

Kāpiti Flood Hazard Management

Te Kowhai Model Build Report

Date 26/06/2024

Excellence Heart Innovation

TE KOWHAI MODEL BUILD REPORT

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EXECUTIVE SUMMARY

Awa Environmental (AWA) were engaged by Kāpiti Coast District Council (KCDC) to update the Te Kowhai Catchment model to the same standard as the surrounding urban area models.

The model build has been undertaken utilising TUFLOW modelling software (Release 2023-03-AE) and includes all Council-owned manholes, 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 an update on the TUFLOW model developed in 2021. Key changes from the previous model include:

The new TUFLOW model includes the Peka Peka general residential catchment area.

1. The Te Kowhai 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.
2. 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.
3. 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 report is structured as follows:

Section 1 - Overview of the study location.

Section 2 - Summary of model features and approaches applied.

Section 3 - Summary of the model build process.

Section 4 - Conclusions and recommendations

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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 Te Kowhai catchment.

In 2021 a high-level sub-catchment based 2D TUFLOW model of the Hadfield Stream catchment was built by AWA, which excluded the Peka Peka residential catchment area.

The details of the standards used and the methodology for the model build are covered in section 01 of the Stormwater Modelling Methodology Report.

1.2. OBJECTIVES

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

To provide KCDC with a TUFLOW stormwater model of the Te Kowhai 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 section 01 of the Stormwater Modelling Methodology Report.

Specific objectives of the Te Kowhai model build were to develop a TUFLOW stormwater model of the Te Kowhai 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:

- 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. MODELLING APPROACH

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

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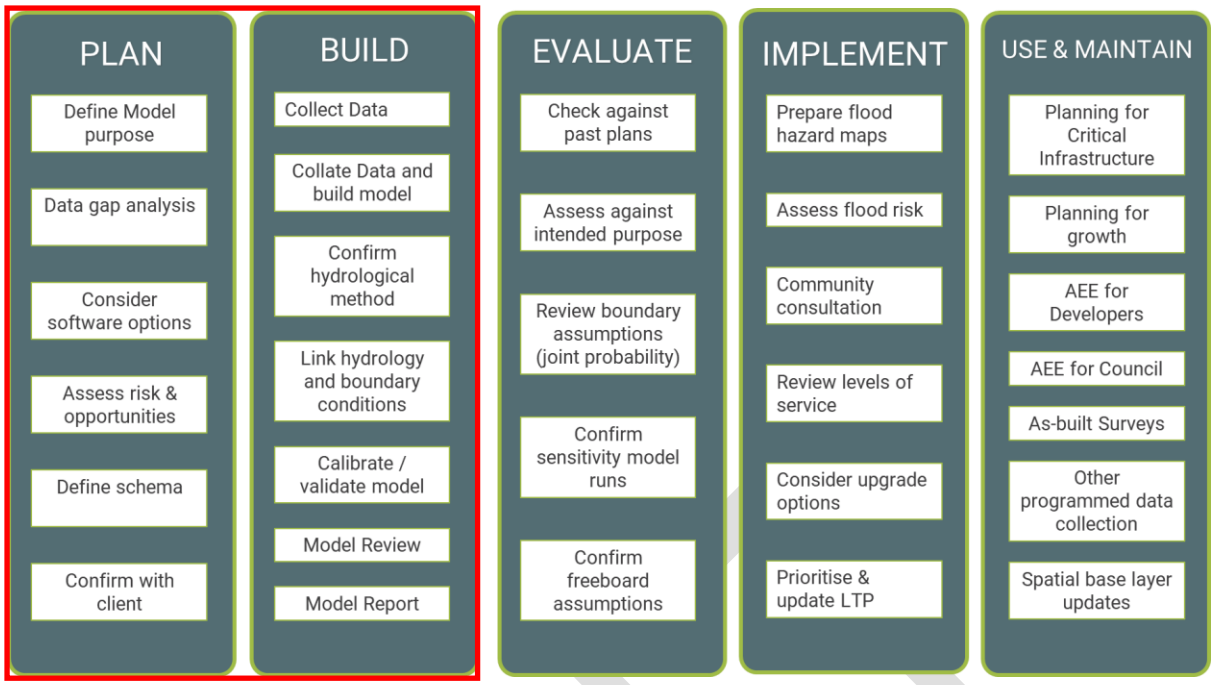


Figure 1. Modelling approach.

1.4. 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 - Conclusions and recommendations

1.5. IMPORTANT MODEL FEATURES

1. The new TUFLOW model includes 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, especially in coastal areas affected by Sea Level Rise (SLR).
2. The Te Kowhai 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 Te Kowhai catchment covers an area of approximately 9.5 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 Peka Peka Beach to North-Western side, as shown in Figure 2.



Figure 2: Te Kowhai 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.

2.3. EXISTING LAND USE

The Te Kowhai catchment reflects the various growth phases which have occurred across the wider Kāpiti district. South-East of SH1, in the steeper ranges, the land use is predominantly native and exotic species. This gives way to residential development in the lower reaches of the ranges moving

toward the coast. Residential development is generally concentrated in the southern catchment extent and along the southern coastal margin where Peka Peka is located.

The centre catchment extent is dominated by undeveloped low-lying areas and farmland. The catchment is under continual development.

2.4. STORMWATER SYSTEM

The Peka Peka stormwater network consists of pipes, catchpits, manholes, detention ponds and interconnected streams and drains with culverts under road and rail crossings.

There is an extensive stormwater network within the catchment which intercepts run-off from the incised open channels in the ranges and routes it to the coast. There are several open channels within the catchment including the Hadfield Drain. These are heavily modified along their length with several culvert crossings and piped sections.

The southwest catchment is characterised by low-lying areas which are tailwater controlled and are impacted by tidal levels.

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3. MODEL BUILD

3.1. MODEL OVERVIEW

The purpose and use of the models is discussed in the Methodology (Section 1) of the Kāpiti Flood Hazard Management report.

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

Table 1. Key details of the model build.

ITEM	DESCRIPTION
Software	TUFLOW version 2023-03-AE
Coordinate system	New Zealand Transverse Mercator 2000 (NZTM 2000)
Vertical datum	New Zealand Vertical Datum 2016 (NZVD2016)
Validation scenarios	No information available.
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). • Tailwater conditions incorporating Sea Level Rise, Storm Surge and the Mean High-Water Springs (MHWS) tidal cycle for Waikanae catchment, adjacent to Te Kowhai. These tidal boundaries have been prepared in conjunction with the Takutai Kāpiti team.

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.

3.2.1. SPATIAL DATA

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

DATA	DETAILS	DATE SUPPLIED
Topography	KCDC - KCDC_2021_1m_DEM_NZVD2016_NZTM_TeKowhai_clipped.asc	2021
	XR_SW_001_CombinedDesignContours_NZVD2016_Expressway.asc (Peka Peka to Otaki Expressway design contours converted to raster)	09/05/2019 (Drawing Version 3 Date)
Stormwater asset data	KCDC - KCDC_SW_Data_20240429-SW_Pipe.gdb	29th April 2024
	Peka Peka to Otaki Expressway construction drawings	09/05/2019 (Drawing Version 3 Date)
Land cover	Lynker - Kāpiti_Coast_Landcover_20210527.gdb	27th May 2021
	Koordinates - Landcare Research - Land Cover Database version 5 (LCDB v5)	N/A
Soil map	Koordinates - The Fundamental Soil Layers New Zealand Soil Classification (FSL) dataset, updated July 2017	N/A
	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 (last updated 7th February 2024 and flown in January 2021)

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DATA	DETAILS	DATE SUPPLIED
	LINZ - nz-building-outlines-all-sources.shp	Last Updated 7th February 2024
	KCDC – 2021 Aerial Imagery	Flown in January 2021
Rainfall	HIRDS - HIRDS v4 gridded (2km 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
Tide (design)	Design tides generated by AWA	N/A
Google Maps - Kāpiti	Street View October 2019, June 2021, November 2023.	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

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3.3. MODEL DOMAIN

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

Table 4. Computational approaches and key parameters for various aspects of the model.

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.
Overland flow	The 2D computational grid is discretised into regular 2m 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, pump-stations, 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. 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	The open channels are modelled using TUFLOW's sub-grid sampling feature (SGS) which represents the channel bed at a 1m sampling distance.
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 9.

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DATA	DETAILS
	The extent of the soil compaction layer is shown in Figure 8. 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.

