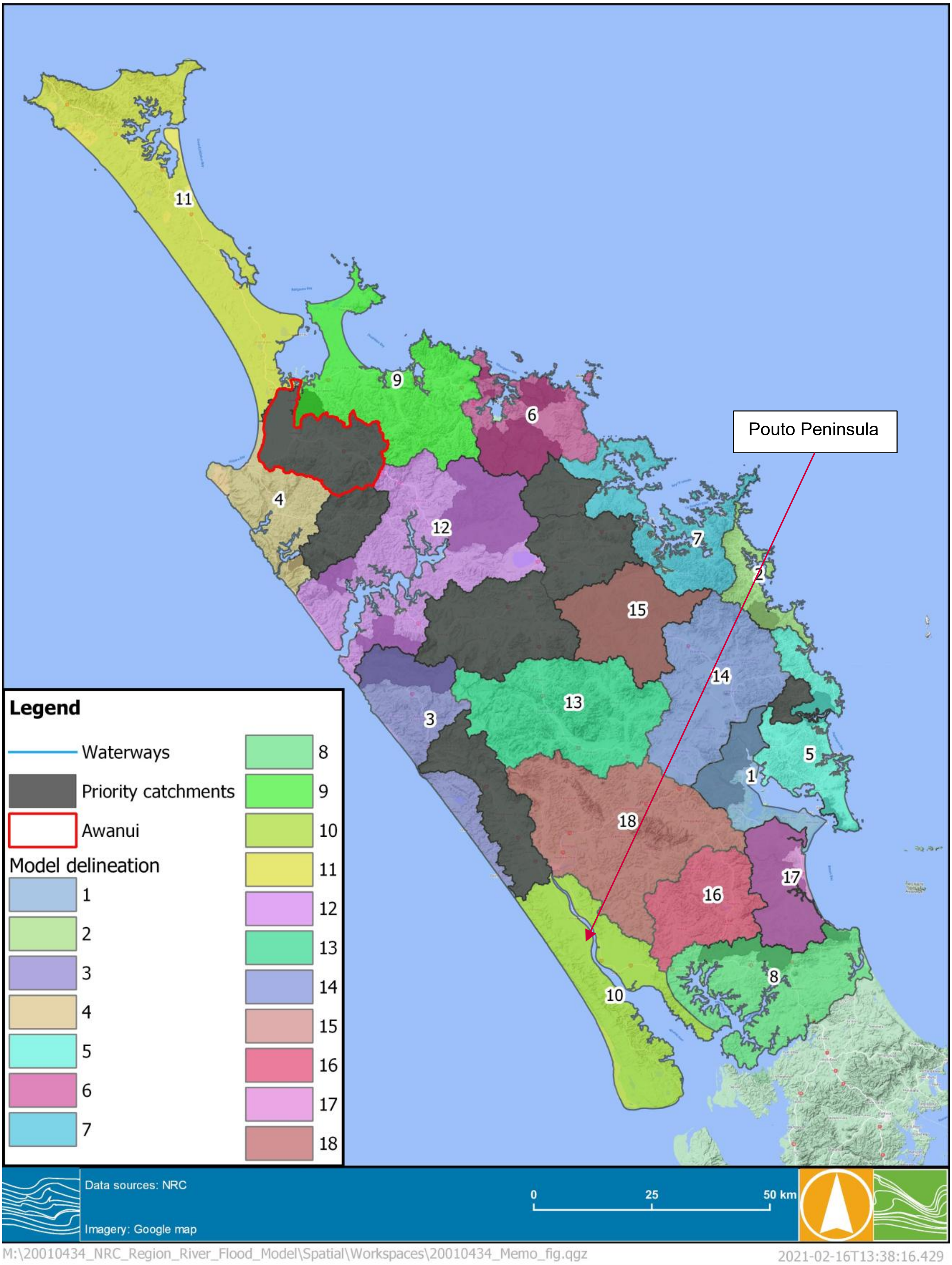

FIGURE 1-1 MODEL DELINEATION

2 STUDY AREA

The Model 10 catchment is coastal catchment, comprising the Pouto Pensinsula and covering a total area of approximately 792 km^2 with Ruawai and Te Kopuru its main townships. The Wairoa River is major waterway dividing the catchment into two parts. Numerous smaller waterways drain into the Wairoa River before discharging into the Kaipara Harbour and the sea. Figure 2-1 displays the study area of the catchment Model 10.

FIGURE 2-1 STUDY AREA

3 DESIGN MODELLING

3.1 Overview

A hydraulic model (TUFLOW) of the Pouto Peninsula catchment (M10) 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 the Hakaru Catchment (refer to Validation report M08). M08 is adjacent to M10 and is found to provide suitable regional parameters. 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, nine 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/

