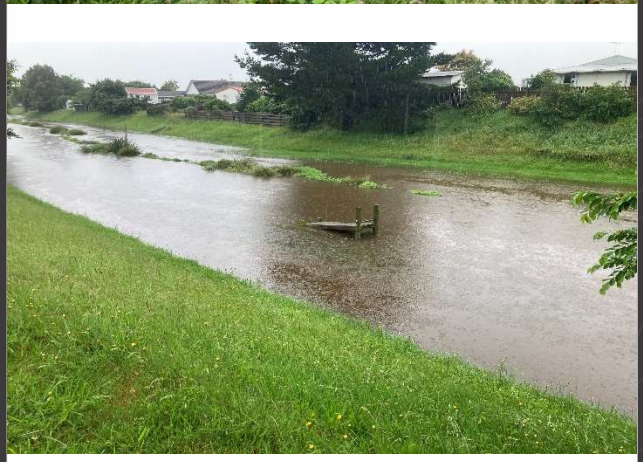






Kāpiti Flood Hazard Management

Mazengarb Model Build Report

24/03/2025



Kāpiti Flood Hazard Management

Mazengarb Model Build Report

Project number	J000294 - CD-589 - KCDC Flood Hazard Study and Model Re-Build
Version number	Flood Hazard Management, Mazengarb Model Build Report 0.6
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Additional technical contributors	Carl Johnson, Craig Martell

VERSION	DATE	DESCRIPTION	AUTHOR	REVIEWED
0.1	15/11/2023	Draft	Tony Trueman	CMM
0.2	20/12/2023	Final Draft	Tony Trueman	CMM
0.3	21/12/2023	Peer Review (BMT)	Tony Trueman	TT
0.4	15/01/2024	Updates	Tony Trueman	CMM
0.5	2/09/2024	Final Draft for Review	Tony Trueman	RO
0.6	24/03/2025	Final Draft	Tony Trueman	SS

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Executive Summary

Awa Environmental (AWA) were engaged by Kāpiti Coast District Council (KCDC) to build a hydrological and hydraulic model of the Mazengarb catchment.

The model build has been undertaken utilising TUFLOW modelling software (Release 2023-03-AB) and includes all Council-owned manholes, pump-stations, sumps, and pipes identified from KCDC's asset database; privately-owned pipes are excluded along with publicly owned pipes that discharge to the kerb and channel.

The model is a substantial update on the historic models developed over 20 years in the DHI MIKE software suite. Key changes from the historic model include:

1. The new TUFLOW models include the modelling of static groundwater layers from Greater Wellingtons' Regional Groundwater Model. This limits the available storage in the soil over the course of modelled storms and highlights areas that are impacted by groundwater flooding. This is currently an issue of concern in the district and is expected to change with climate change, especially in coastal areas affected by Seal Level Rise (SLR).
2. The Mazengarb model uses a hybrid hydrological modelling approach:
    - the rain-on-grid hydrological approach is applied to low-lying, flat land, particularly where there is the potential for ponding and where interaction with groundwater is likely; and
    - the sub-catchment-based hydrological approach is applied to steeper catchments where flow is channelised.
3. Open channels throughout the district have been modelled using sub-grid sampled 2D grids rather than traditional 1D cross sections. This generally provides more stable models and faster runtimes.
4. The models include a great deal of additional data including updated ground surface levels, additional stormwater network detail, and the inclusion of the new State Highway.

The model has been validated using available historic data and achieved a good validation. The model and report have also been peer reviewed by BMT and suggestions from these reviews integrated back into the model build and report.

The report is structured as follows:

Section 1 - An overview of the study location.
Section 2 - A summary of model features and approaches applied.
Section 3 - A summary of the model build process.
Section 4 - A summary of the model results.
Section 5 - Calibration and validation discussion.
Section 6 - Conclusions and recommendations.

The model has been validated to the May 2015 and December 2021 storm events. Several iterations were carried out as part of model validation, with parameters defined in the 2nd validation simulation applied to design simulations. The model has been used to simulate the existing development (2017), 20%, 10%, 2%, 1% AEP joint probability events.

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1. Introduction

1.1. Background

Awa Environmental (AWA) were engaged by Kāpiti Coast District Council (KCDC) to build a hydrological and hydraulic model of the Mazengarb catchment.

KCDC have a legacy MIKE FLOOD stormwater model of the Mazengarb Catchment which has been modified over time in response to evolving modelling requirements.

- (SKM, 2012) model utilised for generating results to define the latest current District Plan flood hazard layer.
- (SKM, 2013) model updated to a three-way coupled model utilised for undertaking effects assessment analysis.
- (Jacobs, 2014) model updated to include the Mackays to Peka Peka (M2PP) Expressway and hydrology for the 2115-climate-horizon, 100 year-ARI storm events.

The legacy model is currently configured to simulate the 2115-climate-horizon 100 year-ARI storm event and no provision has been made to easily simulate other events. The hydrologic model is complex and difficult to easily update cost effectively. In addition, the model does not incorporate asset data, land use, or network changes since 2014.

Use of the legacy model in current assessments of effects analysis has highlighted the difficulty of using the legacy model and the narrowing of its usefulness as modelling standards have evolved over time.

The details of the standards used and the methodology for the model build are covered in the Kāpiti Flood Hazard Management Methodology Report.

1.2. Objectives

The Overarching objectives of the Mazengarb model build are covered in the initial contract terms.

> *To provide KCDC with a TUFLOW stormwater model of the Mazengarb catchment that allows the model to be more agile and transparent within the wider statutory framework for managing hazards, particularly for the assessment [and communication] of risk implications for a range of future sea-level rise and climate change scenarios and that the models need to be a sufficient quality and detail to ensure outputs are robust, transparent, and defendable.*

The objectives were further developed in a client workshop covered in the Kāpiti Flood Hazard Management Methodology Report.

Specific objectives of the Mazengarb model build were to develop a TUFLOW stormwater model of the Mazengarb catchment which can simulate a range of rainfall and tidal scenarios.

The model will support scenario and mapping capability and assist KCDC with the management of stormwater and flood risk within the catchment. The model must be suitable for:

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- Determining flood levels - depths, extents, and hazard information for a range of design flood events to inform flood information products including flood mapping, property search for flood levels and overlays in the District Plan.
- Support council planning policy and flood risk management.
- Inform strategic network planning - establishing performance of existing public stormwater network and identify deficiencies in the level of service to support network renewals and upgrades.

1.3. Previous Modelling

KCDC have a legacy MIKE FLOOD stormwater model of the Mazengarb Catchment updated by Jacobs in 2014.

Key features of the 2014 legacy model include:

PIPE NETWORK

- Simplified pipe network representation in MIKE URBAN.
  - Pipes > 300mm modelled,
- Sumps not modelled,
  - Sump types not considered,
  - Sump inlet capacity not considered,
- Manholes coupled to surface,
  - Hydrographs loaded into manholes.

OPEN CHANNEL NETWORK

- Open channel representation in MIKE11.
  - Cross-sections from survey data,
  - Channel roughness from imagery,
  - Connection to Waikanae River.

2D DOMAIN

- Domain grid resolution of 4 m.

HYDROLOGY

- Sub-catchment-based hydrology.
  - 2115-climate-horizon 100 year-ARI storm event,
    - No consideration of more frequent events,
  - SCS Curve Number,
    - Curve numbers used to approximate losses,
    - HEC-HMS used to calculate input hydrographs,
  - Groundwater not considered.

MODEL COUPLING

- 3-way coupled M21, M11, MU model.

1.4. Modelling Approach

This report describes the process of building, calibrating, and validating the Mazengarb catchment model. The process follows the steps outlined in Figure 1.

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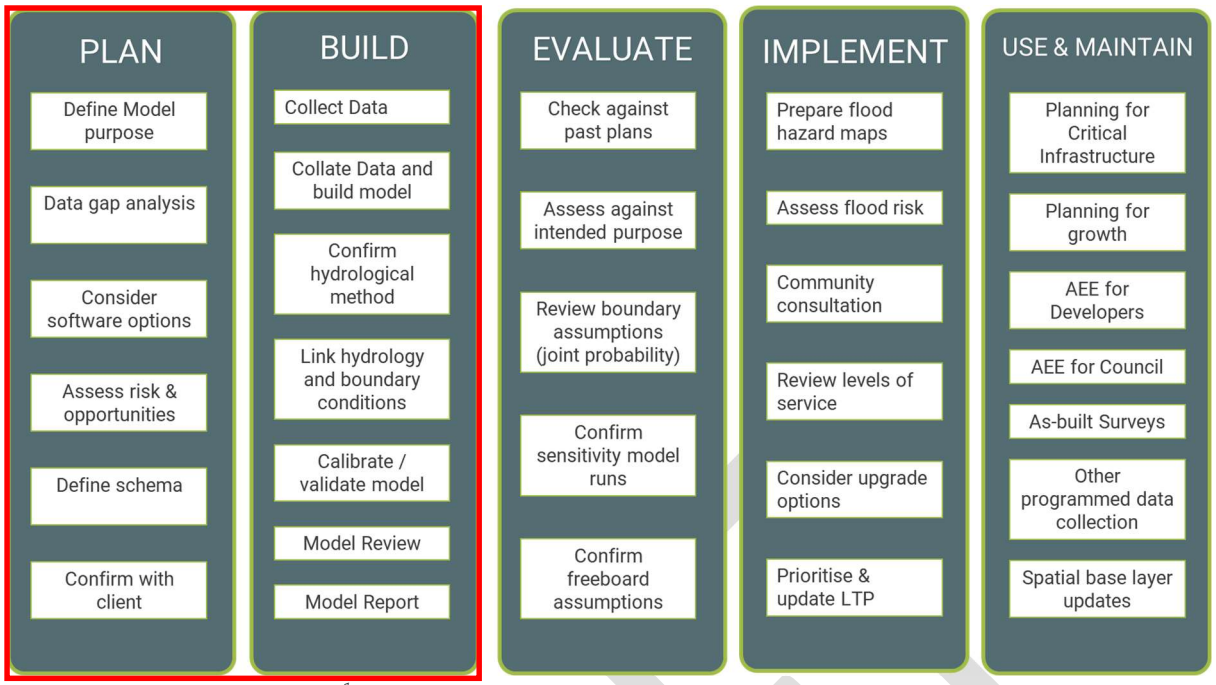


Figure 1. Modelling approach.[1]

1.5. Peer Review

To ensure the model build process is robust and fit for purpose the Mazengarb model has been peer reviewed by BMT Global and they have concluded the model is suitable to meet the modelling objectives.

The peer review comments are included in Appendix A. The issues raised in the review are addressed to the peer reviewer's satisfaction.

1.6. Report Structure

The report is structured as follows:

Section 1 - An overview of the study location.
Section 2 - A summary of model features and approaches applied.
Section 3 - A summary of the model build process.
Section 4 - summary of the model results
Section 5 - Calibration and validation discussion
Section 6 - Conclusions and recommendations

1.7. Important model updates

The model is a substantial update on the historic models developed over 20 years in the DHI MIKE software suite. Key changes from the historic model include:

[1] Adapted from the National Modelling Guidelines

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1. The new TUFLOW models include the modelling of static groundwater layers from Greater Wellingtons' Regional Groundwater Model. This limits the available storage in the soil over the course of modelled storms and highlights areas that are impacted by groundwater flooding. This is currently an issue of concern in the district and is expected to worsen with climate change, especially in coastal areas affected by Sea Level Rise (SLR).
2. The Mazengarb model uses a hybrid hydrological modelling approach:
    a. the rain-on-grid hydrological approach is applied to low-lying, flat land, particularly where there is the potential for ponding and where interaction with groundwater is likely; and
    b. the sub-catchment-based hydrological approach is applied to steeper catchments where flow is channelised.
3. Open channels throughout the district have been modelled using sub-grid sampled 2D grids rather than traditional 1D cross sections. This generally provides more stable models and faster runtimes.
4. The models include a great deal of additional data including updated ground surface levels, additional stormwater network detail, and the inclusion of the new State Highway.

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2. Catchment Description

2.1. Location and topography

The Mazengarb catchment covers an area of approximately 9.3 km^2 and is located within the Kāpiti District. The catchment is bounded by the steep topography of the Tararua Foothills along its south-eastern extent and the Waikanae River to the north. The catchment borders the Wharemauku catchment to the south, and the Paraparaumu Beach catchment to the west, as shown in Figure 2.

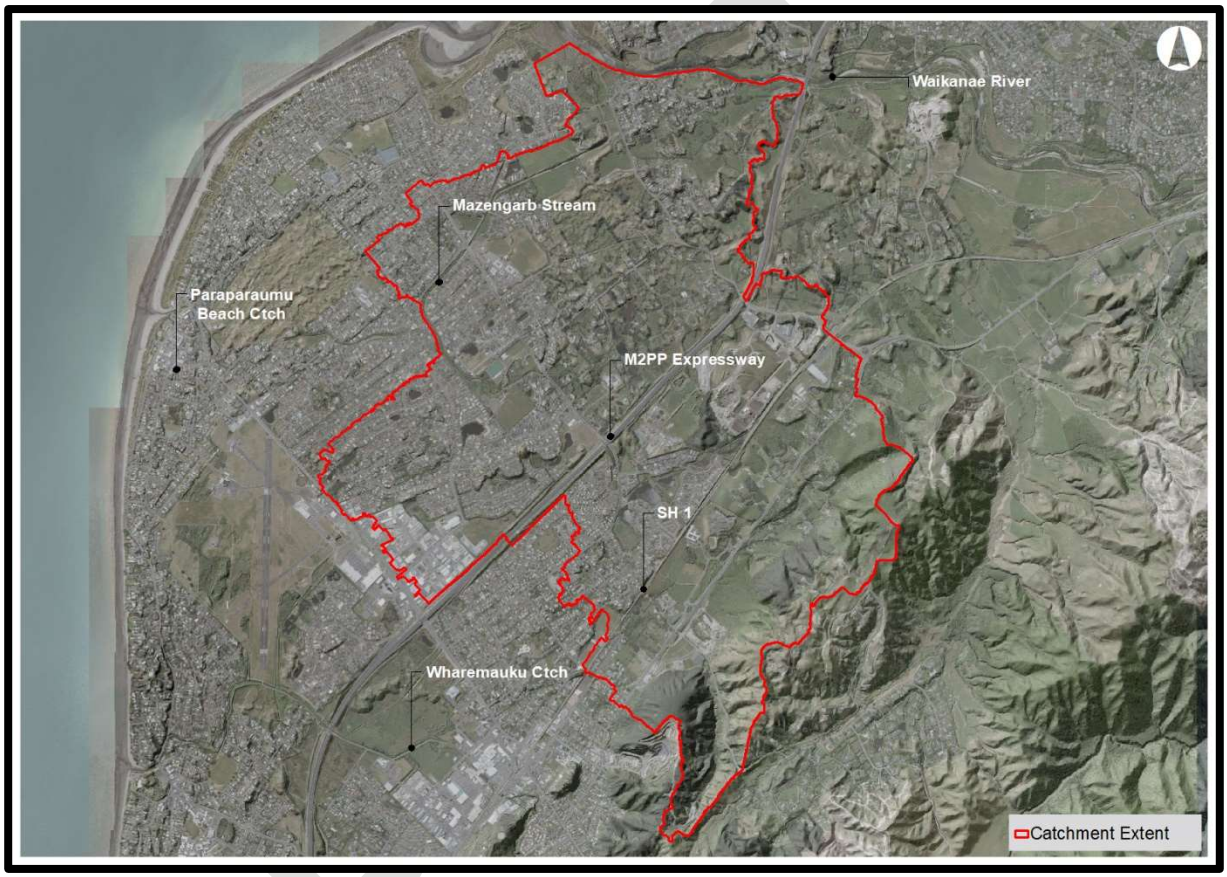


Figure 2. Mazengarb catchment extent.

2.2. Geology

The geology of the catchment has been shaped by the interaction of aeolian and fluvial process resulting in several dune phases, with interdune areas of peat, and floodplain gravels. It is within this context that the urban coastal margin has developed with hydraulic conditions ranging from high soakage sands and gravels to areas of low-lying peat impacted by seasonal groundwater conditions.[2]

[2] Kapiti Flood Hazard Management Methodology Report, 2024.

2.3. Existing Land Use

The Mazengarb catchment reflects the various growth phases which have occurred across the wider Kāpiti district. South/east of SH 1, in the steeper ranges, the land use is predominantly native and exotic species with some rural lifestyle blocks. Intensive development is largely confined to the west of Mazengarb Road and The Drive where land use is predominately residential, with areas of both older, larger lots and more recent, smaller lots and a commercial area located on the western boundary. East of Mazengarb road isolated areas of development give way to rural lifestyle blocks and the decommissioned landfill. Residential development in the north/east is bounded by Otaihanga and Makora Roads.

2.4. Stormwater system

The Mazengarb stormwater network consists of pipes, catchpits, manholes, detention ponds and interconnected streams and drains with culverts under road and rail crossings. The Mazengarb Stream is the main open channel in the catchment and has been modified along its length to increase floodway capacity as it is the primary form of conveyance of runoff out of the catchment.

Historically the Mazengarb Stream drained to the coast to the west of its current location, along the path of the current Tikotu Stream. Circa 1970 the lower reach of the stream was formalised to drain to the east into the Waikanae River.

The Mazengarb Stream enters the lower reaches of the Waikanae River, within the Waikanae Estuary, and is subject to tailwater influence from the Waikanae River and coastal tides.

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3. Model Build

3.1. Model Overview

The purpose and use of the models is discussed in the Kāpiti Flood Hazard Management Methodology Report.

The following section defines the conceptual schema utilised to represent the real-world characteristics of the Mazengarb catchment within the model. Table 1 summarises key details of the model build.

Table 1. Key details of the model build.

AREA	HEADING
Software	TUFLOW version 2023-03-AB
Coordinate system	New Zealand Transverse Mercator 2000 (NZTM 2000)
Vertical datum	Wellington 1953 Vertical Datum (WVD53)
Validation scenarios	The May 2015 and December 2021 storm events.
Design events	• Rain-on-grid rainfall inputs derived from HIRDS v4 gridded (2 km resolution) design rainfall depths (including climate change effects for relevant scenarios). • Sub-catchment rainfall sampled at the sub-catchment centroid from HIRDS v4 gridded (2 km resolution) design rainfall depths (including climate change effects for relevant scenarios). • Waikanae River discharge sourced from legacy GWRC Waikanae model results. • Tailwater conditions incorporating Sea Level Rise (SLR), Storm Surge and the Mean High-Water Springs (MHWS) tidal cycle for Waikanae.

3.2. Data Sources

This section details the key information regarding the sources of data used to create the model, as shown in Table 2 and Table 3.

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3.2.1. Spatial Data

Table 2. Details of spatial data used to build the model.

DATA	DETAILS	DATE SUPPLIED
Topography	KCDC - GroundLasDataset2017.img	1st March 2019
Stormwater asset data	KCDC - KCDC_Stormwater_20200619_gdb	19th June 2020
Land cover	Lynker - Kāpiti_Coast_Landcover_20210527.gdb Koordinates - Landcare Research - Land Cover Database version 5 (LCDB v5)	27th May 2021 N/A
Soil map	Koordinates - The Fundamental Soil Layers New Zealand Soil Classification (FSL) dataset, updated July 2017	N/A
Soil map	Koordinates – LRIS – SMAP Soil Classification, updated August 2021	N/A
Infiltration map	Awa - Derived from field investigation data collection and analysis	2022
Soil compaction	Awa - Derived from GIS desktop investigation	2022
Building footprints	Lynker - Kāpiti_Coast_Landcover_20210527.gdb	27th May 2021
Open channels	KCDC - KCDC_Stormwater_20200619_gdb	19th June 2020
Rainfall	HIRDS - HIRDS v4 gridded (2 km resolution) design rainfall depths	3rd September 2021
Groundwater	T&T – Groundwater level files – • AWA_2130_85H_model_hds_toplayer_50% • AWA_2130_85H+_model_hds_toplayer_50%	20th January 2022

3.2.2. Non-spatial Data

Table 3. Details of non-spatial data used to build the model.

DATA	DETAILS	DATE SUPPLIED
Validation data	KCDC - DETSUM12058.csv – KCDC service requests for period January 2015 to November 2020	23rd November 2020
X-sections (survey)	Jacobs - Mazengarb2009 v2.xns11	6th March 2019
Culverts (survey)	Jacobs - Mazengarb2010v14_NZTM.nwk11	6th March 2019
Tide (validation)	Website - May 2015, December 2021 validation tide data from GWRC live monitoring and research website	N/A

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DATA	DETAILS	DATE SUPPLIED
Rainfall (validation)	Website - May 2015, December 2021 validation rainfall data from GWRC live monitoring and research website	N/A
Tide (design)	Design tides generated by AWA	N/A
Discharge hydrograph	GWRC – Waikanae legacy model (Waikanae 2017 Design Q100CC) – DesignFlows2009-phaseshift	2023
As-builts	KCDC - 21505 ASB DWG v10 (KCDC).dwg – Niu Sila Way as-built contour plan	30th March 2021
Network (survey)	KCDC – Manhole Condition Survey	2021
River (survey)	GWRC – Waikanae legacy model (Waikanae 2017 Design Q100CC) - Waikanae 2017 design Q100CC	2023
Google Maps - Kāpiti	Street View April 2008 to December 2019	N/A
Aerial Imagery	Service Layer Credits: Eagle Technology, Land Information New Zealand, GEBCO, Community maps contributors	N/A
Soakage Rates	KCDC – Soakage rate data for various locations across the district	2021

3.3. Model Domain

The extent and computational method for each of the key model features are defined in Table 4.

Table 4. Extent and computational method for each of the model's key features.

DATA	DETAILS
Model boundary	• GIS-based drainage analysis was used to define watersheds within the catchment. These watersheds were merged to form the extent of the 2D model domain, as shown in Figure 3. • Some modification at the downstream boundary was required to conform to the Waikanae River.
Overland flow	• The 2D computational grid is discretised into regular 2 m x 2 m square elements. • Overland flow processes are simulated within the TUFLOW 2D model domain. • Surface elevations are based on LiDAR data.
Pipe network	• Represented in 1D using TUFLOW's ESTRY module. • All stormwater drainage sumps, pipes and manholes in the catchment identified from KCDC's stormwater asset data layer, except for small diameter private connections which discharge to the kerb and channel, are included in the model.

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DATA	DETAILS
	• Stormwater assets included in the network are summarised in Section 3.4. • The extent of the pipe network is shown in Figure 4.
Open channels	• A 1D representation of the Waikanae River has been used as a downstream boundary condition providing a source of fluvial flood flows and a downstream water level boundary condition. The cross sections are based on the legacy GWRC Waikanae river model. • The main open channels are modelled using TUFLOW's sub-grid sampling feature (SGS) which represents the channel bed at a 0.5 m resolution. This fine-resolution grid has been interpolated from cross section data from legacy model survey. • All other small open channels and swales are represented in the DEM at a cell resolution of 2 m. • The extent of open channels is shown in Figure 5.
Sub-catchments	• Sub-catchments are used to simulate runoff from steep, hill catchments along the south-eastern extent of the catchment. • Soil Conservation Service (SCS) Curve Number method is used to simulate hydrological losses (SKM, 2011). • The Clark Unit Hydrograph method is used to simulate hydrological routing parameters (SKM, 2011). • The location of the modelled sub-catchments is shown in Figure 6. • Further details are included in Section 3.6.
Rain-on-grid	• Initial loss/continuing loss infiltration model, calculated from field infiltration data and analysis, was applied across the 2D model domain to account for hydrological losses. Parameters are spatially distributed to account for the various land use, soil type and compaction assumptions, as shown in Figure 7 and • Figure 8. • The extent of the soil compaction layer is shown in Figure 9. • The extent of the rain-on-grid domain is shown in Figure 6. • Further details are included in Section 3.6.
Lakes, ponds, and wetlands	• Ponds identified in the aerial imagery are represented in the TUFLOW 2D model domain by excavating the pond extent 500 mm below the outlet structure invert level and applying an initial water surface. • For ponds without an outlet structure, the pond extent is excavated 500 mm below the LiDAR estimate of the pond surface and a 500 mm deep initial water surface applied.