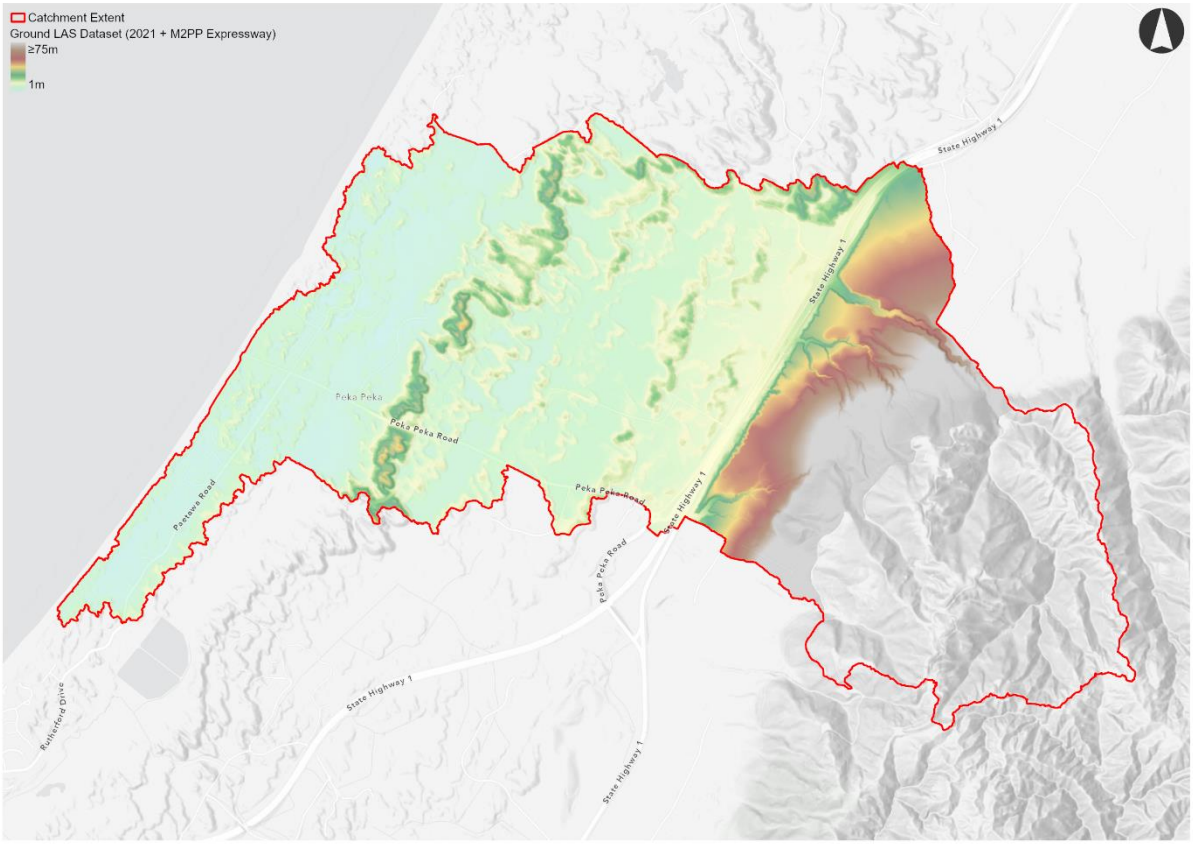


Figure 3: Terrain elevation.



Figure 4: Modelled pipe network extent.



Figure 5. Open channel representation.



Figure 6: Sub-catchment runoff and rain on grid extents.

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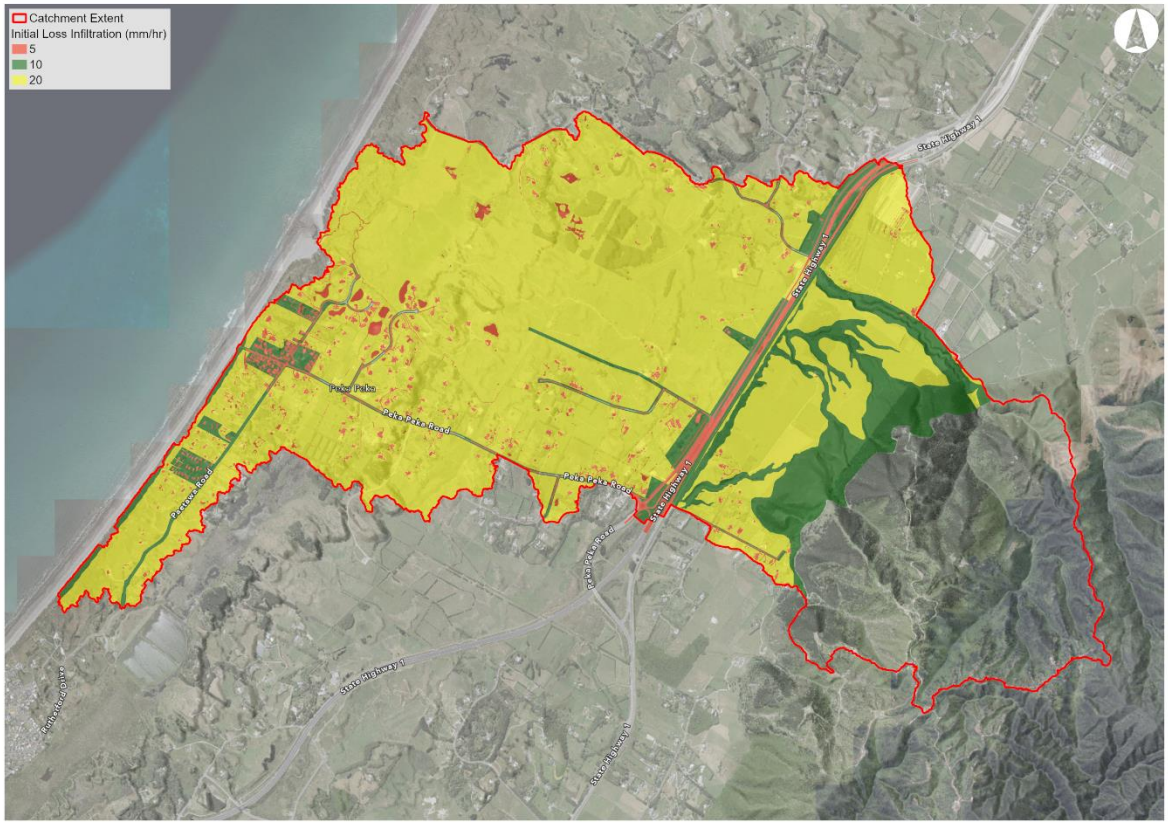


Figure 7: Initial loss spatial distribution.

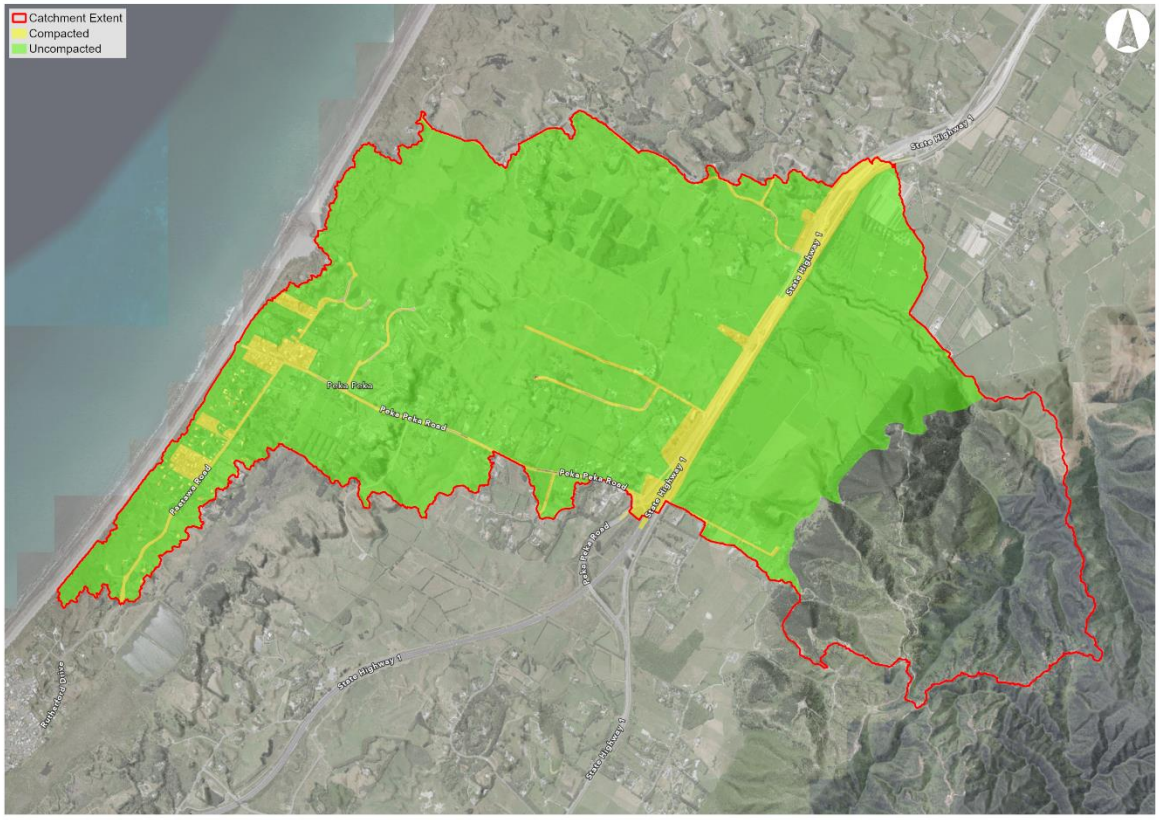


Figure 8. Soil compaction spatial distribution.