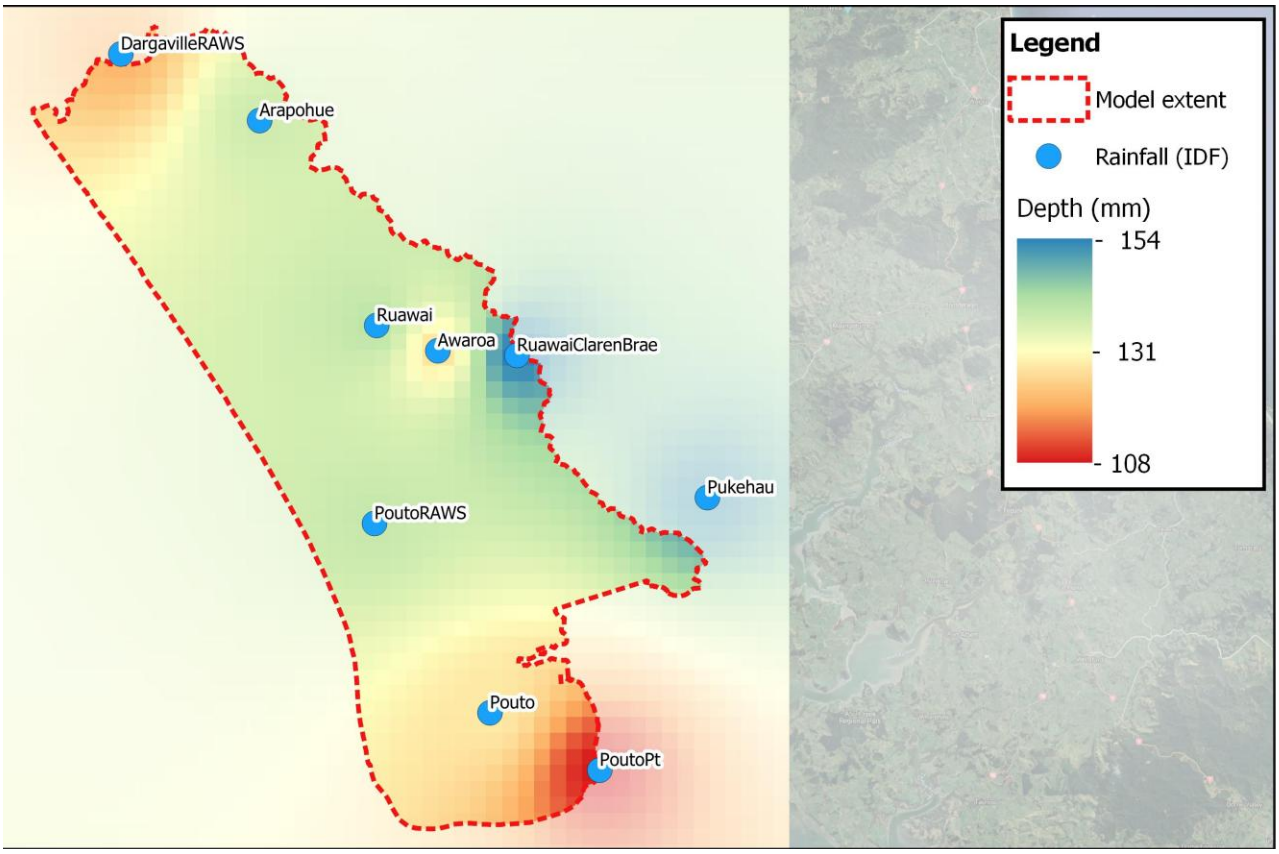

FIGURE 3-1 EXAMPLE OF DESIGN RAINFALL GRID (12-HOUR, 1% AEP RAINFALL) FOR M10

3.2.2 Design Rainfall Temporal Patterns

Design temporal patterns (rainfall hyetographs) were provided by NRC for design modelling. These were developed by HIRDS and subsequently reviewed as part of a 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 of the following AEPs: 10%, 2% and 1% AEP 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 cumulative rainfall across the 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
Awaroa at WallaceRd_641010	48	100	127	155
DargavilleRAWS_O00820	43	93	121	154
Kaipara Harbour at Pouto Pt_643118	47	88	108	129
Pouto RAWS_O00902	50	107	139	176
Pouto_A64212	48	100	128	162
Pukehau_A64221	54	118	151	189
Ruawai_A64101	48	106	140	179
Ruawai Claren brae_A64112	55	121	155	192