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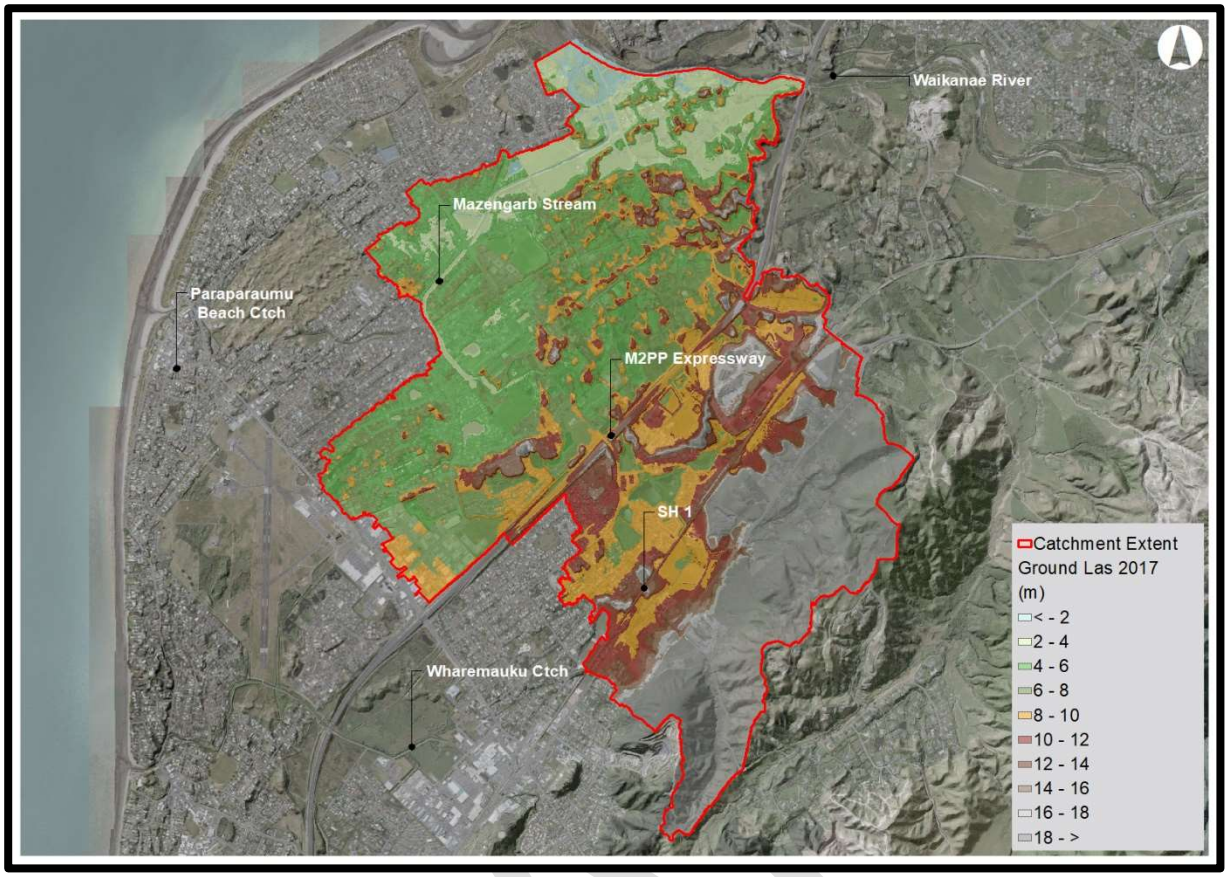


Figure 3. Surface elevation overlaid with model domain (shown in red).

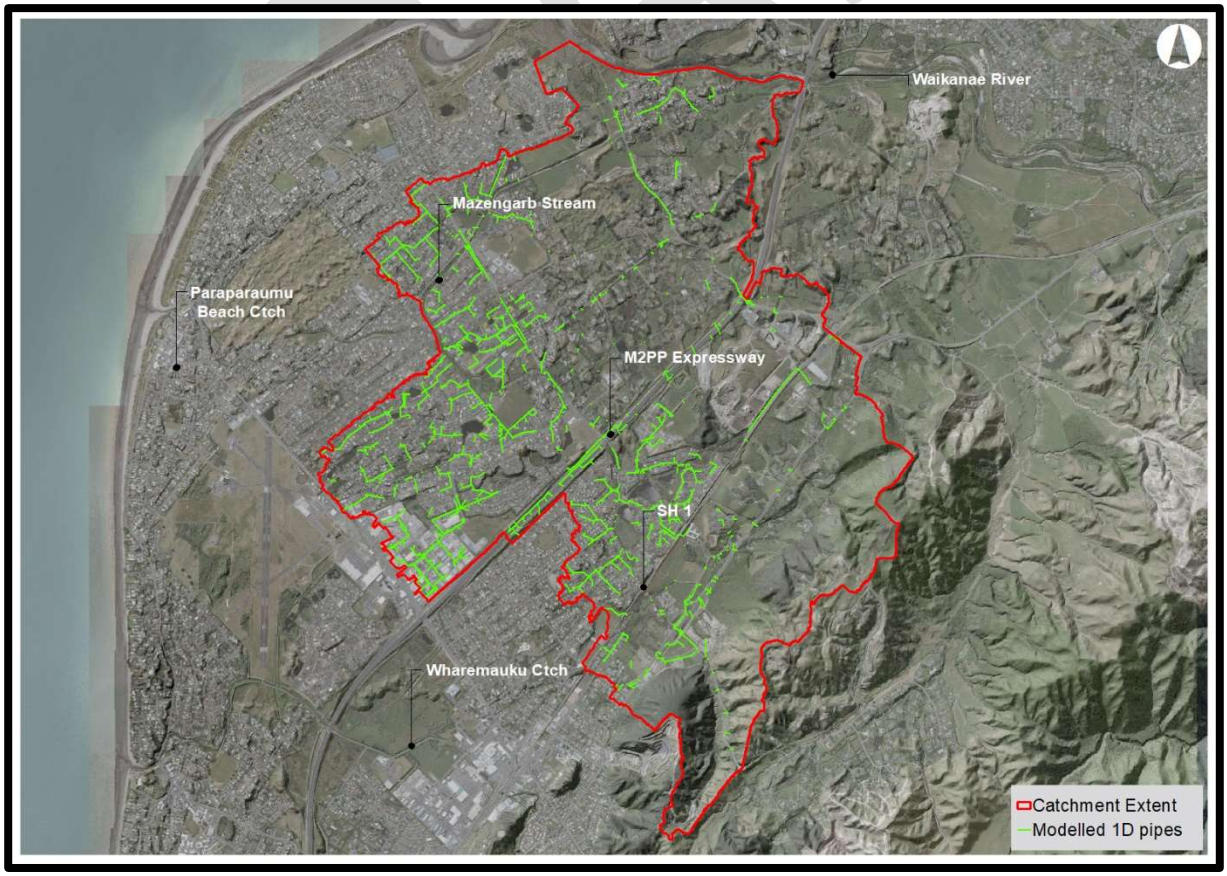


Figure 4. Pipe network extent (shown in green) and model domain (shown in red).

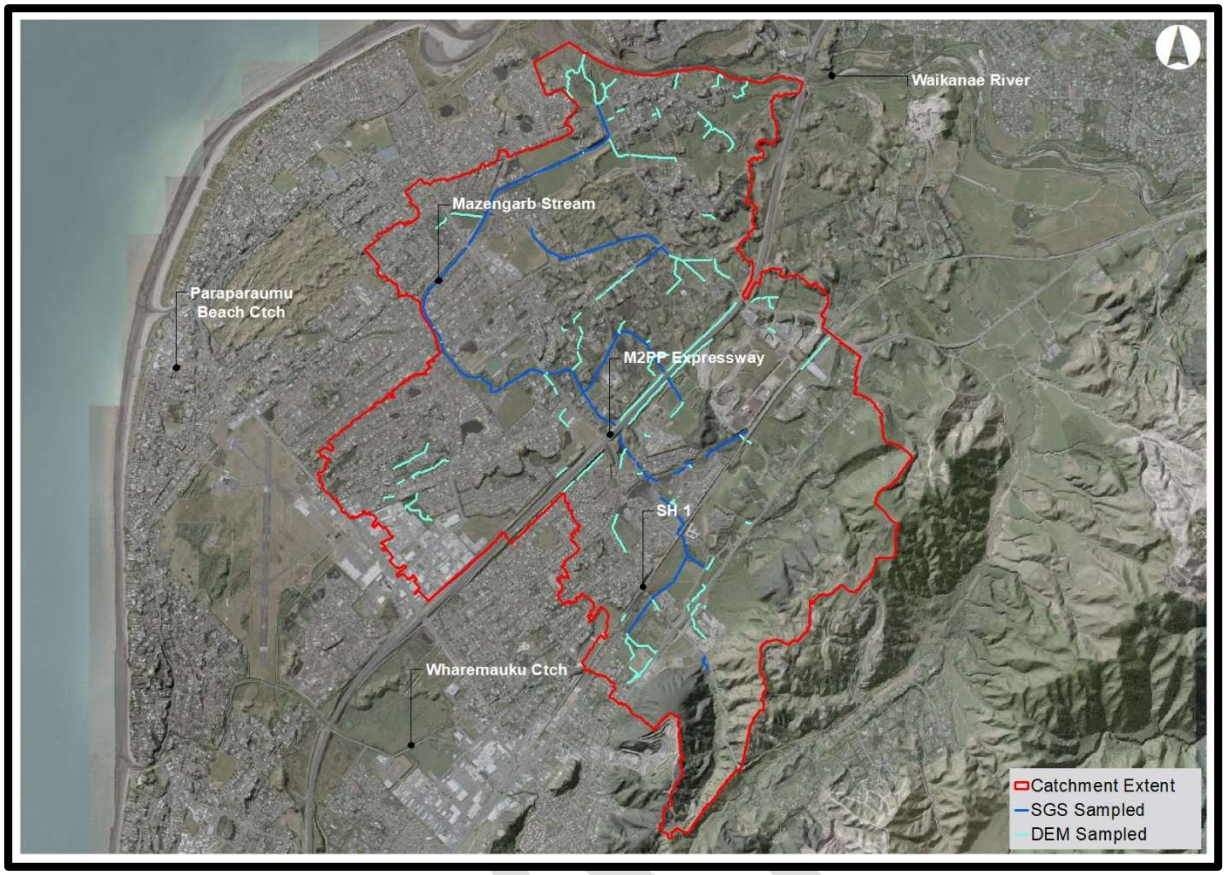


Figure 5. Open channel representation – sub-grid sampling (dark blue) and DEM (light blue).

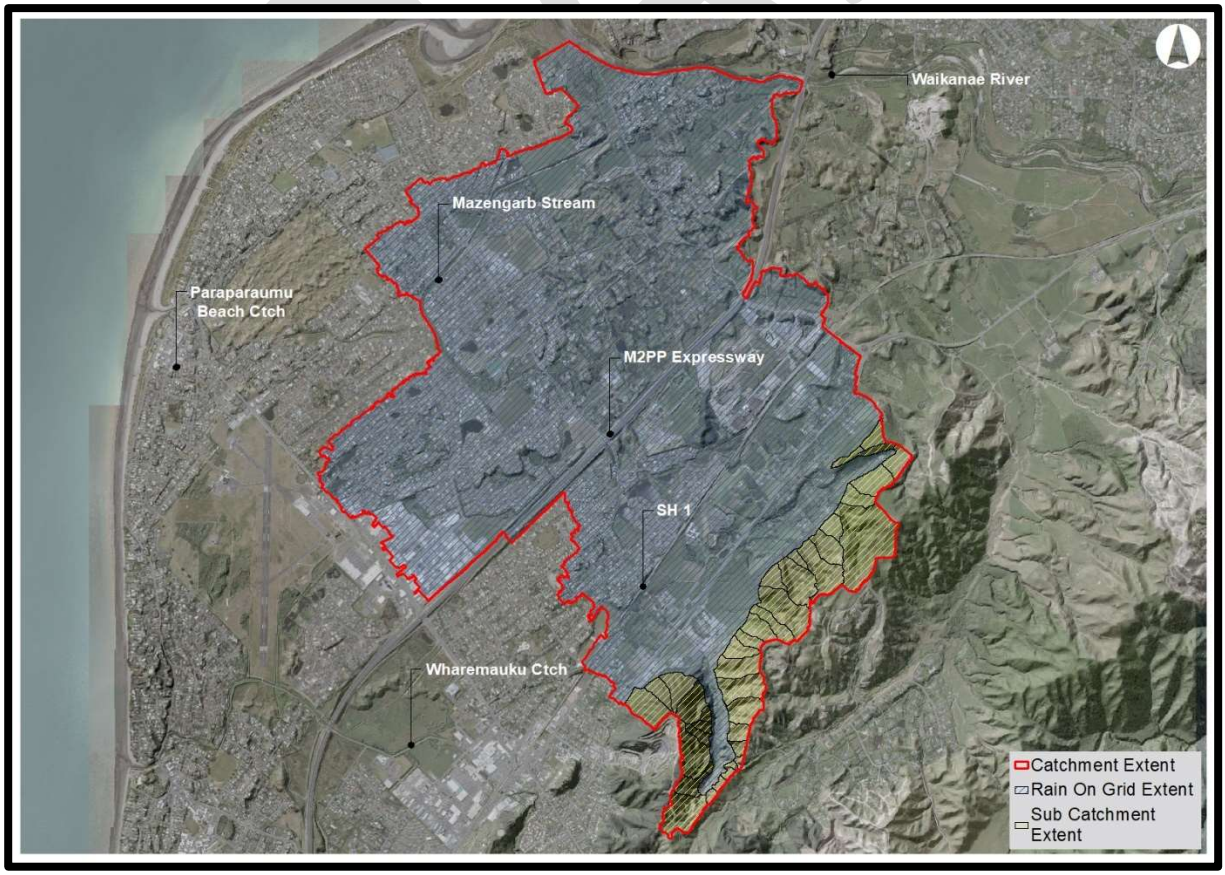


Figure 6. Sub-catchments extent (yellow) and Rain on Grid extent (blue).

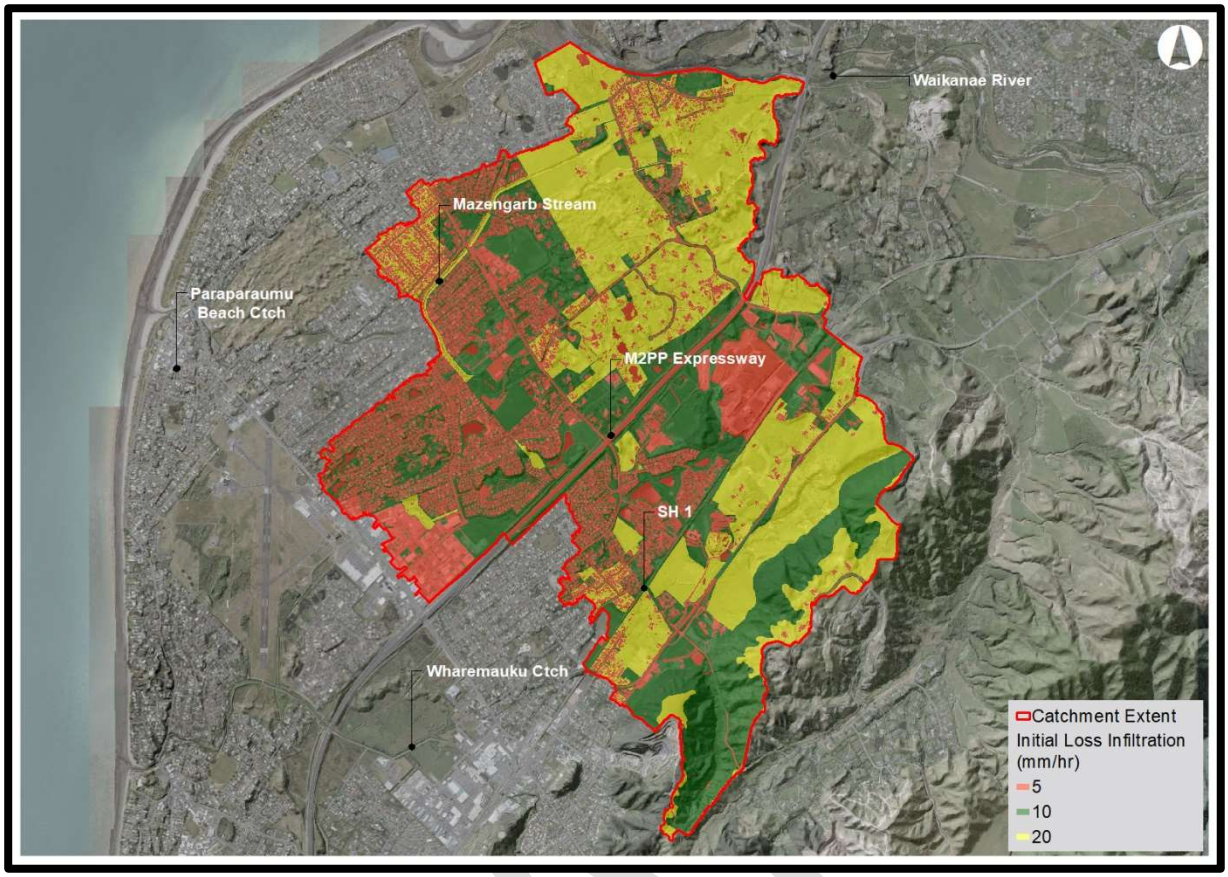


Figure 7. Initial loss infiltration model.

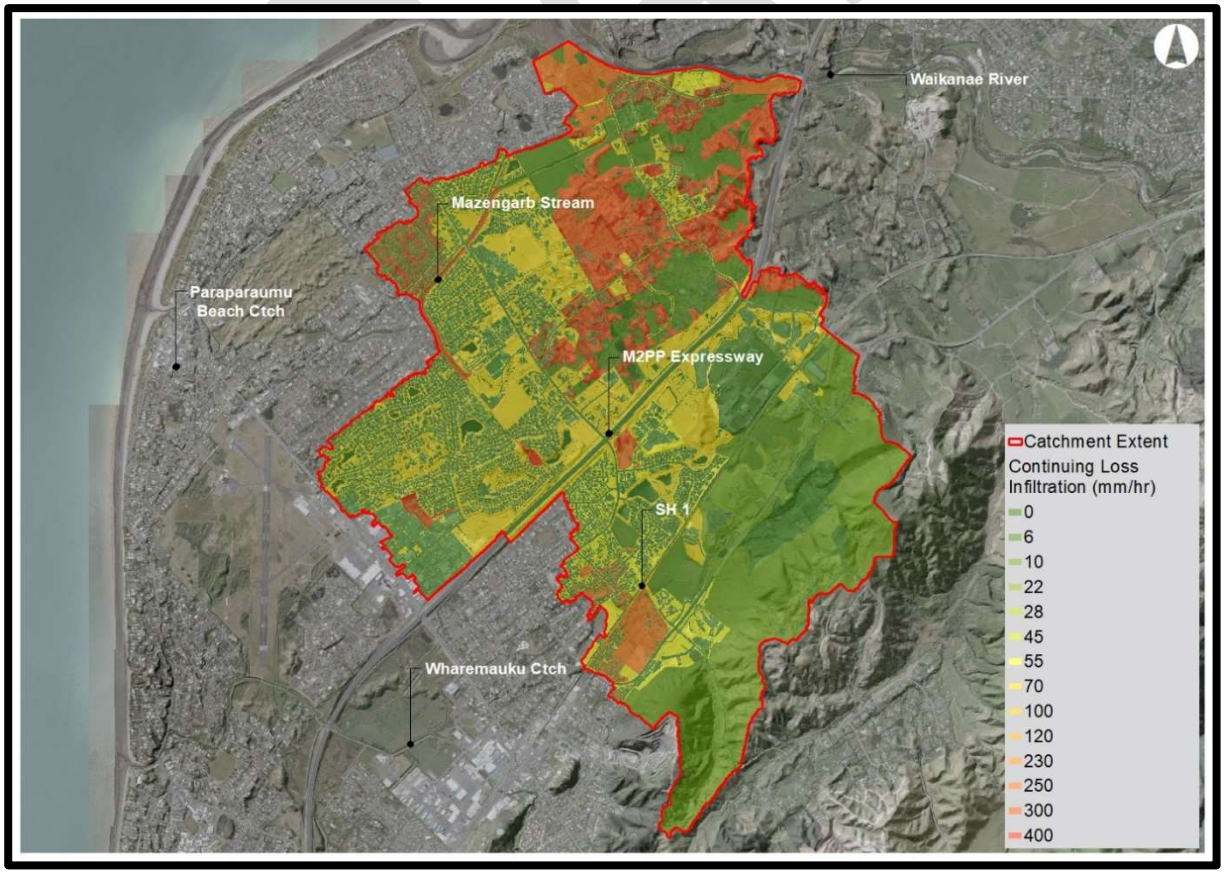


Figure 8 Continuing loss infiltration model.

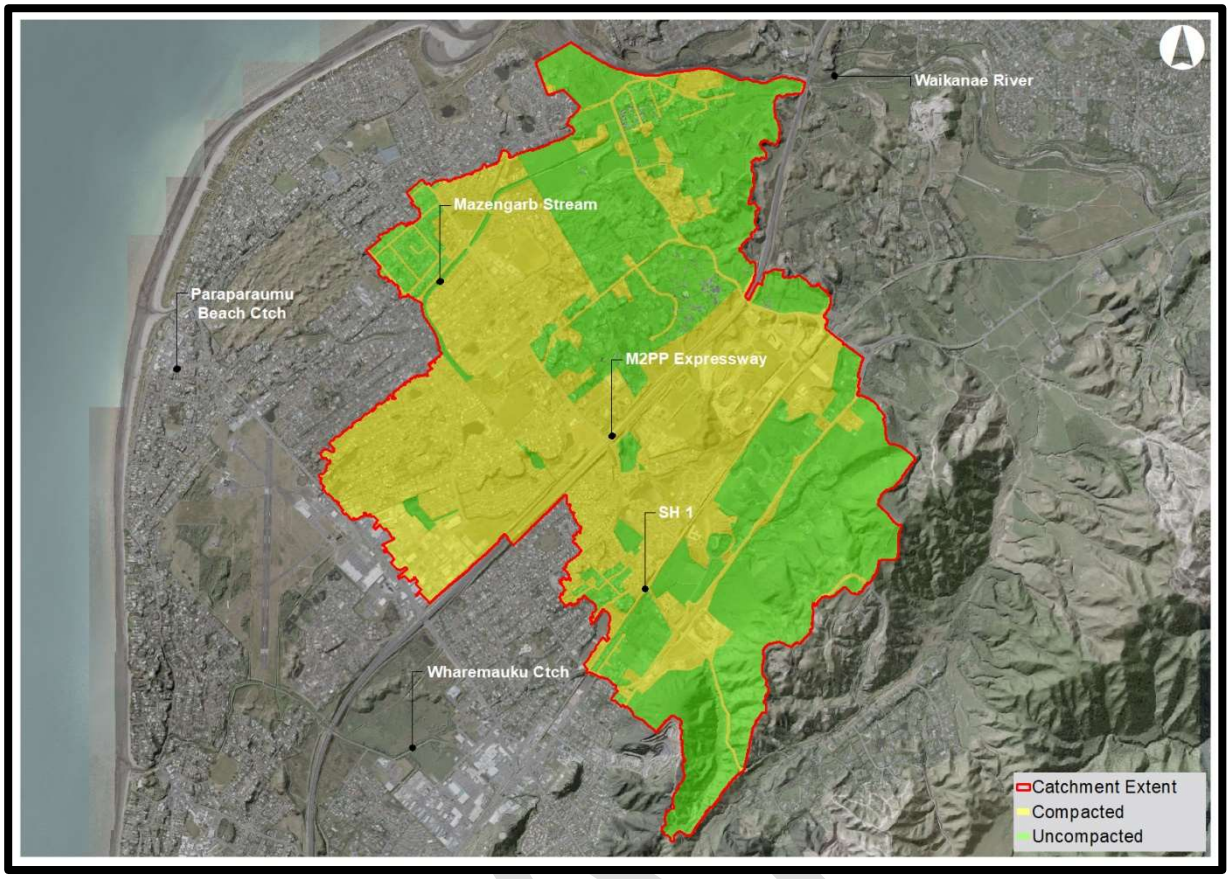


Figure 9. Extent of the soil compaction layer.