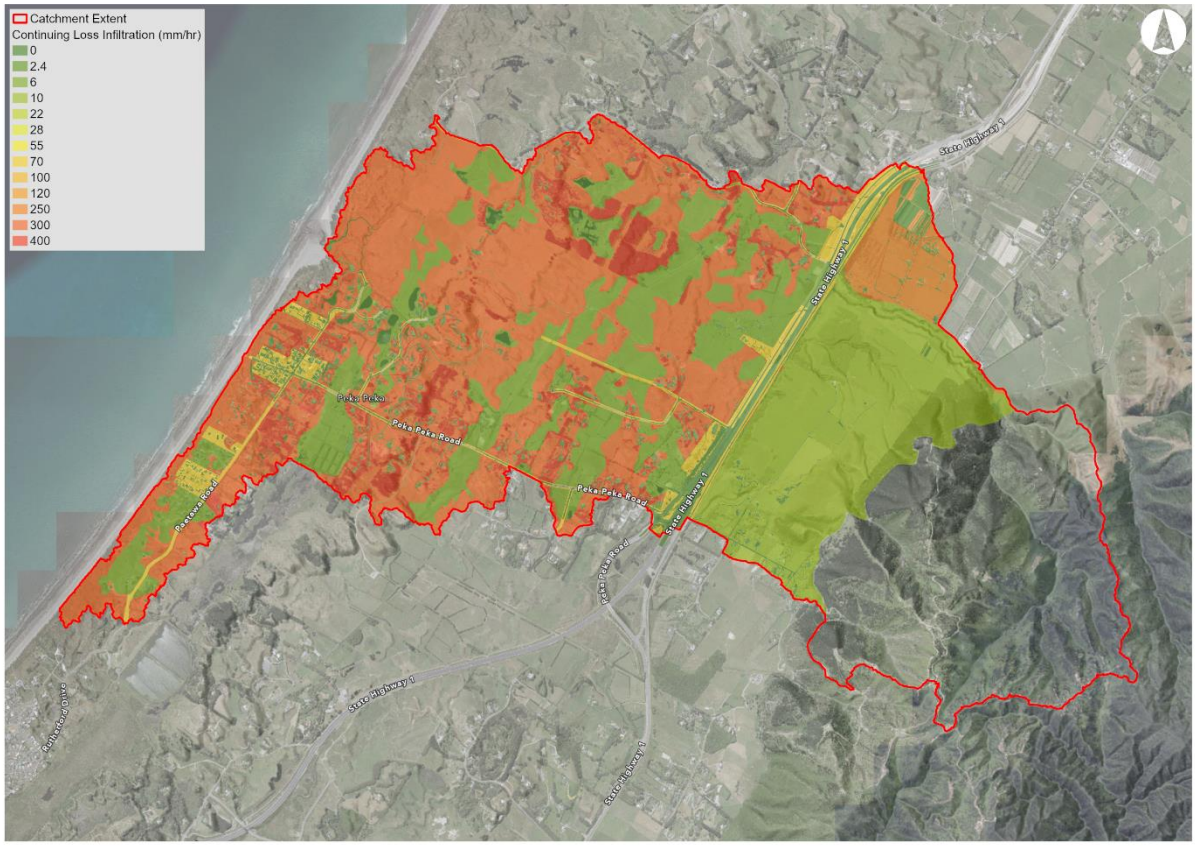


Figure 9: Continuing loss spatial distribution.

3.4. PIPE NETWORK

The 1D network comprises gravity mains which drain to several streams and ponds.

The network includes all stormwater drainage pits, pipes and manholes in the catchment identified from KCDC's stormwater asset data layer, excluding private drainage. Additional pipe network data was included, sourced from the Peka Peka to Otaki Expressway (SH1) construction drawings provided by KCDC dated from 09/05/2019 (drawing No. PP20-DR-SW-0138 to 0147).

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_SW_Data_20240429-SW_Pipe.gdb layer, excluding private drainage, are included in the model. Sump-lead connections in the KCDC_SW_Data_20240429-SW_Pipe.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. 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

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DATA	DETAILS
	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_SW_Data_20240429-SW_Pipe.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. 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. Sump types have been taken from supplied asset database. Identified sumps, not in the asset database, have had sump type defined using street-view.
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	None identified from the KCDC stormwater database.

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DATA	DETAILS
Bridges	Represented in the 2D domain by TUFLOW layered flow constriction feature (2d_lfcsh layers). 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 piers or not). Second layer is the deck level that is 100% blocked. The levels were taken from old mike model and or DEM or survey. The third layer represents the railing that is generally 10%-20% blocked. Assuming a minimum height of 1m. During blockage scenarios the first layer can be adjusted to represent blockages.

3.5. KEY STRUCTURES AND ASSETS

There are several key culverts and bridges within the Te Kowhai 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.

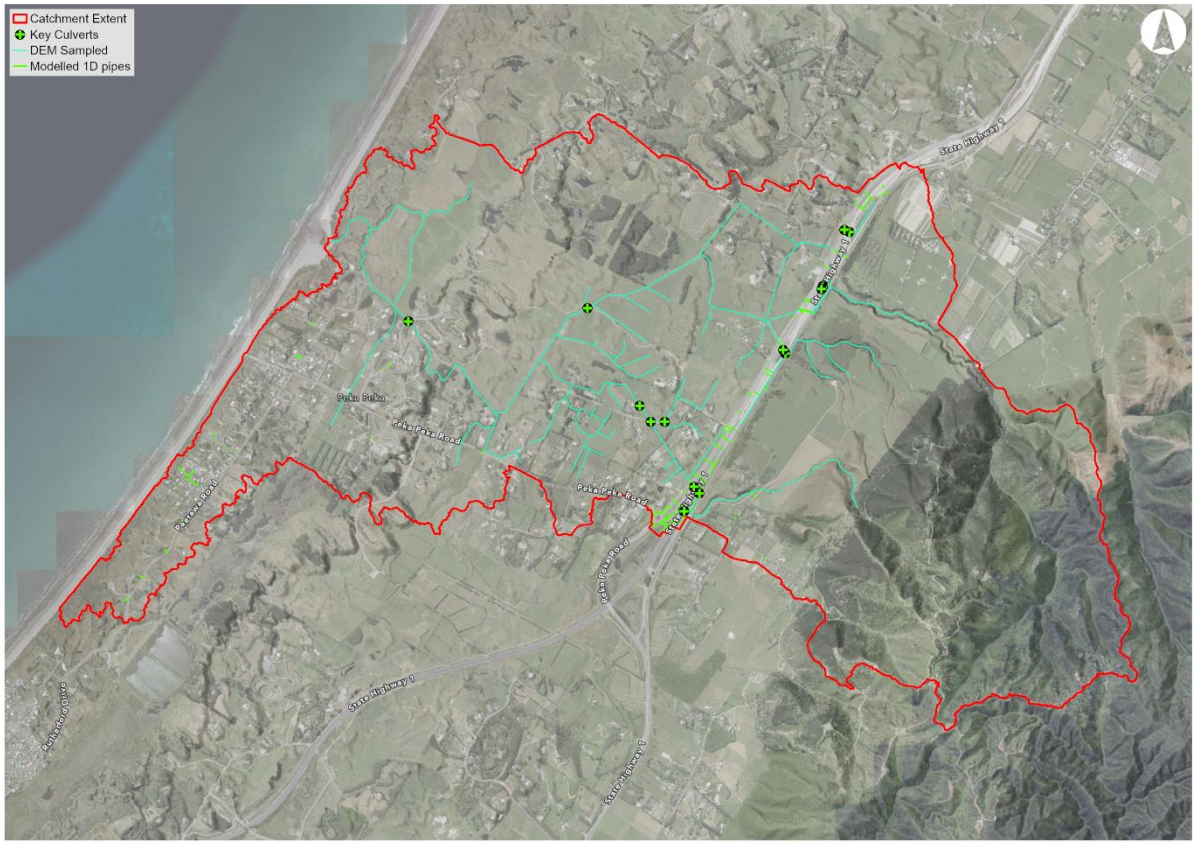


Figure 10. Locations of key open channel structures.

