TE MIRO. WATER

STORMWATER INFRASTRUCTURE ASSESSMENT

DATE: 14/07/2022

TO:	TONY QUICKFALL & TONY COUTTS, WAIPA DISTRICT COUNCIL (WDC)
FROM:	BRITTA JENSEN (AUTHOR) MIKE CHAPMAN (REVIEWER) (TMW)
SUBJECT:	DRAFT PLAN CHANGE 26 (ENABLING HOUSING SUPPLY AMENDMENT ACT): STORMWATER INFRASTRUCTURE ASSESSMENT

Te Miro Water has undertaken a review of the stormwater infrastructure needs and constraints to support:

a. Plan Change 26 - enabling housing intensification in all residential zones of Cambridge, Te Awamutu and Kihikihi.

In summary the report addresses the items requested as part of the IFS scope of services. The scope items are summarised below with our response documented in subsequent sections:

1. *Summary of Flood Hazard Mapping and Modelling.*
2. *Flood Impacted Properties Assessment*
   a. *Description of Waikato Regional Council (WRC) river / stream locations with protection off sets plus river flood extent boundaries. Mapping of these and any additional information available to WDC, e.g. flood plain extents around Golf Road etc.*
   b. *Description of urban flood mapping and areas of flooding (DxV risk plus significant depth ponding / secondary flow paths).*
   c. *Spatial representation of infrastructure constraints (risk areas) represented as traffic light colours for all residential zones in Cambridge, Te Awamutu and Kihikihi as follows:*
      i. *Red – high risk or not feasible for intensification*
      ii. *Amber – moderate risk or insufficient information*
      iii. *Green – low or no risk*
3. *Recommendations on Stormwater Bylaw Statement:*
   a. *Statement around protection of overland flow paths (strengthen stormwater bylaw provision), protection of waterways and not exacerbating present flood areas.*
4. *Representation of network Level of Service (LoS) and properties that impact this LoS.*
   a) *Geographical representation of present areas where there is insufficient reticulation capacity and / or LoS (10 years in new areas and 2-year in older areas) not met.*
   b) *For all residential zones in Cambridge, Te Awamutu and Kihikihi, a spatial representation of infrastructure constraints or risk areas represented by RAG traffic light colours shown spatially as follows:*
      i. *Red – high risk or not feasible for intensification*
      ii. *Amber – moderate risk or insufficient information*

iii. *Green – low or no risk*

This memo does not cover:

5. *Summary of WDC's District Wide Stormwater Consent:*
   a. *Description likely areas of mitigation / enhancement required to mitigate environmental effects and to allow the consent renewal to WRC and stakeholder satisfaction, i.e., likely need for areas of protected planting and treatment / retention devices to be installed in some urban catchments.*

   b. *Mapping of likely areas of works required to satisfy new consent requirements.*

A summary of the district wide consent was not required by WDC.

SUMMARY OF FLOOD HAZARD MODELLING AND MAPPING

The flood hazard mapping presented in this report is from modelling undertaken by Waipa District Council from 2018 to current (2021) by WSP Ltd (Part A.1 Stormwater Modelling Overview Report November 2021). The modelling is to inform Council's Flood Hazard Mapping project (the full WSP model report is in Attachment 3).

The models cover the urban centres of Cambridge, Te Awamutu, and Kihikihi. WSP utilised the most recently available asset data (at the time – October 2018) and survey data from February 2019 provided by Waipa District Council. Growth cells have generally not been incorporated within the model boundaries and where included they are limited to catchments that flow towards an urban area.

It is expected that flood modelling will be part of the structure/master planning stage where possible and the Flood Hazard Maps will be updated at regular intervals. The flood extents are shown in figures 1,2,3.

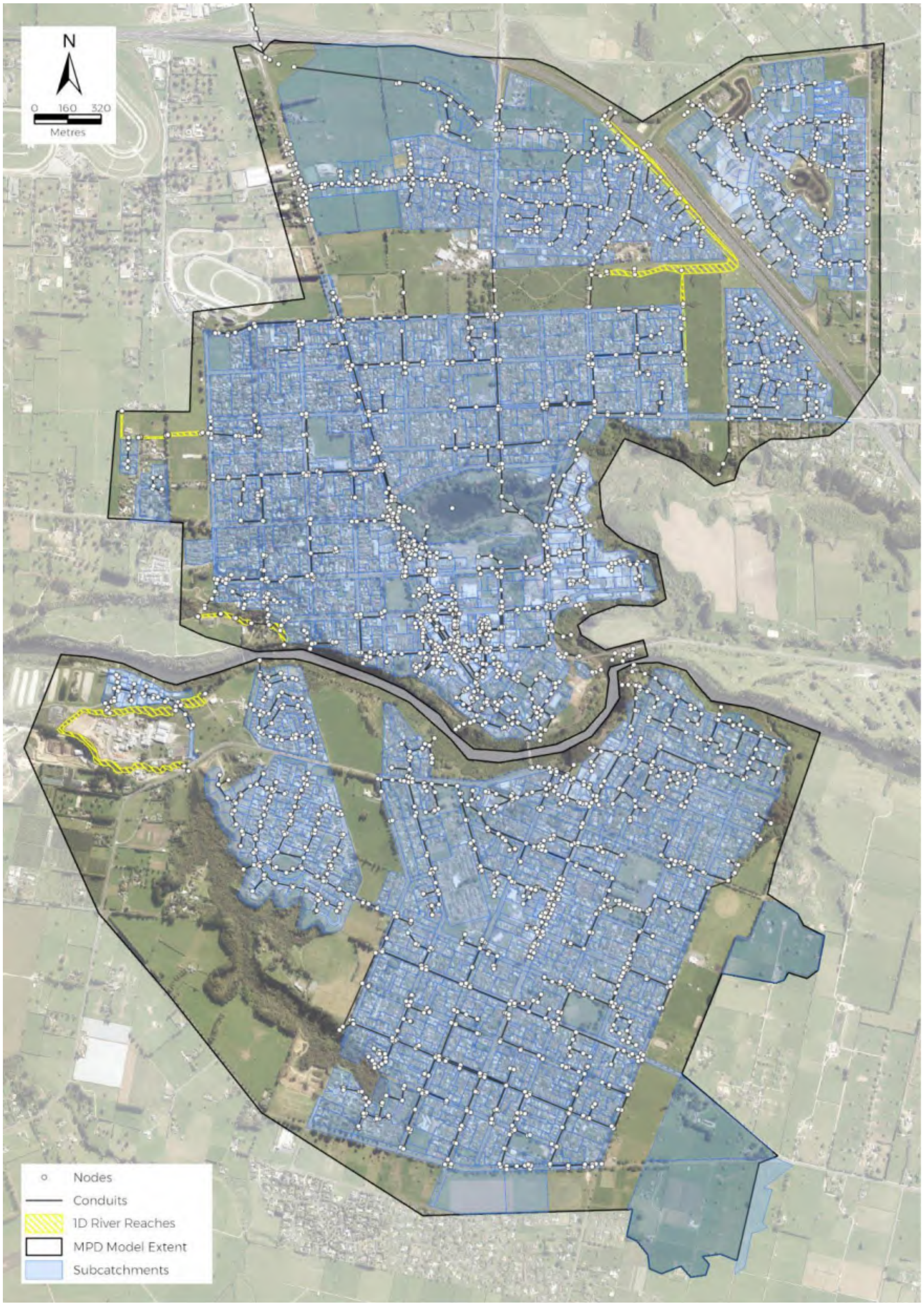

Figure 1. Cambridge model extent

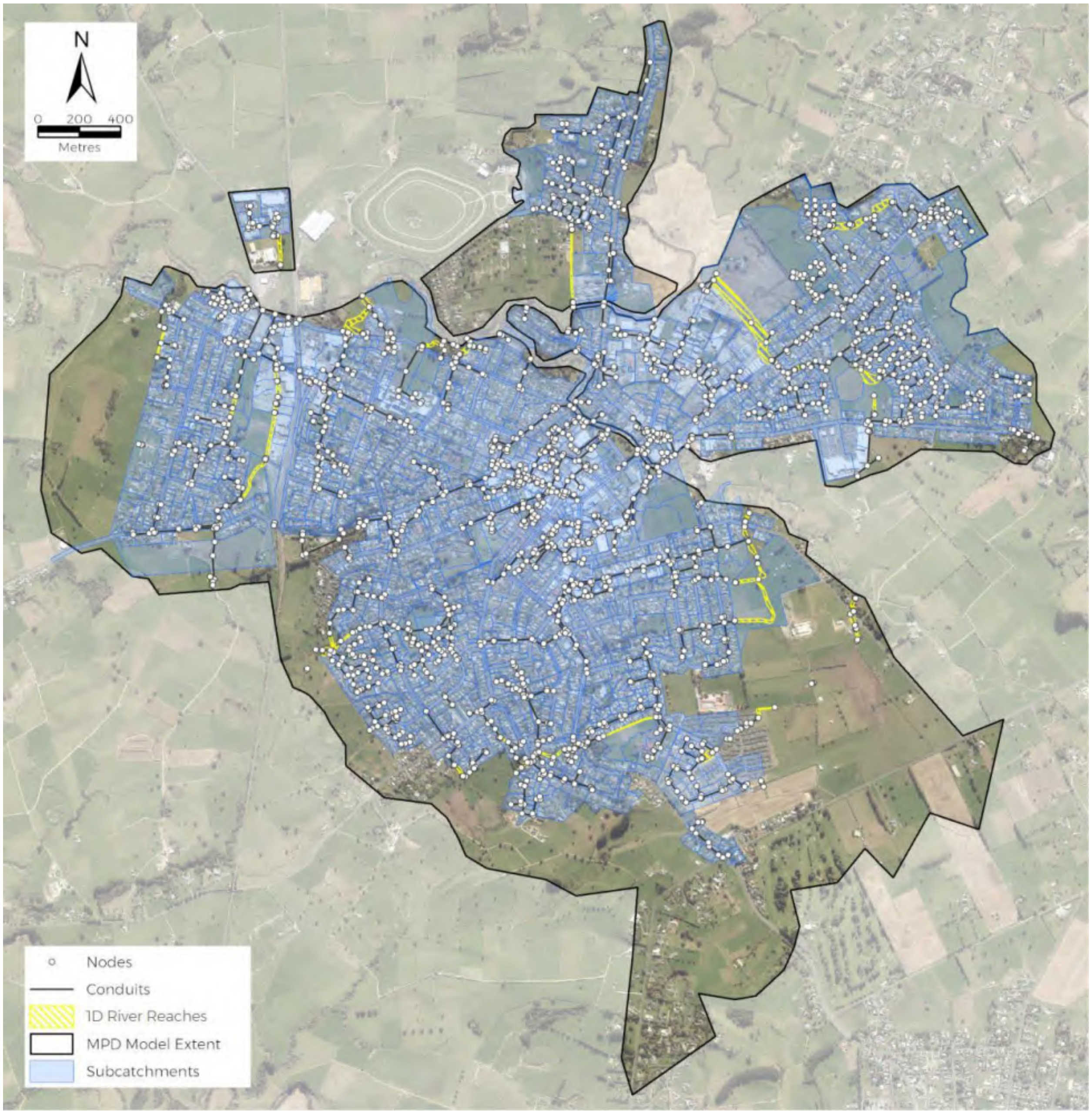

Figure 2. Te Awamutu Model extent

Figure 3. Kihikihi Model

The following model build assumptions are adopted:

1. Schematisation
    - The model is a 1D-2D coupled model using ICM v7.0. The rainfall is applied both with sub-catchments loaded to specific nodes (typically urban areas) and rain on grid (surrounding less developed areas).
    - The model includes pipes, manhole, open channels, and streams (some modelled as 1D river reaches) as well as hydraulic structures such as culverts.
    - Allowance has not been made for drainage infrastructure that was not included in the Waipa District Council asset register.
2. Rainfall
    - The rainfall profile used the specified nested storm profile from the WRC modelling guidelines, with accumulated depths extracted from HIRDS.
3. Hydrology
    - The loss method adopted SCS curve number (CN) method as per Waikato Regional Council Runoff Modelling Guidelines (Shaver, 2020).

- The hydrological soil groups used to define the CN were assumed based on previous model calibration.
- Curve numbers were then assumed based on land cover and hydrological soil group (Shaver, 2020).
- Sub-catchments were primarily delineated by parcel boundaries, which is considered most appropriate for smaller events (i.e., up to the design capacity of the system). This may result in some inconsistencies regarding sub-catchment loading for very large events in cases where the pipe network may not be consistent with the topographic drainage directions (i.e. the ground slope may not match the pipe connections to the SW network).

4. Boundary Conditions
   - For TA, the Mangaone Stream level was used as downstream boundary conditions.

5. Hydraulics
   - Pipes with diameter 300 mm or larger were generally included in the model.
   - Road and residential sub-catchments were modelled separately to allow sensitivity of residential property imperviousness to be assessed.

The following methodology was used to determine the flood hazard and overland flow maps:

1. Flood hazard utilised the Depth (D) x Velocity (V) Risk Assessment - The modelled flood extents, depths and velocity were used to determine the risk to human life using the matrix in Figure 4.

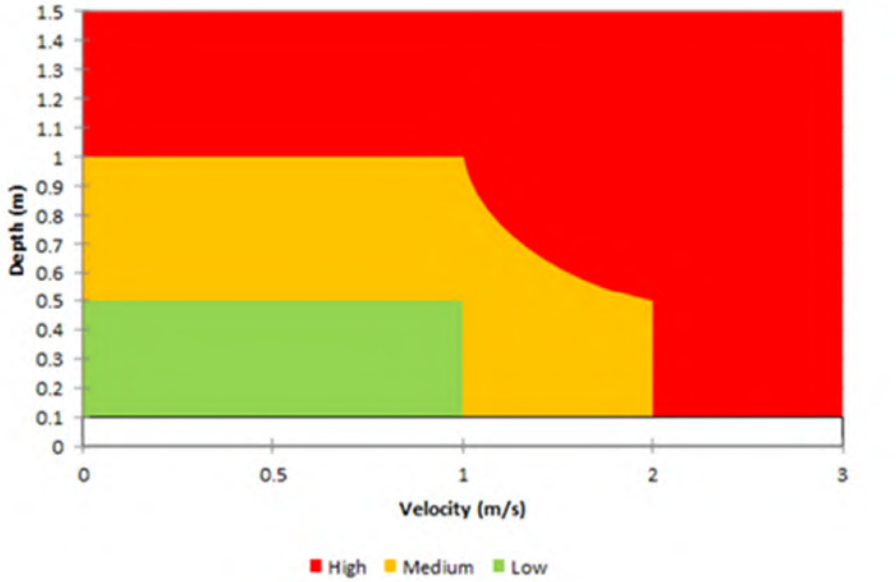

Figure 4. Schematic of adopted Flood Hazard Matrix.

2. Flood hazard was also adopted from the district planning zones as outlined below:

High Risk Flood Zone:

High Risk Flood Zone is a separate district plan zone for land that is subject to river or surface flooding during an event with an annual exceedance probability of no more than one percent, and during such an event:

- The depth of flood waters exceeds 1m; or
- The speed of flood waters exceeds 2m per second; or
- The flood depth multiplied by the flood speed exceeds one.

This zone does not incorporate Waipa’s Flood Hazard or Flood Hazard Layers as outlined in this report.

<u>Natural Hazard</u>:

Natural Hazard Zone is a separate district plan zone for any atmospheric, earth, or water related occurrence (including earthquake, tsunami, erosion, volcanic and thermal activity, landslip, subsidence, sedimentation, wind, drought, fire or flooding), the action of which affects or may affect human life, property, or the environment.

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3. Overland flow paths were adopted though processing flood extents and areas of high velocity. A detailed outline of this methodology is provided in the flood hazard mapping methodology report (V1 Part b January 2022)

FLOOD IMPACTED PROPERTIES ASSESSMENT:

An assessment of residential properties likely to be impacted by the 1% AEP flooding (RCP 6 and existing development scenario) was undertaken as follows:

1. The flood hazard layers for the assessment are:
    a. The District Plan WRC river / stream flood hazard extent boundaries. Assuming all district plan flood extent boundaries are high hazard due to the associated depth of flow.
    b. The flood hazard layers associated with the Waipa District Flood Hazard Mapping Portal, namely:
        i. Depth x Velocity layers (high, medium, and low flood risk)
        ii. The flood extent layers outlining ponded areas and overland flow paths.
2. Properties are classified as high medium or low flood risk based on the following assumptions:
    a. Commercial, industrial, and general park areas were removed from the assessment.
    b. Properties with less than 20% flooding area over the boundary are not categorised. This is due to the likelihood of being able to mitigate flood risk and to remove isolated ponding and lidar errors.
    c. Where a medium hazard ponding area is part of a low hazard and/or overland flow path area, the properties that overlay the flood extent are considered high hazard. This is due to the likely impact this property has on high hazard ponding.
    d. Likewise, where a high hazard ponding area forms part of a low and medium hazard and/or overland flow path area, the properties that overlay the flood extent are considered high hazard. Again, this is due to the likely contribution of this property area to high hazard ponding.

Maps showing properties impact by high, medium, and low hazard zones in Kihikihi, Te Awamutu and Cambridge are shown in Attachment 1.

RECOMMENDATIONS ON THE STORMWATER BYLAW STATEMENT

WDC have asked for a recommended statement to adopt in the Stormwater Bylaw around protection of overland flow paths, protection of waterways and not exacerbating existing flood areas. These statements are as follows:

1. Unless the council approves otherwise or expressly authorised by an operative resource consent, no person may stop, obstruct, alter, interfere with, or divert any watercourse, flood plain, overland flow path, drain, localised ponded area or wetland on public land, in a manner likely to:

(a) adversely affect the performance of the watercourse, flood plain, localised ponded area, overland flow path, drain or wetland;

(b) adversely alter the velocity of stormwater; or

(c) adversely divert the flow of stormwater; or

(d) adversely increase the water level depth or peak flow or stormwater.

2. Unless the council approves otherwise or expressly authorised by an operative resource consent, the owner, occupier, or manager of any premises on private land must ensure that any watercourse, flood plain, overland flow path, drain, localised ponded area or wetland on the premises is kept free from obstruction that is likely to:

   (a) adversely affect the performance of the watercourse, flood plain, overland flow path, drain or wetland.

   (b) adversely alter the velocity of stormwater; or

   (c) adversely divert the flow of stormwater; or

   (d) adversely increase the water level depth or peak flow or stormwater.

REPRESENTATION OF LOS AND PROPERTIES THAT IMPACT THE LOS

An assessment of the stormwater networks that are unlikely to meet the LoS for the 10% and 50% AEP (capacity maps), and the properties that impact LoS was undertaken as follows:

1. 1D network model outputs (stormwater pipe) were sourced from the WDC Flood Model (Part A.1 Stormwater Modelling Overview Report November 2021).
2. GIS analysis to determine which pipes are below capacity (existing development scenario)
3. Catchments with more than 50% of the network below capacity were considered to not meet LOS requirements.
4. Properties within these catchments are highlighted as high risk because they will add pressure (peak flow and runoff volume) to the overall network capacity.