3.4. Pipe Network

The 1D network comprises gravity mains which drain to the Mazengarb Stream with some minor exceptions where isolated network drains directly to the Waikanae River from the Otaihanga Domain to the north.

The network includes all stormwater drainage pits, pipes and manholes in the catchment identified from KCDC's stormwater asset data layer, excluding private drainage. The network includes a development area, Niu Sila Way, which has been identified from as-built drawings.

The asset types included in the pipe network model and key information on how they are represented is shown in Table 5.

Table 5. Stormwater asset model representation.

DATA	DETAILS
Pipes	• All pipes in the KCDC_Stormwater_20200619_gdb layer, excluding private drainage, are included in the model. • Sump-lead connections in the KCDC_Stormwater_20200619_gdb layer are included in the model. Small diameter privately owned lateral connections and pipes discharging to the kerb and channel are excluded from the model. • Additional laterals are added to connect sumps to the network where necessary and the diameter assumed.

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DATA	DETAILS
	• Parameters specified in the asset database are used where appropriate. Where available, survey data is used to correct anomalies, otherwise network assumptions and engineering judgement are used to interpolate gaps in the data or correct apparent errors in the pipe network.
Inlets	• Inlet structures - ground levels at the structure are adjusted to match the invert level of the connected pipe. • Where invert information is not available, the pipe invert has been adjusted to match the LiDAR. • Inlets are coupled to the 2D surface allowing for the exchange of surface flow into the pipe network.
Outlets	• Outlet structures - ground levels at the structure are adjusted to match the invert level of the connected pipe. • Where invert information is not available, pipe inverts are adjusted to match the LiDAR. • Outlets are coupled to the 2D surface allowing for the exchange of surface flow into the pipe network.
Manholes	• All manholes in the supplied dataset are included in the model, except where they are isolated from other network. • Additional manholes are added to the model to fill gaps in the GIS dataset. • Manhole inverts are assigned the minimum of the connected upstream or downstream pipe invert levels in the first instance. Where pipe inverts are not available, inverts are calculated from the Depth field of the asset data and the LiDAR ground level. Where no depths are specified, inverts are estimated based on the connected pipe diameters and an assumed pipe cover depth of 450 mm or interpolated using engineering judgement to maintain a consistent grade. • Lid levels are set from the LiDAR surface elevation DEM. • Manhole diameters are specified in the asset data. For manholes missing from the asset data, diameters are set to accommodate connected pipes or assumed to be 1050 mm diameter. • Manholes are not coupled to the 2D surface, effectively sealed, so no exchange of surface flow into the manholes occur.
Junctions	• Junctions in the supplied KCDC_Stormwater_20200619_gdb layer are included where sump leads connect to stormwater mains. • Junctions are modelled as circular nodes with parameters to accommodate connected pipes.
Sumps	• Stormwater inlet (sump) discharge-depth relations are based on those defined by WWL (2017) as shown in Table 8. • Lid levels are set from the LiDAR surface elevation DEM. • Upstream inverts of sump leads are set to 450 mm above the sump invert and the sump-lead grade is set to 5%. Where this is not possible, the upstream or downstream inverts are adjusted accordingly. • Sumps are coupled to the 2D surface allowing for the exchange of surface flow into the pipe network.

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DATA	DETAILS
	• Sump types have been taken from supplied asset database. Identified sumps, not in the asset database, have had sump type defined using street-view.
Subsoil drains	• Nova flow pipes are included in the model as standard pipes. • Isolated sections of nova flow pipe are excluded from the model.
Soakage	• All soakage nodes in the supplied dataset are included in the model and categorised as either. • Soak-hole and dimensioned as standard manholes, not coupled to the 2D surface, with connected sumps. • Soak-hole and dimensioned as standard drainage pits represented with a grated lid with/without connected sumps, coupled to the 2D surface. • A soakage rate of 300 mm / hr has been assumed across all identified soakage devices.
Pump stations	• There is a single private pump station within the catchment area servicing an isolated catchment area. This has not been included in the model.
Bridges	• Represented in the 2d Domain by TUFLOWS layered flow constrictions shape (LFCSH). There are up to 3 layers that can have the surface elevation, blockage and loses associated with each layer. A bridge is modelled as having a 0-10% blockage as the first layer (could have piles or not) Second layer is the deck level that is 100% impervious. (Levels taken from old mike model and or DEM or survey). The third layer represents the railing that is generally a 10%-20% blockage. Assuming they are a min of 1.2m high. During blockage scenarios the first layer can be adjusted to represent blockages.

3.5. Key Structures and Assets

There are several key culverts within the Mazengarb catchment which represent constraints in the network. The location of these assets is shown in Figure 10 with the dimensions and configuration shown in Table 6.

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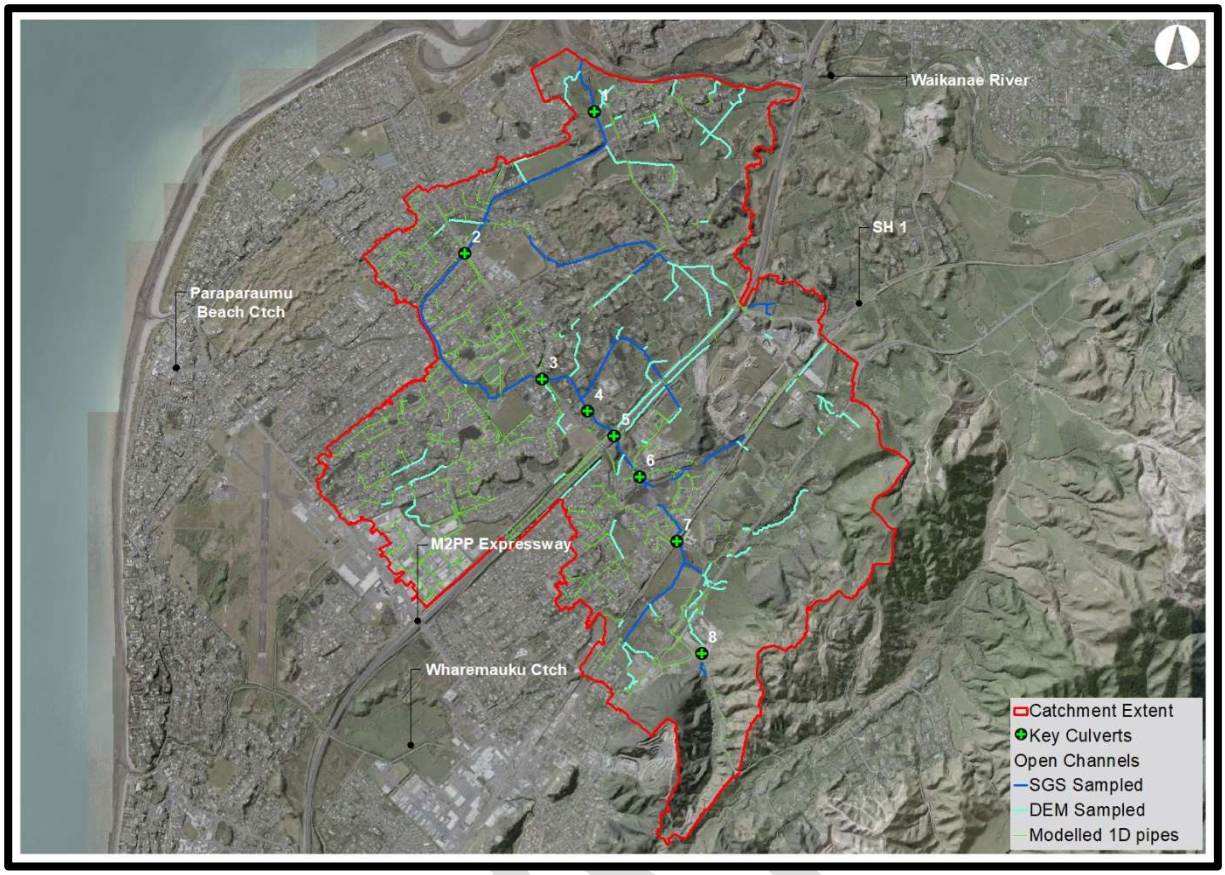


Figure 10. Locations of key open channel structures.

Table 6 Culvert descriptions

CULVERT ID	CULVERT NAME	DIMENSIONS/CONFIGURATION
1	Mazengarb Reserve	2 * 1.05 circular culverts
2	Mazengarb Road 1	2 * 1.79 (H) by 2.5 (W) box culverts
3	Mazengarb Road 2	2 * 1.05 circular culverts
4	Private Access	2 * 1.05 circular culverts
5	M2PP	1 * 3.6 (H) by 1.5 (W) culvert
6	Waterstone Avenue	1 * 3.6 (H) by 1.5 (W) culvert
7	NIMT	1 * 1.80 circular culvert
8	Nikau Palm Road	1 * 1.20 circular culvert

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3.6. Computational Approaches

The computational approaches for the various components are outlined in Table 7, including key hydraulic and hydrological parameters.

Table 7. Computational approaches and key parameters for various aspects of the model.

MODEL ASPECT		DETAILS
Internal model coupling	Overland flow to pipe network	• The model surface is connected to the pipe network via TUFLOW pits. Flow is exchanged according to Q-D relations taken from WWL (2017), as shown in Table 8.
	Open channels to pipe network	• TUFLOW 2D SX link nodes are used to connect pipe inlets and outlets to channel cells. • Instabilities are dampened and, in some cases, eliminated by levelling several cells and connecting the pipe inlet or outlet to them using 2D SX link lines.
	River to overland flow	• TUFLOW 2D HX link lines are used to connect the model surface and Mazengarb Stream bed to a 1D representation of the Waikanae River reach running from State Highway 1 to the coast. This provides a downstream boundary for the catchment model, while allowing for water level variation along the river channel.
Boundary condition application	Waikanae River	• The Waikanae River reach extends from State Highway 1 to the coast. • The upstream inflow boundary is applied at the State Highway 1 bridge and is based on discharge extracted from GWRC legacy Waikanae model results. • The downstream water level boundary is applied at the coast and is based on a recurring Mean High-Water Springs (MHWS) tidal signal with the addition of a sinusoidal storm surge profile and sea level rise offsets.
	Model domain	• For design events, rainfall is applied as a 2 km-resolution grid timeseries. The gridded rainfall is based on HIRDS v4 rainfall depths and a centred nested rainfall pattern. • For the validation event, gauged rainfall is applied as Thiessen polygon zones.

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<table>
<tr><th>MODEL ASPECT</th><th></th><th>DETAILS</th></tr>
<tr><td></td><td>Sub-catchments</td><td>• Rainfall is applied to each sub-catchment depending on the zone or grid cell that the sub-catchment's centroid falls within.
• Each sub-catchment runoff discharge timeseries is distributed across a 2D Source over Area polygon located along the edge of the model domain where the sub-catchment abuts.
• Inflow from hill catchments is calculated outside the TUFLOW model.</td></tr>
<tr><td rowspan="5">Hydrodynamic parameters</td><td>Resistance</td><td>• Mannings n is spatially distributed across the 2D domain.
• The spatial distribution is based on land cover data provided by Lynker in urban areas and Landcare Research's LCDB v5 land cover elsewhere.
• A map of the roughness grid used in the model is shown in Figure 11.
• Manning's n values applied to different land cover classes are provided in the table below.
<table>
<tr><th>• Land cover</th><th>• Manning's n</th></tr>
<tr><td>• Forest</td><td>• 0.1</td></tr>
<tr><td>• Paved</td><td>• 0.02</td></tr>
<tr><td>• Scrub</td><td>• 0.2</td></tr>
<tr><td>• Maintained grass</td><td>• 0.03</td></tr>
<tr><td>• Channel bed</td><td>• 0.025</td></tr>
<tr><td>• Rural grass</td><td>• 0.04</td></tr>
<tr><td>• Crops</td><td>• 0.2</td></tr>
<tr><td>• Gravel</td><td>• 0.03</td></tr>
<tr><td>• Building</td><td>• 0.02</td></tr>
</table></td></tr>
<tr><td>Flood and dry parameters</td><td>• Default wetting and drying parameters are applied.
• Wetting and Drying == ON METHOD B
• Cell Wet/Dry Depth == 0.0002</td></tr>
<tr><td>Map cutoff depth</td><td>• Parameter set to 0.01</td></tr>
<tr><td>Eddy viscosity</td><td>• Default Wu eddy viscosity formulation used with default coefficients of C3D = 7.0 and C2D = 0.0.</td></tr>
<tr><td>Initial conditions</td><td>• Ponds are filled to the invert of the outflow, which makes the ponds 500 mm deep at the start of the simulation.
• A spatially varying groundwater table has been applied as an initial condition to better represent the total soil storage available through the simulation</td></tr>
</table>

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<table>
<tr><th>MODEL ASPECT</th><th></th><th>DETAILS</th></tr>
<tr><td rowspan="2">Pipe network hydrodynamic parameters</td><td>Pipe energy losses</td><td>

Most pipes are circular with a few exceptions: generally larger rectangular or irregular pipes. All pipes, including culverts are treated identically by TUFLOW.
Manning's n values applied to different pipe materials are provided in the table below.

<table>
<tr><th>Material</th><th>Manning's n</th></tr>
<tr><td>Plastic/Stone</td><td>0.0125</td></tr>
<tr><td>Concrete</td><td>0.0133</td></tr>
<tr><td>Cement mortar/Asbestos cement</td><td>0.0130</td></tr>
<tr><td>Iron(cast/ductile)/Ceramic/ Steel</td><td>0.0143</td></tr>
<tr><td>Iron(wrought)/nova flow/ Galvanised iron</td><td>0.0154</td></tr>
<tr><td>Dummy pipes*</td><td>0.0133</td></tr>
</table>
* Dummy pipes are connected to nodes that represent soakage devices. This is required by the software.
Entry and exit loss coefficients are set to 0.5 and 1.0, respectively.
</td></tr>
<tr><td>Manhole energy losses</td><td>

All manholes use the Engelund loss approach.
Km and K_Bend_Max coefficients are set to 0.25.

</td></tr>
<tr><td rowspan="2">2D configuration</td><td>Resistance</td><td>

A Manning's n value of 0.033 has been applied uniformly to the 1D Waikanae River branch at the downstream end of the model. As the river is not a key component of the model, a more sophisticated treatment is not warranted.
Resistance applied to open channels in the 2D domain varies along each channel depending on the land cover estimates: Forest to Channel Bed classifications have been applied corresponding to Manning's n roughness values from 0.1 to 0.025. Roughness has been adjusted as part of validation for the open channels in this catchment as covered in section 5.

</td></tr>
<tr><td>Initial conditions</td><td>

The initial water level is set automatically to the level of the downstream water level boundary at the start of each simulation.

</td></tr>
</table>

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MODEL ASPECT		DETAILS
Hydrology	Rain-on-grid	• Applied to flat areas of interest for flood mapping. • Spatially and temporally varying rainfall is applied directly to the 2D domain. • Initial loss/continuing loss infiltration model, calculated from field infiltration data and analysis, infiltration parameter sets for a range of land cover and soil types are produced for the whole of Kāpiti, as described by Awa (2021). • A spatially varying groundwater table has been applied as an initial condition to better represent the total soil storage available through the simulation.
	Sub-catchment-based	• Applied to steeper rural zones. • Sub-catchments are delineated using a GIS-based drainage analysis, which does not consider hydraulic effects. • Hill sub-catchments are either loaded to the upstream end of cross-drainage pipes under roads or distributed along the sub-catchment boundary with the 2D domain. • The hydrological loss model used is the Clark Unit Hydrograph using the SCS Curve Number method. The following parameters are required for each sub-catchment. • Initial loss calculated as an area-weighted average of 0.0 mm for urban areas and 5.0 mm for all others. • Curve Number based on land use and soil type. A map of CN has been created for the whole of Kāpiti as described in the Kāpiti Flood Hazard Management Methodology Report. • The routing model used is the Clark Unit Hydrograph method. The following parameters are required for each sub-catchment. • Area is taken directly from the sub-catchment area and so assumes that the entire sub-catchment contributes to runoff. • Time of Concentration is calculated according to the approach specified by Cardno (2019). • Storage Coefficient R is calculated from the area-weighted averaged of the Ratio parameter and the Time of Concentration, as described by SKM (2011).

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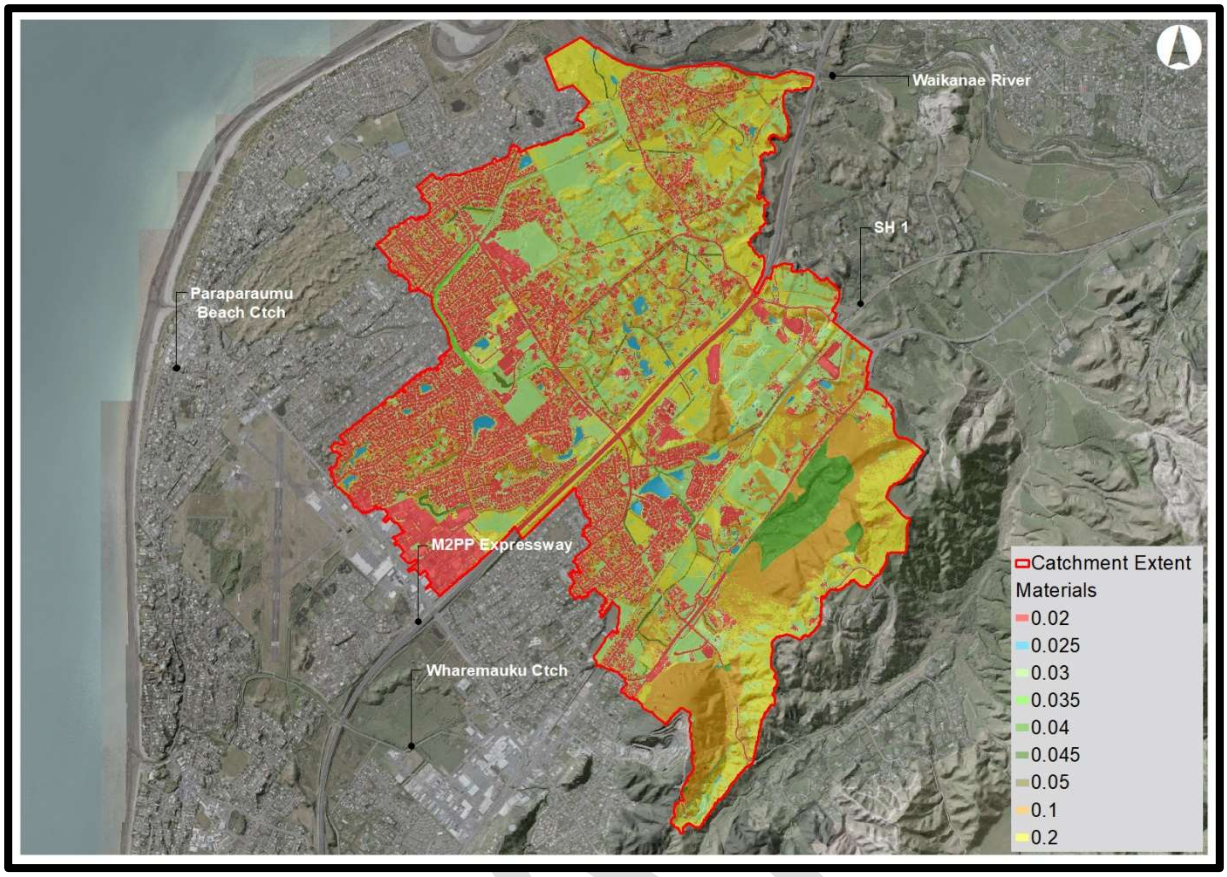


Figure 11. Manning's n overland flow resistance parameters applied to the model.

Table 8. Q-D relations taken from WWL (2017).

INLET CONFIGURATION ID	CODE	CATCHPIT TYPE	INLET AREA (M2)	DISCHARGE COEFFICIENT (-)	QDH (M)
1.1	CP	Standard grate, open with single sump	0.122	0.67	0.25
1.2	CP	Standard grate, in-line with single sump	0.122	0.67	0.3
1.3	DCP	Standard grate, in-line with double sump	0.243	0.67	0.3
1.4	CP	Standard grate, recessed with single sump	0.122	0.67	0.3
1.5	CP	Standard kerb-opening, back entry with single sump	0.063	0.67	0.3
1.6	DCP	Standard kerb-opening, back entry with double sump	0.126	0.67	0.3
1.7	CP	Standard combination, in-line with single sump	0.1845	0.55	0.35
1.8	CP	Standard combination, recessed with single sump	0.1845	0.55	0.35
1.9	DCP	Standard combination, in-line with double sump	0.369	0.55	0.35

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1.10	DCP	Standard combination, recessed with double sump	0.369	0.55	0.35
2.1	SSPLAY	Single splay, in-line with single sump	0.063	0.67	0.3
2.2	SSPLAY	Single splay, in-line with double sump	0.126	0.67	0.3
3.1	DSPLAY	Double splay, in-line with single sump	0.063	0.67	0.3
3.2	DSPLAY	Double splay, in-line with double sump	0.126	0.67	0.3
4.1	SCP	Super pit, in-line with single sump	0.353	0.62	0.4
4.2	DSCP	Super pit, in-line with double sump	0.705	0.62	0.4
5.1	MCP	Mega pit, in-line or recessed with single sump	0.729	0.55	0.05
5.2	MCP	Mega pit, in-line or recessed with double sump	1.458	0.55	0.05
5.3	MCP	Mega pit grate, open with single sump	0.648	0.67	0.5

3.7. Boundaries

Three different types of boundaries are applied to the TUFLOW model, as shown in Table 9. Hydrographs for the hill sub-catchments are generated externally from TUFLOW and are either:

- connected to Source over Area (SA) polygons along the extent of the boundary which abuts the relevant sub-catchment; or
- connected to the upstream end of cross-drainage culverts which pass under roads.

In the case of flows entering cross-drainage culverts, a storage area-height relationship is applied to the upstream node to account for ponding storage upstream and the node is also connected to the boundary to allow for overtopping flows.

Table 9. TUFLOW model boundaries.

BOUNDARY	DETAILS
Rainfall	• Spatially and temporally varying rainfall is applied across the entire 2D domain. • Externally to the TUFLOW model, rainfall is applied to hill sub-catchments based on the location of the sub-catchment's centroid.
Tide	• Applied at the downstream end of the Waikanae River branch at the coast.
Flow	• The Waikanae River inflow boundary is located at the SH1 bridge. • Hill sub-catchment runoff is directed into cross-drainage culverts or onto the 2D surface along the south-eastern edge of the 2D domain.

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3.8. Model Limitations

Model limitations which should be considered when using the model or interpreting outputs are discussed in Table 10.

Table 10. Limitations of the model.