Table 6. Culvert description.

ID	CULVERT NAME	SHAPE	NUMBER OF CULVERTS	DIAMETER (m)
1	CULV_59	Circular	1	0.85
2	CULV_59DS	Circular	1	0.85
3	CULV_64a	Circular	1	0.74
4	CULV_64b	Circular	1	0.74
5	CULV_64c	Circular	1	0.74
6	had_new_0004	Circular	1	1.06
7	had_new_0005	Circular	1	1.06
8	had_new_0007	Circular	1	0.27
9	had_new_0011	Circular	1	0.74
10	KSWP008740	Circular	1	1.06
11	KSWP010538	Circular	1	1.70
12	KSWP010550	Circular	1	0.53
13	KSWP010613	Circular	1	1.70
14	KSWP012367_A	Circular	1	1.27
15	KSWP012367_B	Circular	1	1.27

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.
Boundary condition application	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.

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<table>
<tr><th colspan="2">MODEL ASPECT</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>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 on Landcare Research's LCDB v5 land cover and Aerial Imagery 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</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>Stream/Channel</td><td>0.04-0.45</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>
<tr><td>Pond/Wetland</td><td>0.075</td></tr>
</table></td></tr>
<tr><td></td><td>Flood and dry parameters</td><td>TUFLOW default wetting and drying parameters are applied.

Wetting and Drying == ON METHOD B</td></tr>
</table>

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<table>
<tr><th>MODEL ASPECT</th><th colspan="2">DETAILS</th></tr>
<tr><td></td><td></td><td>Cell Wet/Dry Depth == 0.0002 [m]</td></tr>
<tr><td></td><td>Map cutoff depth</td><td>Parameter set to 0.01</td></tr>
<tr><td></td><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></td><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.

The ground water table (used to limit soil capacity) is initialised to the Mean Sea Level (MSL) for the climate horizon being simulated: for 2130 (RCP8.5M) this corresponds to 1.32 m RL.</td></tr>
<tr><td>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></td><td>Manhole energy losses</td><td>All manholes use the Engelund loss approach.</td></tr>
</table>

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MODEL ASPECT		DETAILS
		Km and K_Bend_Max coefficients are set to 0.25.
2D configuration	Resistance	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.
	Initial conditions	The initial water level is set automatically to the level of the downstream water level boundary at the start of each simulation.
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 steep areas where determination of runoff is the principal concern. Sub-catchments are delineated using a GIS-based drainage analysis, which does not consider hydraulic effects. Hill sub-catchments are 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 Stormwater Modelling Methodology report.

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MODEL ASPECT	DETAILS
	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).

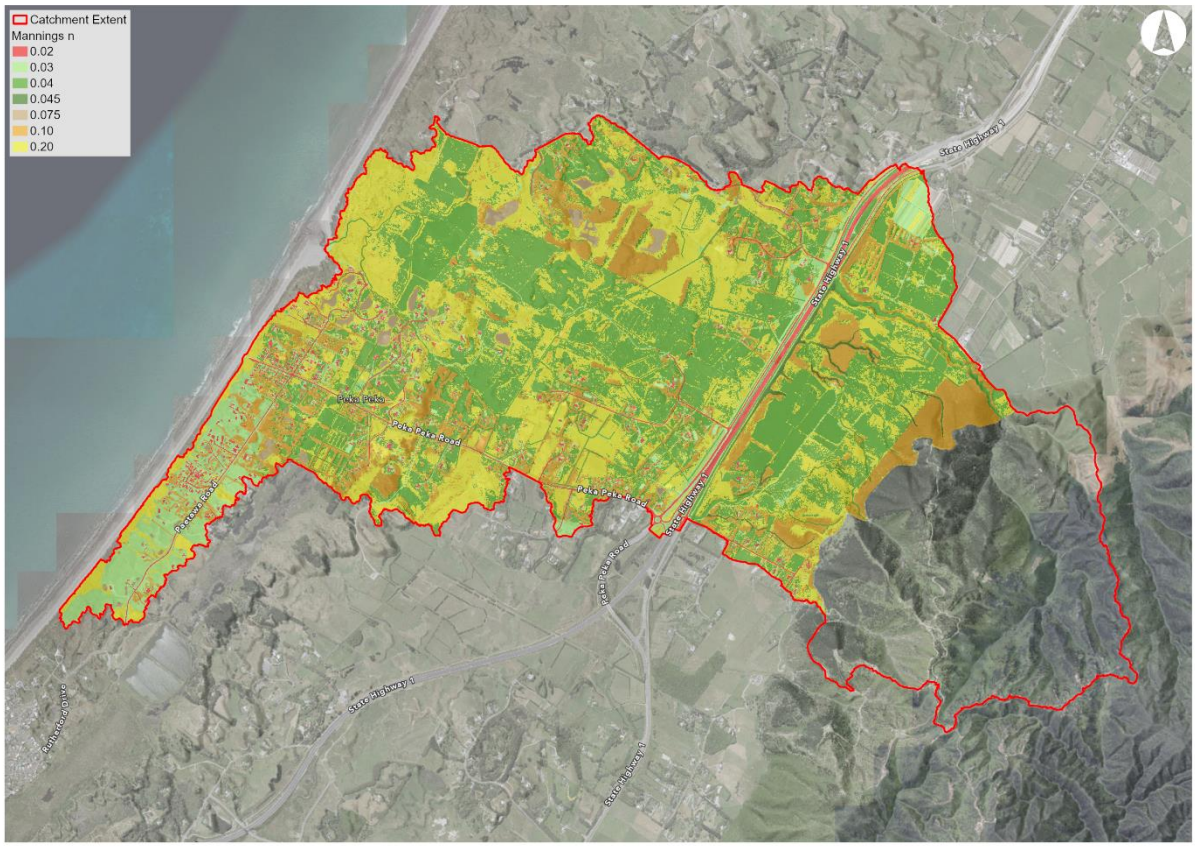


Figure 11. Manning's n overland flow resistance parameters applied to the model.

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
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

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INLET CONFIGURATION ID	CODE	CATCHPIT TYPE	INLET AREA (M2)	DISCHARGE COEFFICIENT (-)	QDH (M)
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 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 Te Kowhai model at the coast. Two boundaries are applied: one at the downstream end of Hadfield Drain where it discharges to Te Horo Beach and another at Peka Peka Beach at the end of Peka Peka Road.
Flow	Hill sub-catchment runoff is directed onto the 2D surface along the south-eastern edge of the 2D domain.

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.
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.
Validation	It was not possible to undertake validation of the Te Kowhai hydraulic model due to data unavailability. During the data search process, the following sources were consulted: • KCDC complaints database within the area of study. • Social media (through tags, public community groups and pages) • Online news (through search engines). • Identification of significant historic rainfall events at nearby gauges through the GWRC Live Data Viewer (https://graphs.gw.govt.nz/). • Satellite imagery (https://www.sentinel-hub.com/).

3.9. ASSUMPTIONS

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

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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 2021 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 2021 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. RECOMMENDATIONS

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.

It was not possible to undertake validation of the Te Kowhai hydraulic model due to data unavailability. It is recommended that in the future a validation process is done once data is gathered to provide additional confidence in the hydraulic model performance.

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 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. This should be prioritised for this catchment.
- 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.
- Some consideration should be given to installing a groundwater piezometer (or two) into the catchment to provide a good understanding of groundwater in the longer term.