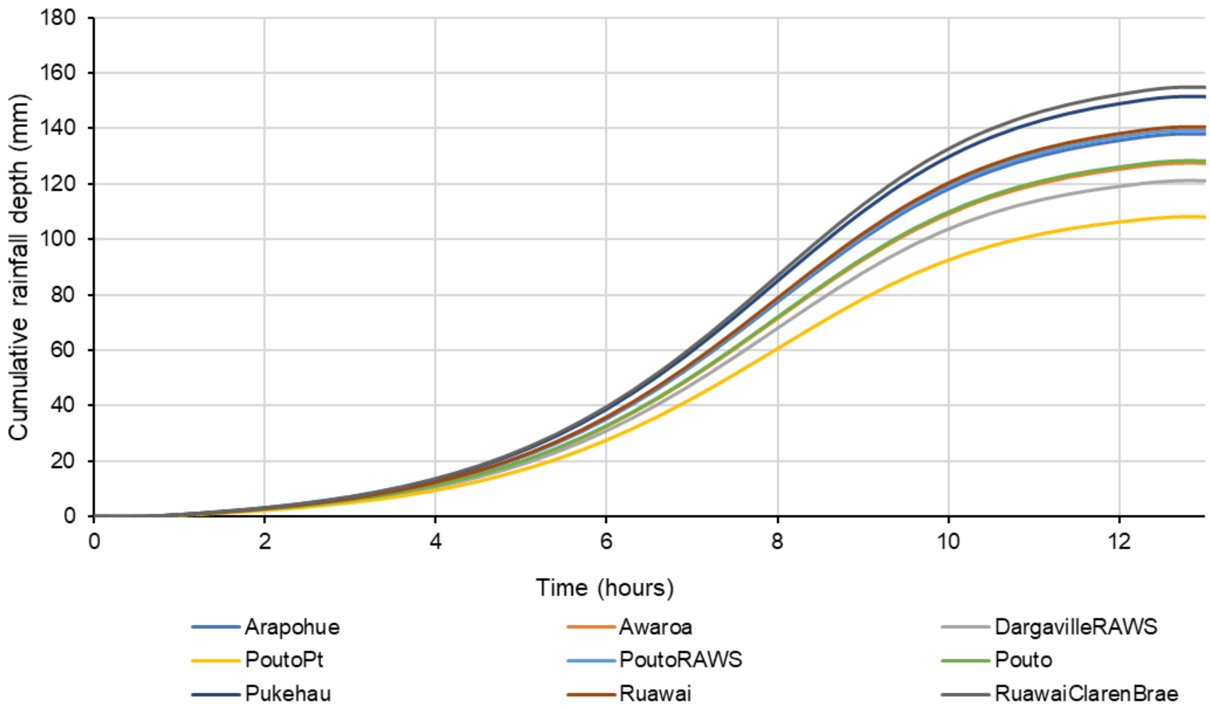

FIGURE 3-2 TEMPORAL PATTERN FOR DESIGN RAINFALL OF 12-HOUR, 1% AEP EVENT

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

Each model cell was assigned a Manning's "*n*" (surface roughness), initial loss and a continuing loss based on land use types and importantly hydrological 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 an adjacent Kaipara District catchment (i.e. M08). 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 M10 catchment	Forest	0.18	42	1.5
	Grassland	0.15	42	1.5
	Cropland – perennial	0.06	20	1
	Cropland – annual	0.06	20	1
	Wetland – open water	0.04	0	0
	Wetland – vegetated	0.05	10	1
	Urban areas	0.10	5	1.5
	Waterways	0.08	0	0
	Other	0.06	15	1.5

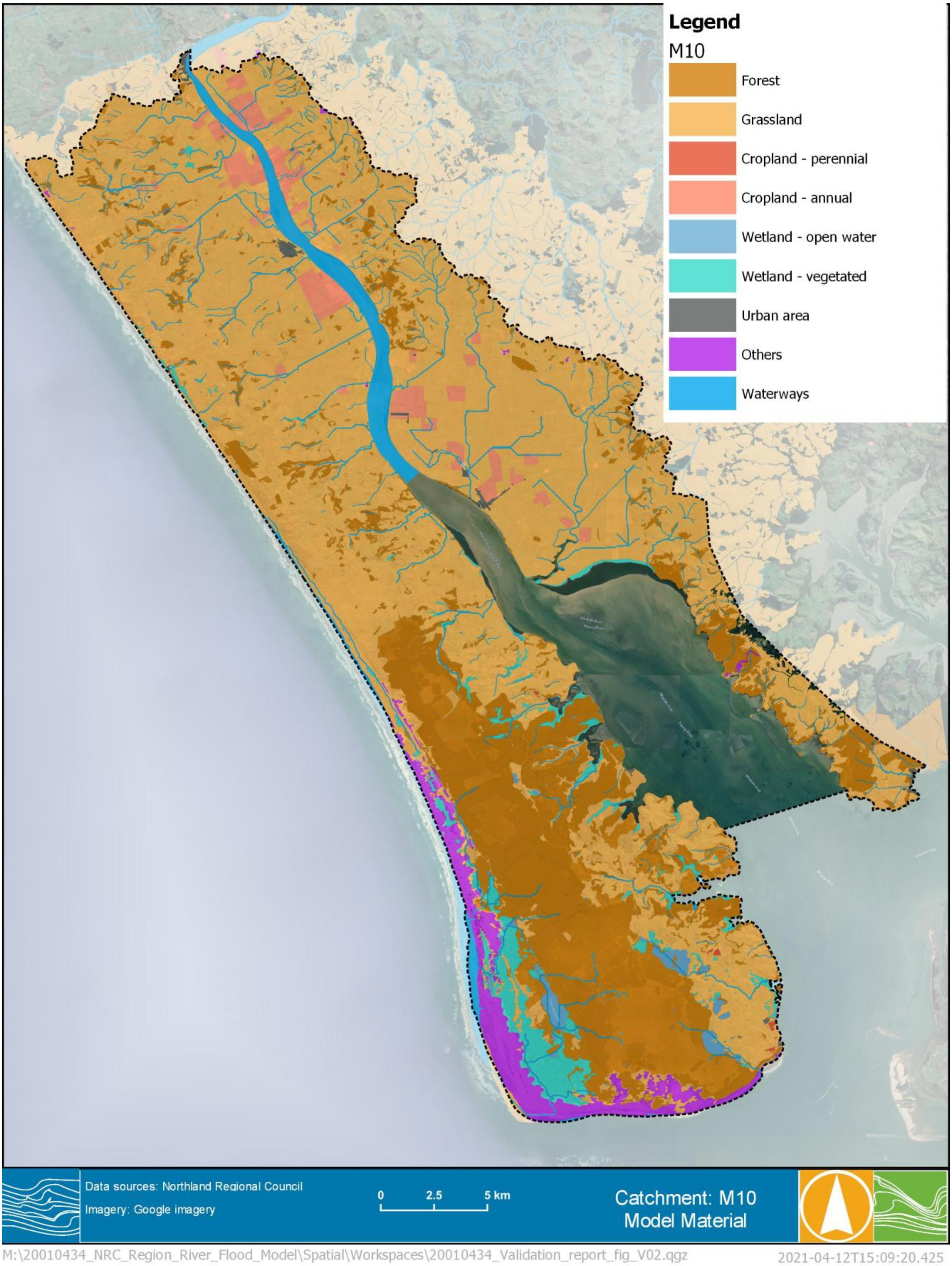

FIGURE 3-3 HYDRAULIC MODEL MATERIAL LAYER

3.2.4 Boundaries

As the Pouto Peninsula catchment is a coastal catchment, a static tail-water (i.e. 2161 mm OTP) outflow boundary based on the 2 year ARI tide level[3] at Pouto Point was applied for the design modelling. A 1.2 m sea level rise was adopted for climate change runs based on the project brief.