LIMITATION	DETAILS
Data quality	Some errors, omissions, and anomalies in the GIS asset data were identified through automated error detection and resolved using as-built drawings where available and, in the absence of data, engineering judgement based on terrain and surrounding assets.
Cross section data	Cross-section data for the TUFLOW SGS defined open channels were based on MIKE 11 open channel cross sections extracted from the legacy MIKE FLOOD model. Therefore, the invert level in the open channel in these locations may have changed over time depending on aggradation or scouring of the channel.
Sub-catchment discharge effects	Discharges from the hydrological model are loaded onto the TUFLOW 2D surface, via dummy nodes in TUFLOW 1D. If the catchments are too large the point loading of the flow onto the grid could result in water "mounding" at the discharge location. Catchments are delineated to a relatively small size to distribute the discharges across the model and ensure that mounding is not significant.
Grid cell resolution	Some of the finer surface features that influence overland flows and catchment delineation are not fully represented by the resolution of the terrain (2 m). Features such as kerb lines are at a sub grid size scale and some preconditioning of the terrain had to be undertaken prior to sub-catchment delineation. This involved cutting kerb lines into the terrain and adding localised high points into the surface at key locations. These edits were applied during sub-catchment delineation and have been carried through into the final model.

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3.9. Assumptions

Assumptions made during the model build process are discussed in Table 11.

Table 11. Assumptions made during the model build.

TYPE	ASSUMPTION
Hydrological assumptions	• The hydrological method specified by SKM (2011) reproduces the significant hydrological responses of the hill sub-catchments. • The 2017 LiDAR is a reasonable representation of catchment topography, and minor channels are overwhelmed during flood flows. • While surface infiltration rates will vary the parameters used in the model are a reasonable estimate of mean rates.
Hydraulic assumptions	• The 2017 LiDAR is a reasonable representation of the current state of the catchment. • Manhole lid levels are adequately estimated by the LiDAR. • Pipes and hydraulic structures are sediment free. • Inlets, outlets, and sumps are sediment and blockage free. • Where data is of low quality, engineering-design-based estimates of pipe and manhole inverts and grades are reasonable. • The land cover estimates are sufficiently accurate for use in distributing hydraulic parameters, such as overland flow resistance and infiltration rates.

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4. Model Summary

4.1. Results Comparison

While the legacy MIKE FLOOD Mazengarb Catchment model (2014) followed a different model build methodology to the recent TUFLOW modelling, it is worth undertaking a high-level comparison of the modelling results as the two models should be the same order of magnitude when comparing the 2115 100-YR ARI rainfall event (MIKEFLOOD) to the 2130 100-YR ARI rainfall event (TUFLOW).

The Peak water level comparisons at various locations are shown in Figure 12 - Figure 17. It is worth noting the MIKEFLOOD model does not represent flooding in the 1D channels in these figures.

There is general agreement in peak flood levels between the two models over a majority of the catchment. The TUFLOW model (rain-on-grid) shows ponding within isolated depressions in the bathymetry which are not captured in the MIKE FLOOD model as the sub-catchment hydrology has been loaded directly to the network or open channels with only larger isolated catchments loaded into the bathymetry surface.

It is likely the ponding within isolated depressions, along with infiltration grid is mitigating the increased rainfall intensity associated with the (TUFLOW 2130) compared to (MIKE FLOOD 2115).

There are three main areas of difference in flood levels located adjacent Mazengarb Road, Otaihanga and adjacent the Council depot.

In Otaihanga and adjacent the Council depot the TUFLOW model (rain-on-grid) captures the available storage within the catchments (Otaihanga East, KCDC Pond D, KCDC Pond E) before flows enter the downstream open channels. In the MIKE FLOOD model, the catchment is loaded directly to the downstream open channels, as shown in Figure 18.

Having reviewed the results our conclusion is the differences between the MIKE FLOOD and TUFLOW models are a result of the increased detail in the new TUFLOW model. This includes the rain on grid methodology along with a significant improvement in the quality of the network data. Flood storage is more widely distributed in the TUFLOW model and there is a significantly greater level of connectivity in the local networks that has improved the quality of understanding of local flooding. The 100YR-ARI 2130 peak depth results are shown in Appendix C.

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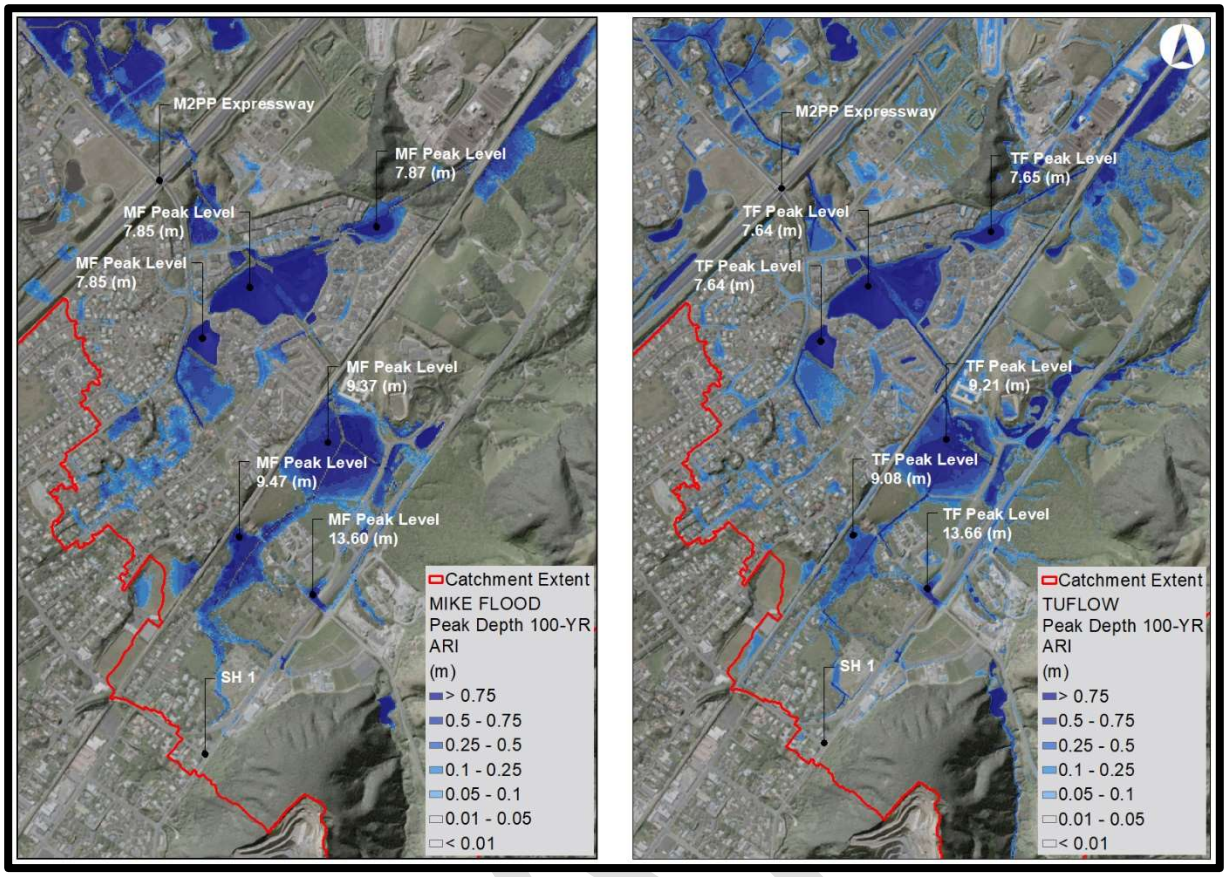


Figure 12. Mazengarb sheet 1 – peak water level results compare MIKE FLOOD verses TUFLOW.

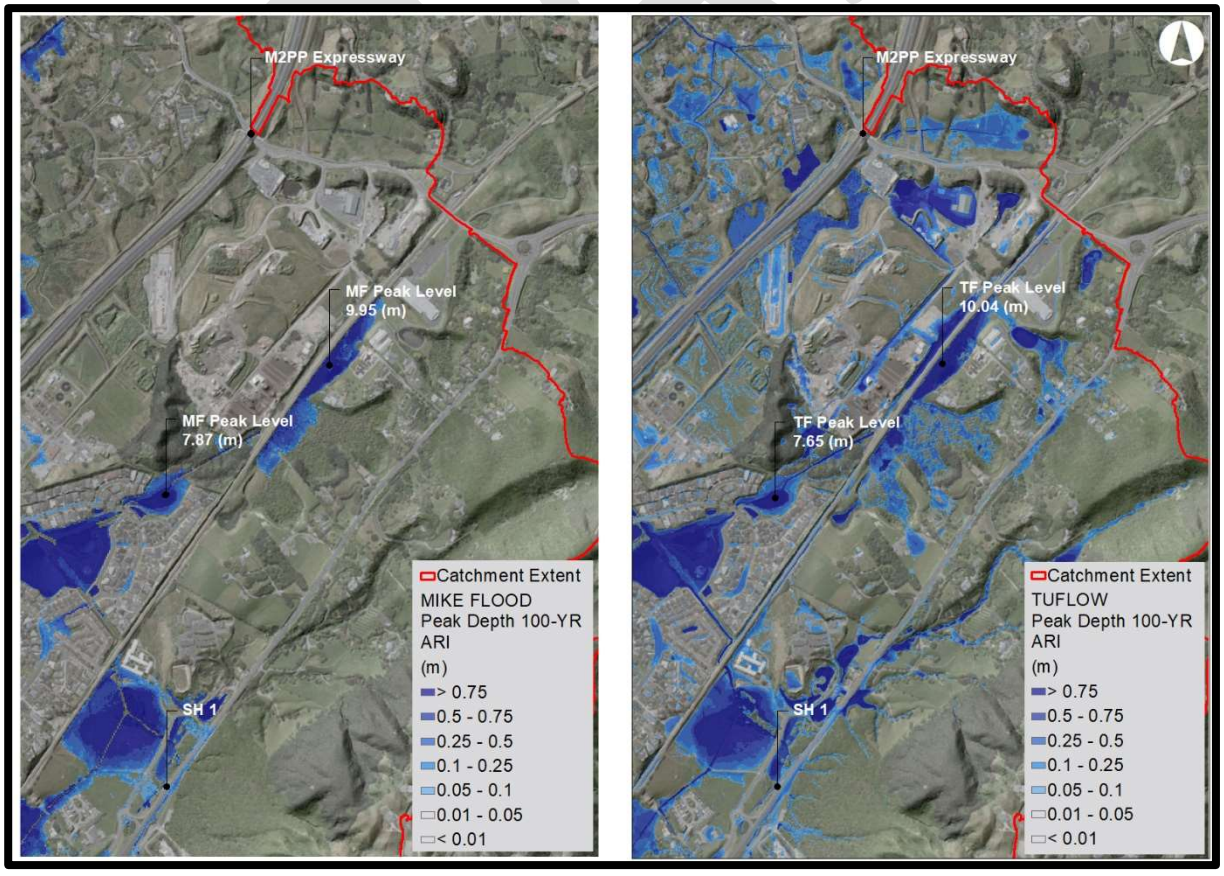


Figure 13. Mazengarb sheet 2 – peak water level results compare MIKE FLOOD verses TUFLOW.

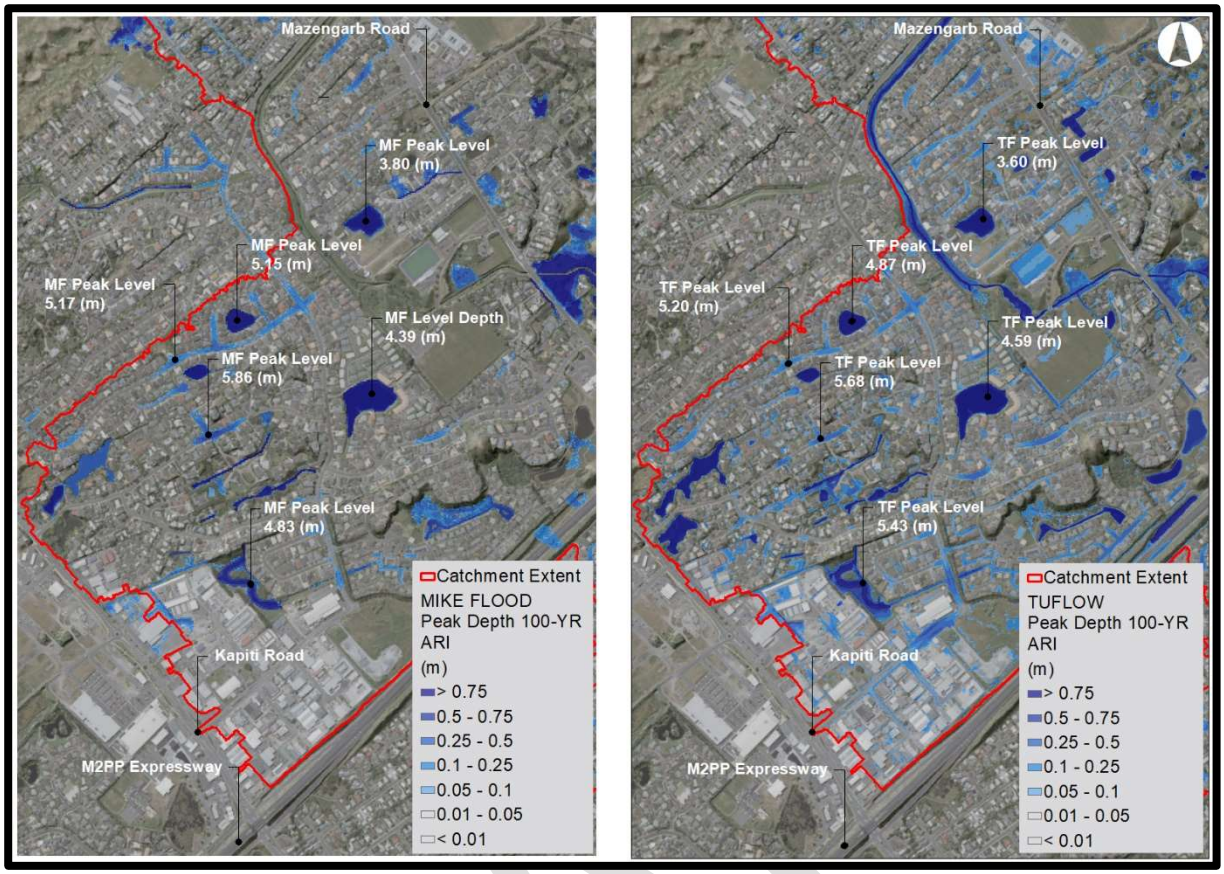


Figure 14. Mazengarb sheet 3 – peak water level results compare MIKE FLOOD verses TUFLOW.

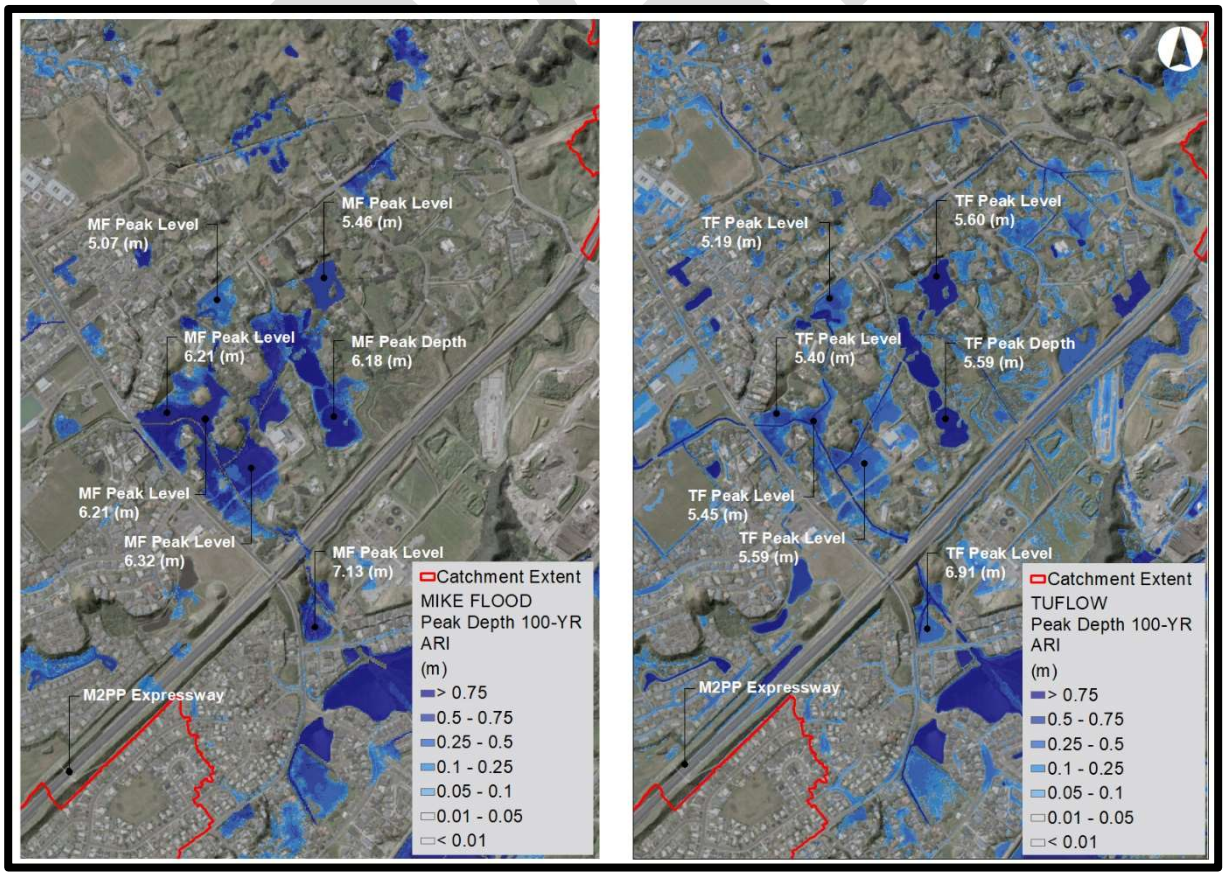


Figure 15. Mazengarb sheet 4 – peak water level results compare MIKE FLOOD verses TUFLOW.

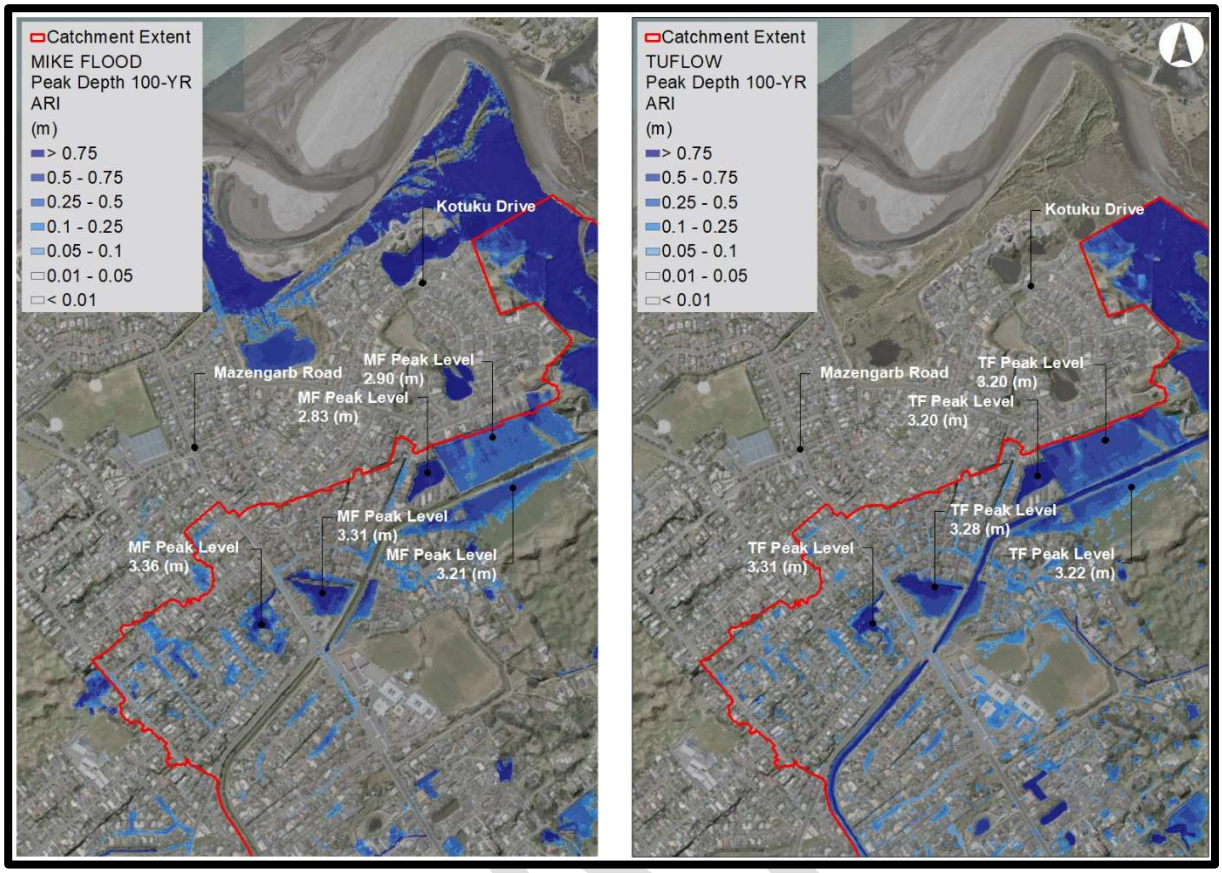


Figure 16. Mazengarb sheet 5 – peak water level results compare MIKE FLOOD verses TUFLOW.

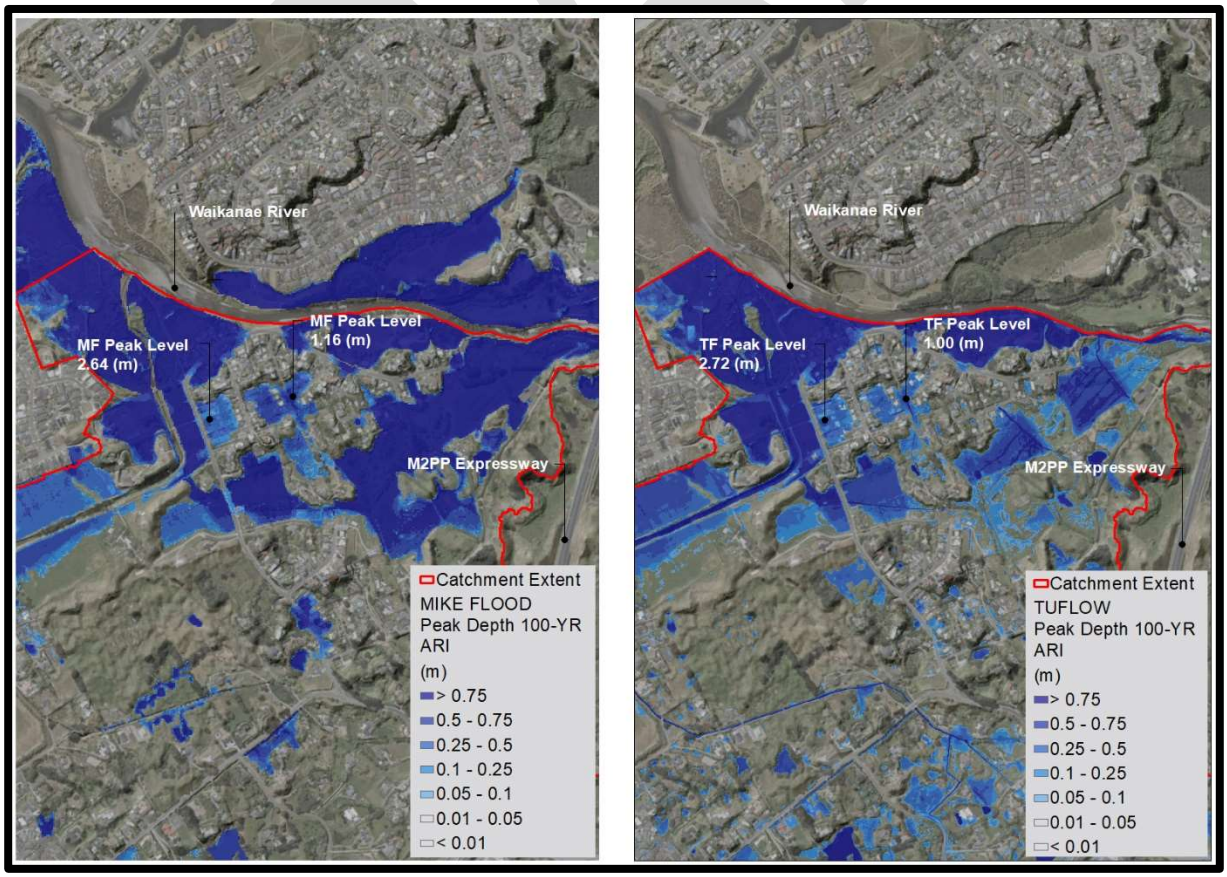


Figure 17. Mazengarb sheet 6 – peak water level results compare MIKE FLOOD verses TUFLOW.