The pipe capacity maps are shown in Appendix 2 and the full WSP stormwater modelling report is in appendix 4 of this report (which contains all assumptions, model development etc). The pipe networks with a low level of service (50% and 10 % AEP including RCP 6) as well as properties within the catchment are provided in the maps in Attachment 2.

The pipe capacity maps are based on the modelled maximum surcharge state – which indicates whether the flow rate in the system exceeds the capacity of the drainage network to the extent that levels rise within manholes at any time during the model simulation.

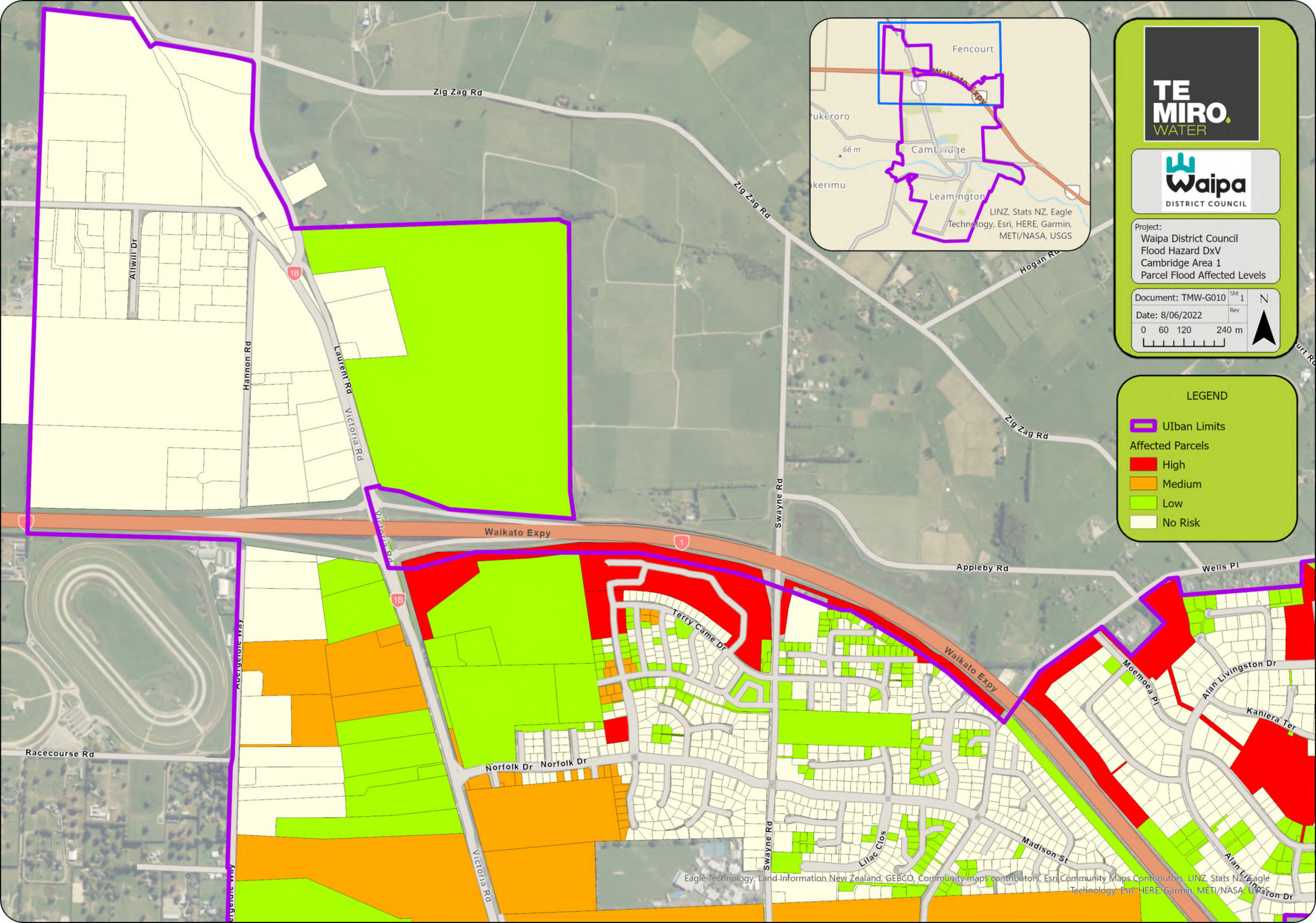
The Surcharge state indicates whether the flow rate in the system has exceeded the capacity of the drainage network to the extent that levels rise within manholes. Surcharge is categorised into one of three values:

<1: Pipes not surcharged (the water level is below the soffit level at both ends of the pipe).

1: Pipes surcharged with capacity (water level at the upstream and / or downstream end of the pipe is above the soffit level, and the flow is less than or equal to the pipe's full capacity).

2: Pipes surcharged without capacity (water level at the upstream and / or downstream end of the pipe is greater than the soffit level, and the flow is greater than the pipe's full capacity).

ATTACHMENT 1 – PROPERTIES IMPACTED BY FLOOD HAZARD



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Waipa DISTRICT COUNCIL
Project:
Waipa District Council
Flood Hazard DxV
Cambridge Area 1
Parcel Flood Affected Levels
Document: TMW-G010
Sht 1
Rev
Date: 8/06/2022
0 60 120 240 m
N
LEGEND
UIban Limits
Affected Parcels
High
Medium
Low
No Risk
Fencourt
Pukeroro
Cambridge
Leamington
66 m
LINZ, Stats NZ, Eagle Technology, Esri, HERE, Garmin, METI/NASA, USGS
Zig Zag Rd
Hogan Rd
Allwill Dr
Hannon Rd
Laurent Rd
Victoria Rd
Waikato Expy
Swayne Rd
Appleby Rd
Wells Pl
Terry Came Dr
Moemoea Pl
Alan Livingston Dr
Kaniera Ter
Racecourse Rd
Abergeldie Way
Norfolk Dr
Lilac Clos
Madison St
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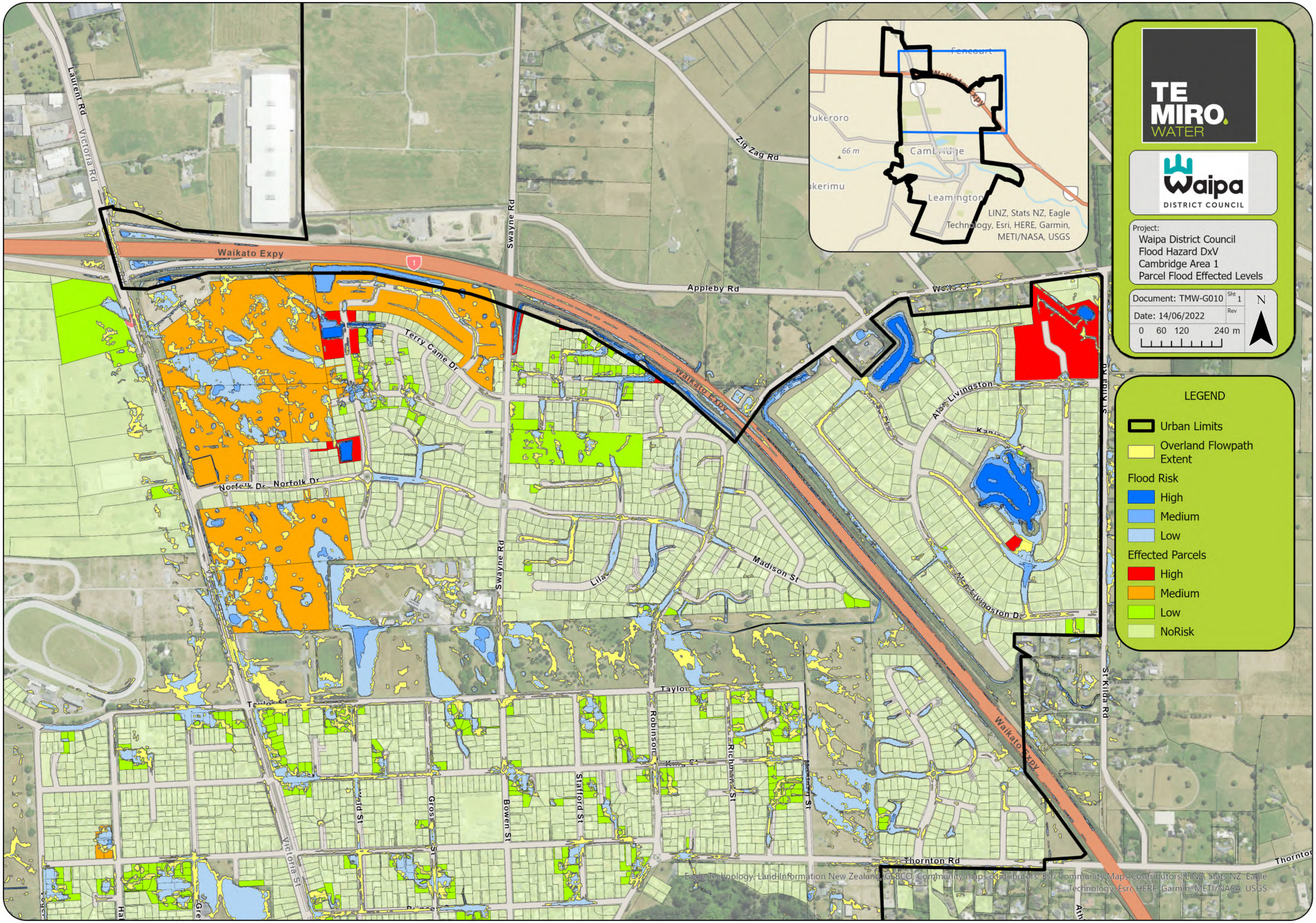
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Flood Hazard DxV
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LEGEND
Urban Limits
Overland Flowpath Extent
Flood Risk
High
Medium
Low
Effected Parcels
High
Medium
Low
NoRisk
Fencourt
Pukeroro
Cambridge
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LINZ, Stats NZ, Eagle Technology, Esri, HERE, Garmin, METI/NASA, USGS
Waikato Expy
Laurent Rd
Victoria Rd
Swayne Rd
Zig Zag Rd
Appleby Rd
Terry Came Dr
Norfolk Dr
Madison St
Alan Livingston Dr
St Kilda Rd
Taylor St
Robinson St
King St
Richmond St
Bowen St
Stafford St
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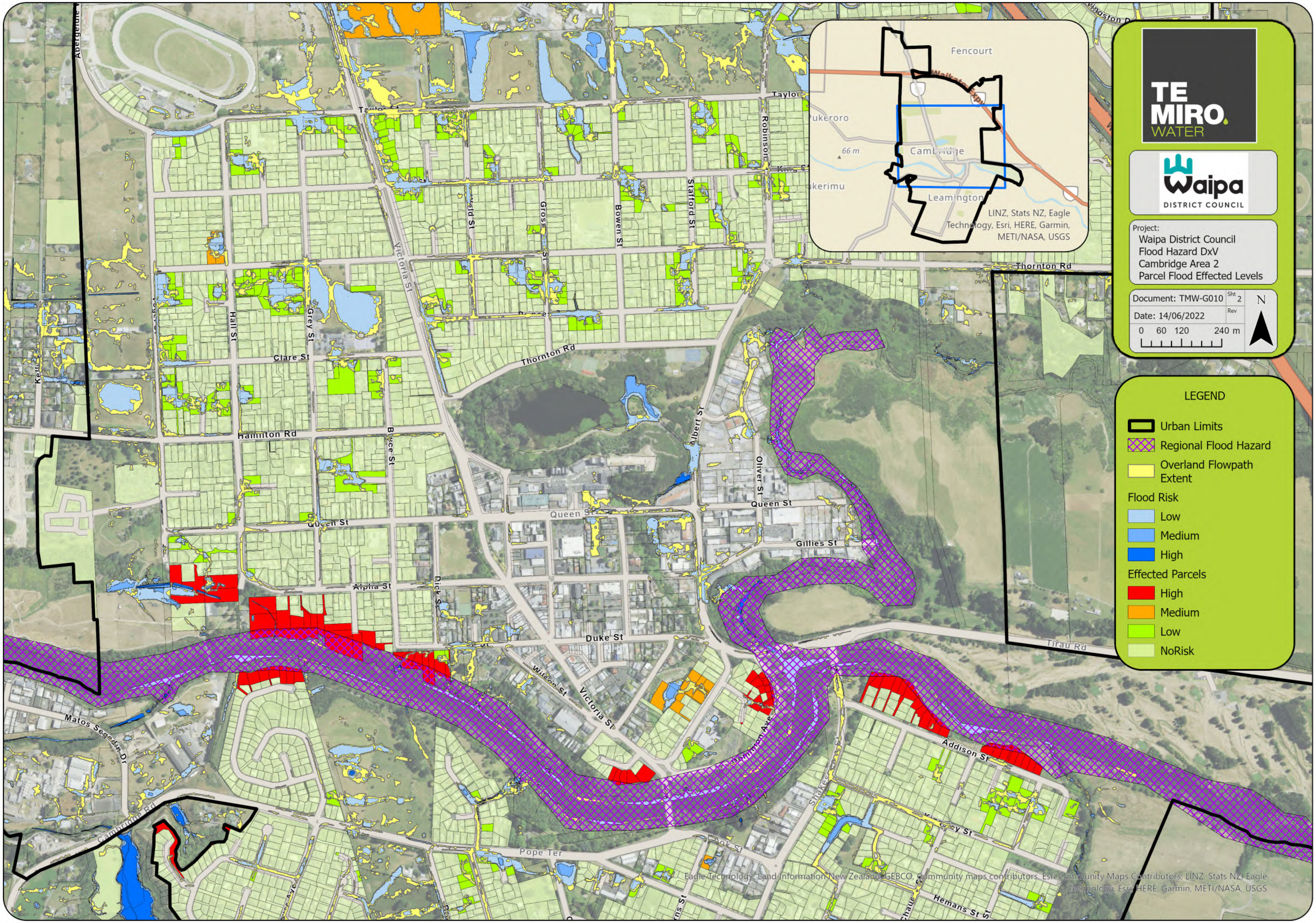
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LEGEND
Urban Limits
Regional Flood Hazard
Overland Flowpath Extent
Flood Risk
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Effected Parcels
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NoRisk
Fencourt
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Cambridge
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LINZ, Stats NZ, Eagle Technology, Esri, HERE, Garmin, METI/NASA, USGS
Thornton Rd
Hall St
Grey St
Clare St
Hamilton Rd
Queen St
Alpha St
Duke St
Victoria St
Bowen St
Stafford St
Robinson St
Albert St
Oliver St
Gillies St
Tirau Rd
Addison St
Pope Ter
Hemans St
Matos Segedin Dr
Wilson St
Bryce St
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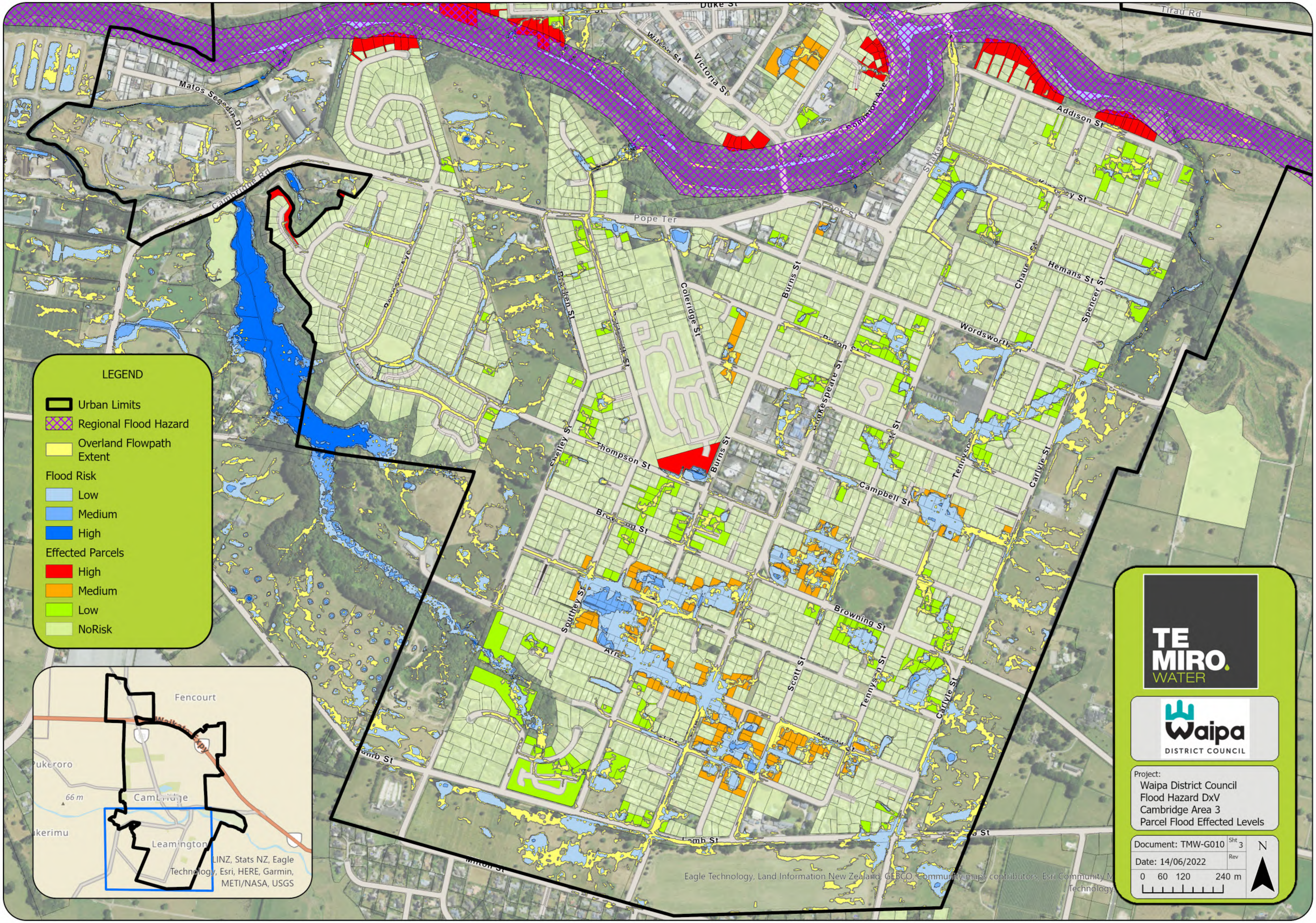

