VARIATION 3 FLOOD MAPS

NGAARUAWAAHIA

UPDATED MAPS - FINAL (NOVEMBER 2023)

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2023 FLOOD MODEL BUILD REPORT
Ngaaruawaahia

This report provides a comprehensive overview and critical analysis of the Ngaaruawaahia TUFLOW hydraulic model.

The Ngaaruawaahia hydraulic model focuses on the catchment within and surrounding Ngaaruawaahia. Ngaaruawaahia is situated at the confluence of the Waikato and Waipa rivers. From a hydrological perspective it is known for its distinctive floodplain characteristics.

Modelling Goals & Objectives

The main objective of this rapid flood model is to provide the flood extents for maximum probable development (MPD) to identify areas that additional residential development may be adversely affected by increasing the flood risk. This includes adverse effects to upstream and downstream properties in regards to erosion and flood levels.

The modelling work undertaken includes:

- Acquire and integrate the most recent data and assumptions with regards to topographic, hydrological, and meteorological data into the TUFLOW hydraulic model.
- Identify inaccuracies or deficiencies in the asset data (WDC's GIS stormwater asset information) related to critical infrastructure and revise the hydraulic model to improve the accuracy of the flood risk assessment.
- For the Ngaaruawaahia model all the available pipe data was included in the model (not just critical pipes).
- Utilise the TUFLOW hydraulic model to estimate the flood extents in the study town(s) under Maximum Probable Development (MPD) conditions, considering the anticipated effects of climate change based on the RCP 6.0 scenario (2.3 degree temp. increase) year 2081- 2100.
- Simulate and assess the flood extents for the proposed Maximum Probable Development (MPD) scenario, considering the anticipated effects of climate change based on the RCP 6.0 scenario (2.3 degree temp. increase).
- Evaluate the potential impact of future flooding including flood extents, water depths and velocities (high risk flood hazard D x V as per the district plan hazard criteria).
- Provide insights and data regarding flood extents to inform decision-making processes related to land use planning, infrastructure development and flood risk management.

Model Build Assumptions and Methodology

This hydraulic model incorporates various assumptions crucial to understanding its application, scope, and limitations. These assumptions, inherent in all hydraulic models, aim to reduce the complexity of the natural hydrologic and hydraulic processes to a manageable level while ensuring an acceptable degree of accuracy.

The hydrologic and hydraulic model selection and parameters are outlined in Table 1.

Table 1 Hydrologic and Hydraulic Model Parameters

PARAMETERS	DETAILS AND ASSUMPTIONS
SUMMARY	The flood assessment uses a 1D/2D TUFLOW (Version 2020-10-AE) hydraulic model. Design flood hydrographs (applied as both rain on grid (net rainfall) and lumped hydrographs) have been developed using HEC-HMS software for the 1% AEP events including Climate Change to 2100. In summary, the parameters used in the TUFLOW model include: • Waikato District Council (WDC) asset data was used for dimensions of stormwater assets (length, inverts, size and material/roughness). Where there was insufficient information to define asset data (i.e. pipes inverts not available), assumptions of invert levels were made based on standard cover to top of pipes (600mm) and existing ground topography for grading assumptions. • A Manning's 'n' roughness distribution has been applied to reflect changes in vegetation and land use type within zoned development areas. Roughness values have been determined from the land use coverage from LINZ data in a shapefile format for areas outside of the urban zones. • The 2D TUFLOW model uses a 2m x 2m grid with the ground level applied within each grid cell as the average of the LIDAR points within that cell. Some sensitivity check runs have utilised a 3m x 3m grid to decrease run times where required. • No soil infiltration was considered in the hydraulic model, as this is accounted for in the hydrologic modeling. • The boundary condition downstream consists of a free outfall with a nominal slope applied (assumed as a 1% in most water body discharge scenarios and 0.5% for land-based discharge scenarios- modified where considered necessary to represent more closely actual topography). For streams discharging into the Waikato River, the tailwater level has not been included as it is considered, as per the WRC flood modelling, that the river levels will not restrict (or significantly affect) the outlet capacity of the network (further refinement of the modelling in the future may include a more detailed representation of the Waikato and other river levels).
MODELLING APPROACH	
The model incorporates 'rain on grid' and lumped sub-catchment approach using excess precipitation for Maximum Probable Development (MPD).	
MODEL BOUNDARIES/ MAPPED RESULTS	The model is made up of three distinct result boundaries that are reflected in the model. These are: 1. **Rain on grid areas:** These are areas that assign rain fall directly onto the ground model. These areas represent flooding within areas of interest (MDRS and urban zones) with the