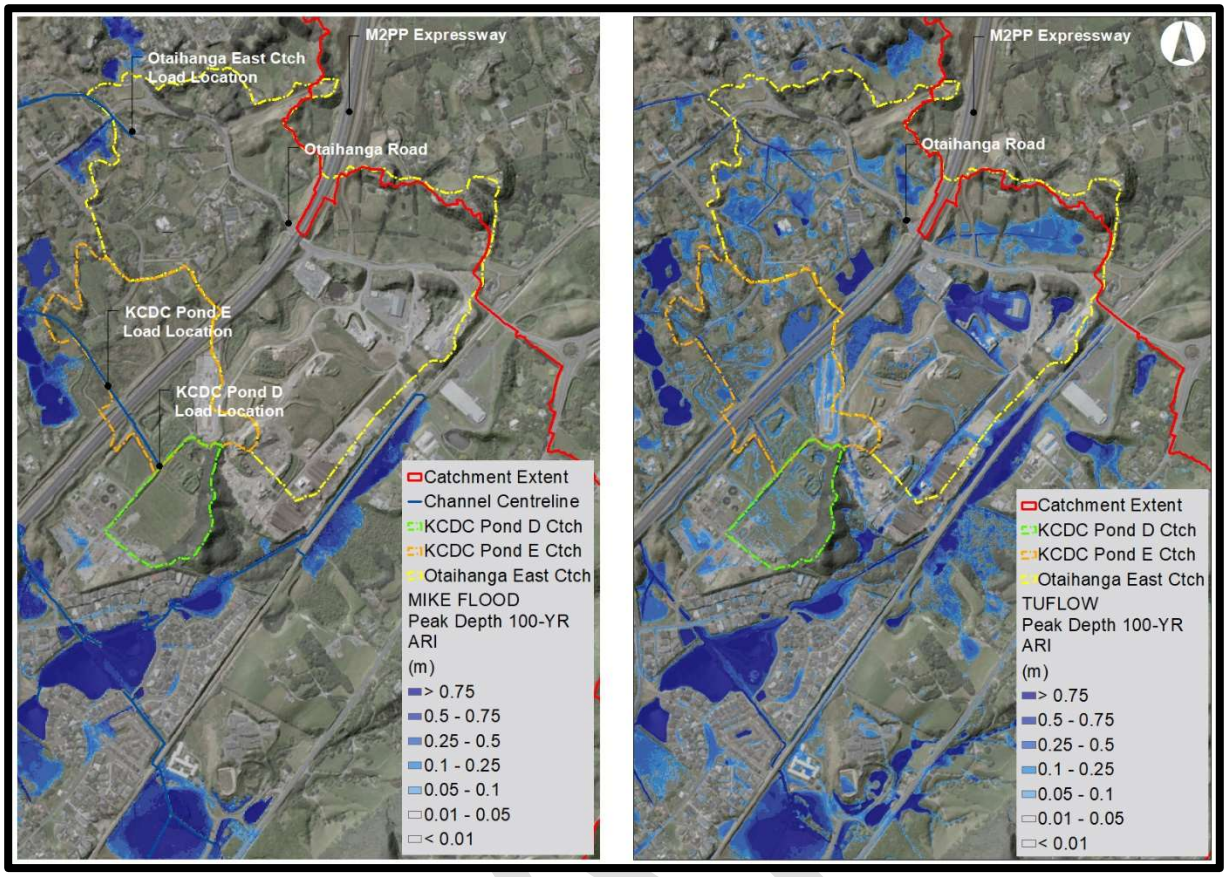


Figure 18. Difference in ponding as a result of modelling methodology (MIKE FLOOD verses TUFLOW).

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5. Model Validation

5.1. Introduction

To ensure confidence in the Mazengarb hydraulic model build a process of validation has been undertaken against two historic rainfall events with comparisons made between modelled predictions and actual observations of the event in the field.

This calibration process allows for the hydrologic parameters in the model to be revised to better reflect local conditions. It also provides a check on the construction of the model as it can highlight areas where flooding may have been recorded where it is not represented by the model and vice versa.

5.2. Flood Events

The Mazengarb model has been validated against two significant historic rainfall events.

- May 2015
- December 2021

The basis for the validation has come from several sources including.

- KCDC flood incidence database
- Observations
- Public reports
- Field observations

To understand the nature of these two rainfall events, historic rainfall and ground water data was collated and analysed. Three rainfall gauges were analysed, Paraparaumu Aero*, Te Horo, and Waikanae Water Treatment Plant (Figure 20). This rainfall gauge data was sourced from Cliflo and captured ~80 years of rainfall data, as shown in Table 12.

Table 12. Gauging station period

GAUGE STATION	PERIOD OF DATA COLLECTED
Paraparaumu Aero EWS (E04995)	1996 - 2023
Te Horo Wetland at Shoveler Lagoon	2009 - 2023
Waikanae Treatment Plant	1995 - 2023

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5.2.1. May 2015

On the 14th-15th of May 2015 there was a significant rainfall event which affected much of Kāpiti Coast. This was a high intensity event with 6-, 12-, and 24-hour peak rainfall depths all more than the 100-year ARI at the Paraparaumu Aerodrome, as shown in Table 13.

Table 13. May 2015 peak rainfall, return period at Paraparaumu EWS (E04995).

TIME (HRS)	PEAK RAINFALL (MM)	RETURN PERIOD (ARI)[3]
1	31 (0430 14/5 – 0530 14/5)	20
2	42 (0405 14/5 – 0605 14/5)	20
6	91 (0405 14/5 – 1005 14/5)	100+
12	120 (0220 14/5 – 1420 14/5)	100+
24	153 (0220 14/5 – 0220 15/5)	100+
48	163 (2320 13/5 – 2320 15/5)	60-80
72	182 (2200 11/5 – 2200 14/5)	80

The rainfall depths at the three key gauging sites are shown in Figure 19. The storm lasted approximately 28 hours and had a total depth of 91mm (Te Hapua) to 157mm (Paraparaumu Airport). The location of the three rain gauges is shown in Figure 20.

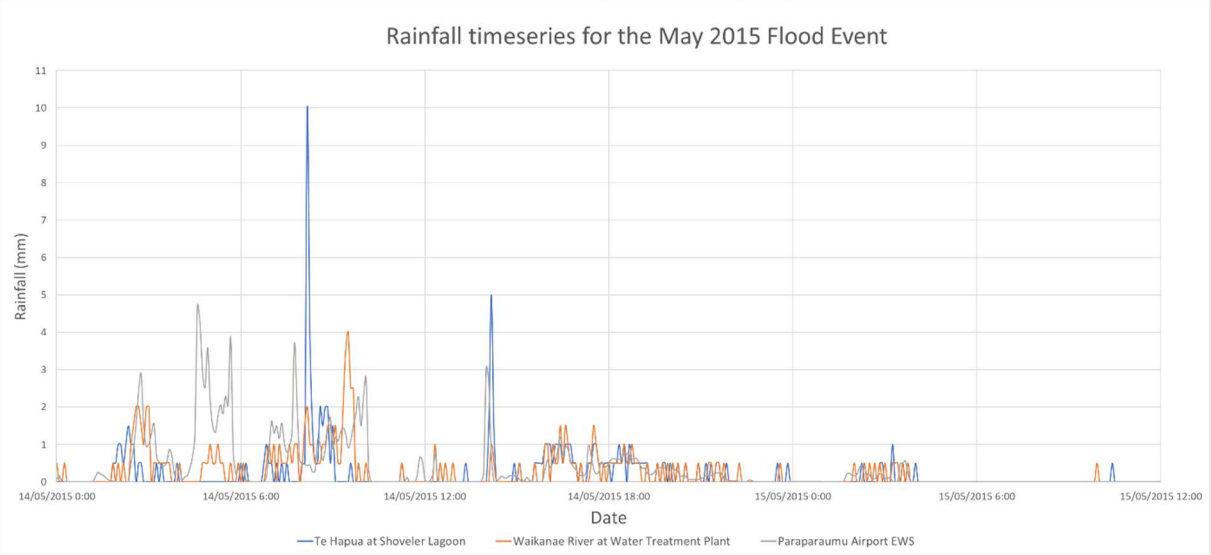


Figure 19. Rainfall depths at three gauging stations.

[3] Return period (ARI) are based on NIWA HIRDS V4.

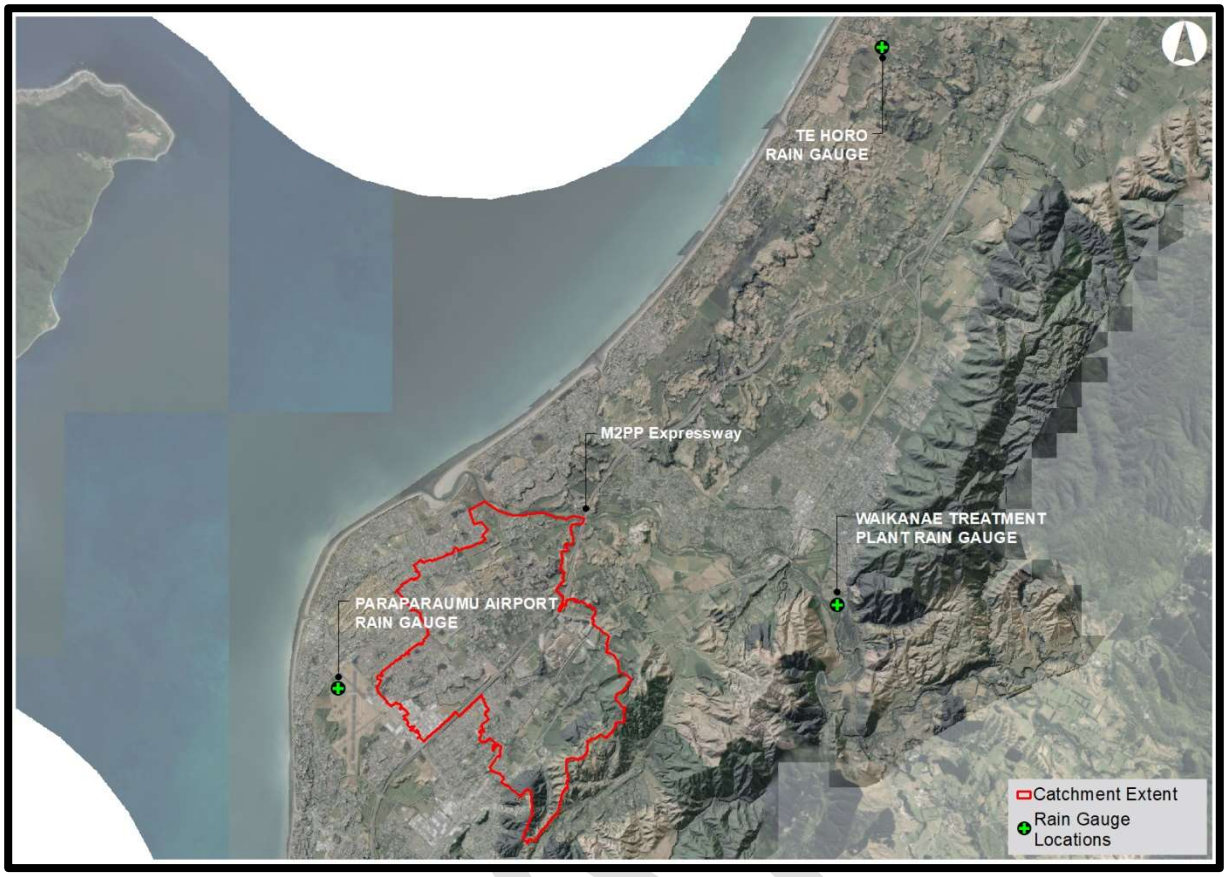


Figure 20. Rain gauge locations.

This rainfall event was significant enough to generate several flooding complaints to the Council which are spatially recorded in the incidence database as shown in Figure 21. The records for this event are descriptive in nature, "*flooding entering garage at number 27*", and largely do not include photographic evidence showing flood depth and extent.

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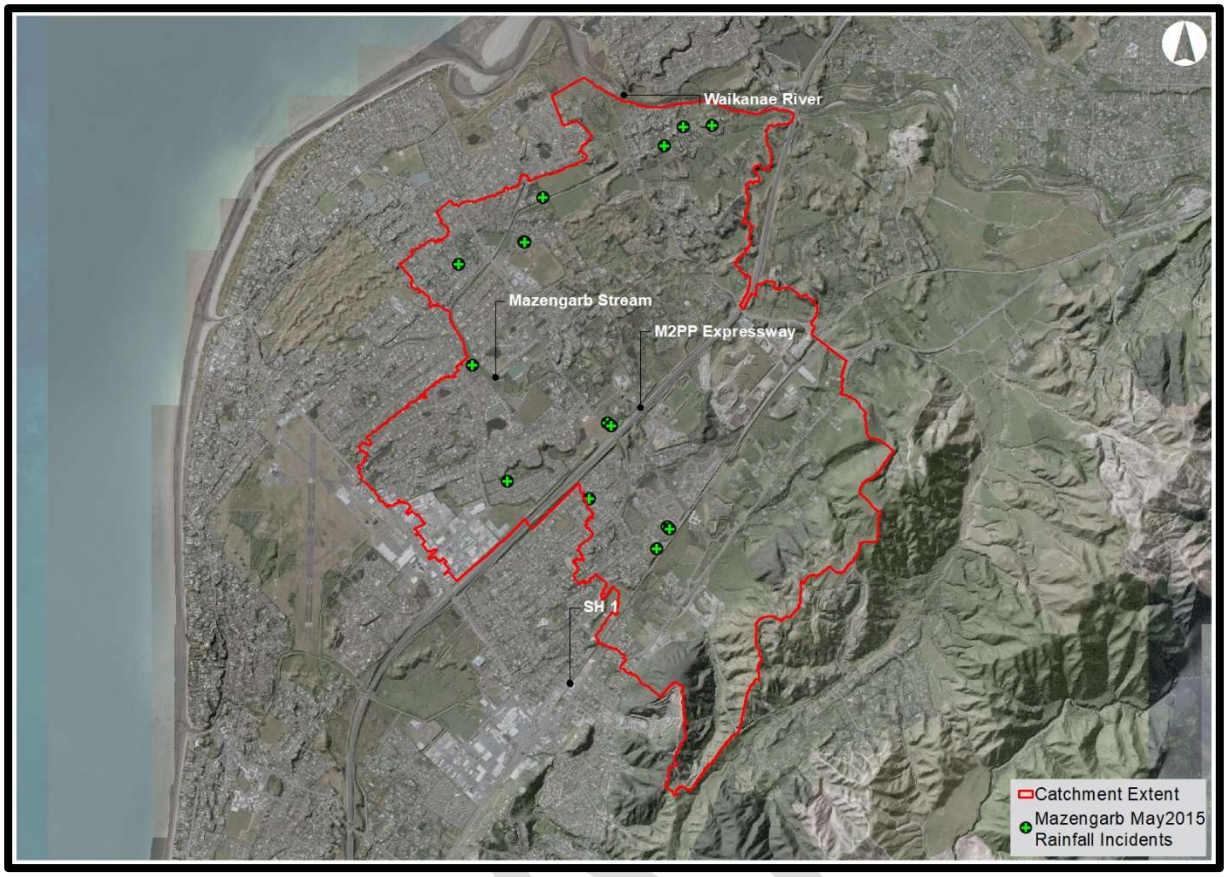


Figure 21. May 2015 Council complaints database locations.

5.2.2. December 2021

On the 5th-8th of December 2021 there was a significant rainfall event which affected much of Kāpiti Coast. This was a moderate intensity event, with very high volume over the longer time periods with 6hr-, 12-, 24-, 48-, and 72-hour peak rainfall depths in the order of 20-40 year ARI at the Paraparaumu Aerodrome as shown in Table 14. This rain fell after a long period of wet weather which meant catchments had high antecedent conditions (which for much of Kāpiti responds to high groundwater levels).

Table 14. Dec 2021 Peak rainfall, return period at Paraparaumu EWS (E04995).

TIME (HR)	PEAK RAINFALL (MM)	RETURN PERIOD (ARI)
1	18 (0500 6/12 – 0600 6/12)	2-5
2	29 (0425 6/12 – 0625 6/12)	5
6	63 (0410 6/12 – 1010 6/12)	10-20
12	96 (0155 6/12 – 1355 6/12)	30
24	111 (0100 6/12 – 0100 7/12)	20
48	144 (2100 5/12 – 2100 7/12)	30
72	148 (1755 5/12 – 1755 8/12)	20

The rainfall depths at the three key gauging sites are shown in Figure 22. The storm lasted approximately 52 hours and had a total depth of 143mm (Paraparaumu EWS) to 168mm (Waikanae River at Water Treatment Plant) depending on rain gauge location.

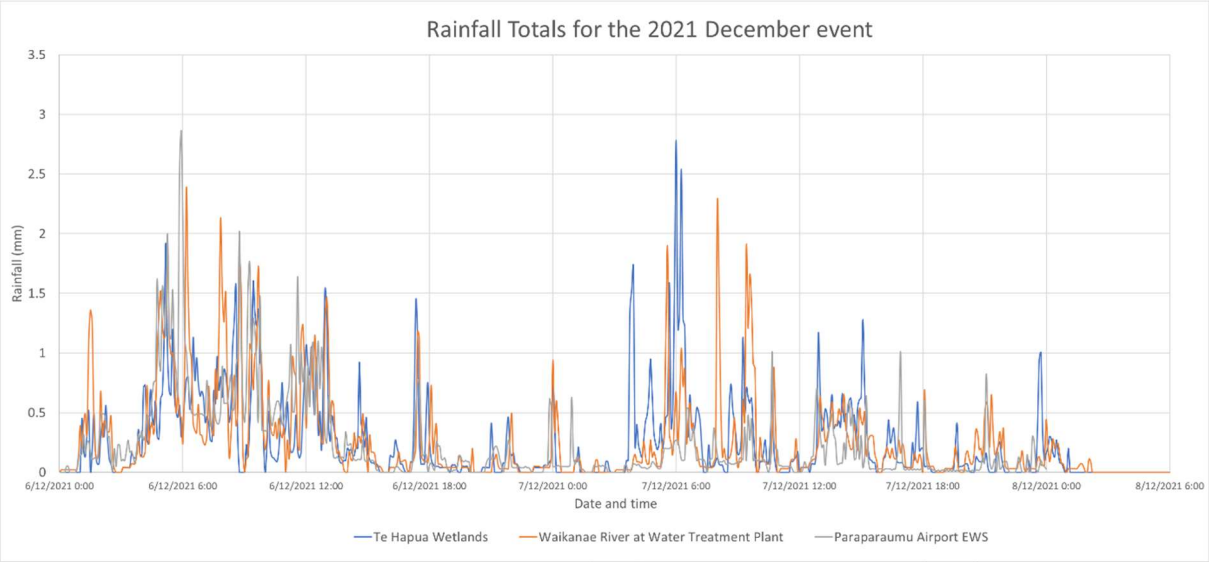


Figure 22. Rainfall depths at three gauging stations.

While not as significant as the 2015 event, the 2021 event was significant enough to generate several flooding complaints to the Council which are spatially recorded in the incidence database as shown in Figure 23.

There was also work undertaken by the Councils consultants to gather time stamped photographic evidence for model validation/calibration. While the evidence collected was not exhaustive, nor was it collected at the peak of the storm, it does provide a sound basis for validation of the model.

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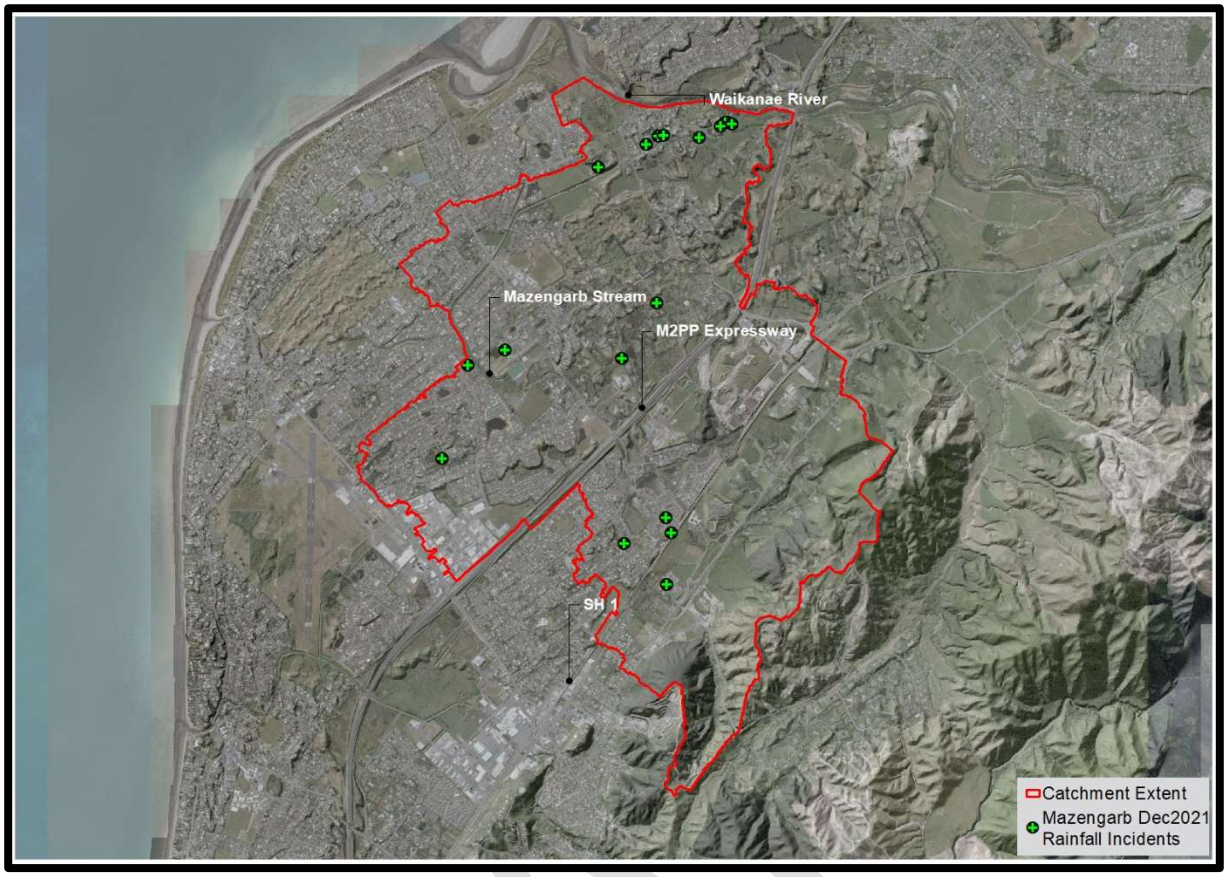


Figure 23. December 2021 Council complaints database locations.

For each recorded complaint there is varying levels of information recorded in the incident database system. An example of an affected property showing caller description and modelled peak flood depth for the 2015 rainfall event is shown in Figure 24.