There is no upstream inflow coming from upstream catchments applied in this catchment model.

[3] MWH, 2010 *Priority Rivers – Flow Assessment, Sea Level Rise and Storm Surge*, prepared for Norhland Regional Council

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), flood 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 a single data set for each AEP from the 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).

Step 2:

- The maximum gridded results are then remapped to a finer DEM grid using LiDAR data resampled to a 5-m grid resolution. 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 M10. Figure 4-4 shows the flood depth map zoomed in at Ruawai 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

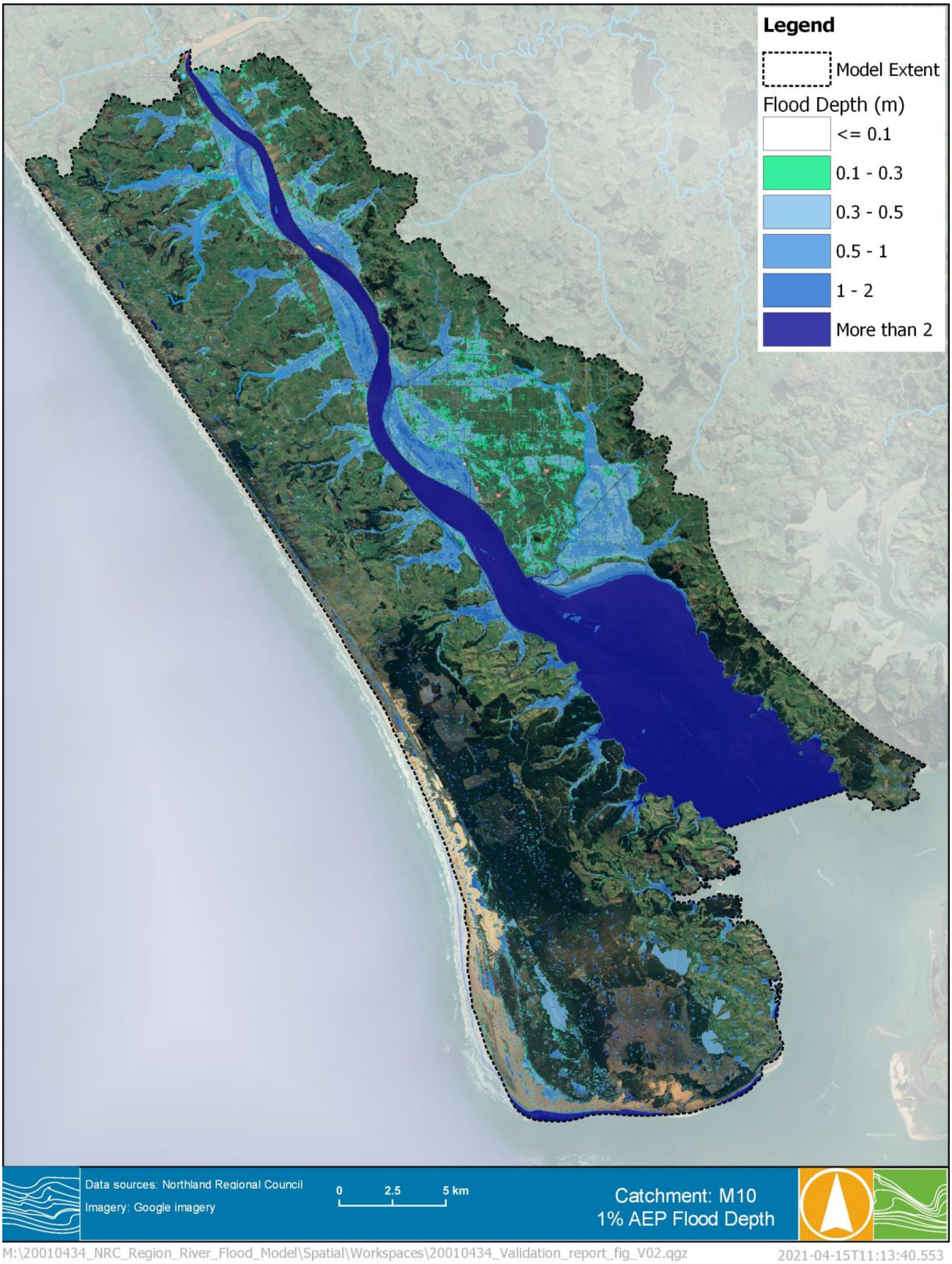

FIGURE 4-1 DESIGN MODELLING OF 1% FLOOD DEPTH