	exception of the individual road catchments (1d catchments directly routed to catchpits/manholes). 2. **1D catchments**: These catchments are represented by a numerical 1D model (Hec-hms) for model efficiency. As such the mapping of flow/water level depths in these areas are not shown. These areas are outside the areas of interest. 3. **2D Catchments:** These areas of 2D terrain show the 1D lumped catchment inflows as well overland flow from the rain on grid areas. These areas are restricted to major flow paths/stream network and do not pick up smaller overland flow to the same level as provided within the Rain-on-grid areas. There areas are outside the areas of interest
HYDROLOGIC ASSUMPTIONS	
HYDROLOGICAL LOSSES	Hydrological losses for the MPD scenario were Calculated using the SCS method, which uses different curve numbers (CN) based on soil drainage and land use. Because of the variety of soils in the area, the CN values were determined for each sub-catchment. Adopted curve numbers have been sourced from S-Map (soil maps) and as per the Waikato Hydraulic Modelling Runoff Guidelines. The weighted curve numbers for developed areas also incorporated another % of impervious areas in the model. The impervious assumptions are based on the table below

Zone /Area	% Impervious in MPD
Rural	Area taken from building layer and 100% impervious applied
Existing Residential	70
Residential Growth Cells (includes Roads)	80
Commercial	90
Industrial	90
Existing Roads	Area taken from Road layer and 80% impervious applied

Initial Abstraction (IA) and storage: IA is the amount of rain that soaks into the ground before a rainfall event turns into runoff. This was modelled as per the Waikato Stormwater Runoff Modelling Guidelines. The following equation is utilised to calculate IA in the model.

$$I_a = 0.05 \; x \; S$$

Storage is calculated as per the Waikato Regional Guidance:

$$S = \left(\frac{1000}{CN} - 10\right) 25.4 \quad (mm)$$

CATCHMENT DELINEATION/ RAINFALL AREAS	
NET RAINFALL ZONES	Zones and soil classes form the 2d areas that are used for the 2D rainfall areas.

EXTERNAL AND INTERNAL 1D CATCHMENTS AND ZONES.

Hydrologic sub-catchment delineation is initially developed using the watershed definition algorithm within the GIS environment. This tool defines sub-catchment boundaries based on the digital terrain data (LIDAR) analysis and the identification of flow paths based on topography

There are 2 types of sub-catchments within this hydraulic model. These are:

1. 1D Catchments that drain into the areas of interest. These areas are represented by a HEC-HMS model input and shows no overland flow paths or flooding (as these are outside of the area of interest), but contribute (inflows) to areas of interest.
2. Individual Road Catchments: These are delineated for manholes and catch pits inside the road polygon. The catchments are delineated in a way to make sure to have at least one receiving catch pit in each of them.

DESIGN RAINFALL

Rainfall data was taken from the existing model which was sourced from the NIWA HIRDS v4 website on the October 2023 and is outlined below. As per the Waikato Stormwater Runoff Modelling Guidelines for infrastructure an RCP 6 year 2081-2100 (as a minimum) has been adopted.

Town	Duration / AEP event	1% AEP
Ngaaruawaahia	24h - Duration	198mm

LAND USE / ROUGHNESS

The model uses Manning's coefficients to represent energy losses due to channel and floodplain roughness. These coefficients are assumed to be constant across each cell, and spatial variability is handled by using different values in different cells. The area was separated into land cover classifications in QGIS using the latest road and properties layer from LINZ along with aerial photos. The remaining areas of the catchment were assumed to be grass cover. Manning's values are consistent with the Waikato Stormwater Management Guideline.

Houses	Grass	Roads	Water bodies (Low Vegetation)	Bush (Dense Vegetation)	Cultivated Areas (Medium Vegetation)
0.5	0.03	0.015	0.025	0.06	0.04

1D HYDRAULIC MODEL ASSUMPTIONS

PIPES

- The pipes with missing or '0' diameter in the asset were assumed to have the same diameter as the pipe on the immediate downstream.
- Pipes with missing inverts were assigned the invert levels from the surrounding manholes or pipes.
- In case none of the connected manholes and pipes have any invert information, then the inverts were interpolated from ground levels.