An example of an affected property showing description, modelled peak flood depth and photographic evidence of flooding for the 2021 rainfall event is shown in Figure 25.

As part of the model validation each of the complaints has been investigated to ensure the flooding can be explained and replicated by the model.

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REPORTED FLOOD INCIDENT (MAY 2015 EVENT)	
Affected properties	14 and 16 Georgia Grove
Caller description	14 and 12 maybe 10 Georgia Grove Paraparaumu require sandbags. Right away is just below knee deep and starting to come into properties. Water getting closer to house - less than a meter away to coming into the garage which is attached to the house. Home by self with 10-year-old. Any possibility for sandbags at this property.
Description of modelled flooding	The model shows flooding, areas affected are situated in low lying areas.
MODEL RESULT (MAY 2015 EVENT)	

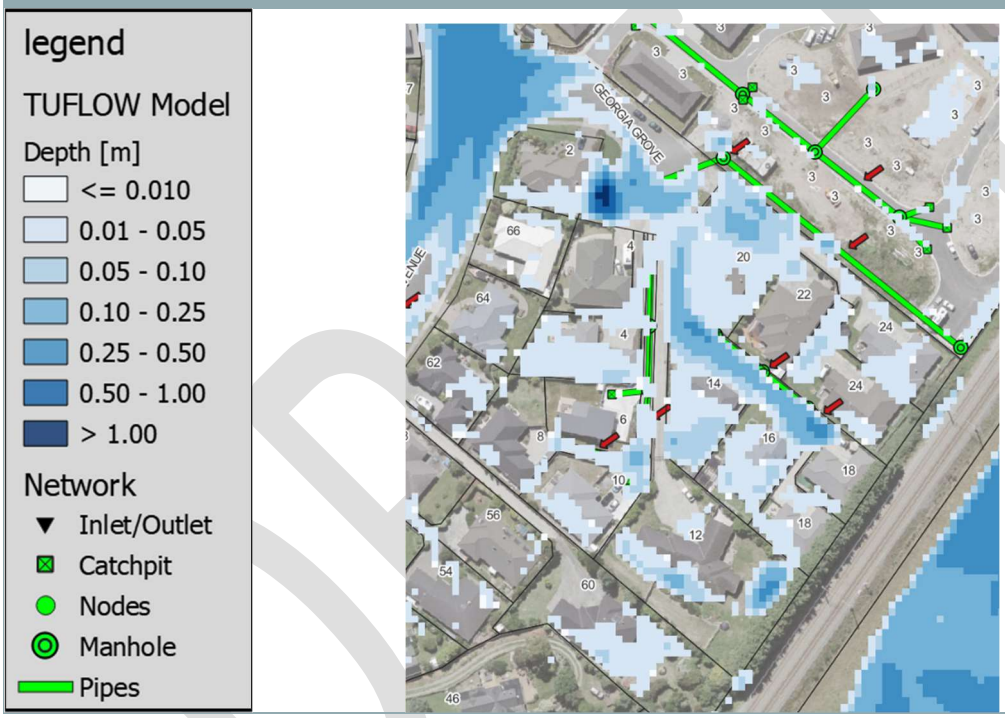
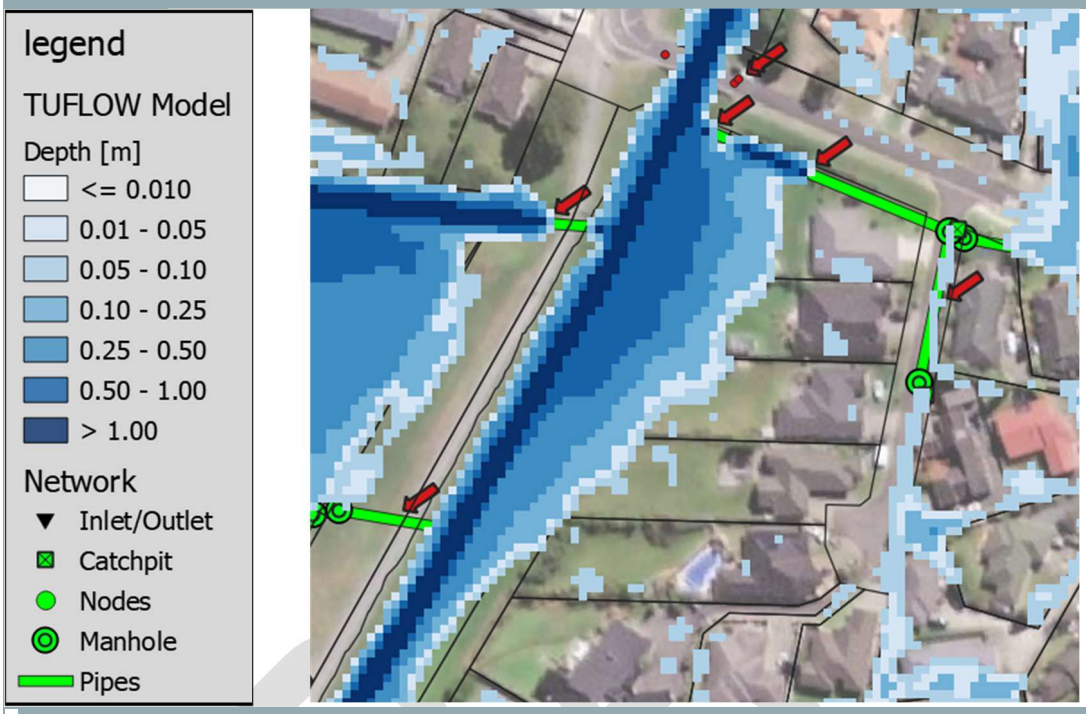


Figure 24. Mazengarb model results.

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REPORTED FLOOD INCIDENT (DEC 2021 EVENT)	
Affected properties	Wood Leigh
Description of modelled flooding	Flooding from open channel filling low lying area.

MODEL RESULT



PHOTOGRAPHIC EVIDENCE (DEC 2021 EVENT)

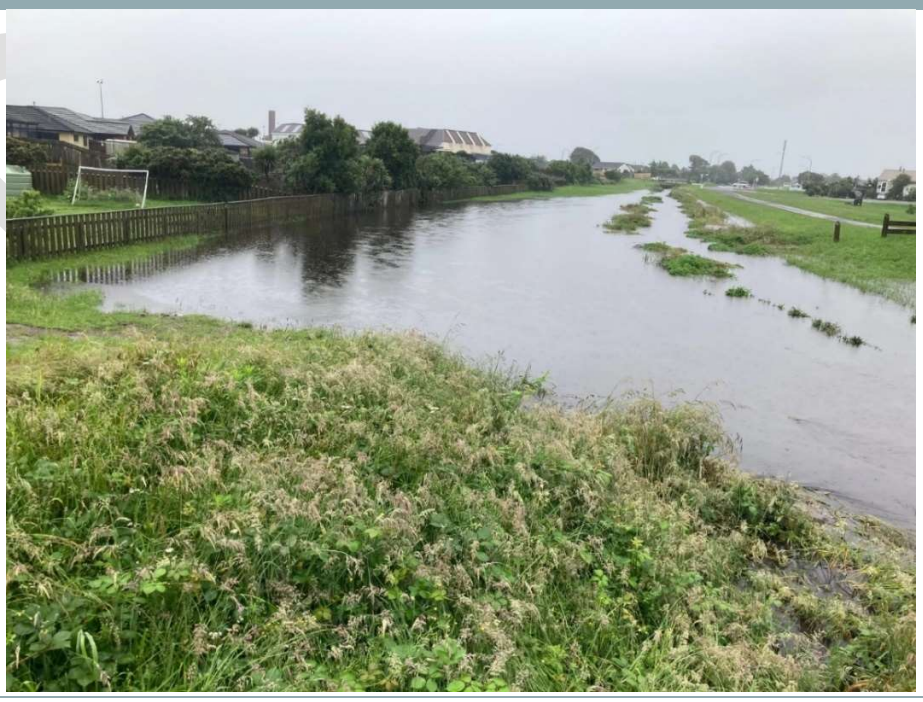


Figure 25. Mazengarb Stream flooding – Wood Leigh

5.3. Validation

The overall approach to model calibration, validation, and verification is detailed in the Kāpiti Flood Hazard Management Methodology Report.

There is some historic low flow gauging data from the Mazengarb Stream at Scaife Drive that was considered for use in model calibration, however this gauging data was for a short period of time, was unrated, and did not include peak flows required for calibration of the catchment model.

Validation of the Mazengarb catchment is based on recorded historic flood complaints. Council holds flood complaints going back to 2015, however these are largely not matched to photographic evidence. For the December 2021 flood event photographic evidence was collected and this provided additional context for model validation.

Validation is an iterative process to align model results with recorded flooding. The Mazengarb was our first validated catchment in the modelling programme and many learnings from this validation were carried through to other models. For the Mazengarb catchment the model went through five iterations with the following changes made to the model through this process, refer Appendix B.

Rainfall – The transition to a rain on grid methodology required some adjustment of the infiltration parameters to match the measured local soil infiltration rates, as discussed in the Kāpiti Flood Hazard Management Methodology Report. Some adjustments were also made to the hill catchment runoff parameters after the calibration of the Wharemauku Stream which informed the Mazengarb validation.

Roughness - The roughness of the stream corridors was updated from a constant roughness value of 0.03 across all stream corridors to classified roughness values for each individual stream corridor ranging from 0.025 to 0.08. This update was applied to better reflect the unique characteristics of each stream reach and was based on site walkover and aerial data.

Tidal Boundary - The tidal data was adjusted by shifting the timeseries data back 25 minutes. This was necessary as the available tidal data sourced at the Mana Cruising Club gauge in Porirua had a significant timing difference with the Waikanae River harbour mouth resulting in delayed flood results.

Network Improvements – In some areas the modelled networks were not functioning as expected and/or had missing data. These areas were investigated and resolved and then re-tested in the model.

Digital Elevation Model – In some cases there were areas where earthworks have been undertaken since the last version of the LiDAR (2017) was secured by the Council. Where these were identified, the DEM was updated to include these anomalies.

Three examples showing the comparison of the impact of model changes between the initial model iteration and the final model iteration utilising photographic evidence from the December 2021 event are shown in Figure 26 - Figure 28.

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Figure 26. Guildford Drive model results comparison (left- initial model results, right- final model results).

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Figure 27. Wood Leigh model results comparison. (left- initial model results, right- final model results).

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Figure 28. Makora Road and Otaihanga Domain model results comparison. (left- initial model results, right- final model results).

In its final version the model achieved a good calibration with recorded flooding. It is important the Council continue to collect physical date stamped evidence of larger storm events to enable adequate verification of the validated model into the future.

6. Recommendations

The model validation has provided confidence in the way the model performs for the Mazengarb Catchment. It is worth noting that some areas of groundwater flooding in the catchment are expected to worsen over time with climate change and several low-lying sites with no formal drainage will be affected by this.

The model has been developed to a high level of detail using GIS and DEM data supplied by KCDC, supplemented with as-built data and engineering judgement were deemed necessary.

6.1.1. Recommendations

The following recommendations regarding the model build are suggested.

- Continued development and maintenance of the model is recommended as additional information on stormwater network assets become available.
- The model should be updated to the latest 2021 LiDAR data.
- The model should be updated from Wellington vertical datum 1953 to New Zealand VD2016 as the use of the more recent vertical datum will become more prevalent in the future.
- The model should be audited periodically as modelling software and best practice methodologies evolve.
- Flood incident data, such as surveyed flood levels, should be collected across the catchment during large storm events.
- Measured data, such as stream and pipe network flow gauging, should be carried out within the catchment and used in future model validations.
- Some improvements could be made to the groundwater model to the benefit of the model. This is particularly the case around some existing urban waterways that are not well represented in the groundwater model.

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Appendix A – Peer Review Memo 2021 & 2023

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Our Ref: L.B24364.001_Mazengarb_Peer_Review.docx

2 November 2021

Awa
Level 1
1 Ghuznee Street
Te Aro
Wellington 6011

Attention: Tony Trueman

RE: MAZENGARB PEER REVIEW

BMT has been engaged by Kapiti Coast Regional Council (KCRC) to undertake hydraulic model reviews of seven stormwater flooding catchment models. The models are being developed by Awa Environmental Ltd. (Awa) and use TUFLOW software.

This letter documents BMT's peer review of the Mazengarb catchment. The model has been developed for use in simulating design floods noting that at the time of this review the model has been developed but the design hydrologic parameters have not been finalised. It is therefore understood that the supplied results are subject to change.

Review Methodology

The review is of the supplied TUFLOW hydraulic model and covers the following aspects:

- General model schematisation and parameterisation
- Schematisation of structures
- Hydraulic roughness parameters
- Model results including general model heath, stability and mass balance.

The review does not cover hydrologic modelling except insofar as the application of pre-determined hydrologic inflows applied to TUFLOW. The review does also not provide any comment or opinion on how model results are analysed, used or interpreted in any ongoing assessment.

Review Limitations

In preparing this report, BMT has relied upon, and presumed accurate, information (or absence thereof) provided by Awa. Except as otherwise stated in this review, BMT has not attempted to verify the accuracy or completeness of any such information. If the information is subsequently determined to be false, inaccurate or incomplete, then it is possible that our observations and conclusions as expressed in this review may change. Furthermore, BMT has undertaken only limited checking of re-running the supplied flood model with a focus on ensuring that the supplied model includes all the necessary inputs required for it to run. It is assumed that the results provided by Awa correspond to the definitions in the control file provided for the model run.

Supplied Data

The TUFLOW model including inputs, log files, results were supplied along with a covering letter that provides a summary of the modelling (*MazengarbCoverLetterForPeerReview_v0.2.pdf* dated 20 October 2021).

The supplied Tuflow control file (TCF) is:

Mazengarb-2017-2130_1pcAEP_T5pcAEP.tcf

Review Findings

Modelling Approach

The extent of the hydraulic model is just over 8km^2 and covers the majority of a small tributary catchment of the Waikanae River. A significant proportion of the tributary catchment is urbanised and includes a network of small watercourses (typically 2m to 6m wide) and lakes.

The approach taken to model the catchment runoff is to represent catchment runoff from the upper slopes using a separate hydrologic model. The runoff hydrographs from this model are then applied as external boundaries to the TUFLOW model. The remaining catchment area is within the TUFLOW model extent and runoff is generated using a rain on grid approach.

The downstream boundary of the model is the Waikanae River, a short reach of which is modelled in 1D to generate an appropriate tailwater condition.

Sub grid sampling (SGS) is enabled in the model which is a TUFLOW feature allowing the model to make maximum use of the underlying terrain data. Drainage channels and other features of the landscape can therefore be represented in the model to the same degree at which they are represented in the underlying terrain data.

The stormwater network (pits and pipes) is included within the model as a 1D network dynamically linked to the 2D domain. This 1D network includes representation of soakaways within the catchment.

Overall the adopted modelling approach is considered to be appropriate for the flood study. Use of a rain on grid approach in combination with the high resolution terrain model will be better at capturing urban drainage flow paths than could likely be achieved using a separate hydrologic model to generate inflow hydrographs across the model domain.

General Model Setup

The model is configured to run using TUFLOW HPC in software build 2020-10-AA-iDP-w64. The double precision version of the model software is used. Whilst double precision is still recommended for TUFLOW Classic simulations that utilise direct rainfall, it is not considered necessary for TUFLOW HPC simulations whose solution scheme inherently conserves model mass. Awa may see improved simulation times and reduced memory requirements if the model is switched to use single precision, although there will be little to no change in model results. There is also now an updated TUFLOW software release (2020-10-AB) which contains a number of bug fixes. Our general advice is to use the latest available release.

The overall model setup is configured using a standard approach to TUFLOW folder/file structures.

The supplied TCF file has the modelled event hard coded into the tcf file name. This approach will require multiple tcf files for different modelled events. Whilst this approach is appropriate, a more efficient approach is to utilise TUFLOW's event and scenarios feature which allows multiple events to be run from a single tcf. If model updates are later required, only the one set of model files will then need to be updated

A cut of depth of 0.01m is applied to mapping which is considered suitable for direct rainfall models. Awa may want to test a larger cut off depth if a depth of 0.01m results in significant 'speckle' across the spatial result grids.

Model Topography

The model cell size is specified as 2m. The base topography in the model is represented by a DEM of 2m grid resolution which covers the whole of the model domain and a second grid of 0.5m resolution representing the bathymetry of the watercourses. TUFLOW's sub-grid-sampling feature is enabled with a sample distance set to 2m for the base DEM and 0.5m for the bathymetry DEM. In the case of the base DEM, SGS will make minimal difference as the model cell size matches that of the input DEM. For the bathymetry, SGS will allow for additional detail of the channel to be captured at a sub-grid scale (sub 2m).

Minor adjustments have been made to the topography to adjust bed elevations at the upstream and downstream faces of hydraulic structures.

Elevations of buildings have also been adjusted with a TUFLOW Z-shape feature. An elevation has been specified in the 'Z' attribute and values of 0.1m for residential and 3.0m for commercial and industrial are then added. In this way residential buildings will form a partial obstruction to flow but may be overtopped whereas commercial and industrial buildings are unlikely to be overtopped. Commercial and industrial buildings are effectively assumed impervious to floodwater and so there is a potential reduction in floodplain storage. This has the potential to generate results that are slightly conservative in the sense of giving higher flood levels.

Bridges

The supplied covering letter mentions that bridges are included in the model as layered flow constrictions, but it is noted that there are no layered flow constrictions in the supplied model. The majority of bridges are represented as culverts which is a standard approach for smaller bridges such as the ones included in the model. Very minor bridges are not represented with the bathymetry effectively removing them from the DEM. This is also appropriate. One noted exception was for a bridge on Wood Leigh road which is not represented in the model but appears relatively sizeable based on available data (see Figure 1).



Figure 1 Bridge on Wood Leigh Road which is not represented in the model

Rainfall Losses/Infiltration

The model is set up to include infiltration. A groundwater level of 1.32m is applied across the model domain. A detailed representation of soil types is included and the Green Ampt method of infiltration is applied. The covering letter notes that the infiltration parameters were developed for KCDC as part of the study and are beyond the scope of this review. The implementation within TUFLOW is correct.

Boundaries

Gridded rainfall has been applied across the model domain. Runoff from the catchment area which is upstream and outside of the model domain (hill catchments) is determined using a separate hydrologic model.

Whilst BMT is not reviewing the rainfall depths applied, the model is configured correctly to apply the gridded rainfall.

The hill catchment runoff is applied to the 1D domain (representing the stormwater network) at 6 locations via QT boundaries. Awa has noted that additional hill catchment inflows will also be applied to the 2D domain via source area (SA) polygons but these are not currently included within the model. A supplied 'SA' layer was included with the model and it is assumed this layer will be used to specify the hill catchment inflows to the 2D domain. This layer appears to be appropriate, noting that TUFLOW will apply flow to the lowest cells within each of the respective SA polygons.

The downstream boundary to the 2D domain is a short (approximate 1.5km) length of the Waikanae River which is modelled in 1D and dynamically connected to the floodplain. This allows the river level to vary in time and space along its boundary with the local Mazengarb catchment boundary. The 1D length of modelled river has a QT inflow at the upstream end and an HT boundary at the downstream end. The 1d_nwk layer representing the channel is digitised from downstream to upstream and results in negative flows being reported although this does not have any bearing on the water levels. There is some minor instability in the 1D channel at the very start of the simulation, but this does not affect the peak flood levels.

Overall the setup of the downstream boundary is appropriate and causes a large amount of inundation across the low lying parts of the downstream catchment

Pit/Pipe Network

Overall the pit and pipe network appears to be set up appropriately with a few minor issues noted. There are some instances where the ends of pipes show no connection to the 2D domain (as shown by the 1D_2D check file). Figure 2 below contains an example where the yellow squares show connections between the 1D and 2D domains. The red circles show locations where a connection is expected but where one is not present (upstream ends of pipe KSWP009006 and pipe KSWP009004). It is noted that there are digitised manholes at these locations possibly the intention is that these should be pits.

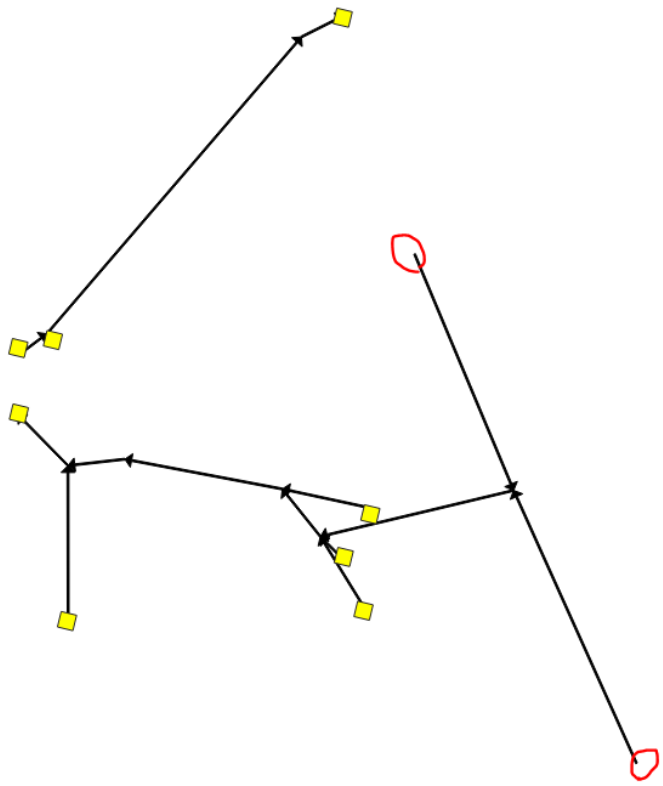


Figure 2 Potential missing model pits (pipes KSWP009006 and KSWP009004)

The TUFLOW messages layer highlights 64 instances of ‘Warning 1313’ indicating that a pipe effectively has either no upstream pipe connection or no downstream pipe connection. It appears the majority of instances are where the inlet pipes have inverts above the obverts of outlet pipes and so the pipes are effectively hydraulically disconnected. It is recommended that these warnings are reviewed and the model updated as appropriate.

Model Results

The model result grids contain values across the entire model domain giving the appearance that no cutoff depth filter is applied despite two map cutoff depths being specified in the tcf as follows:

Map Cutoff SGS == Minimum

Map Cutoff Depth == 0.01

The use of SGS means that the traditional ‘map cutoff depth’ command is handled differently by TUFLOW compared to older software versions and refers to the depth above the lowest SGS sampled elevation within each cell. We generally find that a higher map cutoff depth value is required when using SGS with direct rainfall models. With both Map Cutoff SGS and Map Cutoff Depth specified, the map output will be the higher of the two thresholds. As, in this case, Map Cutoff SGS == Minimum, then the ‘map cutoff depth’ of 0.01 will be the higher value but noting that this is only 0.01m above the lowest elevation in each cell.

One issue identified with build 2020-10-AA is that the default SGS depth interpolation approach was ‘Exact’ whereby the depth is based on the elevation at the cell centres. When this is used in combination with a different depth ‘datum’ for mapping i.e ‘minimum’, this can result in areas which show as ‘wet’ in the depth output but have a depth of 0. This appears to be happening in the Mazengarb model.

This issue was addressed in 2020-10-AB whereby the SGS depth interpolation approach and the Map Cutoff SGS commands have been combined into ‘SGS Depth Output’.

Our recommendation is to use the 2020-10-AB release and adopt a depth datum other than minimum eg SGS Depth Output == Cell Average. This can be used in combination with ‘Map Cutoff Depth == 0.01’ although Awa may wish to experiment with a higher threshold values. ‘Map Cutoff SGS’ would not be required when using the ‘SGS Depth Output’ command. The ‘SGS Depth Output’ command will only apply to depth dependent outputs (e.g. d, q, hazard outputs). By default the peak water level output will apply to the full model extent showing all partially wet cells as being wet. For a direct rainfall model, this will produce a grid covering the majority of the area across which direct rainfall is applied. Awa may therefore want to include the tcf command ‘SGS Map Extent Trim == All’ to also trim the peak water level grid to the extent generated using the specified cutoff depths

If use of build 2020-10-AA is retained then we recommend that Map Cutoff SGS == ‘Exact’ is used, possibly with an additional second argument such as “Map Cutoff SGS == Exact | 0.01”.