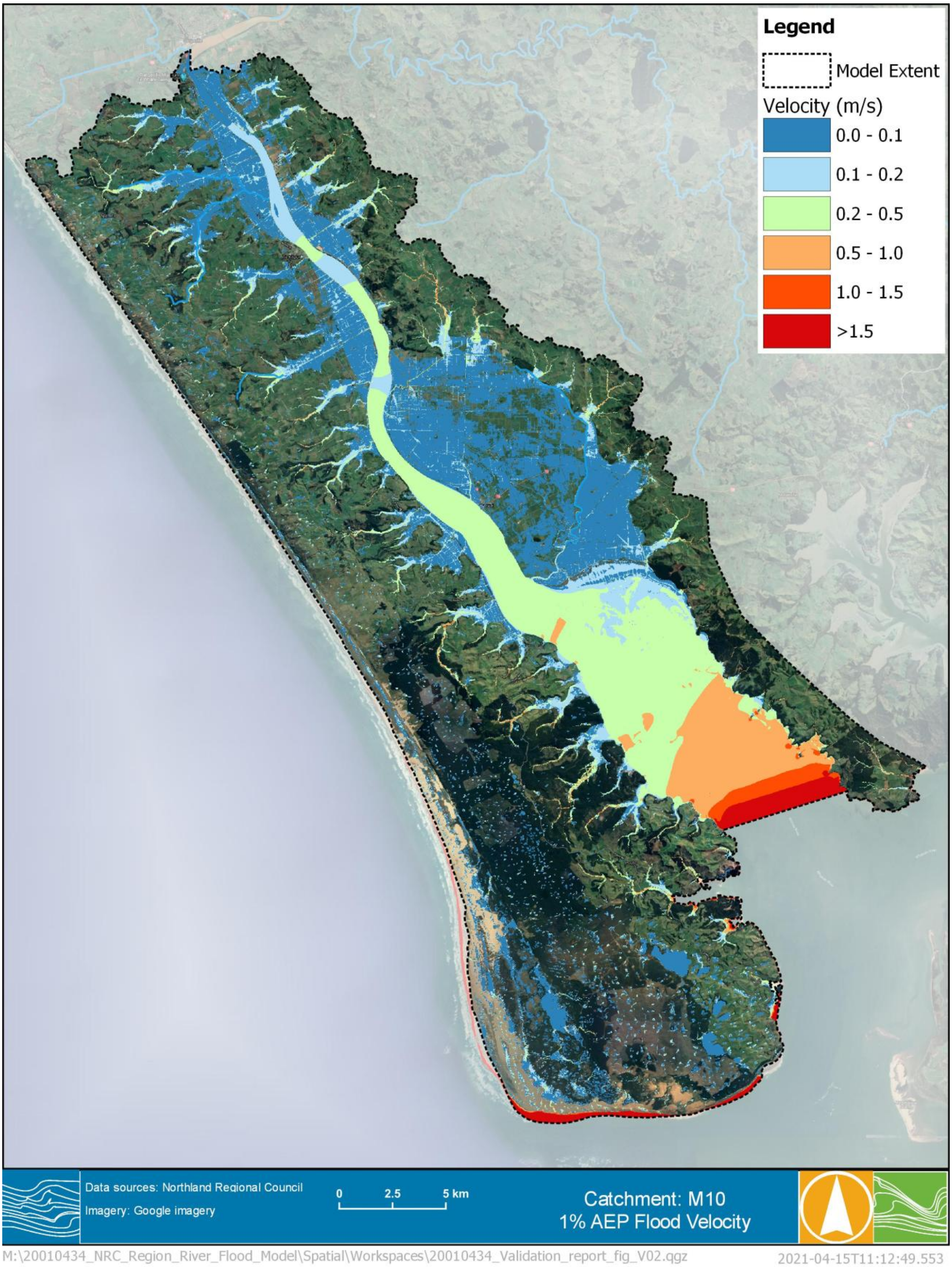

FIGURE 4-2 DESIGN MODELLING OF 1% AEP FLOOD VELOCITY

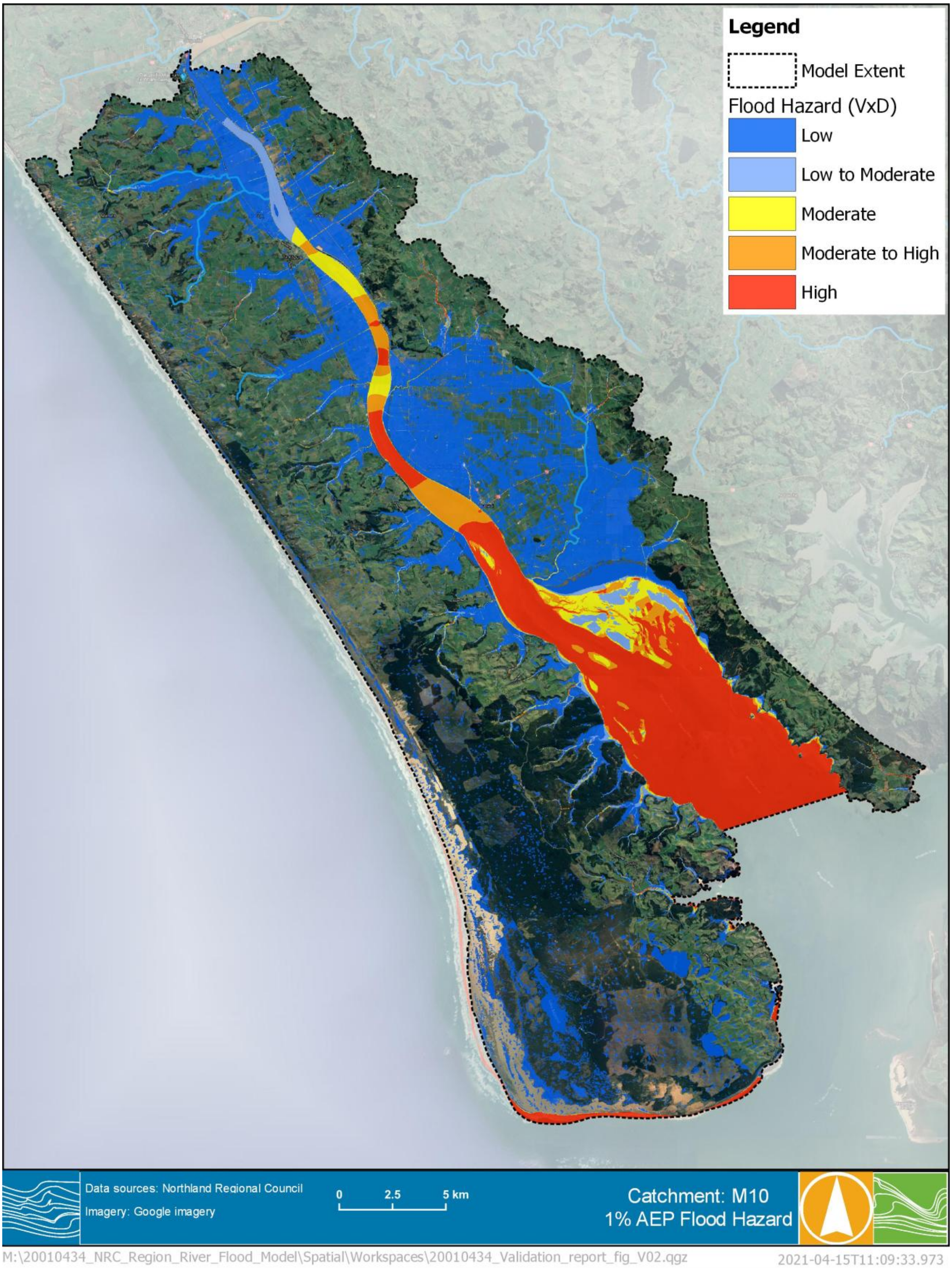

FIGURE 4-3 DESIGN MODELLING OF 1% AEP FLOOD HAZARD

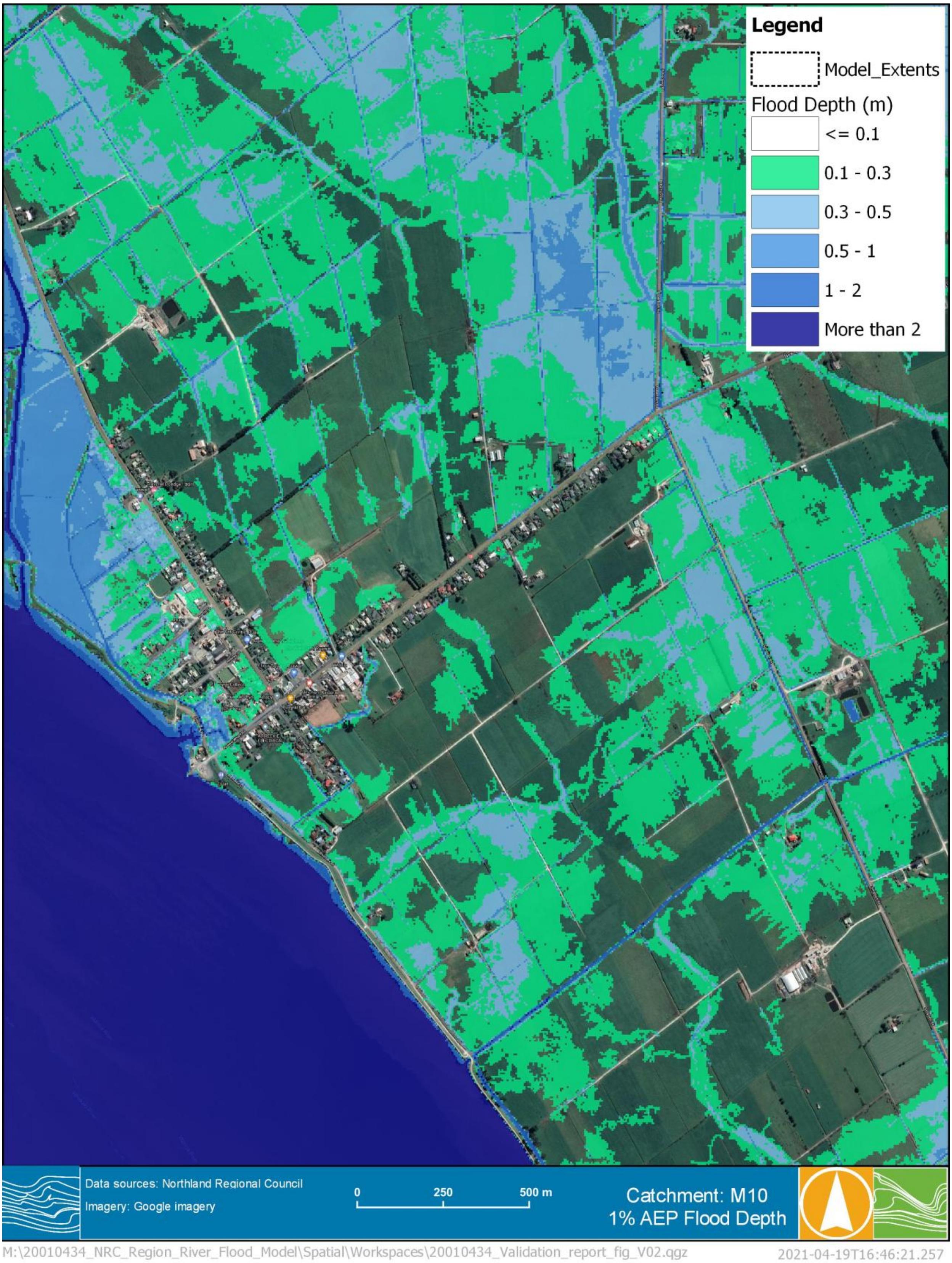

FIGURE 4-4 DESIGN MODELLING OF 1% AEP FLOOD DEPTH ZOOMED AT RUAWAI

5 VERIFICATION OF DESIGN FLOWS

Flow lines were included at several waterways in the hydraulic model as 2D Plot Outputs (2D PO) for design events. This allows flow hydrographs and peak flows to be extracted at these locations. Figure 5-1 displays these PO line locations. It is noted that there is no streamflow gauge found within this catchment.

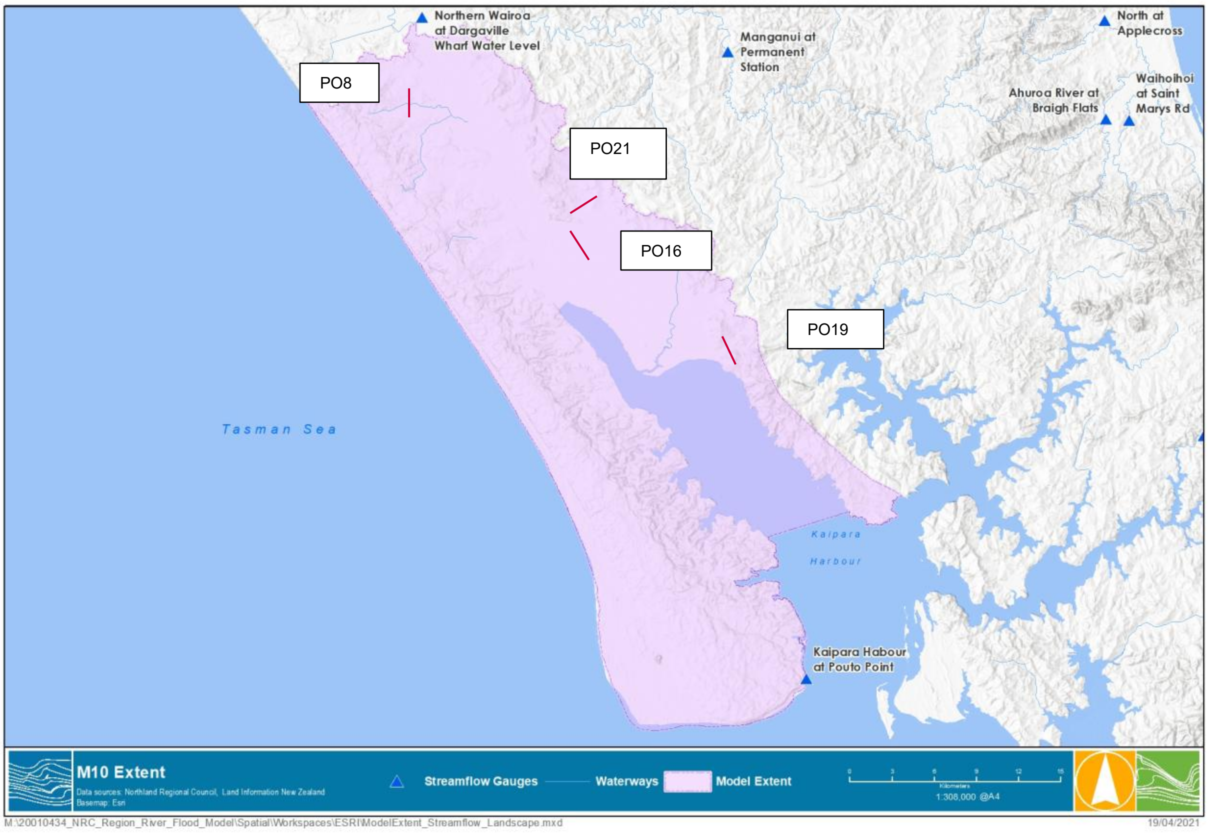

FIGURE 5-1 AVAILABLE STREAMFLOW GAUGES WITHIN POUTO PENINSULA CATCHMENT

The modelled peak flow for the 1% AEP design flood was compared with hydrological estimates, including the 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 estimate peak design flows. These methods were checked for each Flow Line 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[4] 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, 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)[5].

5.1.2 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.

[4] NIWA Flood Frequency tool, accessed via: https://niwa.co.nz/natural-hazards/hazards/floods
[5] 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

5.1.3 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 metres per second
- C is the run-off coefficient
- 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 values at several PO line locations in the Pouto Peninsula catchment and the differences between the estimation methods and modelled results can be visualised in Figure 5-2.

The rational method and the SCS method are only applicable for relatively small catchments, with the SCS method limited to 12 km^2.The sizes of the upstream catchments upstream of these PO lines are small with most of them are less than 10 km^2.

The modelled design flows at PO8 and PO16 have a good match to the empirical estimates and only Henderson & Collins 2018 estimates from NIWA tend to overestimate the peak flows. In contrast, the modelled flows at PO21 and PO19 have a good match to the H&C18 estimates but other empirical estimates tend to underestimate the flows. Overall, the modelled design flows at these PO line locations sit within a reasonable range of these design flow estimates.