  Invert = Ground level - 0.6m – Diameter of the largest connected pipe.

MANHOLES

- Diameters for manholes with missing diameters were assumed to be 1050mm dia unless connected pipe(s) sizes warranted an increased diameter.
- Missing manhole inverts were taken from the invert of the lowest connected pipe.

CULVERT INPUTS	Culverts are incorporated in the model where a significant waterway occurs. Culvert information has been extracted from WDC's GIS database. Where information was not available/missing the following assumptions have been applied: 1. The culvert inverts have been determined from the existing channel terrain data. 2. The pipe diameters and number of culverts have been determined from the stream cross-sections and upstream and downstream pipe diameters. 3. In some cases where the culvert is unable to determined, the crossings have been "burnt in" (embedded into the ground model) to reflect a continuation of flow.
HYDRAULIC LOSSES	Hydraulic losses have been applied to inlet and outlet of culverts and pipes – losses have not been applied to the manholes.
LIDAR	The DEM provided had a resolution of 1m x 1m that forms the base information for the hydraulic model. This data was assumed to be accurate. Where it was observed that water levels and vegetation have not been accurately removed within the LIDAR ground model or there where observed connectivity issues – modification (Z lines) were added to the LIDAR.
GRID SIZE	The 2D TUFLOW model uses a 2m x 2m grid with the ground level applied within each grid cell as the average of the LIDAR points. The SGS approach samples the bathymetric data at a finer resolution than the 2D grid (0.5m x 0.5m), generating depth-varying hydraulic properties for each cell.
BOUNDARIES	Downstream boundaries that discharge from the network are set as a normal slope consistent with the gradient of the land.
RIVERS AND STOP BANKS	Rivers were excluded from the modeling. A normal depth boundary condition with a slope of 1% was assumed along the river stop banks. No abnormal ponding or glass wall effect were seen in the final results.
SENSITIVITY RUNS	Sensitivity analysis has been undertaken using different scenarios. This is outlined in the below Quality Assurance and Sensitivity Checking section.
ASSUMPTION AND LIMITATIONS	The modelling undertaken aligns, as much as practicable within the project scope, with the Waikato Stormwater Runoff Modelling Guidelines (June 2018).
CALIBRATION	Calibration has not been undertaken on the model as data is unavailable. Calibration and or validation could be undertaken within the stream network if monitoring stations are utilised in the future and survey of debris levels are taken post extreme events.

Quality Assurance and Sensitivity Checking

This section addresses the additional checking and quality assurance outlined in the TMW evidence prepared for the MDRS Variation 3 hearing. This also aligns with the discussions at the hearing in regard to model confidence and standard practice for urban scale hydraulic models.
Additional model runs were undertaken to test the model's sensitivity to certain parameters. This was to provide an indication of how each model is affected by certain key parameters. Although these parameters are selected by following guidance there is an envelope of interpretation required. This methodology enables confidence in the flood maps if the results are similar to the base run as this shows the factors are less critical. If the results are significantly different this highlights the parameter maybe more critical in which case the parameter is re-considered in more detail to confirm it is correct.

Modelling QA Summary:

1. Base model:
    1. Manual removal of small, isolated ponding areas that were considered to represent errors in topography from LIDAR processing or not relevant to the flooding assessment scope (identification of properties with flooding that requires assessment if developed).
    2. Manual removal of small, isolated ponding areas that were considered unlikely to occur due to potential LIDAR processing areas from vegetation.
    3. Checking of connectivity between large flooding area split by roads or embankments.
    4. Cutting in of channels to represent connection under bridges or channels not considered to be accurately represented by LIDAR.
    5. Checking and inclusion of pipes and culverts in areas considered likely to contain pipes and culverts based on knowledge of areas and surrounding topography.