Model Health / Stability

Checks have been performed on the overall health of the model. TUFLOW HPC is inherently mass conserving meaning that cumulative mass error is not an issue for a purely 2D model. Checks show no notable mass error between the 1D and 2D domains.

Other checks have focused on whether there are any spurious results, for example spikes in water level, and that the adaptive timestepping is performing satisfactorily i.e. no bouncing of timesteps as the model struggles to obtain a solution. Overall, the model results show a stable model with only minor instabilities affected a few 1D elements and not at the peak of the flood (see example in Figure 3). If these instabilities are a potential issue for how the results are to be used, they can usually be stabilised by the provision of additional nodal storage at the upstream and downstream ends of the affected pipe.

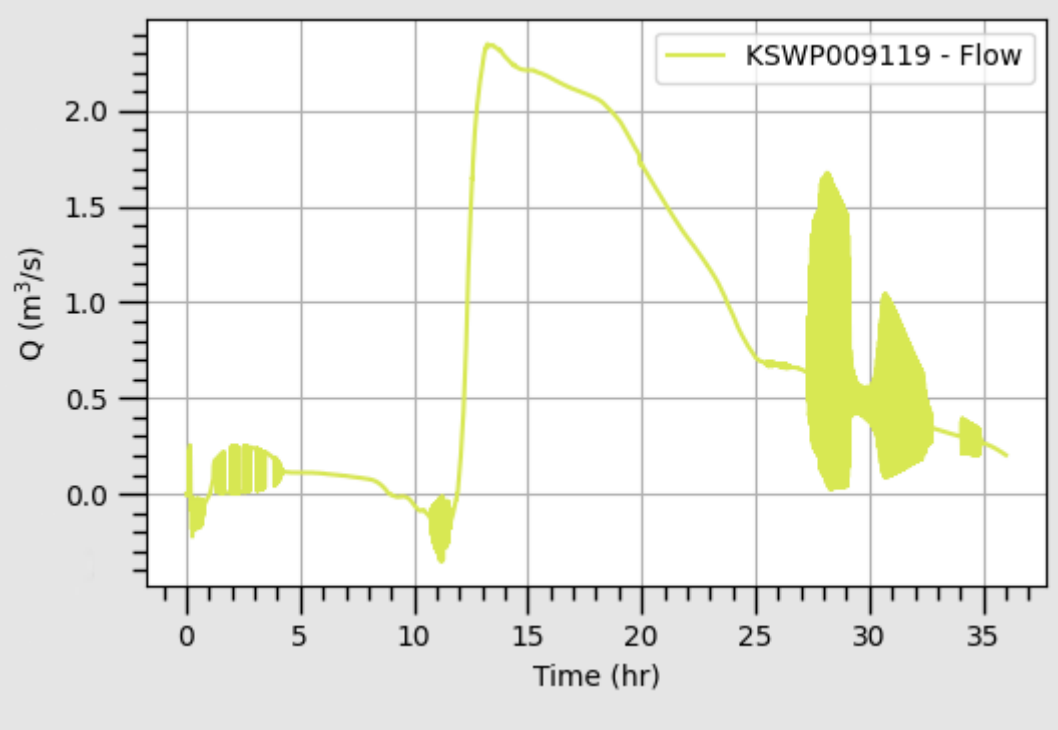


Figure 3 Instances of instability which do not affect the peak flood levels

In TUFLOW HPC the maximum timestep is governed by three control numbers as follows (with the limiting number in brackets):

- Courant Number, Nu (<1)
- Wave Celerity Number, Nc (<1)
- Diffusion Number, Nd (<0.3)

A plot of the control number values over time is shown in Figure 4 and shows that the limiting process is Nc or Nd with the latter occurring during the period of increased rainfall.

Figure 5 shows the variation in model timestep throughout the 36 hour period of simulation. Following initialisation, the timestep remains healthy throughout with no bouncing or notably low values. The smallest timesteps occur from a period of around 12 to 28 hours. This corresponds to where the TUFLOW's diffusion control number (Nd) controls the timestep and is likely to do with the peak flows leading to greater water depths. The model run time for the simulation results provided is approximately 13 hours. In our opinion this is a reasonable simulation time and can possibly be further shortened by use of the single precision TUFLOW executable.

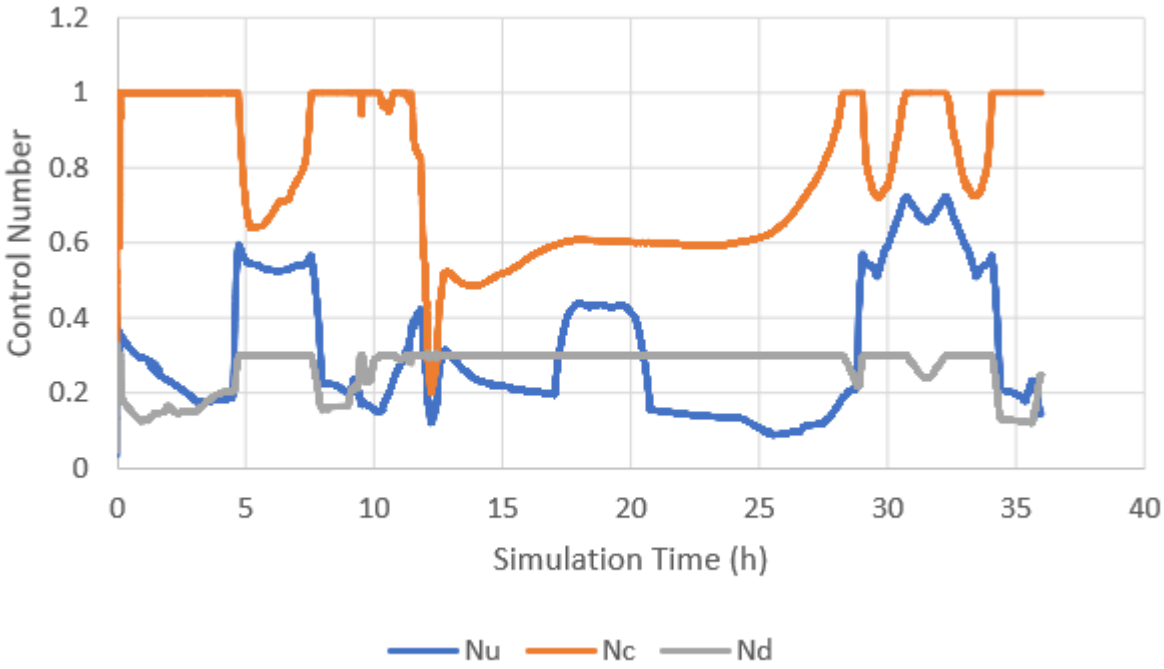


Figure 4 TUFLOW HPC Control Numbers During Simulation

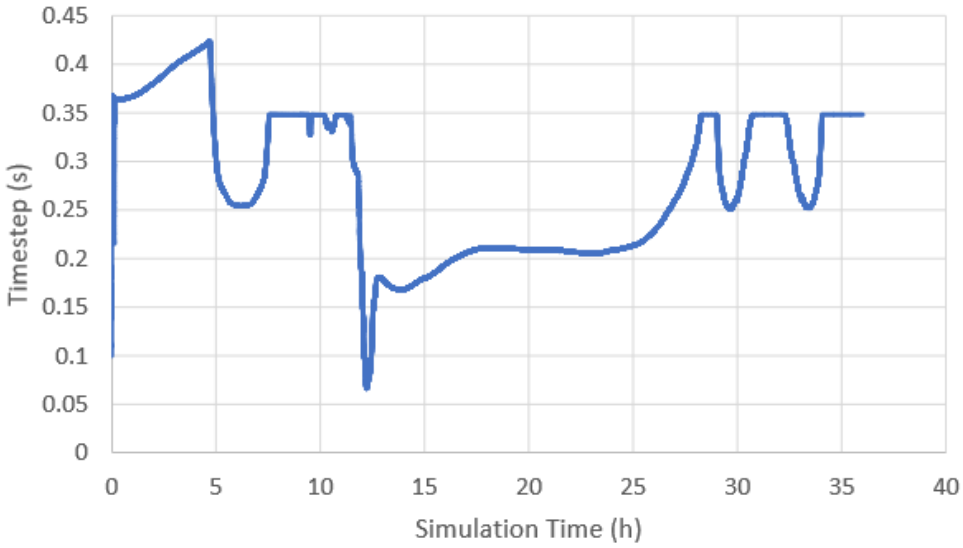


Figure 5 Model Timesteps

Conclusions

BMT has reviewed the supplied model and conclude that, subject to minor updates, the model is fit for purpose in establishing design flood levels for local catchment runoff across the area of interest.

Our recommendations are summarised in Table 1 below.

Table 1 BMT Model Review: Summary of Recommendations

ID	Recommendation
1	Recommended to use the latest TUFLOW build 2020-10-AB and consider using the single precision version for improved simulation times.
2	Consider using TUFLOWs events/scenarios feature to avoid the need for multiple TUFLOW control files.
3	Consider inclusion of bridge on Wood Leigh Road within model
4	Include external hydrologic (hill catchment) inflows as 2D SA or QT type boundaries within TUFLOW
5	Review pipe network for pipes which have no upstream connections to a model boundary (pit or inflow). The 1d_to_2d check file is useful for this purpose
6	Review instances of 'Warning 1313' in messages layer whereby connecting pipes have offset invert levels to the degree that no hydraulic connection is present.
7	Review SGS depth output options. We recommend that build 2020-10-AB is used with the following output options: SGS Depth Output == Cell Average Map Cutoff Depth == 0.01 ! or desired value SGS Map Extent Trim == All These settings will avoid the majority of the model domain showing as inundated.

BMT is happy to discuss any of the review findings so please don't hesitate to get in touch.

Yours Faithfully
BMT



Barry Rodgers
Principal (Flooding)

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Technical note

Project	Mazengarb Peer Review		
From:	Luana Stefanon, Barry Rodgers		
Date:	21/12/2023	To:	Rita O'Brien Kapiti Coast District Council
Doc Ref:	M.003120.001.00		
Subject:	Peer-Review of Mazengarb Model Build Report		

1 Introduction

1.1. Background

BMT was appointed by Kapiti Coast District Council (KCDC) to undertake a peer-review of the "Mazengarb Model Build Report" prepared by Awa Environmental (AWA) for KCDC.

The TUFLOW hydraulic model of the Mazengarb catchment was reviewed by BMT in November 2021. At that stage, the hydraulic model was setup for design event simulations only and the hydrologic parameters had not yet been finalised.

1.2 Supplied Data

The present peer-review is based on the following documents provided by KCDC:

- Draft "Mazengarb Model Build Report" prepared by AWA for KCDC on 9 November 2023.The provided report summarises the methodology and results of the flood modelling undertaken by AWA in the Mazengarb catchment.
- Mazengarb_100YR_ARI_2130_PeakFloodDepthsOverview.pdf, which includes an overview of the flood map insets prepared for the 100 year ARI 2130 design event simulations.
- Mazengarb_100YR_ARI_2130_PeakFloodDepthsDataDrivenPages.pdf, which includes a series of zoomed-in flood maps covering the whole catchment extent.

1.3 Peer-Review Process

The peer-review covers a high-level technical review of the model for general configuration, parameters and validation performance based on the information included in AWA's report. This review has been carried out by considering best practice in hydraulic model development, as well as compliance with the TUFLOW software manual.

The peer-review focuses on the model setup, validation and design event simulations undertaken using the TUFLOW rain-on-grid model only. The hydrologic analysis performed to estimate the runoff hydrographs from the upper steep sub-catchments of the Mazengarb catchment is described in the *Stormwater Modelling Methodology* report prepared by AWA and does not form part of this peer review.

A review of the TUFLOW model files was undertaken by BMT in November 2021. It was outside of the agreed scope of work to undertake a further review of the updated model setup and structures except insofar as they are documented in the supplied (2023) report.

1.4 Limitations

In preparing this report, BMT has relied upon, and presumed accurate, information (or absence thereof) provided by AWA in their report. Except as otherwise stated in this report, BMT has not attempted to verify the accuracy or completeness of any such information. If the information is subsequently determined to be false, inaccurate or incomplete, then it is possible that our observations and conclusions as expressed in this report may change. It is assumed that the results provided by AWA correspond to the hydraulic model setup described in AWA's report.

2 Review Findings

2.1 General Methodology

The Mazengarb catchment was modelled by applying a combined hydrologic modelling and rain-on-grid (i.e., direct rainfall) approach.

The low-lying and flat portion of the Mazengarb catchment was modelled by adopting a rain-on-grid approach in the TUFLOW model. The rain-on-grid approach features the application of rainfall hyetographs directly onto the hydraulic model grid, and the overland flowpaths are calculated by TUFLOW based on the underlying topography and hydraulic conditions. As such, no separate hydrologic modelling of this portion of the catchment is required.

The upper portions of the catchment are fairly steep and characterised by channelised flows. As such, a hydrologic analysis of these sub-catchments was developed using the Soil Conservation Service Curve Number (SCS-CN) method to estimate the inflow hydrographs to be applied along the upstream boundary of the hydraulic model where the upper creeks cross the hydraulic model boundary.

This general approach is deemed appropriate by BMT and it is also in line with the recommendations provided by BMT's 2021 peer-review.

2.2 Model Setup

Software Release

A discrepancy in the adopted TUFLOW software release has been identified in the report. The *Executive Summary* indicates that the 2020-10-AC release was used to undertake the modelling, whereas *Section 3.1 Model Overview* indicates that the 2023-03-AB release was used instead. We recommend the *Executive Summary* is updated for consistency.

Model Extent

The model extent is deemed appropriate by BMT. A typographical error was identified in Figure 6 caption (please refer to image below), where the dark blue should represent the rain-on-grid extent and the yellow should represent the hydrologic model extent. It is noted that the legend included in the figure is correct.

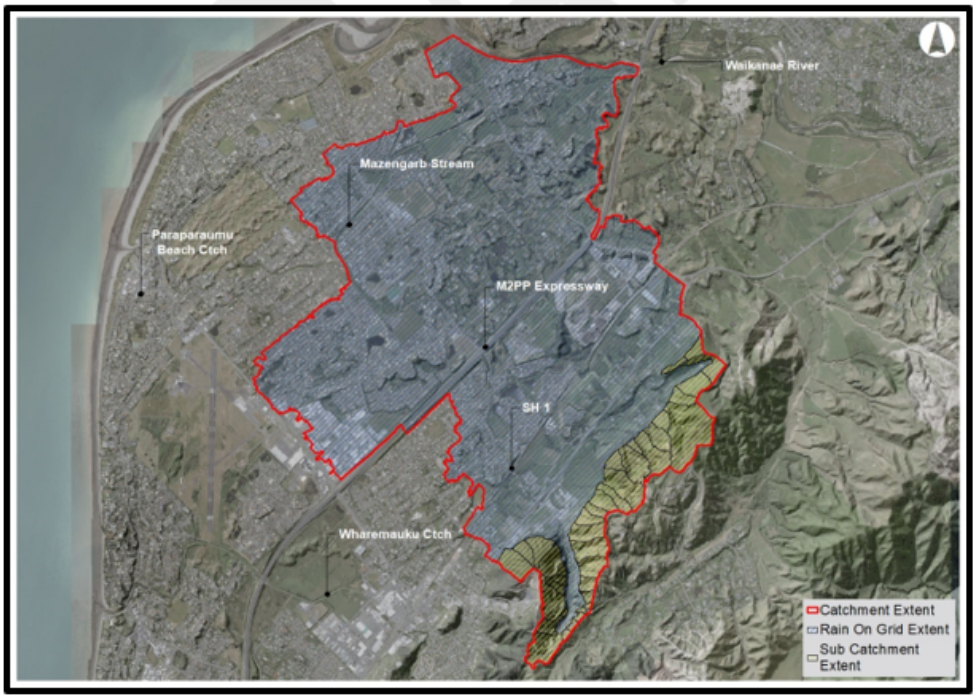


Figure 6. Sub-catchments extent (dark blue) and Rain on Grid extent (yellow).

Grid Cell Size

A grid cell size of 2m was adopted in the hydraulic model and the Sub-Grid Sampling (SGS) feature was activated with a sampling distance of 0.5m to improve estimation of the flow conveyance of small open channels and topography features at a sub-grid level. This approach is deemed appropriate by BMT.

Open Channel Representation

It was not possible to provide a commentary regarding the representation of open channels in the model as only limited detail is provided in the report. The report mentions that the main open channels were represented using SGS at a resolution of 0.5m, and that minor open channels were represented using a resolution of 2m. However, SGS is usually applied to the entire model, therefore, the flow conveyance calculations within all the open channels are based on a 0.5m topography resolution. It is recommended that additional detail is provided on how open channels are represented for example, using LiDAR only or reinforced with breaklines.

Pipe Network & Culverts

The documented representation of the stormwater pipe network and culverts is deemed appropriate by BMT.

Roughness Coefficients

The Manning's n roughness coefficients were applied in accordance with the land-use classification derived from land cover data. The Manning's n coefficients were also refined during the model validation. The Manning's n values applied to each land-use class, pipe materials and within the Waikanae River are within typical ranges set by best industry practice and are deemed appropriate by BMT.

Soil Infiltration
The initial (IL) and continuing (CL) rainfall losses were applied within TUFLOW using the soil infiltration method (i.e., via tsoilf file). The applied IL and CL values vary depending on the land-use, soil type and soil compaction assumptions. This approach is considered thorough and appropriate.

Groundwater
Groundwater level conditions were applied to the model to take into consideration the high groundwater levels resulting from antecedent rainfall events and, therefore, limit the soil infiltration capacity. Please note that no information regarding the groundwater setup within the TUFLOW model was included in the report, therefore, it was not possible for BMT to provide any specific commentary in this regard.

Downstream Boundary Conditions
The downstream boundary of the catchment consists of the Waikanae River, which was represented using 1D ESTRY cross-sections starting from the State Highway 1 bridge to the coast. A water level over time (type HT) boundary condition characterised by a dynamic tide was applied at the downstream cross-section of the river. An inflow discharge was also applied at the upstream cross-section of the Waikanae River at the State Highway 1 bridge. The inflow discharge was taken from previous legacy models of the Waikanae River. This approach is deemed appropriate by BMT.

Upstream Boundary Conditions
The flow hydrographs generated by the upper steep sub-catchments were estimated using the SCS-CN and the Clark Unit Hydrograph techniques. The flows generated by the hydrologic analysis were then applied as inflows to the hydraulic model using TUFLOW 'source-area' (type SA) polygons located along the upstream boundary of the model. This approach is deemed reasonable by BMT.

2.3 Model Validation
The Mazengarb catchment TUFLOW model was validated by comparing the flood extent and levels computed by the model with flood complaints and photographic evidence collected during the historical flood events of May 2015 and December 2021.

For model validation purposes, the May 2015 and December 2021 were simulated in the TUFLOW hydraulic model by applying the rainfall hyetographs recorded at the rainfall gauges during the historical flood events. The spatial rainfall distribution was estimated by applying the Thiessen polygon technique.

During the model validation, refinements to the infiltration parameters, Manning's n values, tide peak timing, pipe network and local topography were undertaken to improve the match of the computed flood extent and levels with the incident records and photographs collected during the flood events.

Given the lack of flood level and/or flow discharge gauge data recordings during the historical flood events, the model validation undertaken by AWA is considerate appropriate and suitable for the scope of this study.

The following typographical issues were identified in the *Model Validation* section of the report:

- Section 5.1 and Section 5.3 are both called *Validation*. We suggest renaming Section 5.1 as *Introduction*.
- The second paragraph of *Section 5.3 Validation* (page 37) mentions December 2019 in lieu of December 2021. This should be amended.
- The fifth paragraph on page 38 (*Section 5.3 Validation*) mentions December 2023 in lieu of December 2021. This should be amended.

We suggest specifying in the report the following additional information:

- The initial rainfall loss values adopted in the simulation of May 2015 and December 2021 events. Figure 7 included in the report shows the continuing loss values only.
- The 'Map Cutoff Depth' value adopted in the model as this parameter can have significant impacts on the computed flood extent and levels and, hence, on the comparison between the computed and observed flood extent.

2.4 Design Event Modelling

Simulation of the 100 year ARI 2130 RCP8.5 climate change scenario was performed as part of this study. The design event simulation was carried out by applying the following assumptions:

- Application of the rainfall using 2 km-resolution grid timeseries. The gridded rainfall was based on HIRDS v4 rainfall depths and a centred nested rainfall pattern.
- Application of a Mean High Water Spring (MHWS) tide at the ocean boundary of the Waikanae River. The MHWS was increased by applying a sinusoidal storm surge and sea level rise offsets.

For completeness we suggest specifying in the report the following additional information:

- The initial rainfall loss values adopted in the design event simulations.
- The 'Map Cutoff Depth' value adopted in the model for the design event simulations.
- The ARI of the inflow hydrograph applied along the upstream boundary of the Waikanae River in order to provide information on the joint probability assumptions made for local (Mazengarb) and regional (Waikanae River) flooding.
- We also suggest including some commentary regarding the flood peak timing compared to the tide peak timing in order to explain whether and to what extent the tide peak timing can affect the flood levels in the Mazengarb catchment.

2.5 Flood Maps

The flood maps shown in "Mazengarb_100YR_ARI_2130_PeakFloodDepthsDataDrivenPages.pdf" are deemed appropriate by BMT.

The flood map included in "Mazengarb_100YR_ARI_2130_PeakFloodDepthsOverview.pdf" is not centred into the page, resulting in the flood map being cut out in the middle along the northern boundary. It is recommended to fix this map by centring the catchment within the figure frame.

3 Conclusions

BMT has reviewed the "Mazengarb Model Build Report" and associated flood maps and concluded that the modelling and report are fit for purpose.

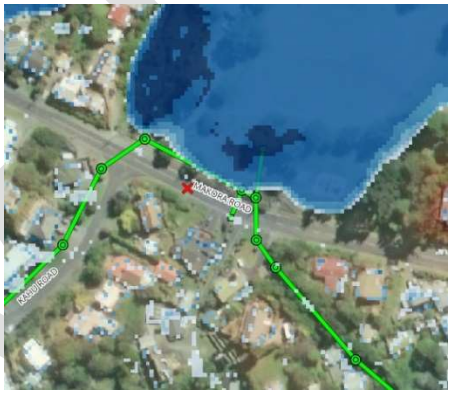
Our peer-review has identified only typographical errors and instances where we recommend providing more commentary and/or explanation regarding the adoption of specific methodology and parameters. A summary of BMT's observations and recommendations is provided in Table 1.1.