DRAFT

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APPENDIX A - FLOOD MAPS

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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

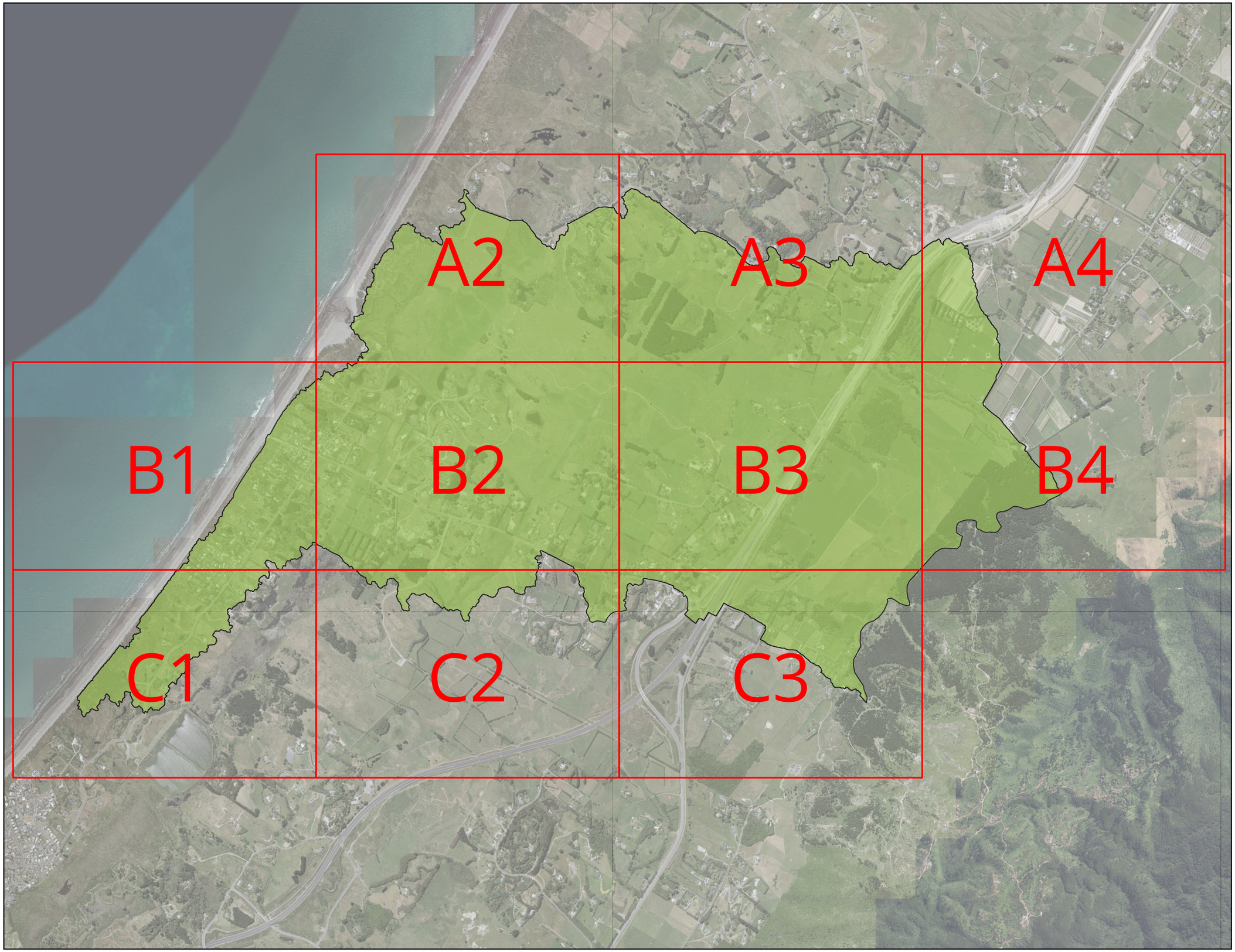
  Where a proposal occurs within Greater Wellington Regional Council's flood model extent, its written approval should be sort. Although the outputs from GWRC models are incorporated within the District Plan flood hazard maps, KCDC holds none of the supporting information. Both Councils have a duty under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

Te Kowhai 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

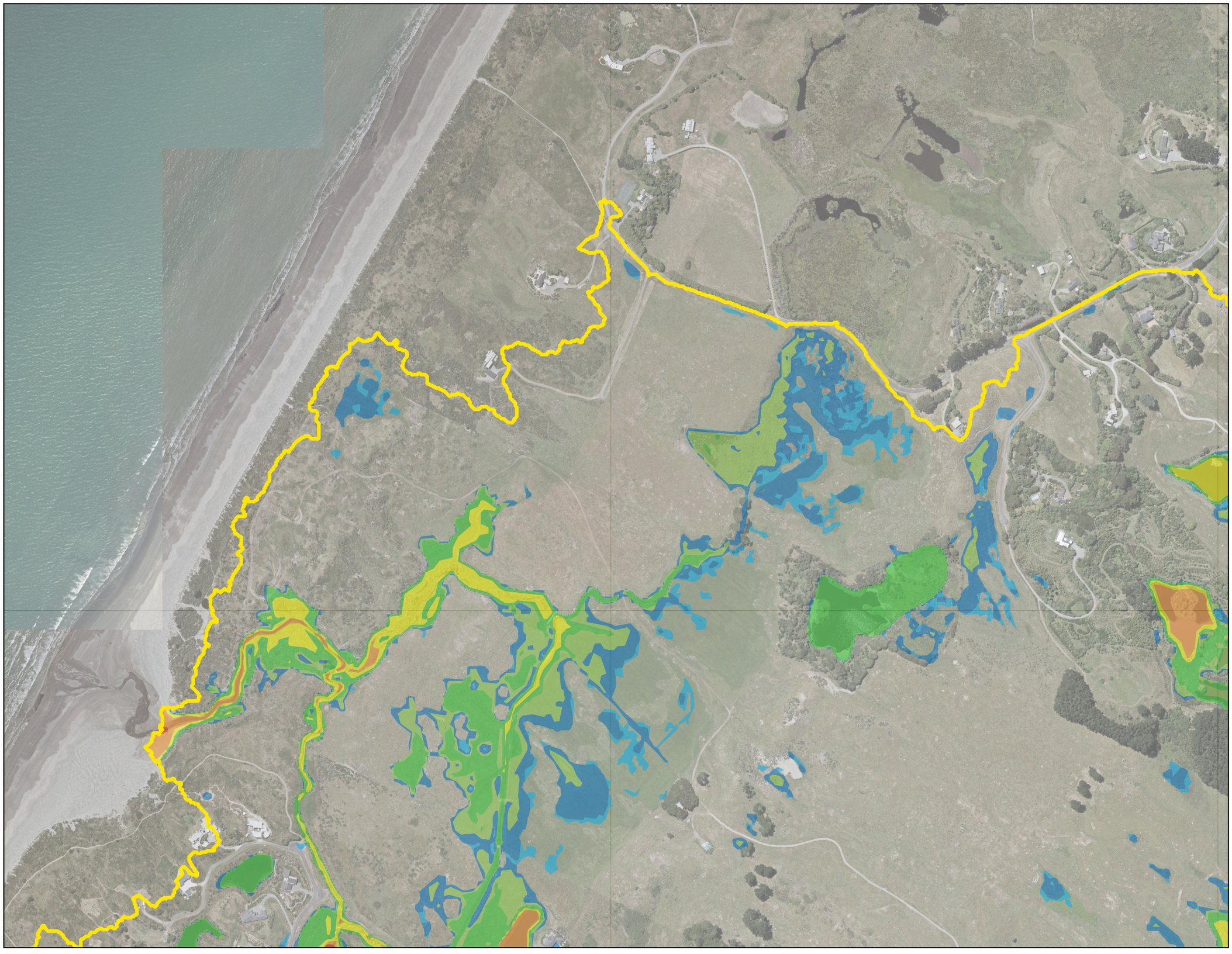
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- Page Reference
- Catchment Extent

Disclaimer:
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Te Kowhai Flood Depth in a 100-Year Rainfall Event

2130 Projection - Page A2



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

0 150 m

Legend

Catchment Boundary

Te Kowhai Catchment

Depth

- 0.05 - 0.1 m
- 0.1 - 0.3 m
- 0.3 - 0.5 m
- 0.5 - 1.0 m
- 1.0 - 1.5 m
- 1.5 - 2.0 m
- 2.0+ m

Disclaimer:
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Te Kowhai Flood Depth in a 100-Year Rainfall Event

2130 Projection - Page A3



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0 150 m

Legend

Catchment Boundary

Te Kowhai Catchment

Depth

- 0.05 - 0.1 m
- 0.1 - 0.3 m
- 0.3 - 0.5 m
- 0.5 - 1.0 m
- 1.0 - 1.5 m
- 1.5 - 2.0 m
- 2.0+ m

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Te Kowhai Flood Depth in a 100-Year Rainfall Event

2130 Projection - Page A4



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0 150 m

Legend

Catchment Boundary

Te Kowhai Catchment

Depth

- 0.05 - 0.1 m
- 0.1 - 0.3 m
- 0.3 - 0.5 m
- 0.5 - 1.0 m

Disclaimer:
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Te Kowhai Flood Depth in a 100-Year Rainfall Event