2. Blockage Scenarios
    1. Base Blockage Scenario (as included in finalised flood maps): Critical pipes only included in model: If pipes are included in model (refer pipes modelled maps) then these are considered to be at 100% capacity (0% blocked). Initially all pipes below 300mm were excluded, however during the QA stage some pipes 300mm dia and smaller were included if they had potential to impact ponding areas.
    2. Blockage Scenario 1: 100% blockage on all pipes within model (Bridges and Z channels = 0% blockage).
    3. Blockage scenario 2: Blockage scenario for all pipes included in model are outlined in the table below:

Pipe size(s)	<300mm	300-600mm	600-900mm	>900mm	Bridges/open channels (Z Cuts)
% blockage	100%	75%	50%	25%	0%

3. Runoff factors:

Current CN Values as included in finalised flood maps

Soil Type	Cover type / Soil Description	CN values				
		Forest	Grass	Dirt	Cropland	Impervious
A	Moderately Well Draining & Well Draining	30	39	72	67	98
B	Imperfectly Well Draining	55	61	82	78	98
C	Poorly Drained	70	74	87	85	98
D	Very Poorly Drained	77	80	89	89	98
Impervious		98	98	98	98	98

Sensitivity check CN Values: 25% added to existing (Existing CN * 1.25 + rounded to nearest whole number to a max of 98). Increased values are underlined.

Soil Type	Cover type / Soil Description	CN values				
		Forest	Grass	Dirt	Cropland	Impervious
A	Moderately Well Draining & Well Draining	<u>38</u>	<u>49</u>	<u>90</u>	<u>84</u>	98
B	Imperfectly Well Draining	<u>69</u>	<u>76</u>	<u>98</u>	<u>98</u>	98
C	Poorly Drained	<u>88</u>	<u>93</u>	<u>98</u>	<u>98</u>	98
D	Very Poorly Drained	<u>96</u>	<u>98</u>	<u>98</u>	<u>98</u>	98
Impervious		98	98	98	98	98

4. Hydrology:
    1. Existing = 24 hour rainfall event + 6 RCP climate change scenario (as included in finalised flood maps) for years 2081-2100.
    2. Check = 24 hour event + 8.5 RCP climate change scenario for years 2081-2100.

5. Comparison to existing models
    1. WRC flood model – This comparison showed a good correlation with the WRC flood maps. Due to the WRC flood modelling data used (based on more coarse LIDAR) this rain on grid model picked up similar areas of flooding but in finer detail. It showed that a number of flooding areas extend further than the WRC modelling boundary and appears to have given a more detailed extent in these areas.
    2. Previous WSP rapid flood hazard modelling. This mapping was based on previous LIDAR which is less accurate than the 2022 LIDAR. This also excluded all pipes. This quick method for flood area identification showed good correlation in the gully areas.

6. Sensitivity results comparison:

The following compares the results from each sensitivity run to the base model Each run utilises a 3m x 3m grid and hasn't been cleaned (removal of small isolated ponding areas). Refer to summary table below for results.

Figure 1: Base map (Flood depths)

Figure 2: Blockage Scenario 1 – Shows increased flooding by the 100% blockage scenario. This shows an increase in flood levels but still contain within the gully areas. This blockage scenario is unlikely to occur as large culverts are less likely to completely block. No difference in areas that are not constrained by culverts. Result: Not considered a critical factor.

Figure 3: Blockage Scenario 2 – Shows a slight increase in flooding from the base model and a reduction in flood level from the 100% blockage scenario as would be expected. Result: Not considered a critical factor in the flood model as very similar to base model.

Figure 4: CN Increased Scenario: Shows slight increase from base model (small isolated flooding areas not cleaned). Result: Not a critical factor in the flood model as very similar to base model.