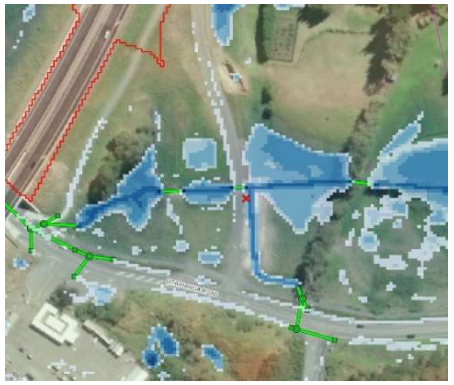
Table 1.1 BMT Model Review: Summary of Recommendations

ID	BMT Observation	BMT Recommendation
1	The Executive Summary indicates that the 2020-10-AC release was used to undertake the modelling, whereas Section 3.1 Model Overview indicates that the 2023-03-AB release was used instead	Please amend/update for consistency.
2	A typographical error was identified in Figure 6 caption, where the dark blue should represent the rain-on-grid extent and the yellow should represent the hydrologic model extent	Please fix the typographical error identified in Figure 6 caption.
3	The methodology used to represent the open channels in the model would benefit from additional commentary.	Please specify the methodology used to model the open channels (e.g., LiDAR only or LiDAR with enforced z-shape polylines).
4	Section 5.1 and Section 5.3 are both called Validation.	We suggest renaming Section 5.1 as Introduction.
5	The second paragraph of Section 5.3 Validation (page 37) mentions December 2019 in lieu of December 2021.	Correct the typographical error.
6	The fifth paragraph on page 38 (Section 5.3 Validation) mentions December 2023 in lieu of December 2021.	Correct the typographical error.
7	Figure 7 included in the report shows the CL values only.	We recommend specifying the IL values adopted in the simulation of May 2015 and December 2021 events, as well as those adopted in the design event simulations.
8	No Map Cutoff Depth value was specified in the report.	We recommend specifying the Map Cutoff Depth parameter adopted in the model validation and design event simulations.
9	The report does not include specifications on the ARI of the flow hydrographs applied along the upstream boundary of the Waikanae River.	We recommend that further information is provided on the ARI of the inflow hydrographs applied to the Waikanae River upstream boundary in order to understand the joint probability assumptions employed in the modelling.
10	The report does not include any commentary regarding the flood peak timing compared to the tide peak timing, and whether and to what extent the tide peak timing affects the flood levels in the Mazengarb catchment.	We recommend including commentary regarding the flood peak timing compared to the tide peak timing.
11	The flood map included in “Mazengarb_100YR_ARI_2130_PeakFloodDepthsOverview.pdf” is not centred into the page, resulting in the flood map being cut out in the middle along the northern boundary.	It is recommended to fix this map by centring the catchment within the figure frame.

Appendix B – Comparison between the version 1 and version 5 of the model for May 2015 event.

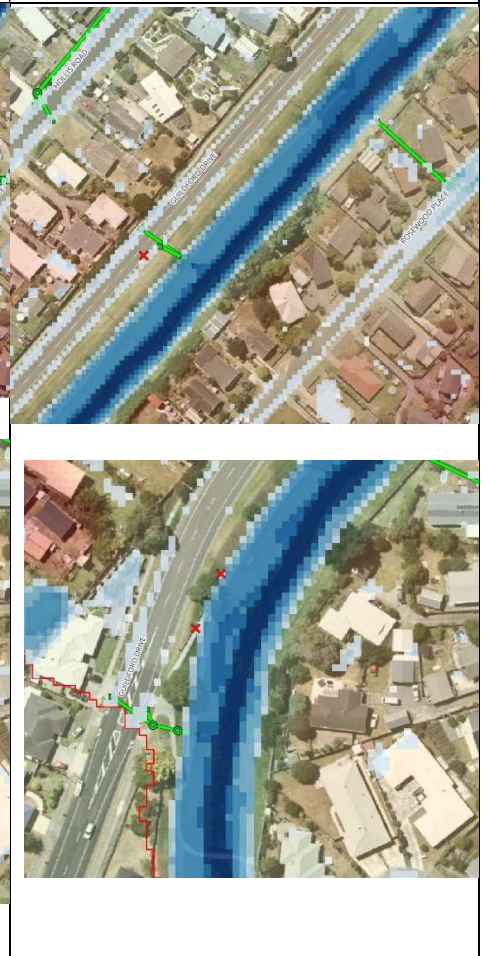
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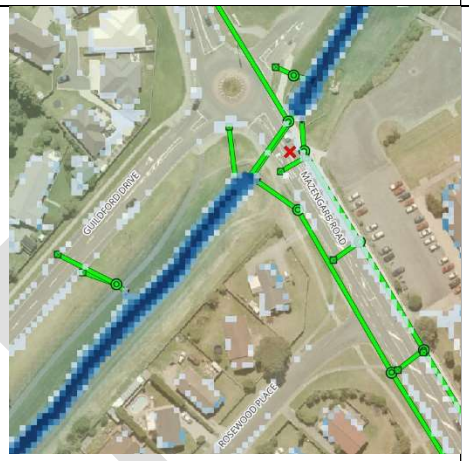
Location	Photo	Version 1	Version 5
Awatea Ave and McGreggor Place			
Makora Road and Otahanga Domain			

Location	Photo	Version 1	Version 5
Otaihanga Road			
Scarfe Drive	   		

Location	Photo	Version 1	Version 5
	 		

DRAFT

Location	Photo	Version 1	Version 5
Guildford Drive			

Location	Photo	Version 1	Version 5
Mazengarb Drive	  		
Wood Leigh	 		

DRAFT

Appendix C – 100YR ARI 2130 Peak Flood Depths

DRAFT

Model Outputs / Flood Map disclaimer:

Note: Kāpiti Coast District Council's current suite of flood hazard models [legacy models] for the District Plan and flood hazard mapping are under review. The work has been designed to incorporate updated climate change and groundwater conditions for the district, recent development and major roading projects into the models and aligns with wider resilience work underway. The models have been extended to include Te Kowhai and Muaupoko catchments. Council intends engaging with those in areas which may be affected from September 2024. Ultimately, model outputs will be tested for use in future district plan work which will consider any necessary changes to land use and subdivision controls in areas which may be affected. In the meantime, the new base models are available for use to scenario test proposed development [subject to Council's agreement] or for guidance [subject to this disclaimer].

Until a flood hazard Plan Change is publicly notified, the existing rules in the operative District Plan still apply to any area that is identified in the current flood hazard overlays. The updated model outputs cannot be considered the most up to date flood hazard information [in a statutory sense] until directly affected properties have been engaged with, and all output maps and model-build reports are finalised.

- Kāpiti Coast District Council's flood maps and new model outputs are compiled using an assessment of the best available information.
- The design storms used to generate outputs in the new models are based on HIRDS v4 datasets, provided by NIWA.
- The new model outputs reflect flooding originating from Kāpiti Coast District Council's urban drainage network [piped and minor watercourses within urban areas] only, and as such may not represent flooding originating from any of the watercourses administered by Greater Wellington Regional Council [GWRC] (Our models do cover the Mangapouri Stream in particular). The current flood hazard maps stitch together outputs from KCDC legacy models and GWRC models for rivers under its administration. The Watercourses' Agreement attributes the administration of the following watercourses to GWRC:
    - Waikanae River, and its tributaries above the SH bridge
    - Waimeha Stream
    - Mangaone Stream and drains
    - Pahiko Drains
    - Otaki River and tributaries
    - Ngatoko Stream
    - Mangapouri Stream and tributaries
    - Waitohu Stream and tributaries
    - Ngatotara Drain

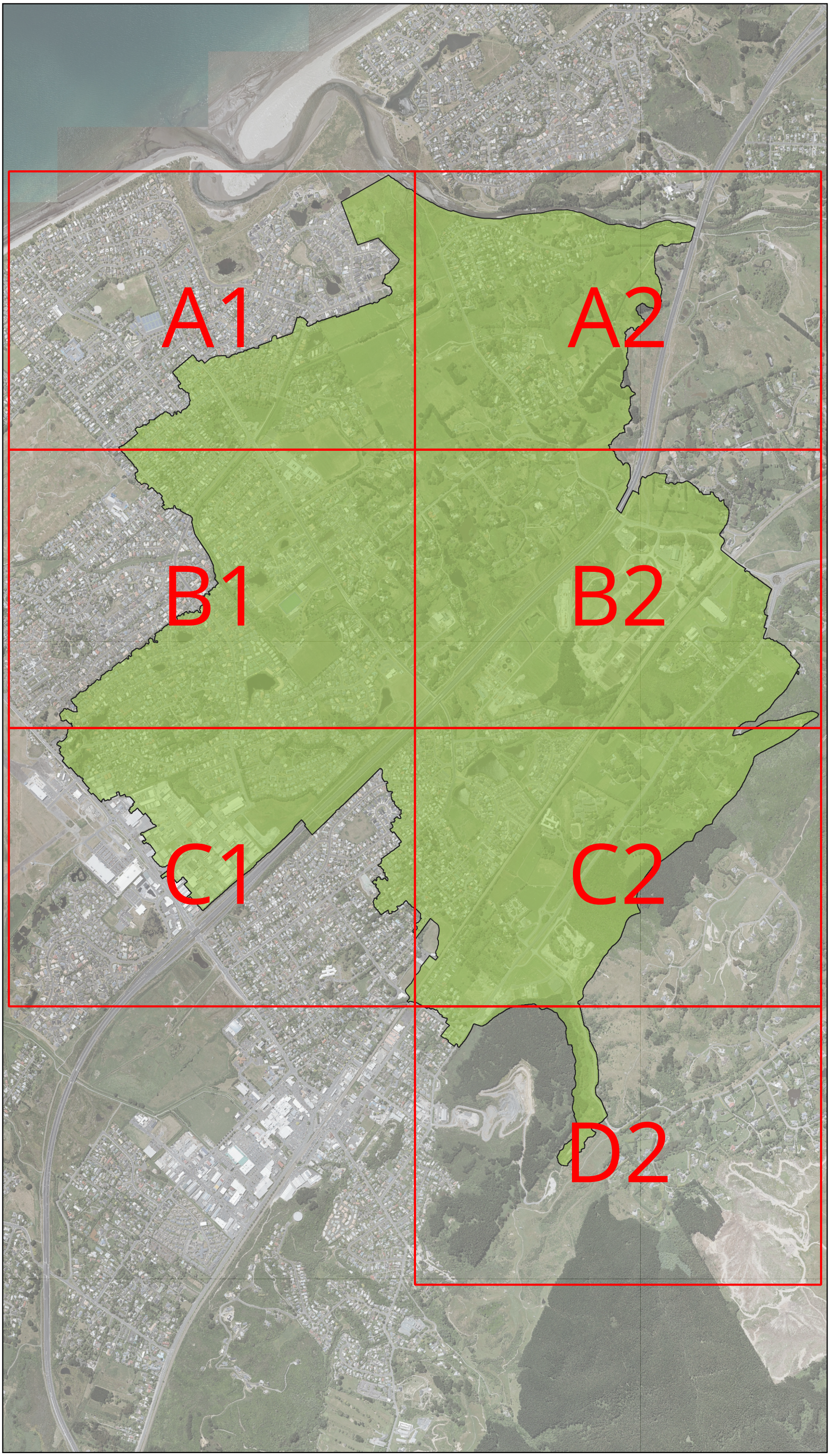
  Where a proposal occurs within Greater Wellington Regional Council's flood model extent, its written approval should be sort. Although the outputs from GWRC models are incorporated within the District Plan flood hazard maps, KCDC holds none of the supporting information. Both Councils have a duty under the Resource Management Act to avoid and mitigate natural

hazards - territorial authorities have a duty to control the effects of use, development or protection of land; Regional Councils have a duty to control the use of land.

- When using these model outputs or flood maps, users should be aware that the results may be subject to change at the discretion of Kāpiti Coast District Council. This is a natural outworking of models being updated over time with new data. Checking with the Council that the District Plans represent the latest information is an important step in the planning process.
- To the fullest extent permitted by applicable law, neither Kāpiti Coast District Council nor any of its members, officers, associates, consultants, employees, affiliates, servants, agents or other representatives shall be liable for loss or damage arising out of, or in connection with, the use of, or the inability to use, the information contained in these maps and/or electronic files including, but not limited to, indirect or consequential loss or damages, loss of data, income, profit, or opportunity, loss of, or damage to, property and claims of third parties, even if Kāpiti Coast District Council has been advised of the possibility of such loss or damages, or such loss or damages were reasonably foreseeable.
- The flood information contained within these plans has been derived from information and techniques available at the time of the study. It is provided to assist in reducing the flood risk for development in the area. However, the agencies and individuals involved in the assessment of the flood hazard assume no responsibility for any action by any agency or individual that is based on the information provided.

Mazengarb Page Reference

For Flood Extent, Hazard, and Depth Maps



Prepared by:
Awa Environmental Ltd
For:
Kapiti Coast District Council

1 Ghuznee St, Te Aro
Wellington 6011
www.awa.kiwi

0 500 m

Legend

- Page Reference
- Catchment Extent

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Mazengarb Flood Depth in a 100-Year Rainfall Event

2130 Projection - Page A1



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0 150 m

Legend

Catchment Boundary

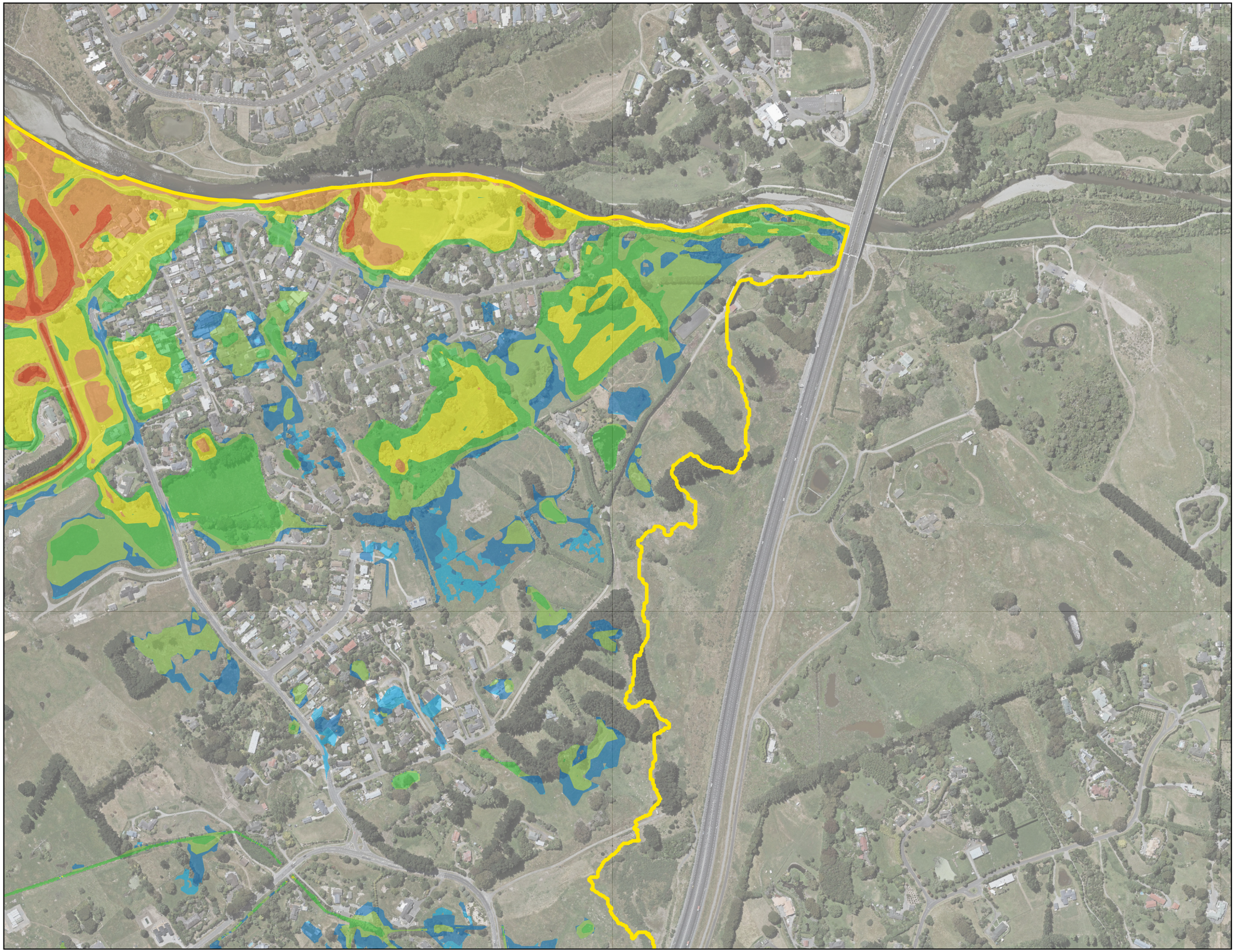
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- 1.0 - 1.5 m
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Mazengarb Flood Depth in a 100-Year Rainfall Event

2130 Projection - Page A2



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Kapiti Coast District Council

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0 150 m

Legend

Catchment Boundary

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Mazengarb Flood Depth in a 100-Year Rainfall Event

2130 Projection - Page B1



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0 150 m

Legend

Catchment Boundary

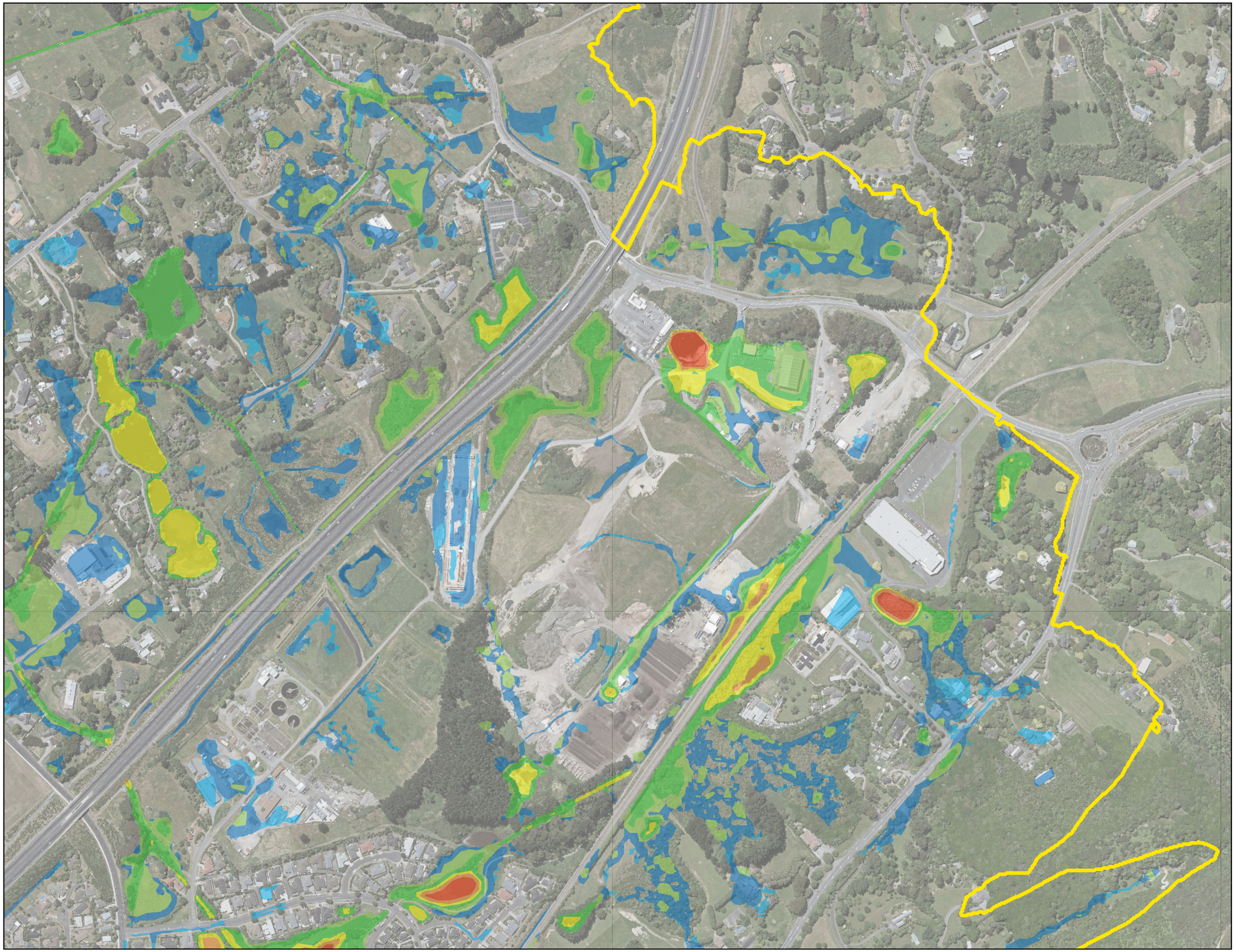
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2130 Projection - Page B2



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2130 Projection - Page C1



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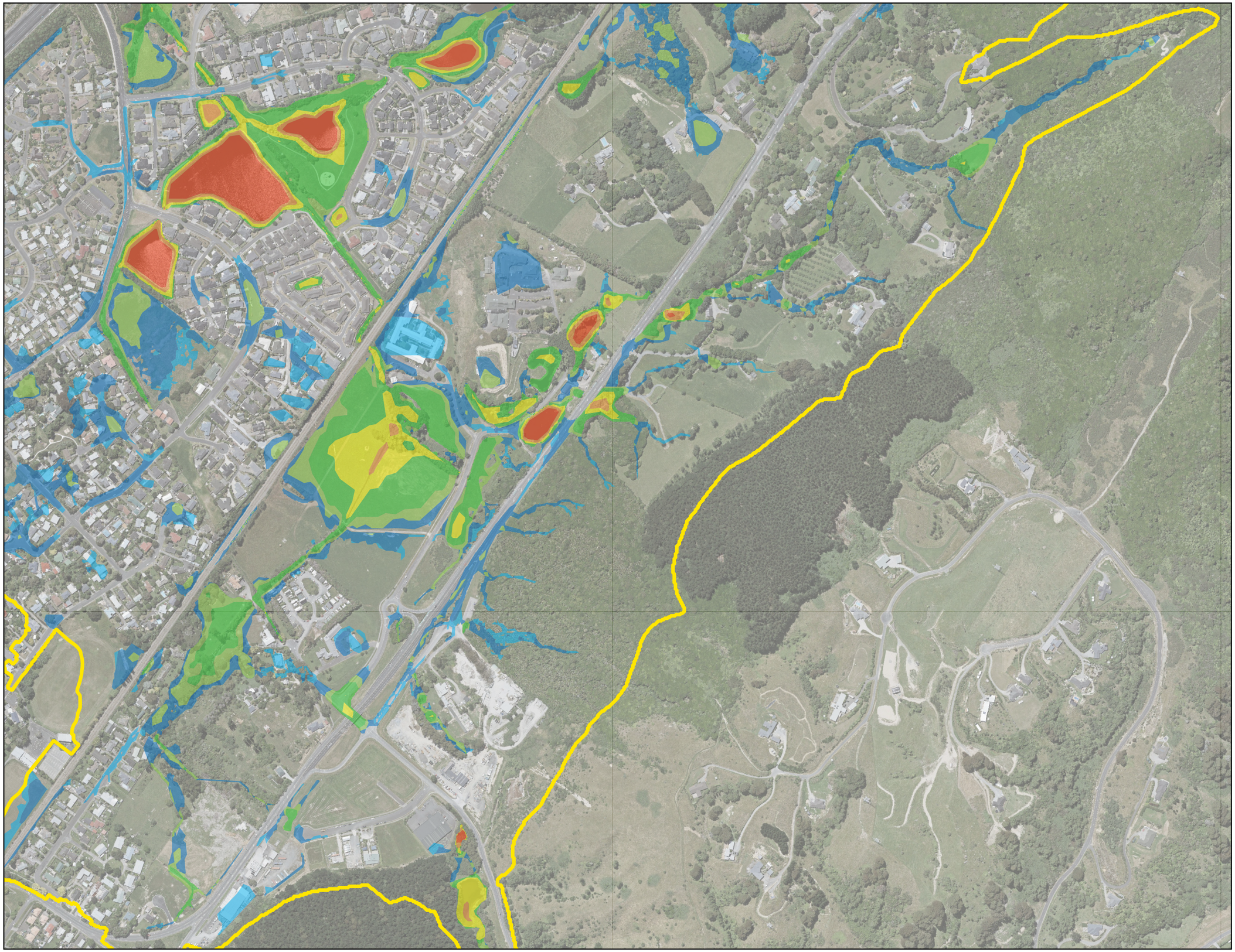
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Mazengarb Flood Depth in a 100-Year Rainfall Event

2130 Projection - Page C2



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Legend

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Mazengarb Flood Depth in a 100-Year Rainfall Event

2130 Projection - Page D2



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