2130 Projection - Page B1



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0 150 m

Legend

Catchment Boundary

Te Kowhai Catchment

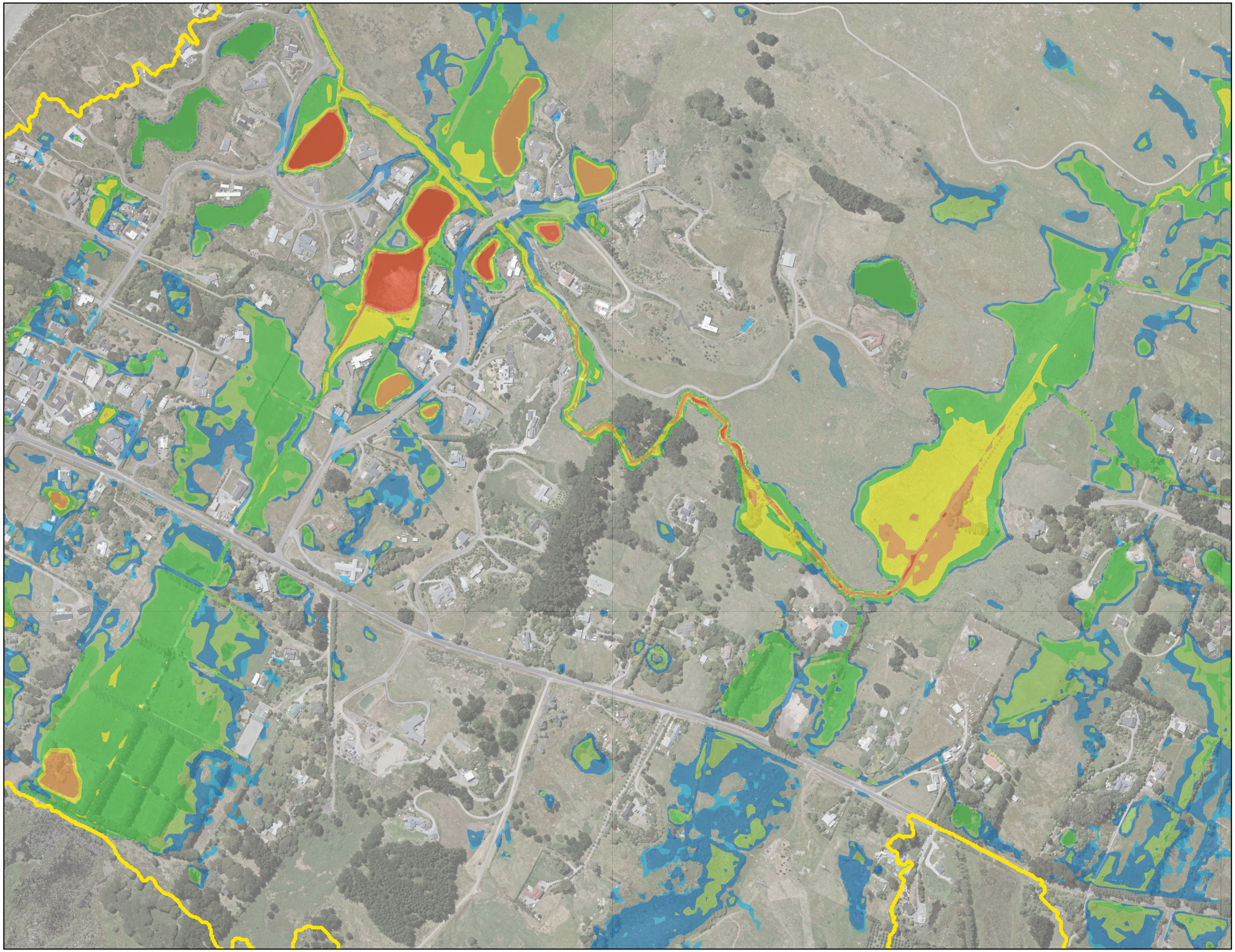
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- 0.5 - 1.0 m
- 1.0 - 1.5 m
- 1.5 - 2.0 m

Disclaimer:
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Te Kowhai Flood Depth in a 100-Year Rainfall Event

2130 Projection - Page B2



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0 150 m

Legend

Catchment Boundary

Te Kowhai Catchment

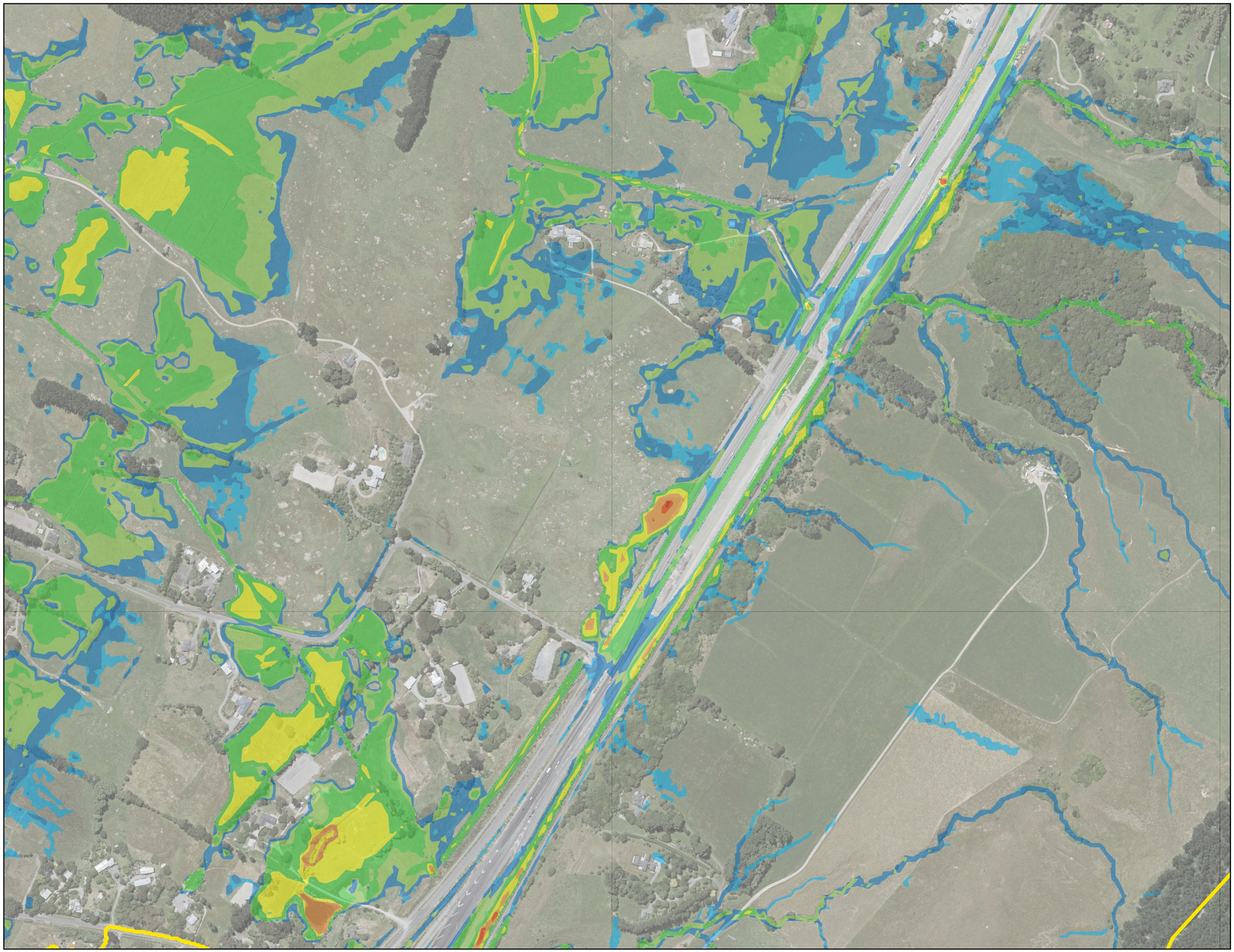
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- 0.3 - 0.5 m
- 0.5 - 1.0 m
- 1.0 - 1.5 m
- 1.5 - 2.0 m
- 2.0+ m

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Te Kowhai Flood Depth in a 100-Year Rainfall Event

2130 Projection - Page B3



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1 Ghuznee St, Te Aro
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0 150 m