LEGEND
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Regional Flood Hazard
Overland Flowpath Extent
Flood Risk
Low
Medium
High
Effected Parcels
High
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Low
NoRisk
Duke St
Tirau Rd
Wilson St
Victoria St
Matos Segedin Dr
Cambridge Rd
Addison St
Pope Ter
Hemans St
Spencer St
Wordsworth
Burns St
Coleridge St
Shakespeare St
Thompson St
Shelley St
Campbell St
Carlyle St
Browning St
Scott St
Tennyson St
Southey St
Lamb St
Milton St
Fencourt
Pukeroro
Cambridge
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Waipa DISTRICT COUNCIL
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Waipa District Council
Flood Hazard DxV
Cambridge Area 3
Parcel Flood Effected Levels
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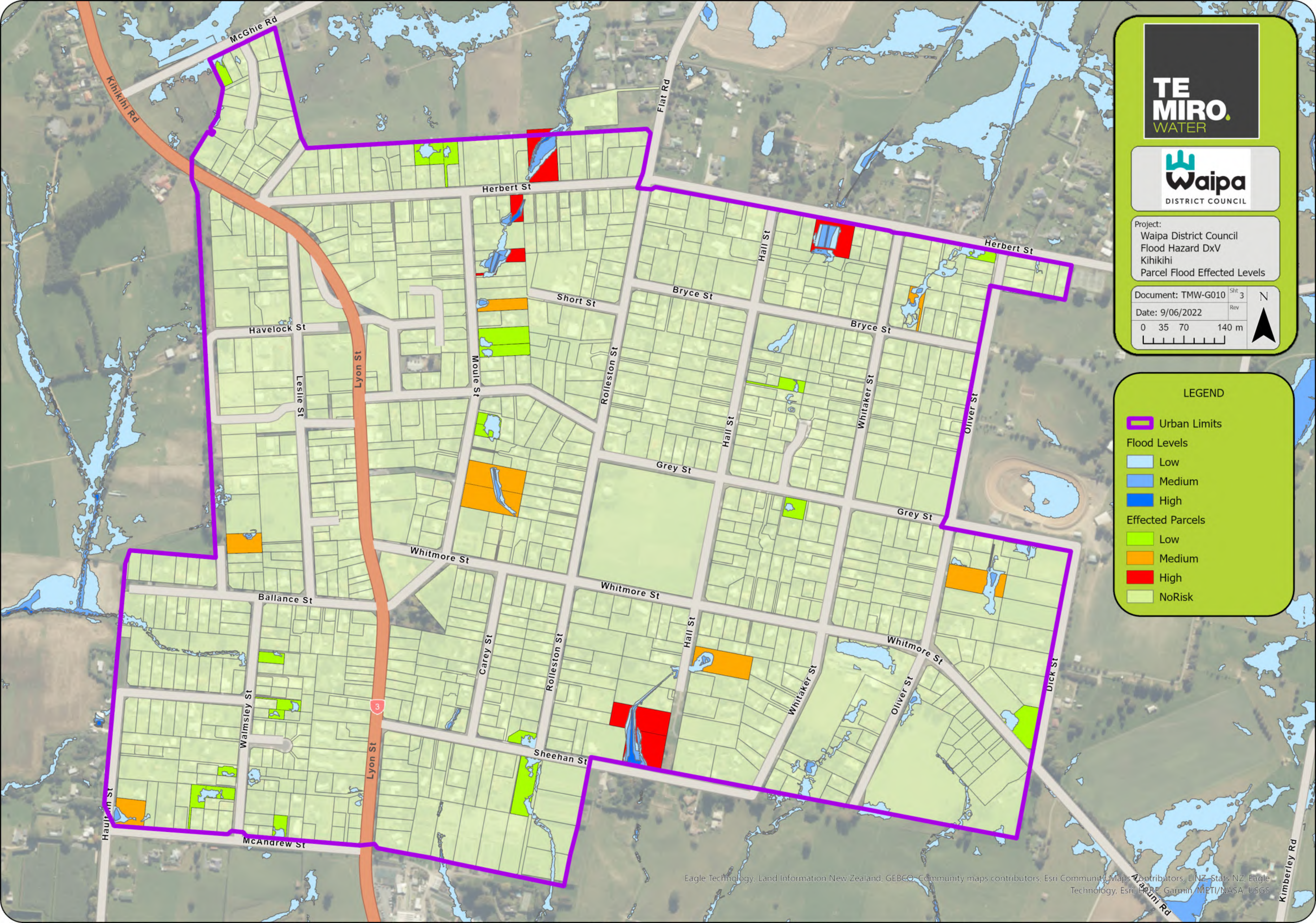

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Waipa District Council
Flood Hazard DxV
Kihikihi
Parcel Flood Effected Levels
Document: TMW-G010
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Date: 9/06/2022
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LEGEND
Urban Limits
Flood Levels
Low
Medium
High
Effected Parcels
Low
Medium
High
NoRisk
McGhie Rd
Kihikihi Rd
Flat Rd
Herbert St
Short St
Bryce St
Havelock St
Lyon St
Moule St
Leslie St
Rolleston St
Hall St
Whitaker St
Oliver St
Grey St
Whitmore St
Ballance St
Carey St
Walmsley St
Sheehan St
Dick St
McAndrew St
Haultain St
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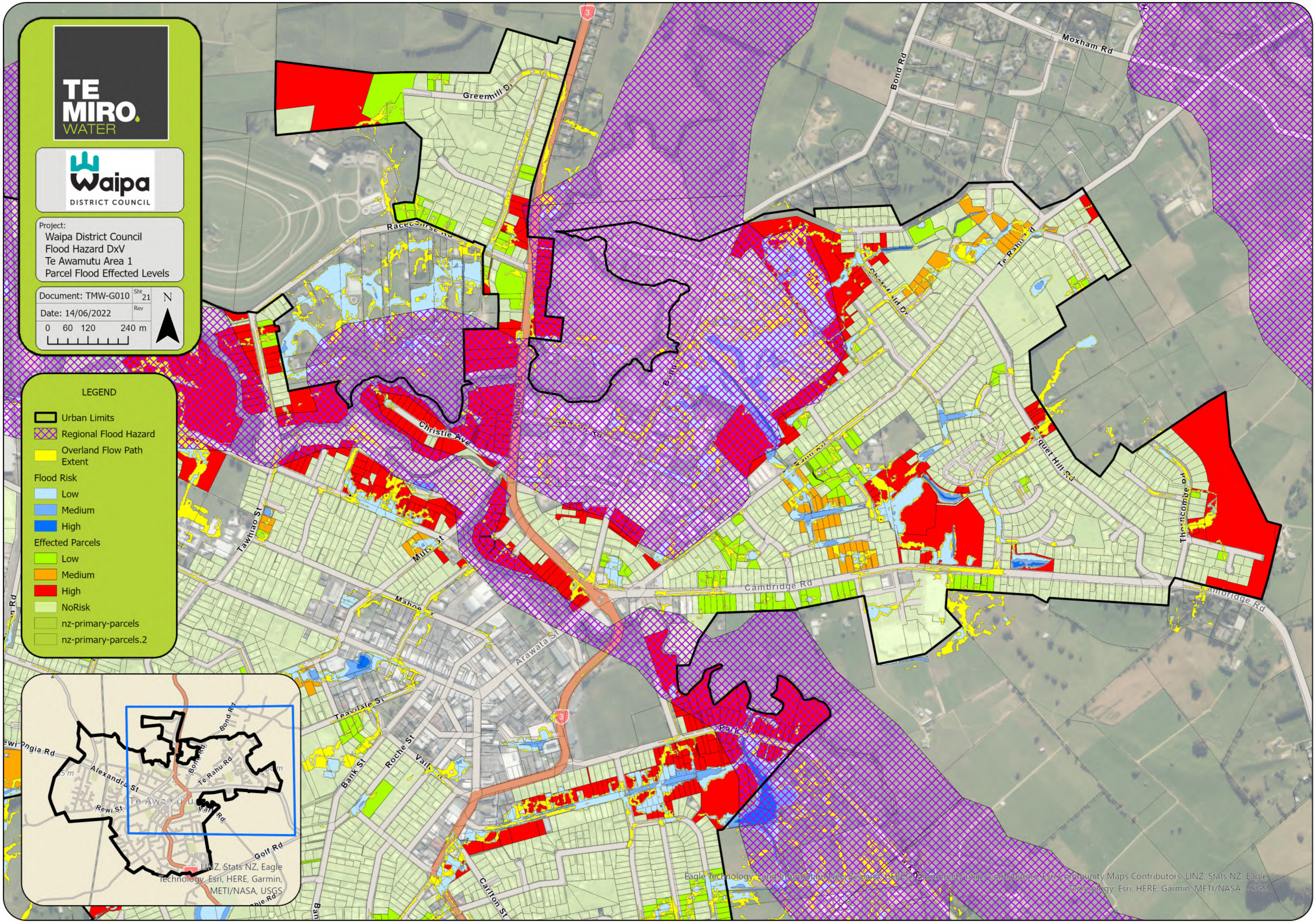
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Document: TMW-G010
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Date: 14/06/2022
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Urban Limits
Regional Flood Hazard
Overland Flow Path Extent
Flood Risk
Low
Medium
High
Effected Parcels
Low
Medium
High
NoRisk
nz-primary-parcels
nz-primary-parcels.2
Moxham Rd
Bond Rd
Greenmill Dr
Racecourse Rd
Te Rahu Rd
Christie Ave
Tawhiao St
Puniu Rd
Cambridge Rd
Thornecombe Pl
Arawata St
Teasdale St
Bank St
Roche St
Park Rd
Carlton St
Alexandra St
Rewi St
Golf Rd
LINZ, Stats NZ, Eagle Technology, Esri, HERE, Garmin, METI/NASA, USGS
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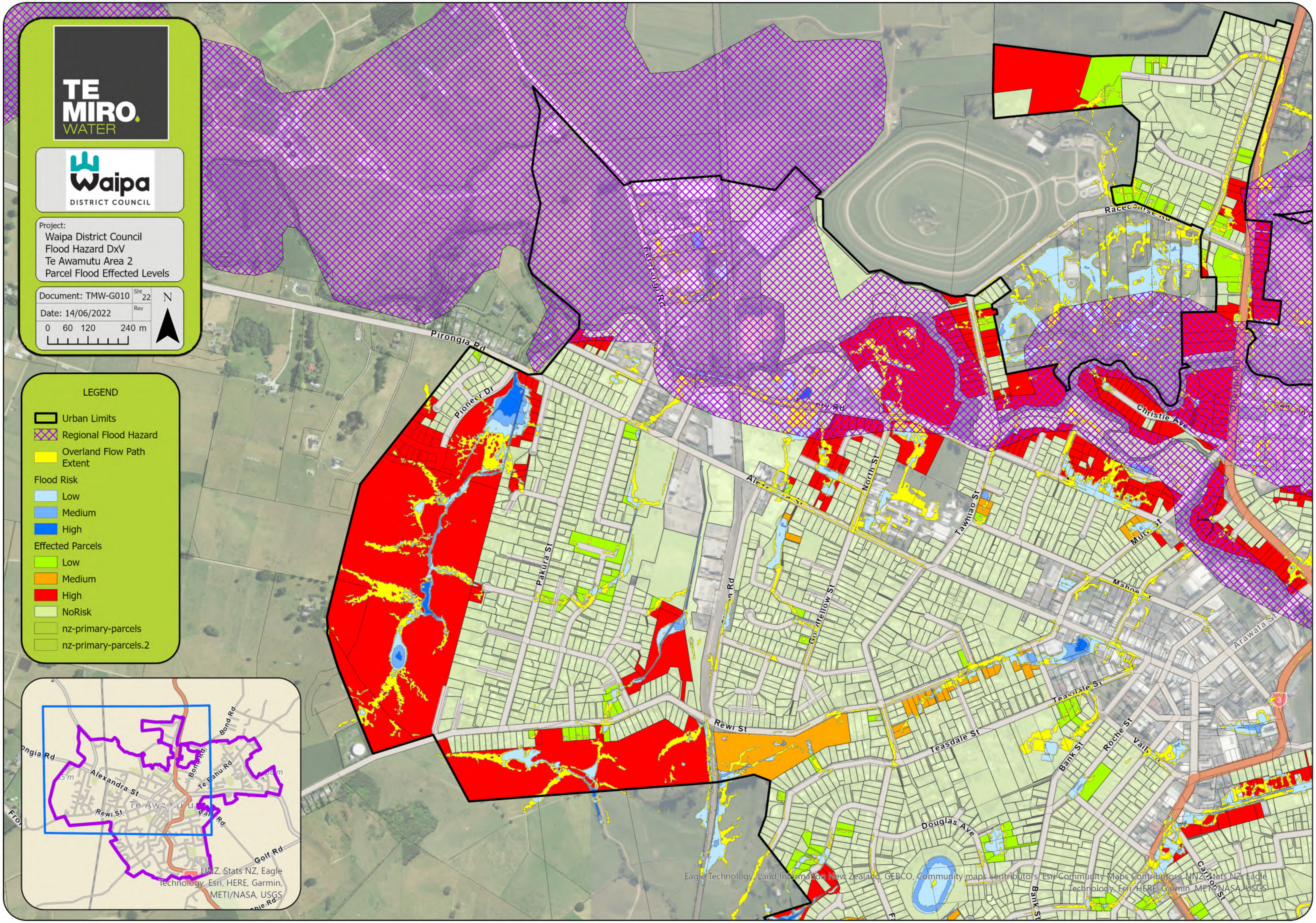
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Parcel Flood Effected Levels
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LEGEND
Urban Limits
Regional Flood Hazard
Overland Flow Path Extent
Flood Risk
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Medium
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Effected Parcels
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NoRisk
nz-primary-parcels
nz-primary-parcels.2
Pirongia Rd
Pioneer Dr
Pakura St
Rewi St
Teasdale St
North St
Tawhiao St
Christie Ave
Racecourse Rd
Mahoe St
Arawata St
Roche St
Bank St
Douglas Ave
Alexandra St
Bond Rd
Te Rahu Rd
Golf Rd
Park Rd
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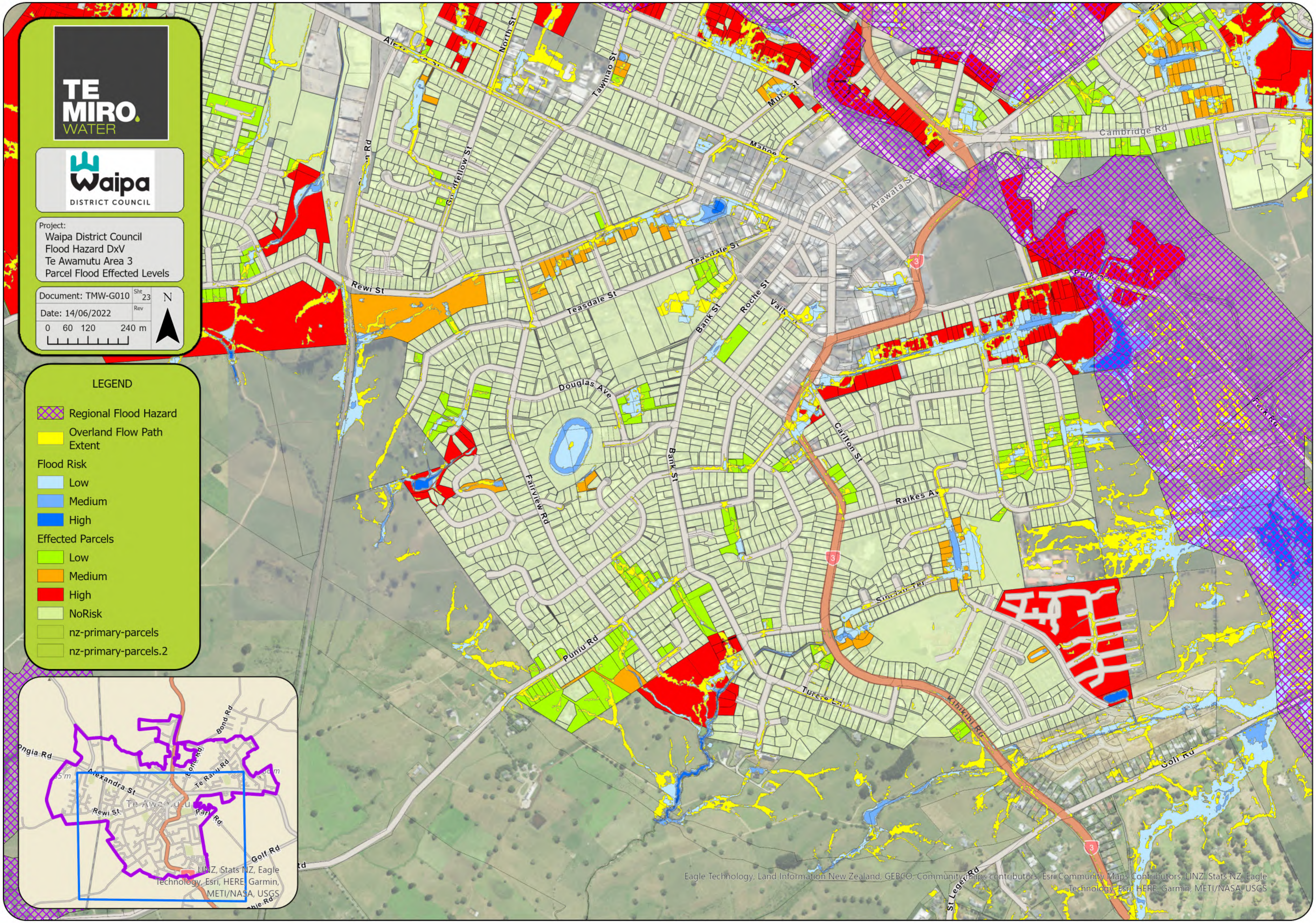