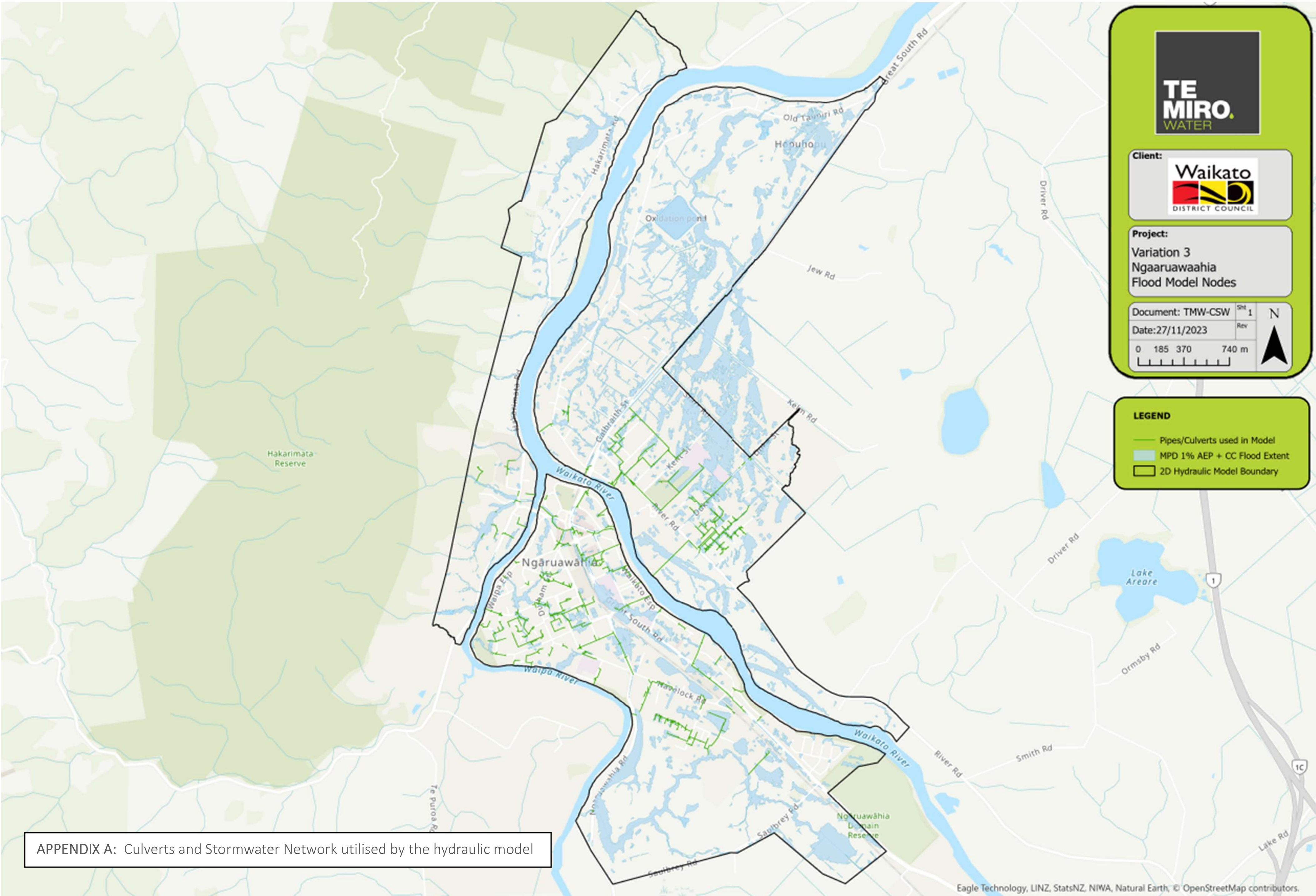
Figure 5: Increased Climate Change Scenario (RCP8.5): Shows slight increase from base model (small isolated flooding areas not cleaned). Very similar to the CN increase scenario. Result: Not a critical factor in the flood model as very similar to base model.

Sensitivity Checking Results summary:

Scenario	Critical	Comment
Blockage 1	**Yes** in areas directly affected by culverts. **No** in areas not affected by culverts (as expected).	Blockage of large culverts is unlikely so not considered a critical issue requiring further testing. Consideration of catchment characteristics in terms of blockage risk could be considered in the future if further refinements are undertaken.
Blockage 2	No	Slight increase only – no additional properties inside flood extent
CN factor increase	No	Slight increase only – no additional properties inside flood extent
Climate change increase	No	Slight increase only – no additional properties inside flood extent

No additional sensitivity checking or changes to the base model parameters are required due to the results above showing that the parameters tested are not critical enough to warrant further testing or adjustments. Any adjustments within the guidance parameters are unlikely to show substantial changes in the flood extent.

Author(s):	Reviewer(s):
Saeed Ashouri and Andrew Boldero	Britta Jensen
24/11/2023	24/11/2023