Legend

Catchment Boundary

Te Kowhai Catchment

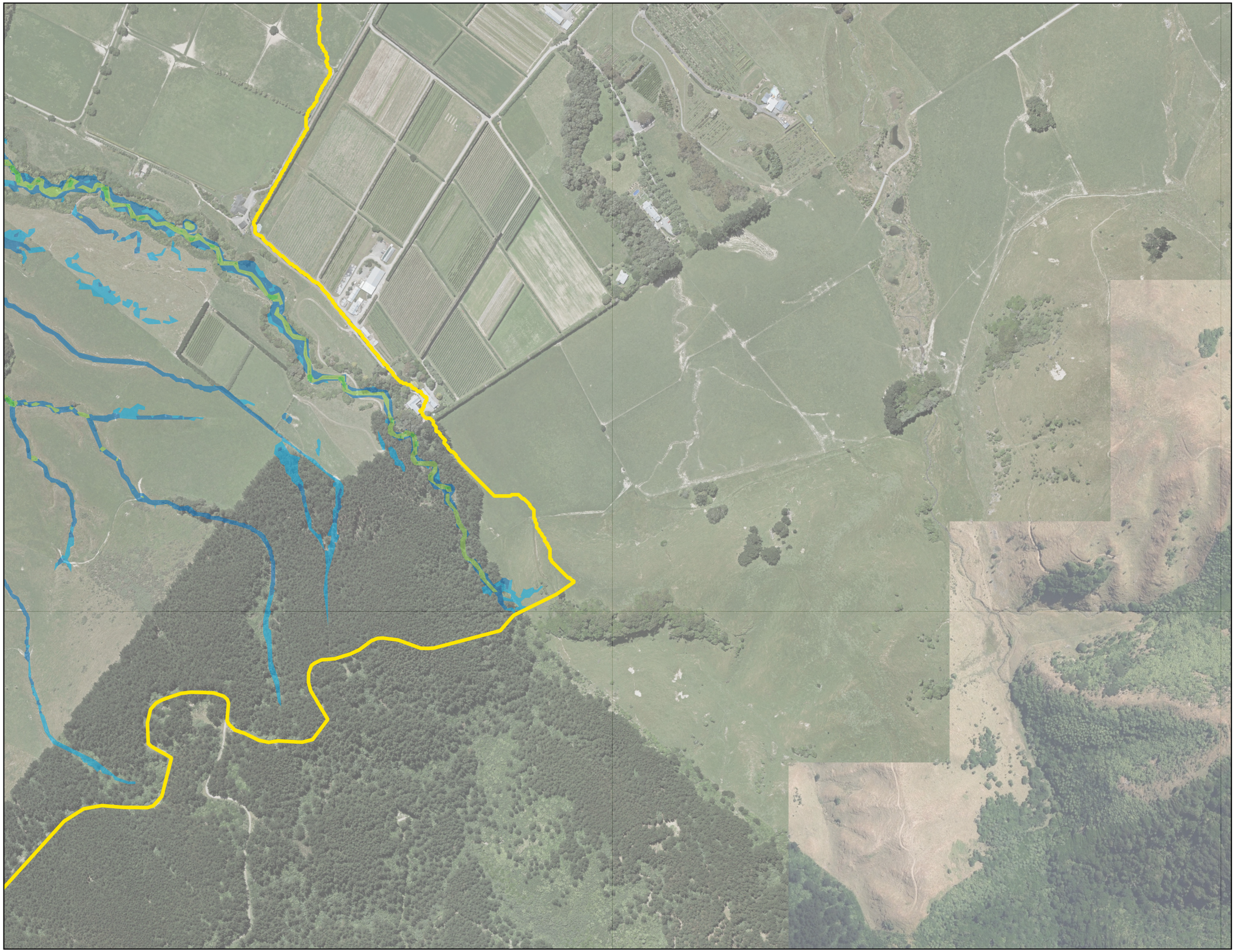
Depth

- 0.05 - 0.1 m
- 0.1 - 0.3 m
- 0.3 - 0.5 m
- 0.5 - 1.0 m
- 1.0 - 1.5 m
- 1.5 - 2.0 m
- 2.0+ m

Disclaimer:
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Te Kowhai Flood Depth in a 100-Year Rainfall Event

2130 Projection - Page B4



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For:
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1 Ghuznee St, Te Aro
Wellington 6011
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0 150 m

Legend

Catchment Boundary

Te Kowhai Catchment

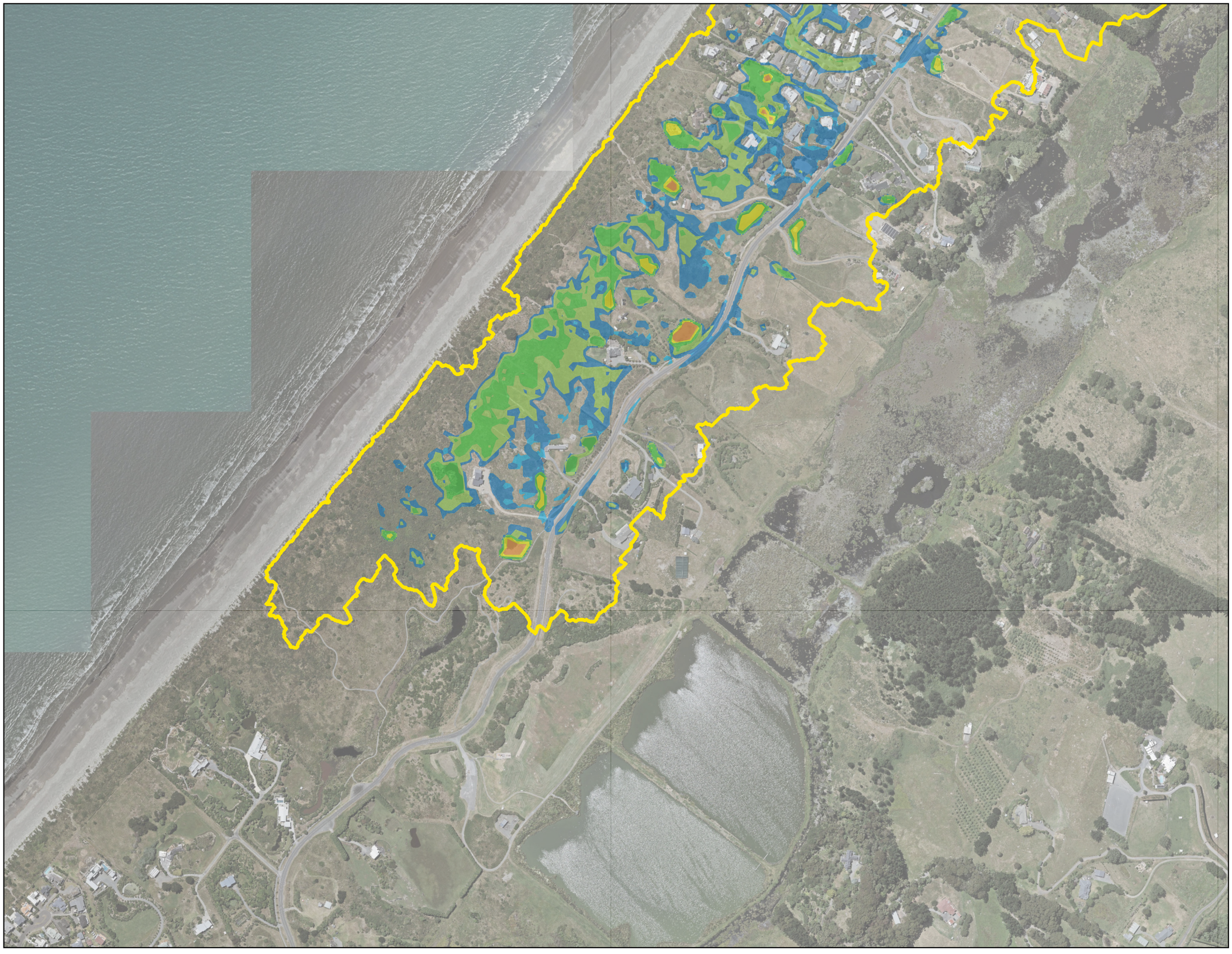
Depth

- 0.05 - 0.1 m
- 0.1 - 0.3 m
- 0.3 - 0.5 m
- 0.5 - 1.0 m

Disclaimer:
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 redusing 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.