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Te Awamutu Area 3
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LEGEND
Regional Flood Hazard
Overland Flow Path Extent
Flood Risk
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Effected Parcels
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Medium
High
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Rewi St
Teasdale St
Douglas Ave
Bank St
Roche St
Fairview Rd
Puniu Rd
Carlton St
Raikes Av
Cambridge Rd
Arawata St
Tawhiao St
North St
Park Rd
Turere Ln
Kihikihi Rd
Golf Rd
St Leger Rd
Alexandra St
Te Rahu Rd
Bond Rd
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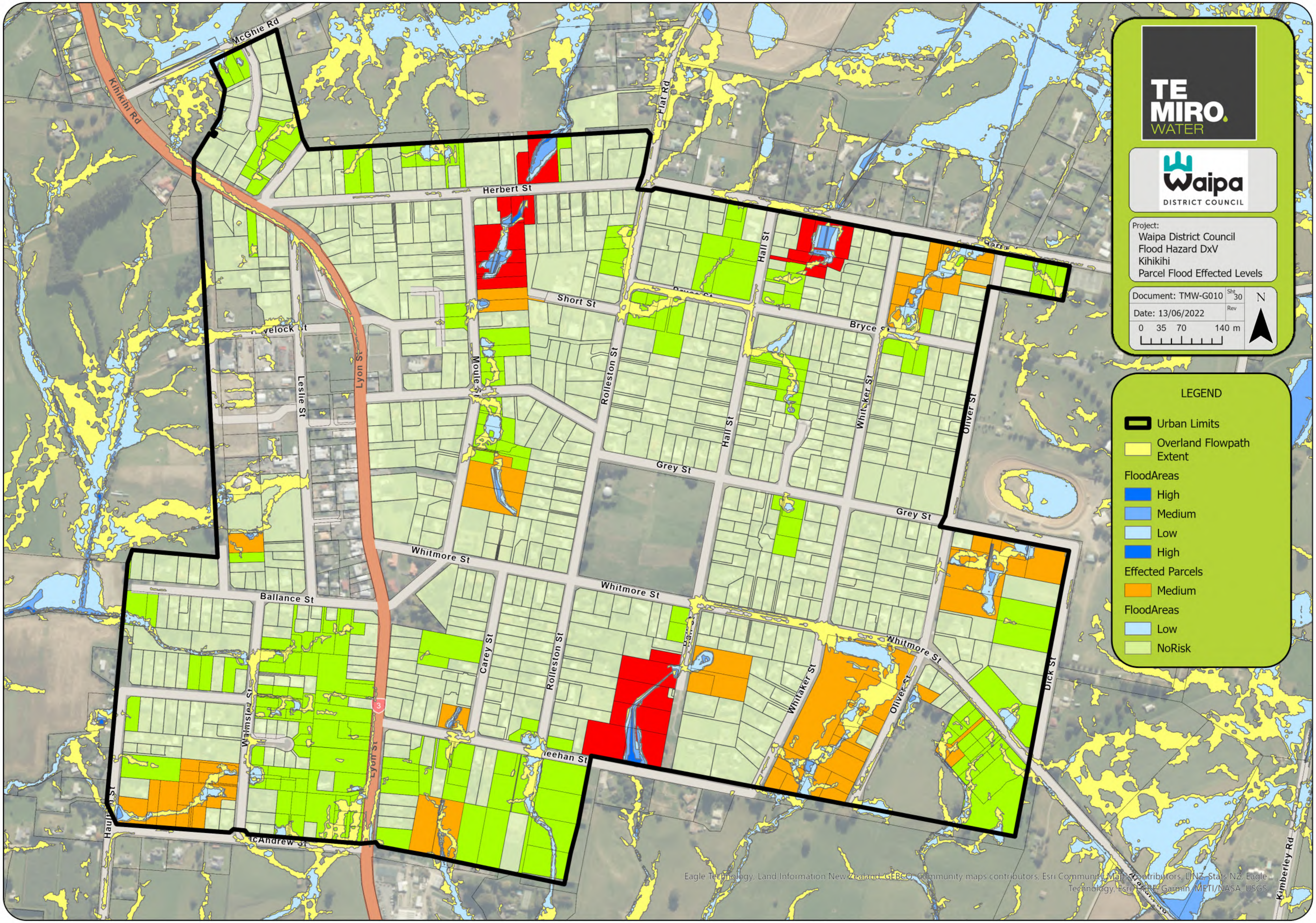

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Flood Hazard DxV
Kihikihi
Parcel Flood Effected Levels
Document: TMW-G010
Sht 30
Date: 13/06/2022
Rev
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LEGEND
Urban Limits
Overland Flowpath Extent
FloodAreas
High
Medium
Low
High
Effected Parcels
Medium
FloodAreas
Low
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McGhie Rd
Kihikihi Rd
Flat Rd
Herbert St
Short St
Hall St
Bryce St
Leslie St
Lyon St
Moule St
Rolleston St
Whitaker St
Oliver St
Grey St
Whitmore St
Ballance St
Carey St
Walmsley St
Sheehan St
Dick St
Kimberley Rd
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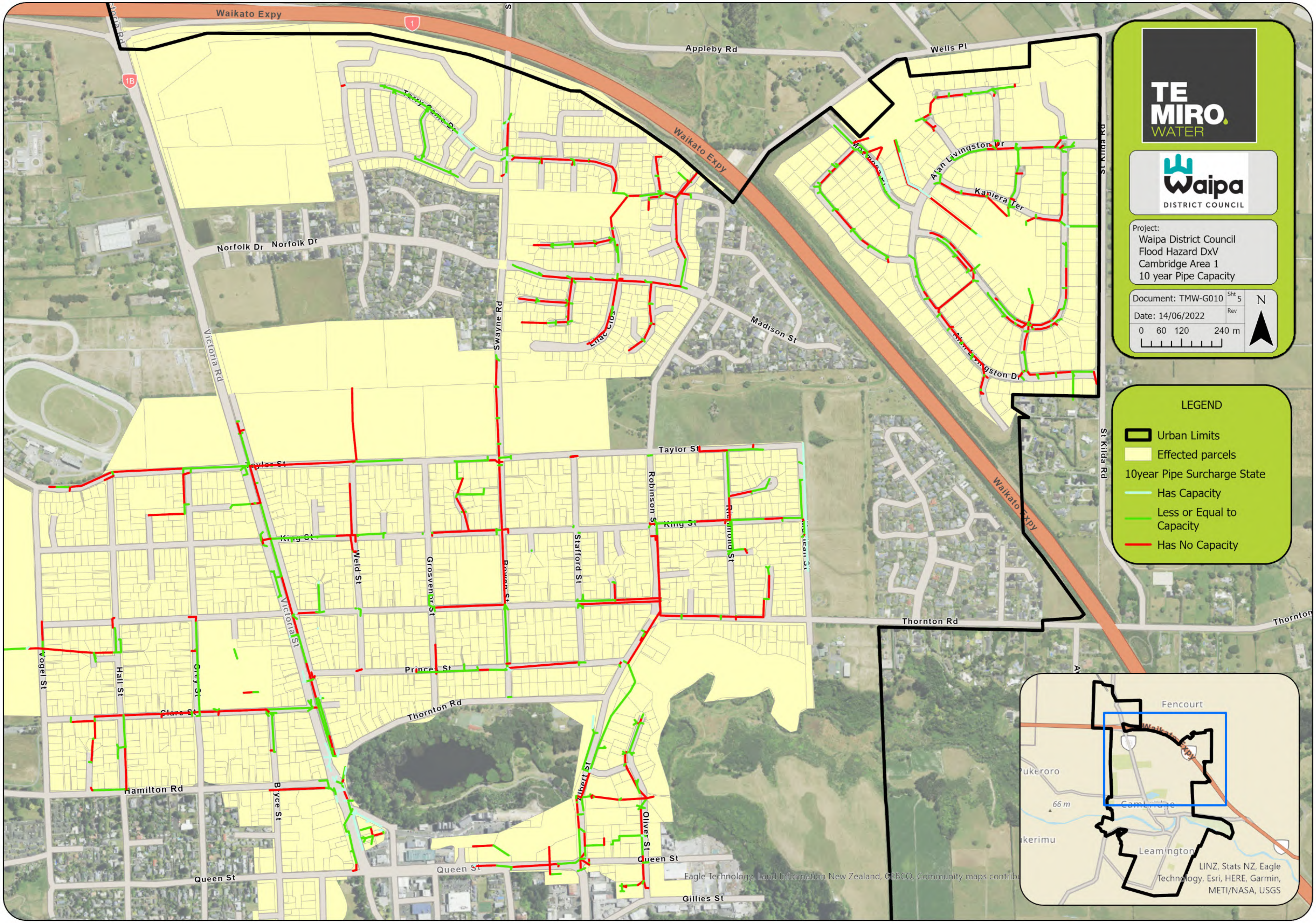
ATTACHMENT 2 – PIPE CAPACITY



TE MIRO WATER
Waipa DISTRICT COUNCIL
Project:
Waipa District Council
Flood Hazard DxV
Cambridge Area 1
10 year Pipe Capacity
Document: TMW-G010
Sht 5
Rev
Date: 14/06/2022
0 60 120 240 m
N
LEGEND
Urban Limits
Effected parcels
10year Pipe Surcharge State
Has Capacity
Less or Equal to Capacity
Has No Capacity
Waikato Expy
Appleby Rd
Wells Pl
Norfolk Dr
Swayne Rd
Victoria Rd
Madison St
Alan Livingston Dr
Kaniera Ter
St Kilda Rd
Taylor St
Robinson St
King St
Weld St
Grosvenor St
Stafford St
Thornton Rd
Victoria St
Princes St
Vogel St
Hall St
Grey St
Clare St
Hamilton Rd
Bryce St
Oliver St
Queen St
Gillies St
Fencourt
Pukeroro
Cambridge
Leamington
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Eagle Technology, Land Information New Zealand, GEBCO, Community maps contrib
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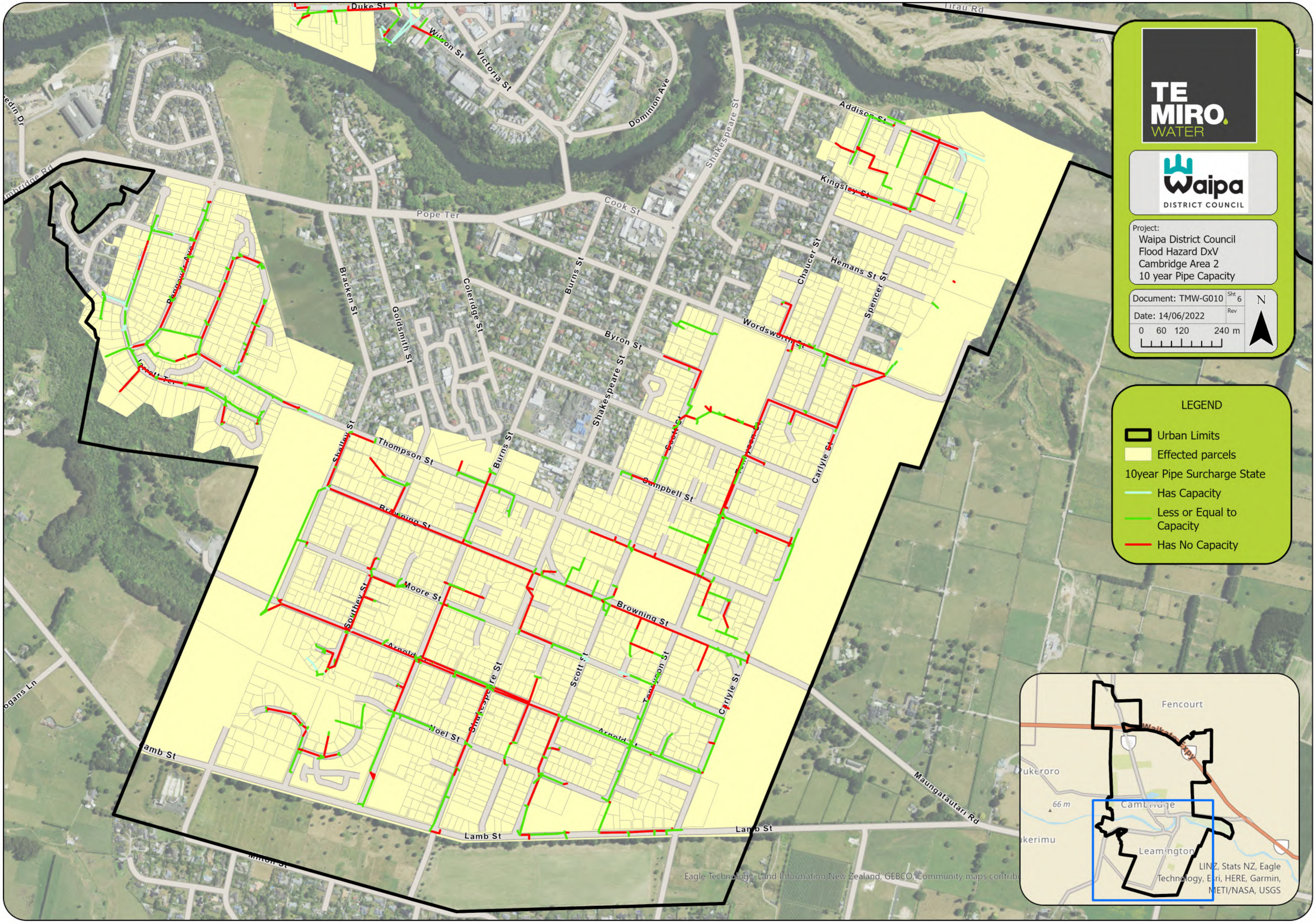

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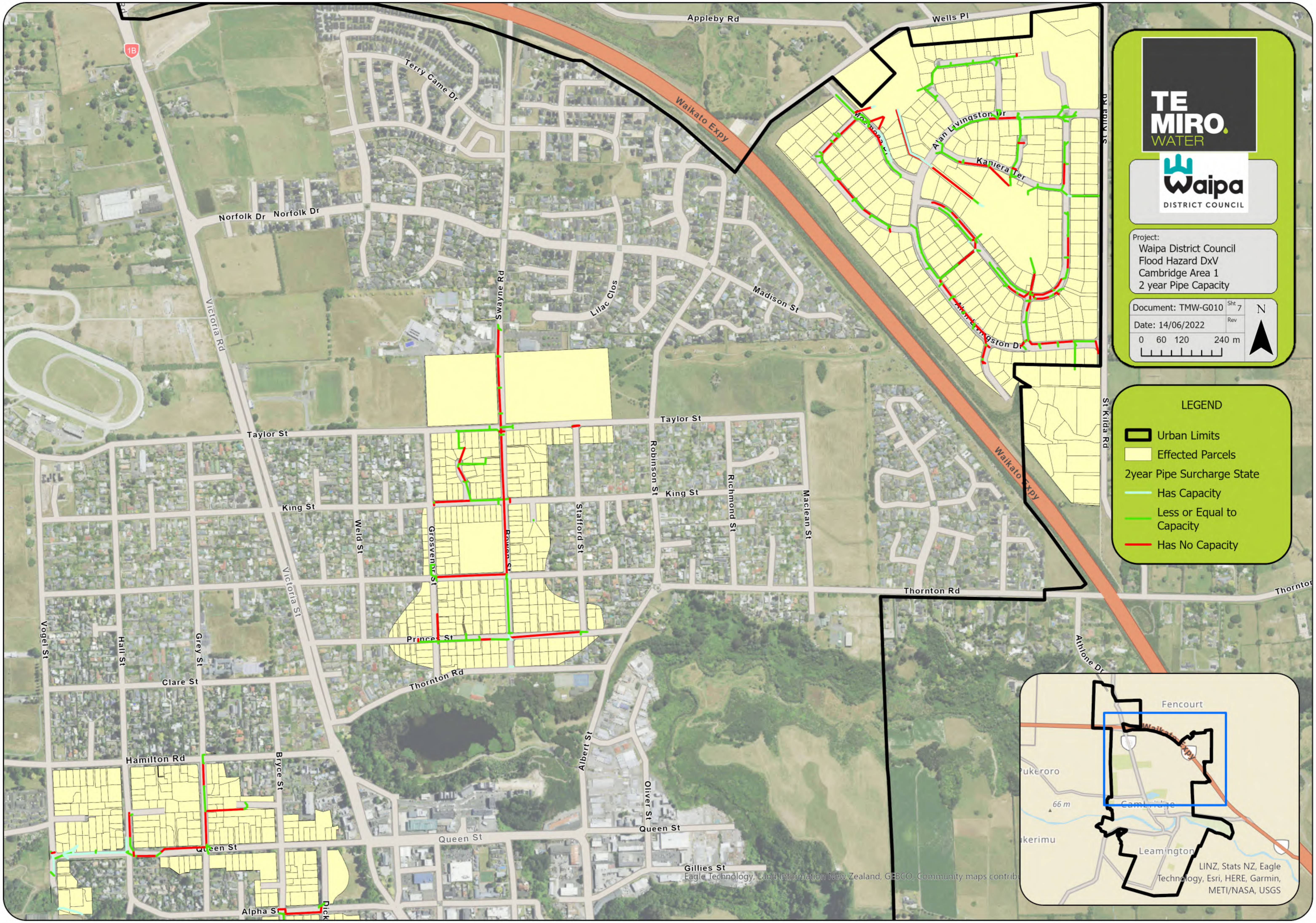
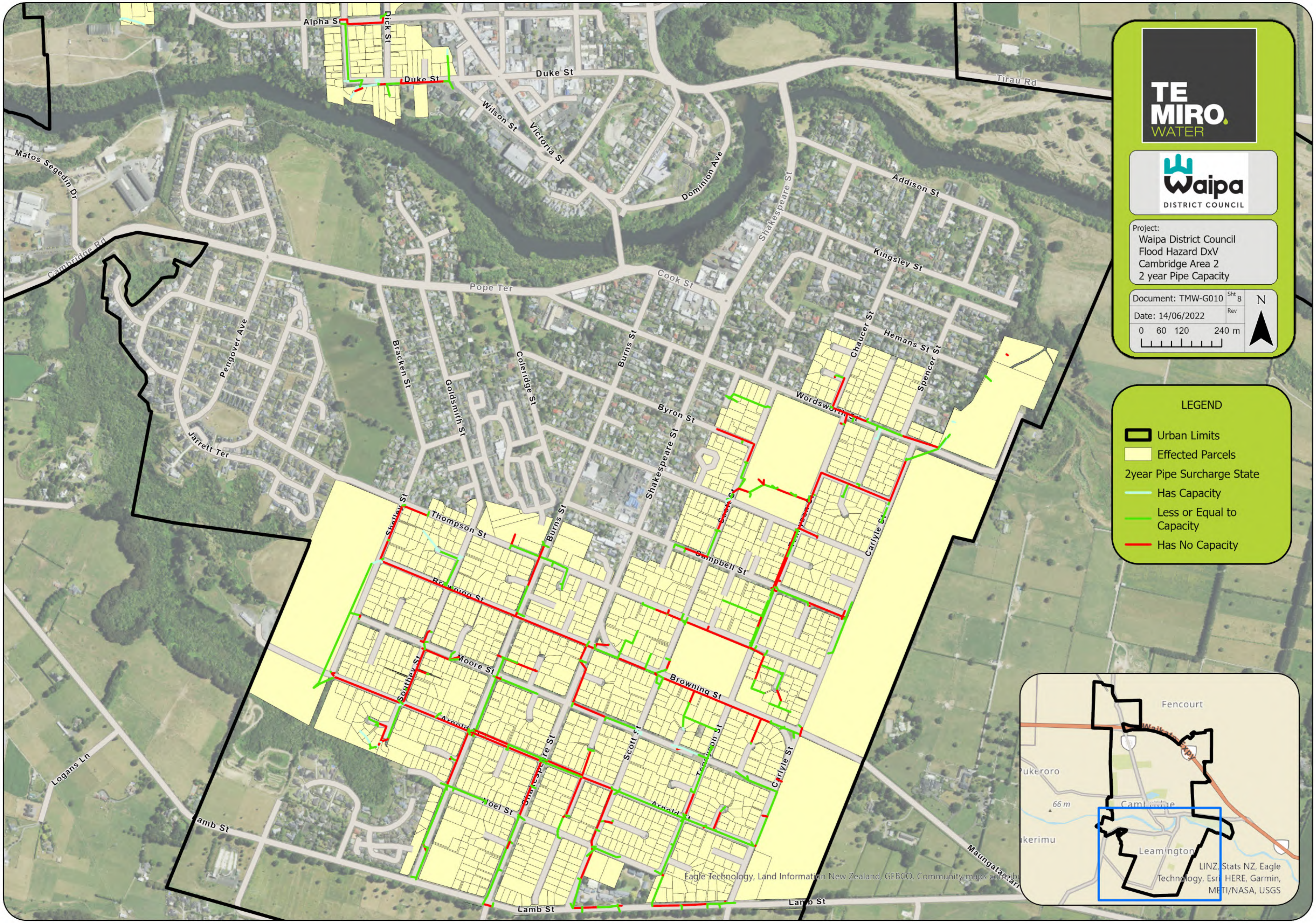
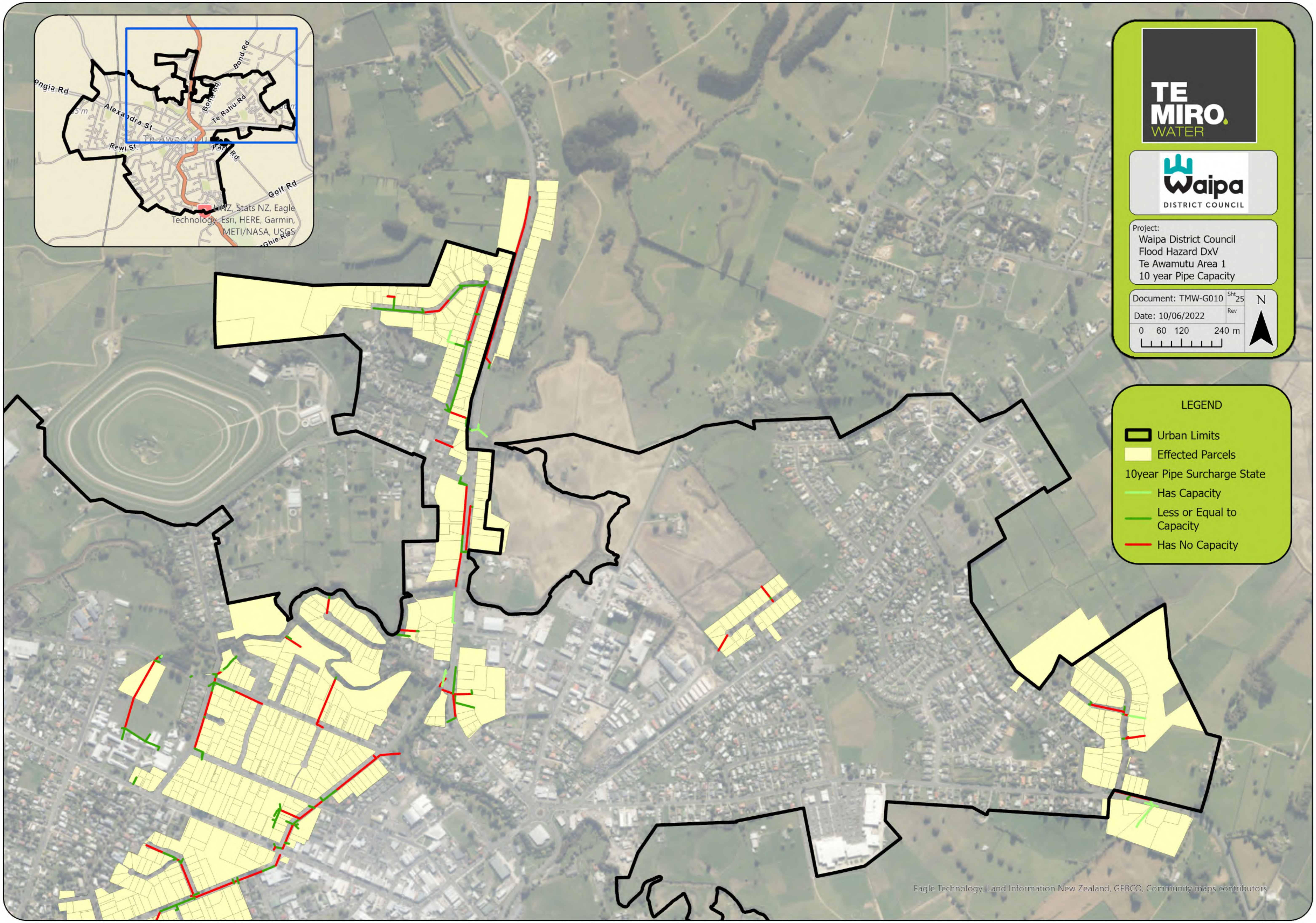
Rev
Date: 14/06/2022
0 60 120 240 m
N
LEGEND
Urban Limits
Effected parcels
10year Pipe Surcharge State
Has Capacity
Less or Equal to Capacity
Has No Capacity
Fencourt
Cambridge
Leamington
Pukeroro
66 m
LINZ, Stats NZ, Eagle Technology, Esri, HERE, Garmin, METI/NASA, USGS
Eagle Technology, Land Information New Zealand, GEBCO, Community maps contrib
Duke St
Wilson St
Victoria St
Dominion Ave
Shakespeare St
Addison St
Kingsley St
Pope Ter
Cook St
Bracken St
Goldsmith St
Coleridge St
Burns St
Chaucer St
Hemans St
Spencer St
Byron St
Wordsworth St
Shakespeare St
Shelley St
Thompson St
Burns St
Scott St
Carlyle St
Campbell St
Browning St
Moore St
Southey St
Browning St
Arnold St
Shakespeare St
Scott St
Tennyson St
Carlyle St
Noel St
Arnold St
Lamb St
Lamb St
Lamb St
Maungatautari Rd
Tirau Rd
Cambridge Rd
Hogans Ln
Milton St