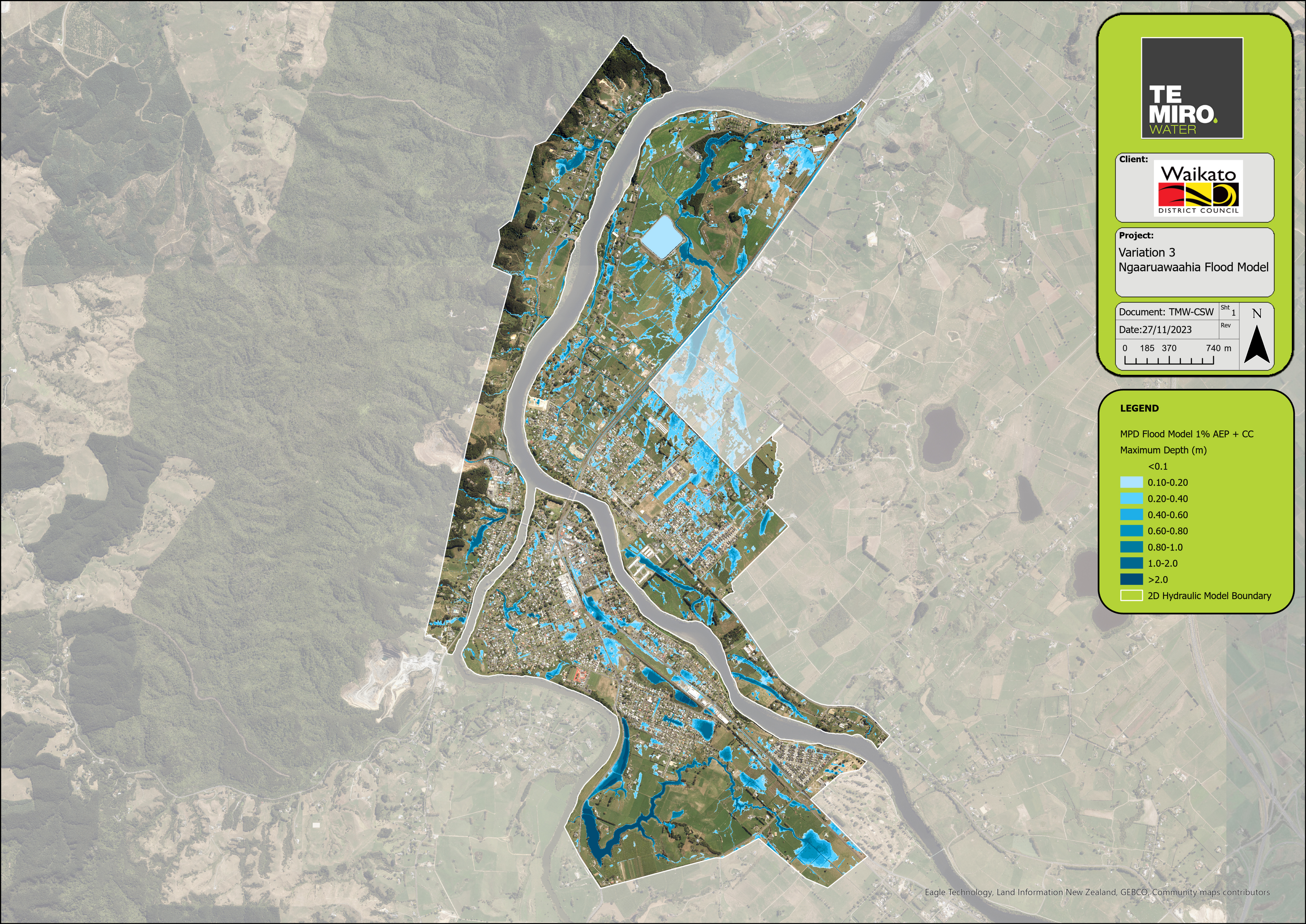
APPENDIX A: Culverts and Stormwater Network utilised by the hydraulic model

VARIATION 3 FLOOD MAPS

NGAARUAWAAHIA

UPDATED MAPS - FINAL (NOVEMBER 2023)