Te Kowhai Flood Depth in a 100-Year Rainfall Event

2130 Projection - Page C1



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1 Ghuznee St, Te Aro
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0 150 m

Legend

Catchment Boundary

Te Kowhai Catchment

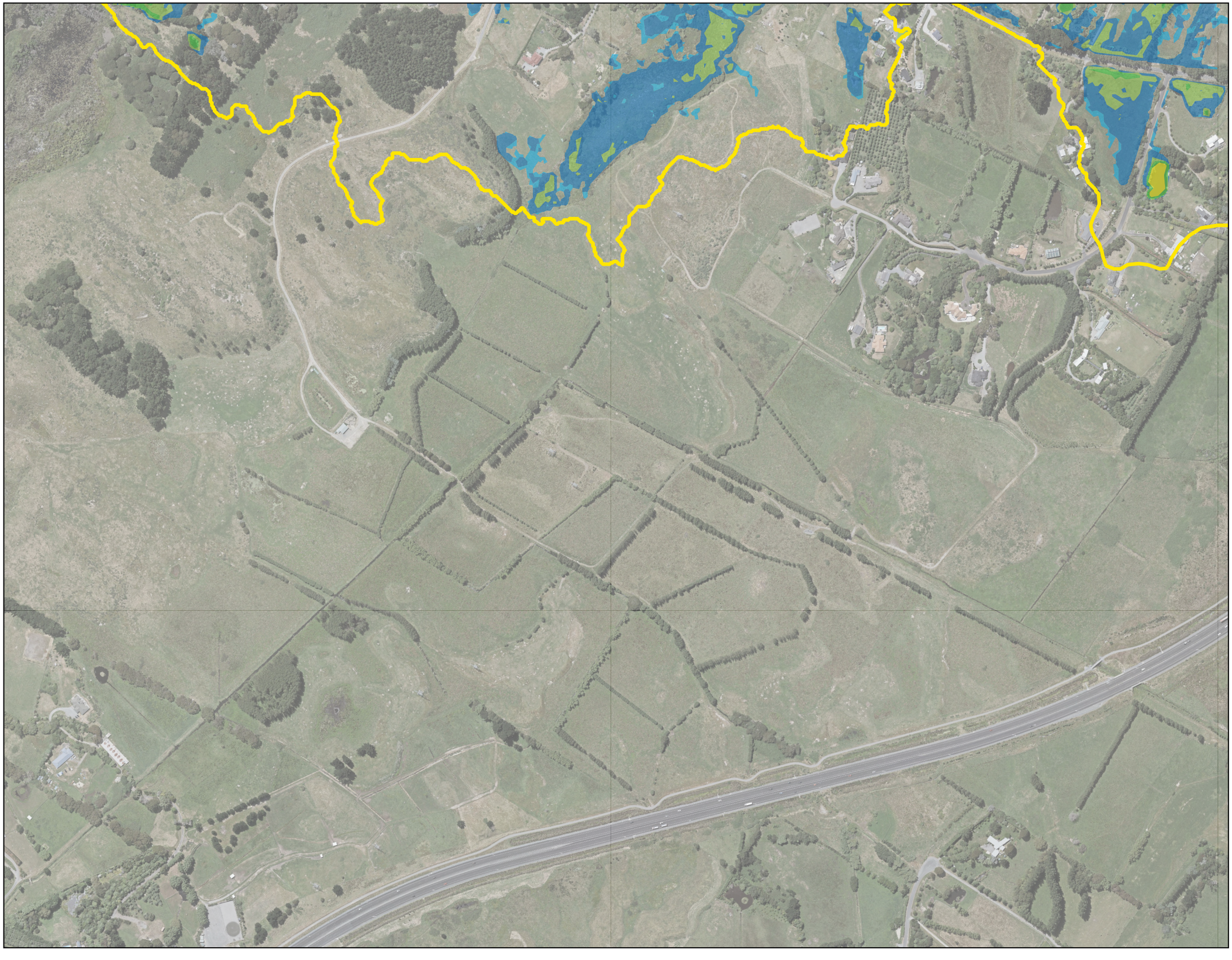
Depth

- 0.05 - 0.1 m
- 0.1 - 0.3 m
- 0.3 - 0.5 m
- 0.5 - 1.0 m
- 1.0 - 1.5 m
- 1.5 - 2.0 m

Disclaimer:
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 redusing 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.

Te Kowhai Flood Depth in a 100-Year Rainfall Event

2130 Projection - Page C2



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

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

0 150 m

Legend

Catchment Boundary

Te Kowhai Catchment

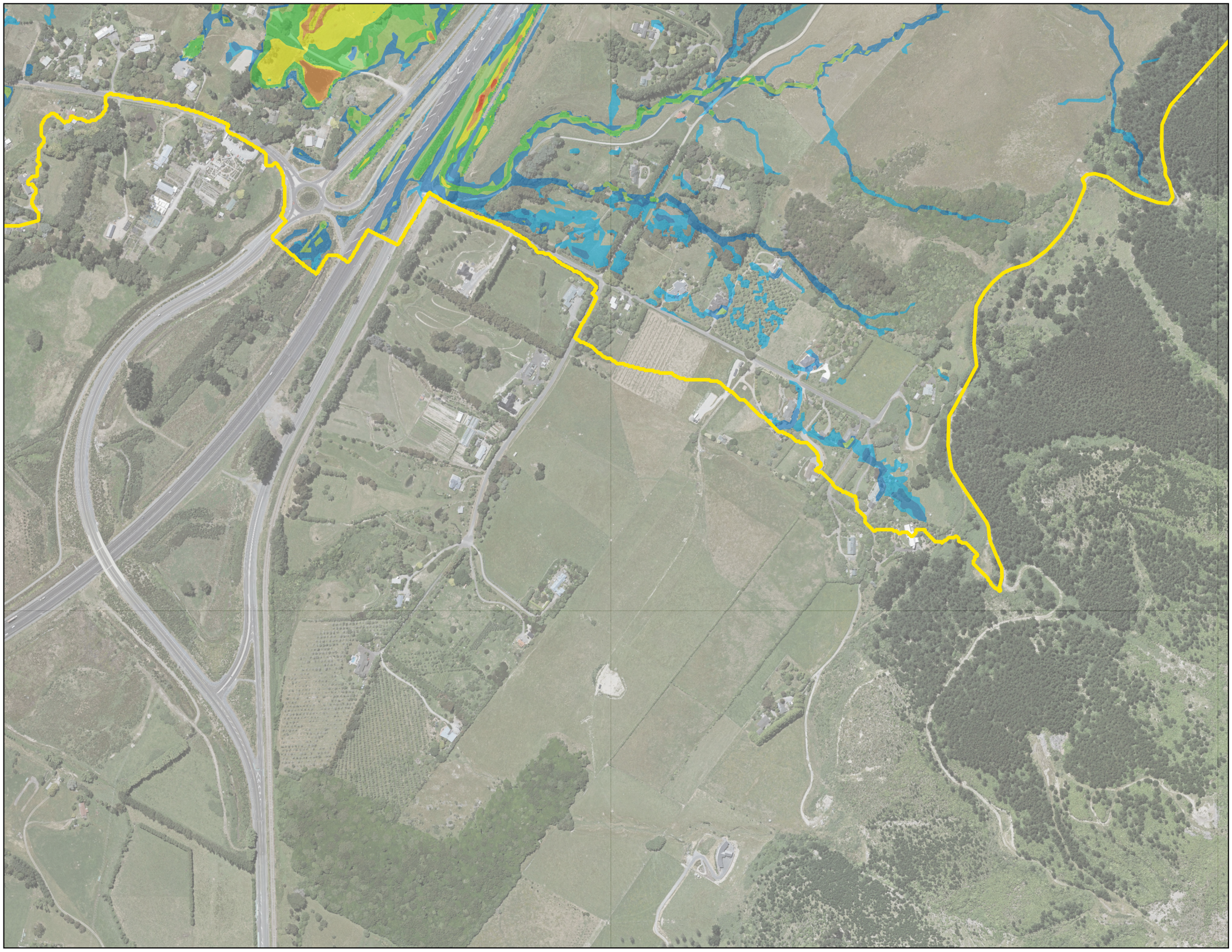
Depth

- 0.05 - 0.1 m
- 0.1 - 0.3 m
- 0.3 - 0.5 m
- 0.5 - 1.0 m
- 1.0 - 1.5 m

Disclaimer:
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Te Kowhai Flood Depth in a 100-Year Rainfall Event

2130 Projection - Page C3



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

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

0 150 m

Legend

Catchment Boundary

Te Kowhai Catchment

Depth

- 0.05 - 0.1 m
- 0.1 - 0.3 m
- 0.3 - 0.5 m
- 0.5 - 1.0 m
- 1.0 - 1.5 m
- 1.5 - 2.0 m
- 2.0+ m

Disclaimer:
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