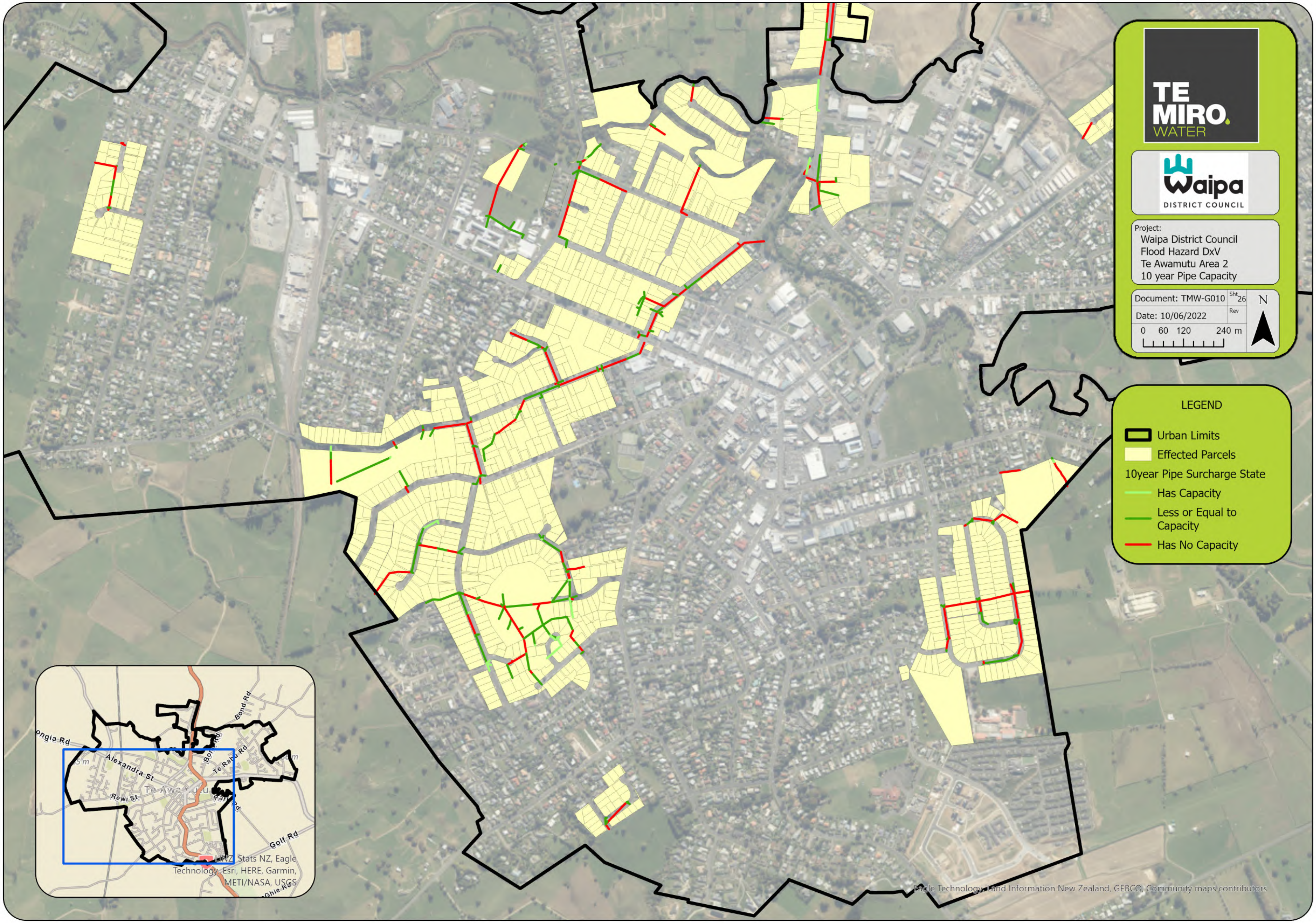


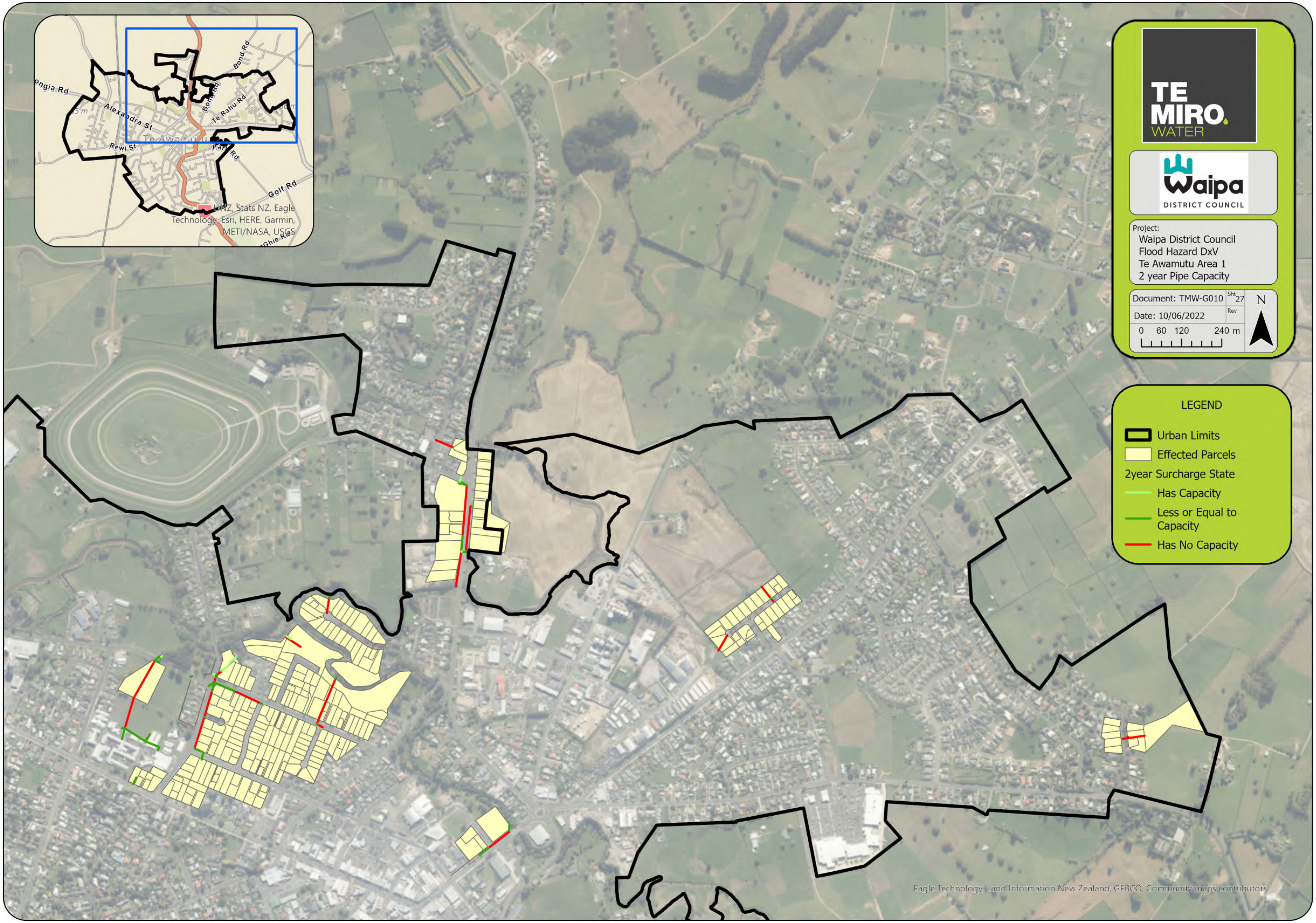
TE MIRO WATER
Waipa DISTRICT COUNCIL
Project:
Waipa District Council
Flood Hazard DxV
Cambridge Area 1
2 year Pipe Capacity
Document: TMW-G010
Sht 7
Rev
Date: 14/06/2022
N
0 60 120 240 m
LEGEND
Urban Limits
Effected Parcels
2year Pipe Surcharge State
Has Capacity
Less or Equal to Capacity
Has No Capacity
Appleby Rd
Wells Pl
Terry Came Dr
Walkato Expy
Alan Livingston Dr
Kaniera Ter
St Kilda Rd
Norfolk Dr
Swayne Rd
Lilac Clos
Madison St
Victoria Rd
Taylor St
Robinson St
Richmond St
Maclean St
King St
Weld St
Grosvenor St
Stafford St
Thornton Rd
Victoria St
Princes St
Vogel St
Hall St
Grey St
Clare St
Athlone Dr
Hamilton Rd
Bryce St
Albert St
Oliver St
Queen St
Gillies St
Alpha St
Fencourt
Pukeroro
Cambridge
Leamington
66 m
Eagle Technology, Land Information New Zealand, GEBCO, Community maps contrib
LINZ, Stats NZ, Eagle Technology, Esri, HERE, Garmin, METI/NASA, USGS



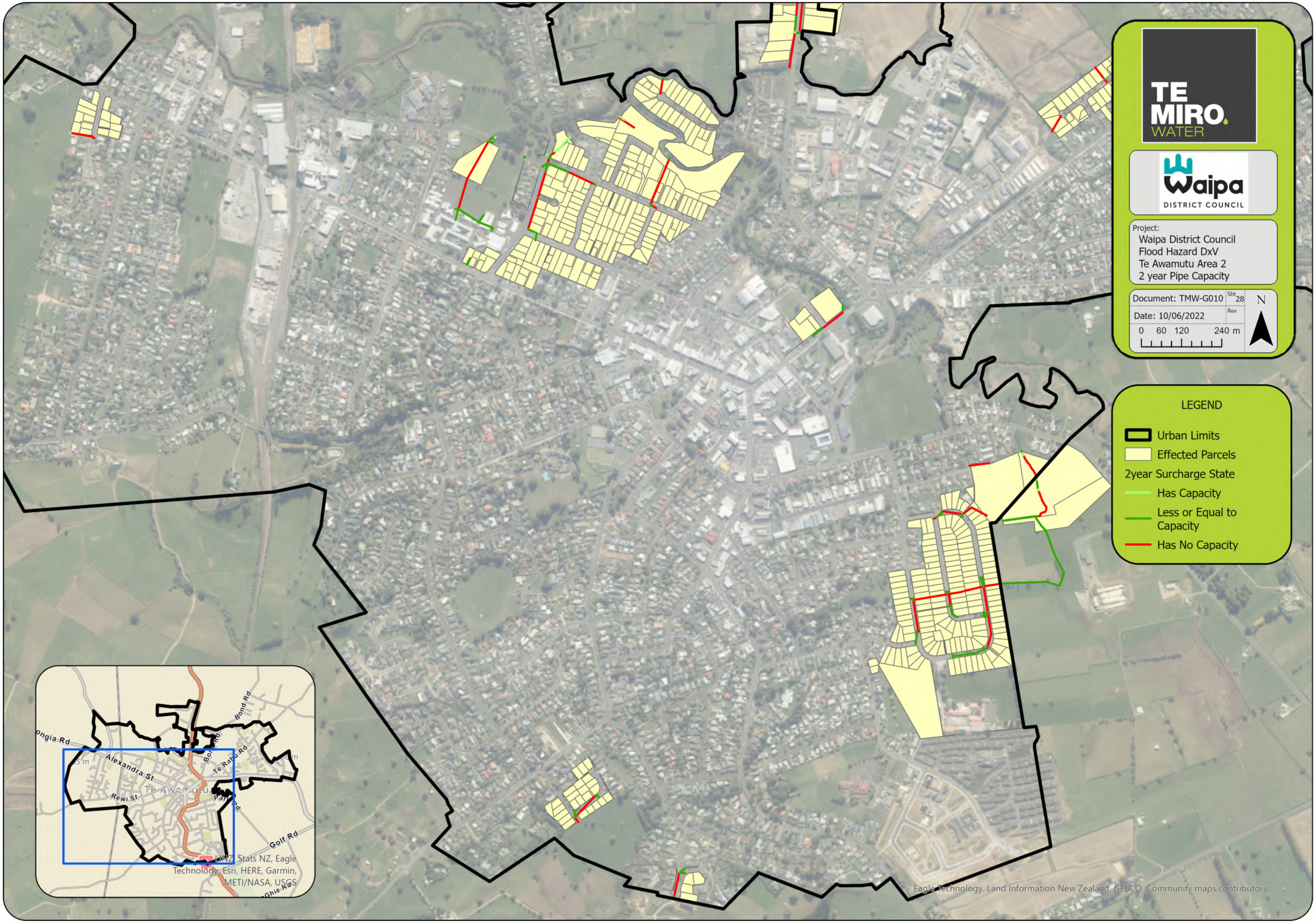
TE MIRO WATER
Waipa DISTRICT COUNCIL
Project:
Waipa District Council
Flood Hazard DxV
Cambridge Area 2
2 year Pipe Capacity
Document: TMW-G010
Sht 8
Rev
Date: 14/06/2022
0 60 120 240 m
N
LEGEND
Urban Limits
Effected Parcels
2year Pipe Surcharge State
Has Capacity
Less or Equal to Capacity
Has No Capacity
Alpha St
Dick St
Duke St
Wilson St
Victoria St
Dominion Ave
Tirau Rd
Matos Segedin Dr
Cambridge Rd
Addison St
Shakespeare St
Kingsley St
Cook St
Pope Ter
Hemans St
Chaucer St
Spencer St
Pengover Ave
Bracken St
Goldsmith St
Coleridge St
Burns St
Wordsworth St
Byron St
Jarrett Ter
Shelley St
Thompson St
Browning St
Campbell St
Carlyle St
Moore St
Southey St
Arnold St
Scott St
Tennyson St
Noel St
Lamb St
Logans Ln
Eagle Technology, Land Information New Zealand, GEBCO, Community maps contrib
Fencourt
Pukeroro
66 m
Cambridge
Leamington
LINZ, Stats NZ, Eagle Technology, Esri, HERE, Garmin, METI/NASA, USGS


ongia Rd
Alexandra St
Rewi St
Bond Rd
Te Rahu Rd
Park Rd
Golf Rd
LINZ, Stats NZ, Eagle Technology, Esri, HERE, Garmin, METI/NASA, USGS
TE MIRO. WATER
Waipa DISTRICT COUNCIL
Project:
Waipa District Council
Flood Hazard DxV
Te Awamutu Area 1
10 year Pipe Capacity
Document: TMW-G010
Sht 25
Rev
Date: 10/06/2022
0 60 120 240 m
N
LEGEND
Urban Limits
Effected Parcels
10year Pipe Surcharge State
Has Capacity
Less or Equal to Capacity
Has No Capacity
Eagle Technology, Land Information New Zealand, GEBCO, Community maps contributors