The verification of the modelled design flows heavily relied on the use of empirical method estimations given estimates based on historic data such as FFA is not applicable for comparison. With the absence of streamflow gauges, this catchment model was not able to be calibrated and its results were not verified against any historic record, however the results are fit for purpose including the of mapping riverine flood hazard zones across the entire Northland region and update existing flood intelligence.

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

PO line location	Hydraulic model (m^3/s)		Empirical estimates (m^3/s)		NIWA Flood Frequency Tool 2018 (m^3/s)	
	Critical duration	Modelled peak	SCS	Rational method	NIWA – Rational method	NIWA – H&C 2018
PO8	12 hr	16.5	6.1	7.2	55.8	6
PO21	6 hr	69.7	13.5	17.7	78.2	18
PO16	12 hr	31.5	26.7	28.7	155.1	26
PO19	6 hr	44.4	14.2	17.4	49.7	7

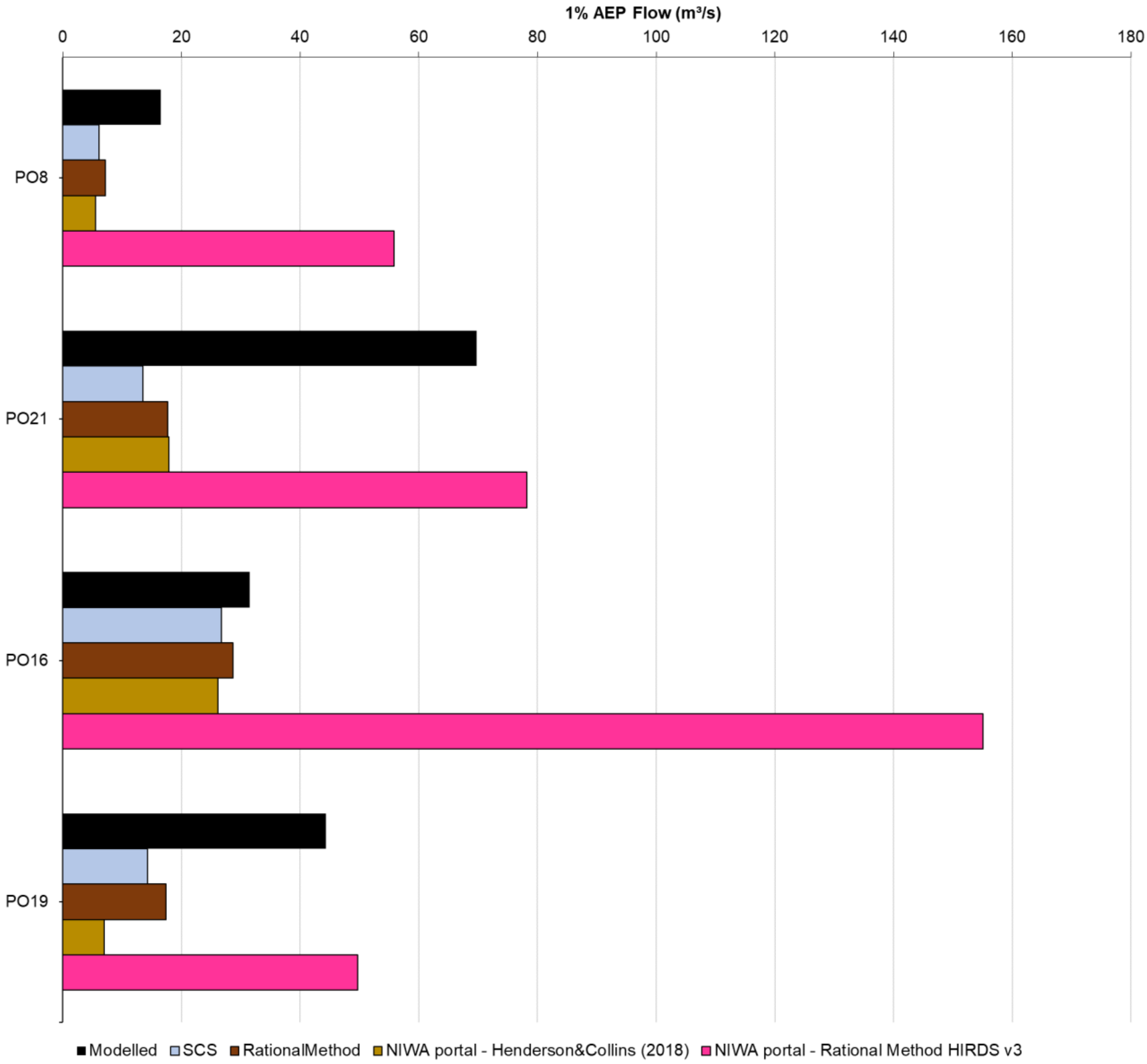

FIGURE 5-2 VERIFICATION OF DESIGN MODELLING RESULTS AGAINST HYDROLOGICAL ESTIMATES

6 SUMMARY

The Pouto Peninsula catchment model (M10) was not calibrated and its model parameters were adopted based on calibrated catchments nearby (i.e. M08) in the Kaipara 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 flows at six PO line locations were verified against several design flood estimation methods. The comparison of design flow provides a general validation check of the modelled results given the accuracy of these estimation methods can be constrained by the general limitations with empirical design estimates. Overall, the modelled design flows at these locations assessed within the study area provided a reasonable fit to 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.