Te Miro Water Consultants, 3 Empire Place, Cambridge, 3434. Waikato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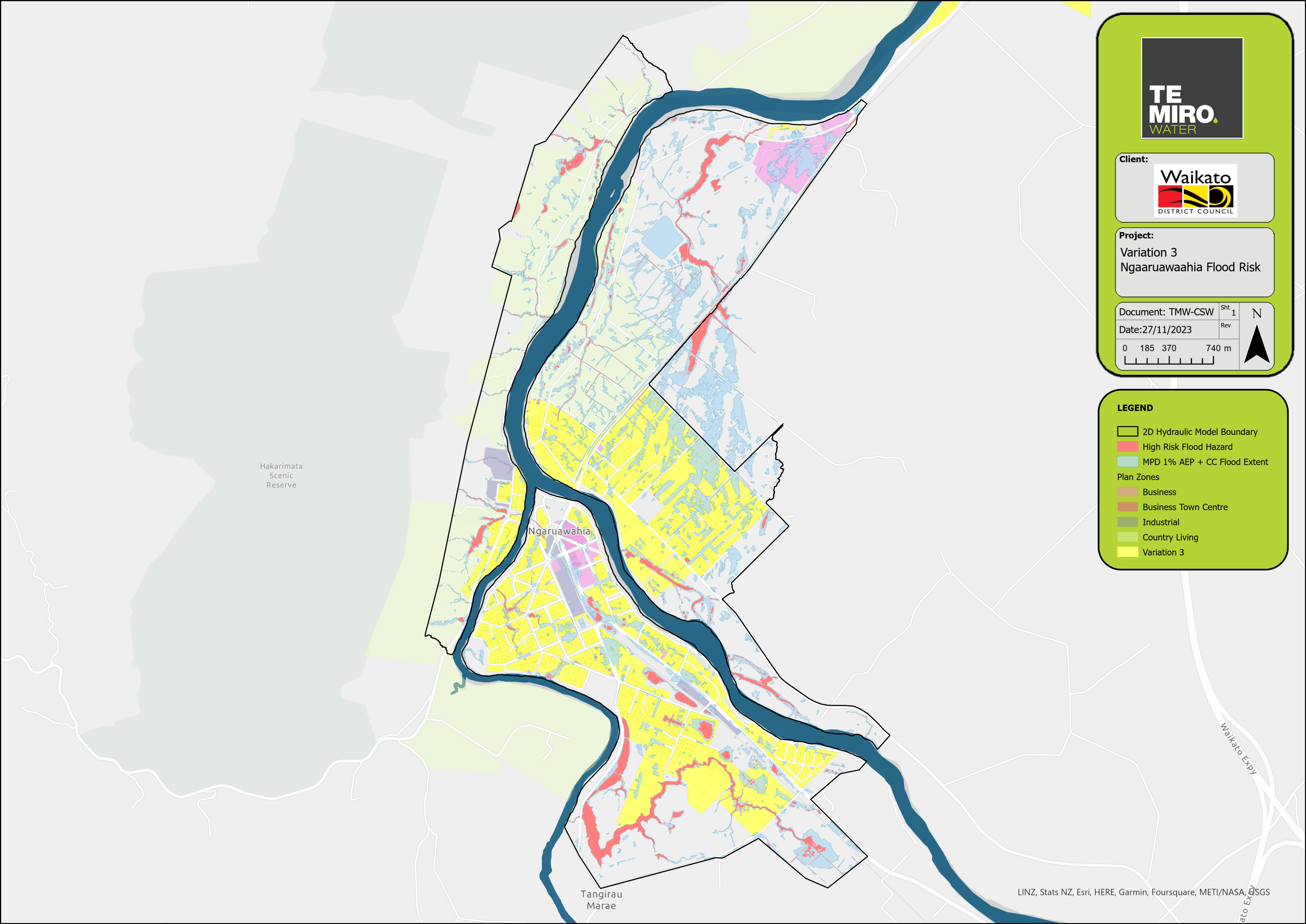
Client:
Waikato DISTRICT COUNCIL
Project:
Variation 3
Ngaaruawaahia Flood Model
Document: TMW-CSW
Sht 1
Rev
Date:27/11/2023
0 185 370 740 m
N
LEGEND
MPD Flood Model 1% AEP + CC
Maximum Depth (m)
<0.1
0.10-0.20
0.20-0.40
0.40-0.60
0.60-0.80
0.80-1.0
1.0-2.0
>2.0
2D Hydraulic Model Boundary
Eagle Technology, Land Information New Zealand, GEBCO, Community maps contributors



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Ngaaruawaahia Flood Risk
Document: TMW-CSW
Sht 1
Rev
Date:27/11/2023
0 185 370 740 m
N
LEGEND
2D Hydraulic Model Boundary
High Risk Flood Hazard
MPD 1% AEP + CC Flood Extent
Plan Zones
Business
Business Town Centre
Industrial
Country Living
Variation 3
Hakarimata Scenic Reserve
Ngaruawahia
Tangirau Marae
Waikato Expy
LINZ, Stats NZ, Esri, HERE, Garmin, Foursquare, METI/NASA, USGS