TE MIRO WATER
Waipa DISTRICT COUNCIL
Project:
Waipa District Council
Flood Hazard DxV
Te Awamutu Area 2
10 year Pipe Capacity
Document: TMW-G010
Sht 26
Rev
Date: 10/06/2022
0 60 120 240 m
N
LEGEND
Urban Limits
Effected Parcels
10year Pipe Surcharge State
Has Capacity
Less or Equal to Capacity
Has No Capacity
Alexandra St
Rewi St
Bond Rd
Golf Rd
LINZ, Stats NZ, Eagle Technology, Esri, HERE, Garmin, METI/NASA, USGS
Eagle Technology, Land Information New Zealand, GEBCO, Community maps contributors



TE MIRO WATER
Waipa DISTRICT COUNCIL
Project:
Waipa District Council
Flood Hazard DxV
Te Awamutu Area 1
2 year Pipe Capacity
Document: TMW-G010
Sht 27
Rev
Date: 10/06/2022
0 60 120 240 m
N
LEGEND
Urban Limits
Effected Parcels
2year Surcharge State
Has Capacity
Less or Equal to Capacity
Has No Capacity
Alexandra St
Rewi St
Bond Rd
Te Rahu Rd
Golf Rd
LINZ, Stats NZ, Eagle Technology, Esri, HERE, Garmin, METI/NASA, USGS
Eagle Technology, Land Information New Zealand, GEBCO, Community maps contributors



TE MIRO. WATER
Waipa DISTRICT COUNCIL
Project:
Waipa District Council
Flood Hazard DxV
Te Awamutu Area 2
2 year Pipe Capacity
Document: TMW-G010
Sht 28
Rev
Date: 10/06/2022
0 60 120 240 m
N
LEGEND
Urban Limits
Effected Parcels
2year Surcharge State
Has Capacity
Less or Equal to Capacity
Has No Capacity
Alexandra St
Rewi St
Te Rahu Rd
Bond Rd
Golf Rd
LINZ, Stats NZ, Eagle Technology, Esri, HERE, Garmin, METI/NASA, USGS
Eagle Technology, Land Information New Zealand, GEBCO, Community maps contributors

ATTACHMENT 3 - WSP FLOOD REPORT

PART A.1: STORMWATER MODELLING OVERVIEW REPORT (PIRONGIA, OHAUPO, KIHIKIHI, CAMBRIDGE, TE AWAMUTU)2018-2021 (WSP)

NOVEMBER / 2021

Contents

Issue	Reason for Issue	WSP Author	WSP Reviewer	Waipa Reviewer	Date
1	Waipa District Council to comment on WSP contents.	Hannah West	Thomas Nikkel	Robin Walker	22/10/21
2	Final WSP Issue	Hannah West	Thomas Nikkel	Robin Walker	30/11/21

Term	Definition
1D Model	One dimensional model that just includes hydraulic representation of the primary network (pipes, manholes culverts, etc) but does not represent the secondary network (i.e., overland flow paths / floodplains)
1D - 2D Model	One dimensional and two-dimensional coupled model which includes the hydraulic representation of both the primary network (pipes, manholes culverts, etc), as well as the conveyance over the 2D surface for very large events (i.e., overland flow, surface flooding etc)
Average Recurrence Interval	The average period between the recurrence of a storm event of a given rainfall intensity. It represents a statistical probability. For example, a 10-year ARI indicates an average of 10 events over a 100- year period.
Baseline model	Model that represents the current situation or fixed point of reference to be used for future comparisons.
Break lines	Represents a line that mesh triangles (for the 2D surface) are created against to maintain the ground model levels.
Composite curve number	A curve number that incorporates the pervious area curve number and impervious area curve number proportionally.
Curve number	An index that represents the runoff potential from a storm event for a specific land area. Curve numbers range from 0 to 100, with a smaller curve number representing low runoff potential and a higher curve number representing high runoff potential.
Dimensionless	Something that has no physical dimension assigned to it (i.e., normalised rainfall profiles which is used to define the shape of the rainfall event).
First pass	Initial go over or run through of something in the anticipation of future improvements.
Hyetograph	A graphical representation of the distribution of rainfall intensity over time.
Mesh	Triangles generated based on the ground model to represent the topography.
Mesh zones	Polygons that are used to modify the ground model in specific areas where characteristics differ from the wider mesh.
Nested storm	Where design rainfall bursts, with a range of durations up to 24-hours, are nested together to create a design storm event (i.e., all selected intensity / duration values for a particular recurrence interval, are represented within a single rainfall profile).

Term	Definition
Nodes	Points in the drainage system that located at the end of all link, reaches and junctions (all links must have nodes at the upstream and downstream ends). Often represents a physical structure at the end of pipe such as a manhole, catch-pit, outfall, or storage structure, but can be simple arbitrary connection point (i.e., between two reaches)
Probable Maximum Precipitation	The theoretically greatest depth of precipitation for a given duration that is physically possible over a given area at a given time of year.
Rain Gauge Polygons	Polygons which are used to define which rainfall profile is applied within different areas of the model.
Rain on Grid model	This involves the application of rainfall to all ground surface cells in a 2D model (instead of sub-catchment flows being loaded to specific points in the model)
Shapefiles	A GIS digital file type which stores geometric location and associated attributes.
Systems performance analysis	Analysis of network capacity based on comparison of modelled results to relevant design capacity.
Flood Hazard	This is the definition of safety criteria for vehicles and people– depth (m) & velocity (m/s) of flow. Waipa flood hazard mapping adopts the HCC criteria and is provided for the 1 in 100-year ARI (existing and future climate (RCP 6)). These layers do not incorporate the district planning zones (i.e., High Risk Flood Zone or the Natural Hazard Zone) or WRC produced flood mapping.

PART 1 - **EXECUTIVE SUMMARY**

This report is a comprehensive overview of the development of the Waipa District Council Stormwater models from 2018 to current (2021), which have been used to inform Council's Flood Hazard Mapping project. This report includes a summary of key assumptions made during previous modelling stages, any limitations of the models, and key decisions and recommendations for future development and/or maintenance of the models. The purpose of this report is to provide background into the work undertaken to date to help inform any future stormwater modelling work.

WSP has built and subsequently developed the Infoworks ICM v7.0 stormwater models for the five main towns in Waipa District: Cambridge, Te Awamutu, Pirongia, Ohaupo and Kihikihi. WSP utilised the most recently available asset data (at the time – October 2018) and survey data (February 2019) from Waipa District Council to build upon the baseline models for each of the five main towns. The models were progressively added to in stages over multiple work packages. The modelling stages (MS) are summarised below and explored in further detail in section 7 of this report:

- **MS1:** Cambridge North model to support the Cambridge North Residential structure plan.
- **MS2:** 1D network baseline model to investigate the level of service and inform an upgrade strategy based on pipes surcharging.
- **MS3:** 1D-2D Coupled Existing Development Kihikihi Model to investigate infrastructure issues in more detail and identify potential mitigating measures.
- **MS4:** 1D-2D Coupled Existing Development Cambridge, Te Awamutu, Pirongia and Ohaupo Model to consider wider catchment in terms of flood hazard, transferred network issues, and infrastructure planning.
- **MS5:** 1D-2D Model Updated to Represent the Future Scenarios to support in master planning of stormwater and set up ultimate growth and committed project model scenarios.
- **MS6:** 1D-2D Network Model updated to follow Waikato Regional Council (WRC) Guidelines and investigate investment options to analyse specified options and scenarios to meet the needs of baseline population and future growth based on Waipa District Council's levels of service.
- **MS7:** 1D-2D Network Model Checks to investigate implications of using WRC modelling guidelines and scope survey to improve model representation.
- **MS8:** 1D-2D Network Model Improvement to improve representation in the stormwater models by adding in survey data and kerb lines.
- **MS9:** 1D-2D Network Model Peer Review to engage with the peer reviewer to facilitate the peer review of Cambridge, Te Awamutu, Pirongia and Ohaupo.

- **MS10:** 1D-2D Network Model Peer Review Updates to Cambridge, Te Awamutu, Pirongia and Ohaupo in response to the peer review comments.
- **MS11:** 1D-2D Network Existing Development and Committed Projects WRC Models methodology scenarios.
- **MS12:** 1D-2D Network Model Rain on Grid Validation Cambridge, Te Awamutu, Pirongia, Ohaupo, and Kihikihi to verify sub-catchment model results.
- **MS13:** 1D-2D Network Pirongia Rain on Grid model schematization to better represent surface water behaviour.
- **MS14:** 1D-2D Network Modelling Completion Tasks to finalise model changes and run remaining model scenarios to support the finalisation of Waipa District Councils flood hazard modelling and catchment management planning (to support the District Wide Stormwater Consent Renewal).

Growth cells have generally not been incorporated within the model boundaries and are limited to catchments that flows towards an urban area. It is expected that flood modelling will be incorporated through the structure/master planning stage where possible and incorporated into the Flood Hazard Mapping at regular intervals.

Waipa District Council used the model outputs from the above scenarios to inform:

- Identification of critical assets
- Level of service upgrade requirements
- Master planning for future development
- Development assessments
- The flood hazard mapping project and public notification for the 1% rainfall event (existing climate). Flood Hazard Mapping is provided in PART 3, with the broad stages being:
  - Notification of properties where the dwelling is potentially at risk of flooding based on the indicated flooding extent extending onto the dwelling footprint.
  - Survey of the floor height of each dwelling that is deemed to potentially be at risk.
  - Comparison of the surveyed floor height against the predicted flood depth, and subsequent notification of properties where dwellings that were no longer deemed to be at risk of over-floor flooding.
  - Separate undertaking of a flood depth and velocity assessment of the flood water to identify areas with high velocity and / or depth which may be a risk to public safety.
  - Usage of flood mapping to inform a Flood Hazard Viewer (to be made publicly available at the end of 2021) that incorporates climate change.

Following the work done to date, future work is recommended to both; maintain the model and flood mapping to ensure it reflects the most current asset data, and, to carry out additional tests to further verify the model set-up. These updates are listed in Table 1-1, Table 1-2 and Table 1-3.

Table 1-1. Recommended maintenance for the Waipa Stormwater Models.

Number	Maintenance
1	Adding new stormwater infrastructure and upgrades into the model network, as more recent asset data becomes available.
2	Adding in new sub-divisions and proposed growth areas into the model.
3	Incorporating new LiDAR data as it becomes available.

Table 1-2. Recommended future updates to the Waipa Stormwater Models.

Number	Future updates
1	Validation of flood levels based on field survey of significant flood events. This would help refine and confirm appropriate hydrology parameters are used.
2	Soakage parameters validation through on-site soakage tests.
3	Back-to-back rainfall event simulation to understand effects of longer duration events on stormwater system.
4	Sensitivity testing of boundary conditions by applying water level to outfalls. Testing using time varying level river levels, would be preferable over a constant level.
5	Additional topographical surveys for the open channels, particularly where flooding is predicted to affect properties.
6	Sensitivity testing of different climate change scenarios.
7	Sensitivity testing of asset blockages to determine criticality of maintaining specific assets.
8	Update model versions from Infoworks ICM v7.0 to the latest Infoworks ICM version (at the time of this report it was v2021).
9	Extend the Cambridge model to include the Mangaone Stream as a backwater condition.

Table 1-3. Recommended maintenance for the Waipa Flood Hazard Mapping (recommendations specified by Waipa District Council).

Number	Maintenance
1	On completion of any model update due to LiDAR, the Flood Hazard Mapping exercise should be repeated to update the flood viewer and to determine if the dwellings at risk have changed. If changes occur, appropriate communications to update owners should be undertaken.
2	Should Waikato Regional Council provide better river flood height data for boundary conditions, incorporate this into the flood viewer and determine if the dwellings at risk have changed. If changes occur, appropriate communications to update owners should be undertaken.
3	Should Waipa District Council undertake rural flood hazard mapping, incorporate this into the flood viewer and determine if the dwellings at risk have changed. If changes occur, appropriate communications to update owners should be undertaken.

PART 2 - DISCLAIMERS AND LIMITATIONS

This report ('Report') has been prepared jointly by Waipa District Council and WSP exclusively for Waipa District Council ('Client') in relation to providing a final report compiling the summary of all modelling work completed since stormwater model inception and master planning to present day ('Purpose') and in accordance with PR5012/5013 – Stormwater Modelling Completion Tasks (19/07/21). The findings in this Report are based on and are subject to the assumptions specified in the Report. WSP accepts no liability whatsoever for any reliance on or use of this Report, in whole or in part, for any use or purpose other than the Purpose stated above or any use or reliance on the Report by any third party.

In preparing the Report, WSP has relied upon data, surveys, analyses, designs, plans and other information ('Client Data') provided by or on behalf of the Client. Except as otherwise stated in the Report, WSP has not verified the accuracy or completeness of the Client Data. To the extent that the statements, opinions, facts, information, conclusions and/or recommendations in this Report are based in whole or part on the Client Data, those conclusions are contingent upon the accuracy and completeness of the Client Data. WSP will not be liable in relation to incorrect conclusions or findings in the Report should any Client Data be incorrect or have been concealed, withheld, misrepresented, or otherwise not fully disclosed to WSP.

PART 3 - **INTRODUCTION**

This report summarises the work undertaken by WSP with regards to the Waipa District Council Stormwater model development from 2018 through to current (2021). The report includes a summary of key assumptions made during modelling, key limitation of the models, and key decisions and recommendations for future development and/or maintenance of the models. The purpose of this report is to provide background into the modelling work undertaken to date to help inform any future stormwater modelling work.

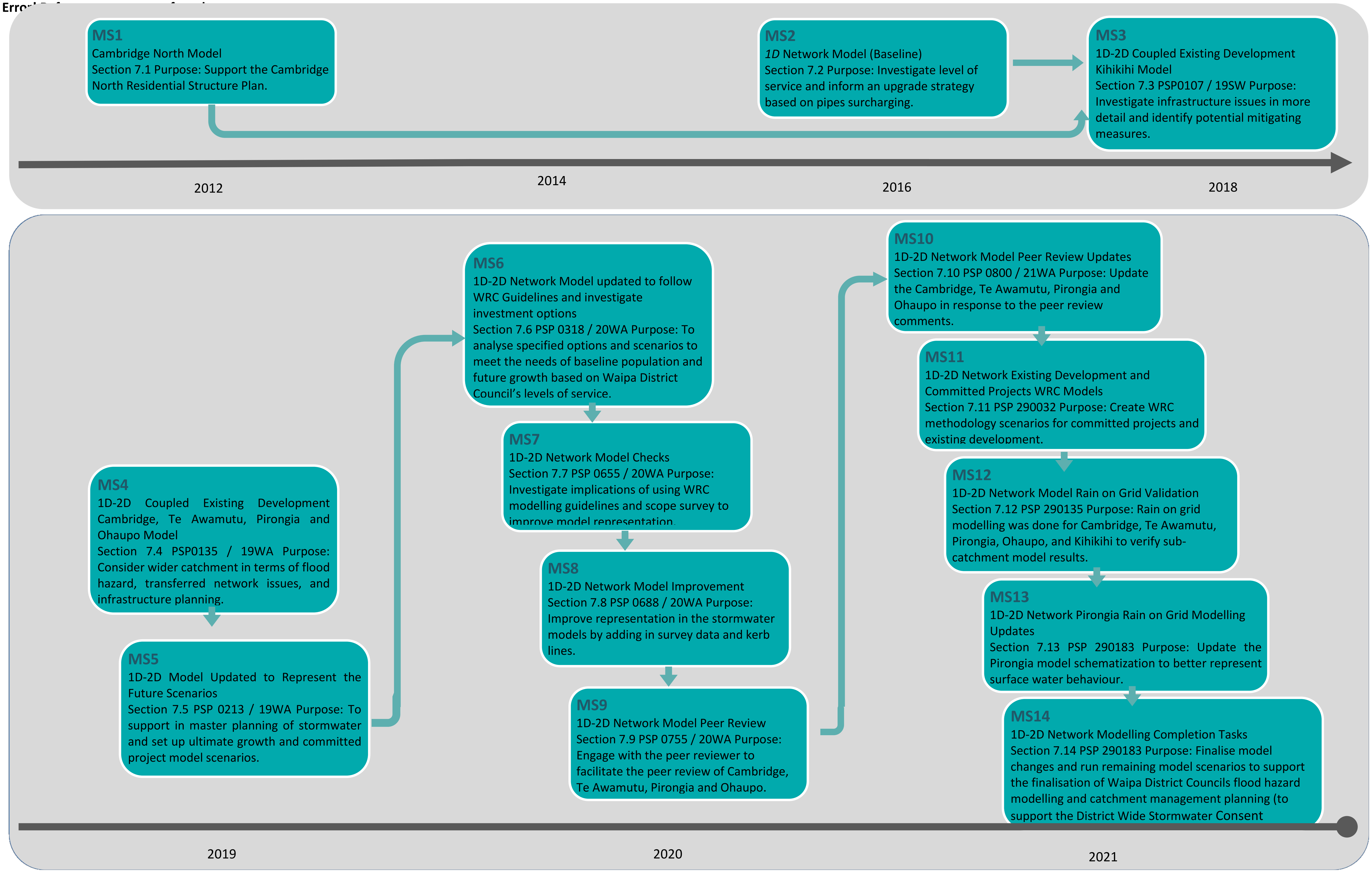
This report has been developed by WSP (Sections 3, 4, 6, 7, 8, 9) and Waipa District Council (Sections 5)).

PART 4 - **MODEL AND FLOOD MAPPING BACKGROUND**

WSP has built and subsequently further developed the stormwater models for the five main towns in Waipa District: Cambridge, Te Awamutu, Pirongia, Ohaupo and Kihikihi.

The timeline of model development is shown on the next page, with each modelling stage (MS) delineated and presented in chronological order.

Each modelling stage (MS1 to MS14) are discussed in further detail in sections 7.1 to 7.14 of this report.


MS1
Cambridge North Model
Section 7.1 Purpose: Support the Cambridge North Residential Structure Plan.
MS2
1D Network Model (Baseline)
Section 7.2 Purpose: Investigate level of service and inform an upgrade strategy based on pipes surcharging.
MS3
1D-2D Coupled Existing Development Kihikihi Model
Section 7.3 PSP0107 / 19SW Purpose: Investigate infrastructure issues in more detail and identify potential mitigating measures.
2012
2014
2016
2018
MS4
1D-2D Coupled Existing Development Cambridge, Te Awamutu, Pirongia and Ohaupo Model
Section 7.4 PSP0135 / 19WA Purpose: Consider wider catchment in terms of flood hazard, transferred network issues, and infrastructure planning.
MS5
1D-2D Model Updated to Represent the Future Scenarios
Section 7.5 PSP 0213 / 19WA Purpose: To support in master planning of stormwater and set up ultimate growth and committed project model scenarios.
MS6
1D-2D Network Model updated to follow WRC Guidelines and investigate investment options
Section 7.6 PSP 0318 / 20WA Purpose: To analyse specified options and scenarios to meet the needs of baseline population and future growth based on Waipa District Council's levels of service.
MS7
1D-2D Network Model Checks
Section 7.7 PSP 0655 / 20WA Purpose: Investigate implications of using WRC modelling guidelines and scope survey to improve model representation.
MS8
1D-2D Network Model Improvement
Section 7.8 PSP 0688 / 20WA Purpose: Improve representation in the stormwater models by adding in survey data and kerb lines.
MS9
1D-2D Network Model Peer Review
Section 7.9 PSP 0755 / 20WA Purpose: Engage with the peer reviewer to facilitate the peer review of Cambridge, Te Awamutu, Pirongia and Ohaupo.
MS10
1D-2D Network Model Peer Review Updates
Section 7.10 PSP 0800 / 21WA Purpose: Update the Cambridge, Te Awamutu, Pirongia and Ohaupo in response to the peer review comments.
MS11
1D-2D Network Existing Development and Committed Projects WRC Models
Section 7.11 PSP 290032 Purpose: Create WRC methodology scenarios for committed projects and existing development.
MS12
1D-2D Network Model Rain on Grid Validation
Section 7.12 PSP 290135 Purpose: Rain on grid modelling was done for Cambridge, Te Awamutu, Pirongia, Ohaupo, and Kihikihi to verify sub-catchment model results.
MS13
1D-2D Network Pirongia Rain on Grid Modelling Updates
Section 7.13 PSP 290183 Purpose: Update the Pirongia model schematization to better represent surface water behaviour.
MS14
1D-2D Network Modelling Completion Tasks
Section 7.14 PSP 290183 Purpose: Finalise model changes and run remaining model scenarios to support the finalisation of Waipa District Councils flood hazard modelling and catchment management planning (to support the District Wide Stormwater Consent
2019
2020
2021

PART 5 - **MODEL USE**

Waipa District Council currently utilise the stormwater models for the following key reasons:

1. To understand the current level of service for historical and new developments. Waipa will use the outputs of the flood hazard mapping to inform future stormwater system renewal and Level of Service discussions.
2. Master planning to assist in undertaking strategic planning with regards to Council's growth projections and levels of service.
3. Natural hazard mapping for the 100-year annual recurrence interval (ARI) (existing and the 6.0 representative concentration pathways (RCP) prediction for climate change).
4. Assessment of predicted dwellings at risk five main towns, namely Cambridge, Te Awamutu, Pirongia, Ohaupo and Kihikihi with associated public notification.

Note: Calculating flooding extents due to rivers rather than directly from rainfall is the responsibility of Waikato Regional Council. Waipa District Council includes the river flood extents in their District Plan as a hazard layer, but these were specifically excluded from the Waipa stormwater modelling project.

PART 6 - SYSTEM DESCRIPTION AND MODEL EXTENTS

6.1 Model Extents

The extent of consideration for the stormwater Infoworks ICM v7.0 models are the five urban centres of Waipa District, these are: Cambridge, Te Awamutu, Pirongia, Ohaupo and Kihikihi. For the maximum probable development models, the extent was increased to include future development areas which would be hydrologically linked to the urban centres. Rural drainage outside of the urban centres and flooding from rivers has been excluded from the extents of consideration. The boundary conditions for all the models have normal conditions, meaning that depth and velocity are kept constant when water reaches the boundary so water can flow out without losses. Figure 6-2 to Figure 6-6 show the model extents.

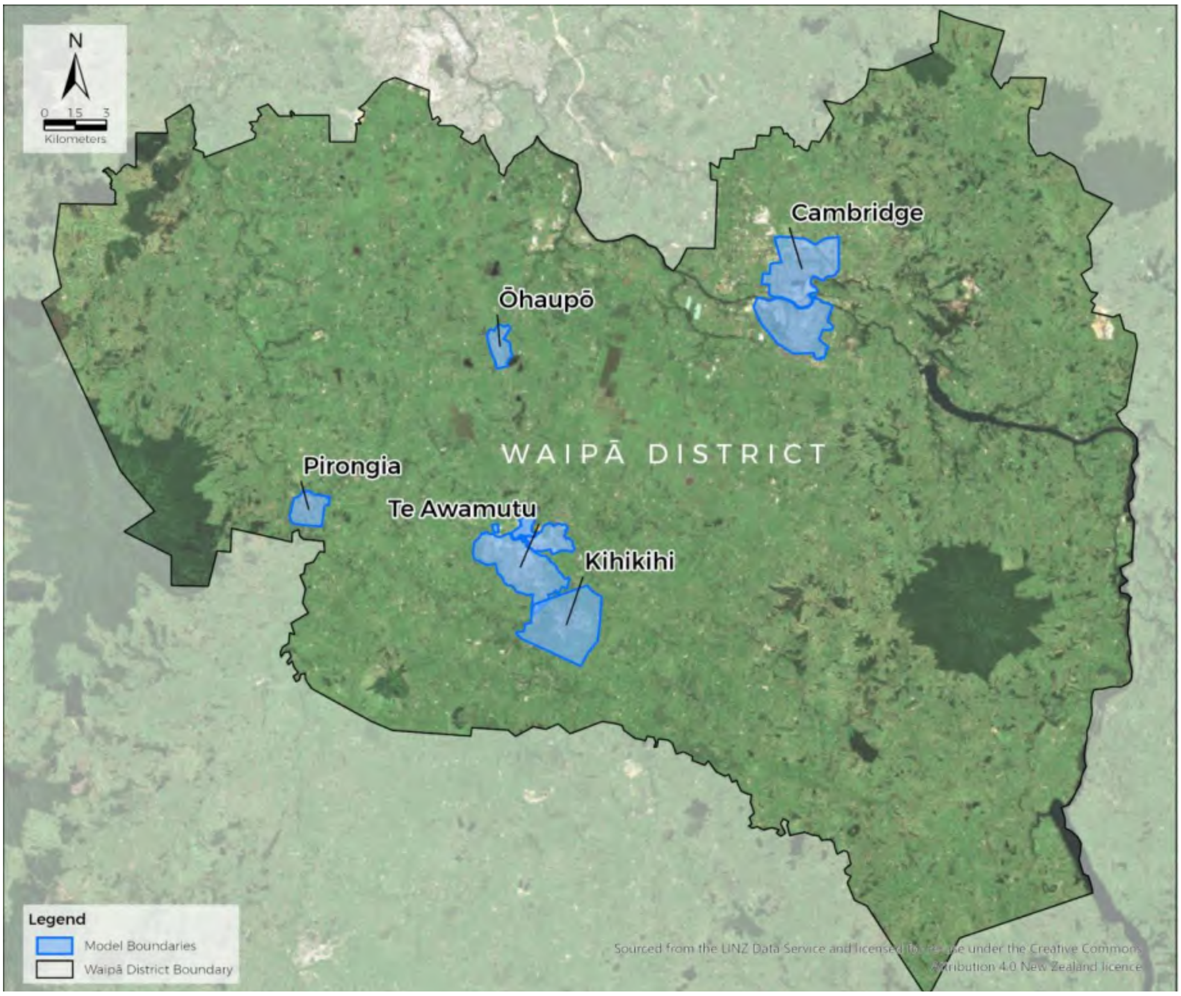


Figure 6-1 : Waipa District extent with model locations.

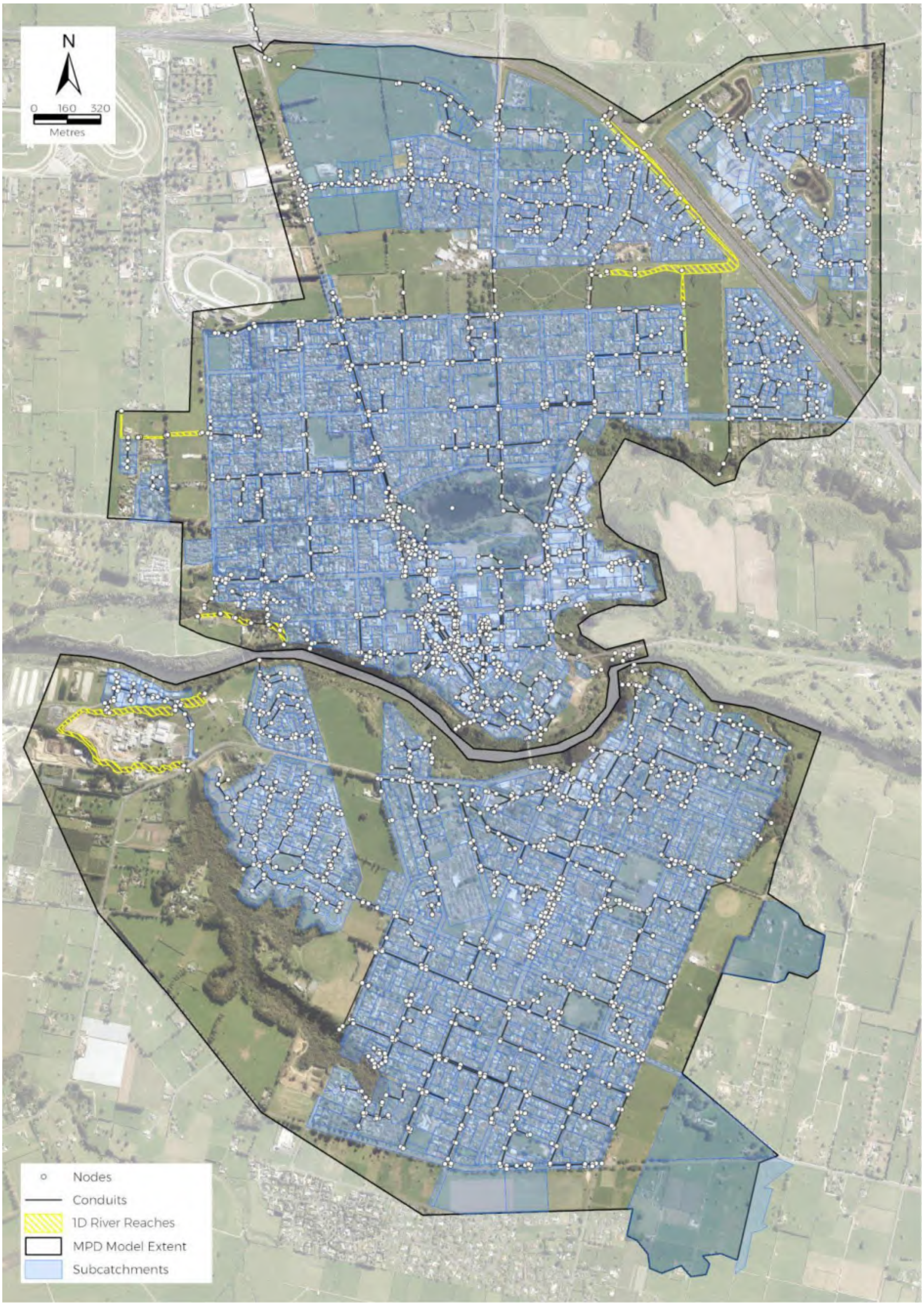


Figure 6-2 : Cambridge Maximum Probable Development Infoworks ICM v7.0 model extent.

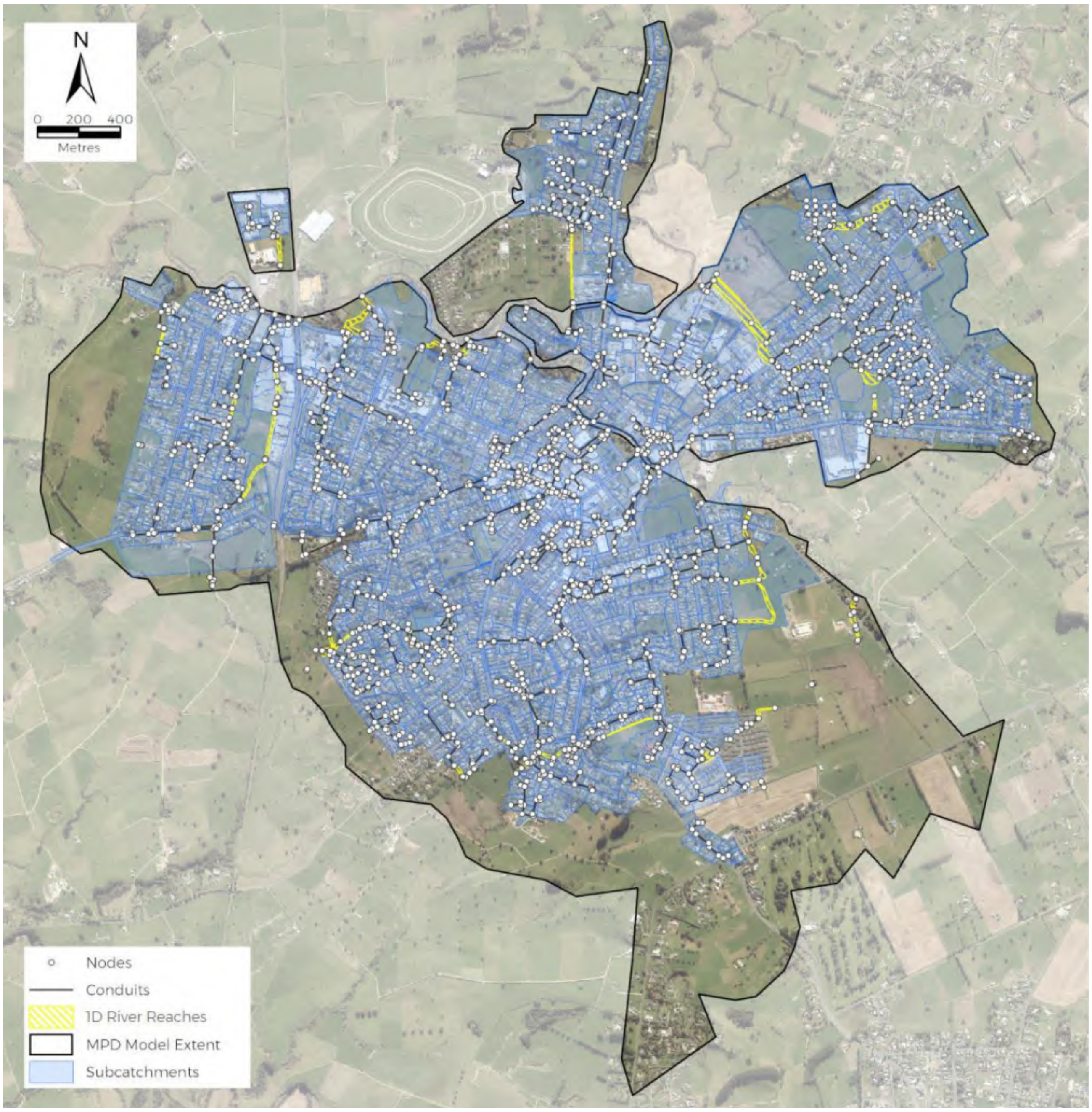


Figure 6-3 : Te Awamutu Maximum Probable Development Infoworks ICM v7.0 model extent.

Figure 6-4 : Pirongia Maximum Probable Development Infoworks ICM v7.0 model extent.

Figure 6-5 : Ohaupo Maximum Probable Development Infoworks ICM v7.0 model extent.

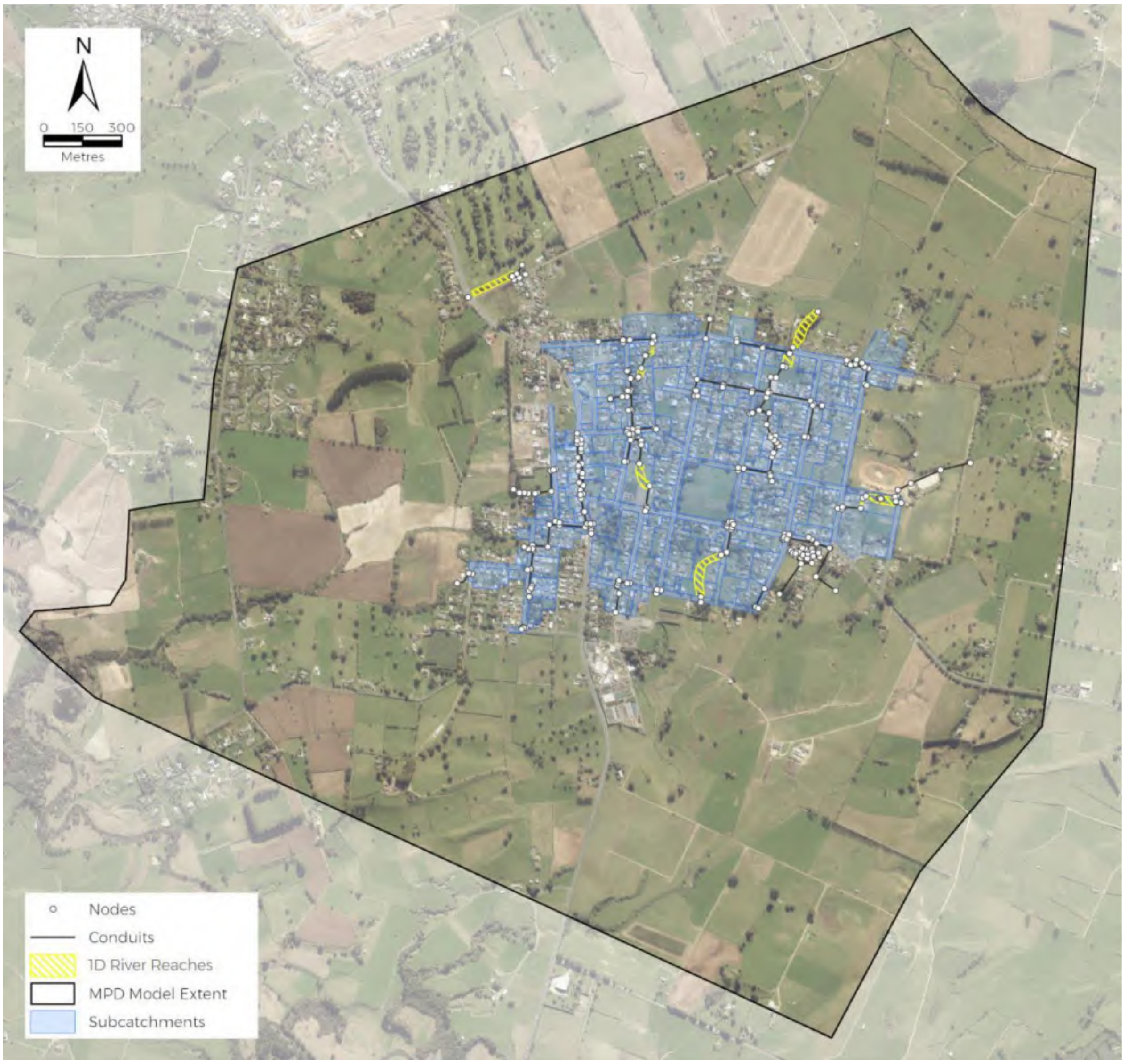


Figure 6-6 : Kihikihi Maximum Probable Development Infoworks ICM v7.0 model extent.

PART 7 - WSP STORMWATER MODEL DEVELOPMENT

This section is intended to present a summary of each stormwater Modelling Stage undertaken by WSP for the towns of Cambridge, Te Awamutu, Pirongia, Ohaupo, and Kihikihi.

Modelling Stages are listed as MS1 through to MS15 and are graphically presented in the Modelling Stage Timeline (Refer to PART 4 -). The intention is to present these in chronological order, although it is noted that some overlapping timeframes occurred between different modelling stages.

It is also important to note that the following sections are intended to provide a high-level overview of the key points regarding scope, assumptions / limitations. The listed items are not to be considered to be exhaustive. For detailed information regarding each modelling stage, please refer to the listed reports (see listed deliverables for each modelling stage).

7.1 (MS1) The Cambridge North InfoWorks ICM v7.0 model

7.1.1 Introduction

WSP built the original Cambridge North model using geospatial (GIS) data from Waipa District Council and information obtained from the Cambridge North Mike Urban model that was developed by Tonkin and Taylor. The intention of this model update was to improve the representation of the network (prompted by peer review comments) to provide inputs into the Cambridge North Residential Structure Plan in 2012. The model was then used carry out optioneering to mitigate any identified issues.

7.1.2 Model Build Notes / Assumptions

- Schematisation
  - The model is a 1D-2D coupled model using ICM v7.0. The rainfall is applied both with sub-catchments loaded to specific nodes (typically urban areas) and rain on grid (surrounding less developed areas).
  - The model includes pipes, manhole, open channels and streams (some modelled as 1D river reaches) as well as hydraulic structures such as culverts.
  - Allowance has not been made for drainage infrastructure that was not included in the Waipa District Council asset register.
- Rainfall
  - The rainfall profile was developed using the PMP (probable maximum precipitation) temporal distribution, with accumulated depths taken from on HIRDS V3 with 2.1°C and 3°C climate scenarios.
- Hydrology
  - Horton’s method was used simulate infiltration losses within pervious areas of the catchment.

- o Sub-catchments were primarily delineated by parcel boundaries, which is considered most appropriate for smaller events (i.e., up to the design capacity of the system) This may result in some inconsistencies regarding sub-catchment loading for very large events in cases where the pipe network may not be consistent with the topographic drainage directions (i.e. the ground slope may not match the pipe connections to the SW network).

- Boundary Conditions:
  - o Mangaone Stream level were used as downstream boundary conditions.
- Hydraulics
  - o Pipes with diameter 300 mm or larger were generally included in the model.
  - o The ‘eastern swale’ was represented in the 1D network based on site measurements from Waipa District Council.
  - o Road and residential sub-catchments were modelled separately to allow sensitivity of residential property imperviousness to be assessed.

7.1.3 Current Use of Model

The Cambridge North model included river reaches and sub-catchments that were copied into the Cambridge model in 2019 (refer to MS4).

Currently the Cambridge North model is still used for specific purposes (design of the Cambridge North stormwater pond and other infrastructure upgrades) as it has the tail water conditions, the Mangaone Stream, included. If the Cambridge North model is not to be used going forward the latest Cambridge model extent will need to be extended to account for the tailwater conditions.

7.1.4 Deliverables

- Cambridge North Residential Zone Stormwater Modelling (Weeds, Mills, & Groves, 2012)

7.2 (MS2) The baseline 1D network models

7.2.1 Introduction

A hydrological and 1D hydraulic model of the stormwater drainage network for each of the main urban areas (Cambridge, Te Awamutu, Pirongia, Ohaupo, and Kihikihi) was developed by WSP using InfoWorks Collection Systems (CS) v15.0.0 software.

The purpose of this model build was to assess the capacity of the pipe network and assist Council in infrastructure planning and decision making.

The 1D models were built with catchpits and manholes, pipes, and open channels.

Asset data was sourced from:

1 Waipa District Council’s GIS (April 2015),

2 Previous Mike Urban hydraulic models developed by Beca (for Cambridge and Te Awamutu),
3 Site visits (2016),
4 Operator knowledge,
5 LiDAR,
6 Previous survey data completed by Beca in 2010.

These models were calibrated in 2015 with flow data collected over a 9-month period during 2014.

7.2.2 Model Build Notes / Assumptions

The following assumptions apply to the model build:

- Schematisation
  - The five models are 1D network models built using InfoWorks CS v15, using sub-catchments to load runoff flows into the network.
  - The models include pipes (generally larger than 225mm), manholes, open channels (1D river reaches) and key hydraulic structures such as culverts. Most catchpits are included in the model, however private connections are not represented.
  - Representation of the secondary system (i.e., overland flow) is not represented; water which spills out of the system is lost to the network.
  - Allowance has not been made for drainage infrastructure that was not included in the Waipa District Council asset register.
- Rainfall:
  - Rainfall accumulated depths were extracted from HIRDS v3 and with a 2.1°C allowance added for climate change. The rainfall depth was applied to a dimensionless rainfall hyetograph for use within the model. The hyetograph profile for rain events up to 6 hours duration was based on the Probable Maximum Precipitation (PMP) 6-hour profile developed by Tomlinson and Thompson.
- Hydrology
  - Horton's method was used simulate infiltration losses within pervious areas of the catchment. Loss parameters were estimated for pervious areas within each town based on the soil data available.
  - Sub-catchments for the system were based on the parcel boundaries and routed using LiDAR, road layout and reticulation layout.
  - The Cambridge model was validated against the 22 July 2012 event with model predictions matching recorded customer complaints to a reasonable level. Care must be taken when using the model for design storm events as the intensities are higher than those used for calibration and validation, especially with the high uncertainty in Horton soil infiltration rates and soakage influences.

- o Te Awamutu, Kihikihi, Ohaupo, and Pirongia Model confidence is high for events like those measured during the flow monitoring period that were used in calibration. The calibration rainfall events are relatively common events, most have an ARI ≤ 1.58 years, so the models are appropriate for assessing nuisance road flooding during the 2-year ARI event. However, care must be taken when using the model for larger design storm events, as the intensities are higher than those used for calibration.

- Tailwater Boundary
  - o Free discharge was assumed for all outlets; the receiving water level is unlikely to have any upstream effects due to the large drop in elevation at the outfalls.
- Network
  - o Private connections to the stormwater system are not explicitly represented.
  - o Open channels were modelled simplistically, and only where necessary for connectivity of the pipe network. Channel dimensions were based on aerials, connecting pipe inverts, ground levels and photos from site (where available). A Manning's roughness value of 0.035 was used to represent a clean and straight natural stream.

7.2.3 Deliverables

The following associated reports present the details of the baseline models:

- Cambridge Stormwater Model Build and Calibration Report (Schicker, Mills, & King, 2016)
- Te Awamutu Stormwater Model Build and Calibration Report (Schicker, Mills, & King, 2016)
- Kihikihi, Pirongia and Ohaupo Stormwater Model Build and Calibration Report (Schicker, Mills, & King, 2016)

7.3 (MS3) PSP0107 / 19SW Kihikihi Stormwater Modelling

7.3.1 Introduction

The key purpose of this modelling stage was to update the existing Kihikihi 1D stormwater model to a 1D-2D model in Infoworks ICM v7.0, to investigate identified stormwater infrastructure issues in more detail and identify potential mitigating measures.

This project also provided an opportunity for Waipa District Council to test the value of 1D-2D stormwater modelling with regards to asset management, system performance, and to assist with comparison of the consequences of certain interventions across individual properties.

See Appendix A for the reports detailing the work done for this project.

7.3.2 Summary of Scope

To create the 2D surface representation in the model, LiDAR was added (as a DEM) and used to generate the 2D mesh.

The existing 1D network was updated with more recent council GIS network shapefiles. Kerb data was used to modify the ground model to improve the model topographic representation. Surveyed cross-sections were added into the model as 1D river reaches in order to represent the conveyance of open channels more accurately.

The data sources used to update the 1D portion of the model are summarised in the following points:

- February 2018 LiDAR,
- Council Asset GIS data (July 2018),
- Kerb data (July 2018),
- Property and adjacent ground levels (September 2018 with further data from July 2019)
- Survey cross-section data (October 2018),
- February 2019 LiDAR, and
- Asset survey data (July 2019).

The model was validated with rainfall data recorded from the 4-6th April 2017 rain event.

Once the model was run, additional survey data was commissioned to increase confidence of the model results in key areas with predicted flooding.

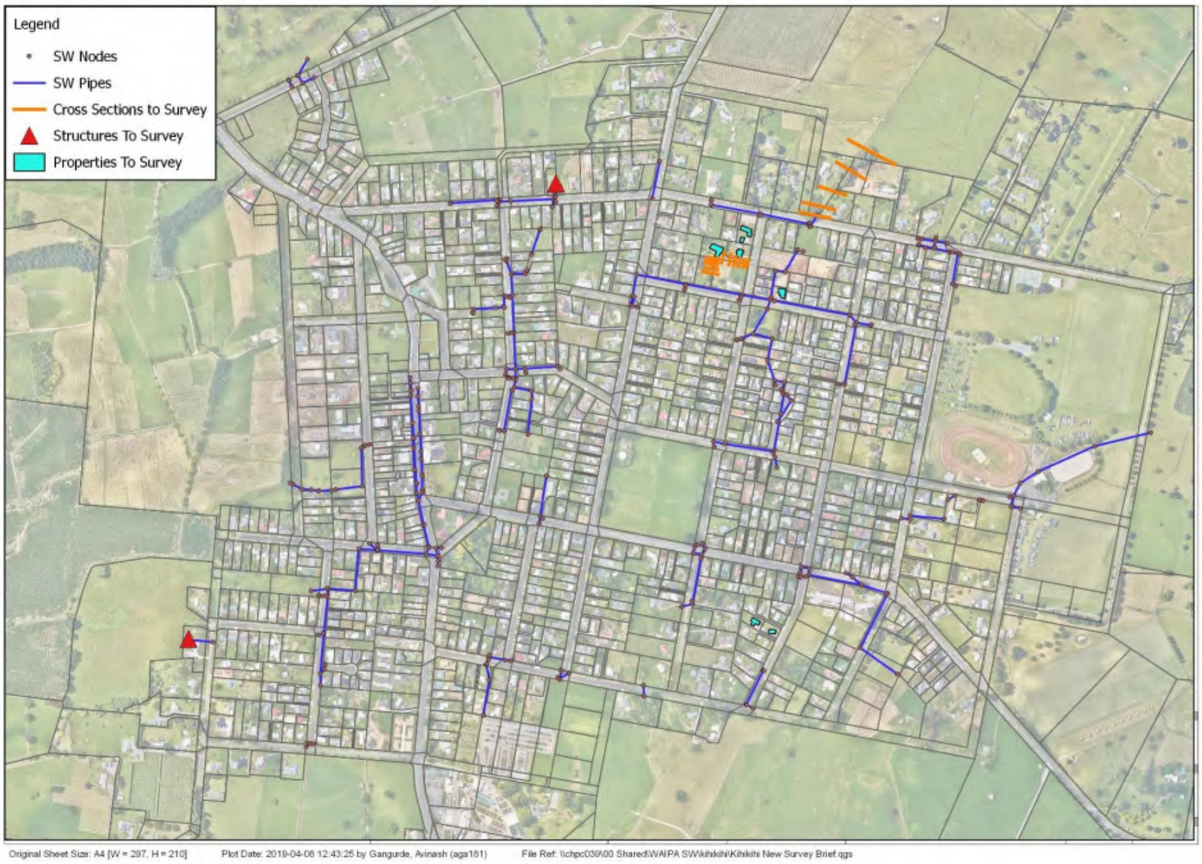


Figure 7-1. 2019 Surveyed Locations.

7.3.3 Model Build Notes / Assumptions

The following assumptions were made to build the model:

- The modelling build approach was generally in accordance with the stormwater modelling specification developed by Auckland Council (as this model predates the development of Waikato specific guidelines). This was to ensure the models were developed in accordance with industry standard modelling practice.
- Schematisation
  - The model is 1D-2D network models built using InfoWorks ICM v7.0.
  - The modelled areas were extended, with new areas (i.e., outside of the 1D model sub-catchments) represented within the 2D zone.
  - Runoff is applied to the models both with sub-catchments loaded to specific nodes (typically urban areas) and rain on grid (surrounding less developed areas where no sub-catchments were present in the 1D models –i.e., MS2).
  - The model includes pipes (generally larger than 225mm), manholes, open channels (as 1D river reaches) and key hydraulic structures such as culverts. Most catchpits are included in the model, however private connections are not represented.
  - Representation of the secondary system represented by the 2D mesh surface, which is coupled both at nodes and open channel lateral boundaries.

- Allowance has not been made for drainage infrastructure that was not included in the Waipa District Council asset register.
- It is noted that two specific property developments were modelled with limited confidence as details of developments were not available at the time of modelling. The developments are:
  - west of Oliver Street and south of Grey Street, and
  - west of Hall Street and north of Bryce Street.

- Rainfall
  - Rainfall profiles are as per the 1D only version of the models, as described in MS2.
- Hydrology
  - Sub-catchments and associated hydrology were taken from the earlier 1D models (refer to MS2) and are predominantly based on property parcel boundaries.
  - Losses in the rain on grid area of the model was assumed to proportional (30%) based on the calibrated Cambridge North model.
- Tailwater Boundary
  - The 2D zone boundary was modelled with Normal conditions.
  - 1D outfalls were assumed to be 'free' outfalls as per MS2.
- Hydraulic Assumptions
  - The drains on the outskirts of Kihikihi that the stormwater system discharges into were not surveyed and not modelled in detail. The 2D surface was relied upon for their definition, however, mesh zones were added so that the invert level matched the invert of the culvert that was discharging to it.
  - Surface resistance (roughness) was defined used manning's 'n' coefficients assigned based on land cover.
  - Future development infill extents were provided by Beca, with an impervious area assumption of 40% applied to these areas, based on the District Plan rule 2.4.2.10.
  - Soakage and rain tanks were not explicitly or implicitly represented in the model.

7.3.4 Deliverables

- Kihikihi Stormwater Modelling – Interim Modelling Results Memorandum (Mackinnon, 2018)
- Kihikihi Stormwater Modelling Memorandum (Mills, 2018)
- Kihikihi Stormwater Modelling – VP01 update Memorandum (Mills, 2018)
- The model was run with 10-year, 50-year and 100-year rainfall. Two scenarios were run: the first was existing development scenario and the second was with infill.

7.4 (MS4) PSP0135 / 19WA District Wide Stormwater Modelling

7.4.1 Introduction

The purpose of this modelling stage was to update the 1D network models (refer to MS2) to better represent the study areas in terms of flood hazard, transferred network issues, and infrastructure planning.

Waipa District Council identified upgrading the 1D model to a coupled 1D-2D model would assist council in achieving some of these outcomes and help obtain a better understanding of some of the critical areas in the network. The models could then provide a master planning baseline to inform and prioritise future investment into stormwater.

7.4.2 Summary of Scope

1 Stage 1: Pre-modelling

The following data was obtained to update the baseline 1D model:

(a) LiDAR (0.5 m x 0.5 m) provided by Waipa District Council (delivered 8 February 2019 and flown 16 – 17 December 2018).
(b) Updated asset data was received from Waipa District Council (taken from GIS at the time of issue dated 29/01/2019). Note: Stormwater pipes and catchpit leads were included in the model, but private stormwater connections were not included.
(c) Customer Complaints (CRM) data was provided by council for the period 13/07/2009 through to 18/05/2016. This data was used as a "sanity check" as part of the first pass 1D – 2D model build process.
(d) Planning information including land use based on district plan zoning, including future growth.

WSP undertook a GAP analysis of the baseline 1D model which was compared with the new data (listed above) to determine if this new data addressed any areas that have been previously identified as questionable or missing. This review identified where further validation was required to inform the scope of additional survey undertaken as part of Stage 3. Appendix B shows the maps of the assets that were requested to be surveyed.

2 Stage 2: First pass 1D-2D Infoworks ICM v7.0 model development

(a) Four separate models were updated to capture the townships of Cambridge, Ohaupo, Pirongia and Te Awamutu. See Section 7.3 for details on Kihikihi.
(b) All four models were updated from a 1D to a 1D-2D coupled model. The models provided an indication of overland flow paths, flood extents, areas of high risk and provided an indication of how the existing network performs and where problems in the network were occurring.

(c) The four models were updated using the sourced LiDAR and the 1D network was updated with the most recent data and planning information (district plan zones to inform percent impervious).

(d) The model update also included 10-year, 50-year and 100-year ARI design storms with and without climate change of 2.1-degree increase (previous modelling had only included the 2-year ARI storm)

(e) Once the model scenarios were run and sanity checked, initial problem areas and areas that required further survey were identified. These areas were identified in GIS and detailed in the reports in Appendix H.

(f) A systems performance analysis for the 2 year and 10-year event was undertaken.

(g) A report for each township detailed the modelling process and a list of the areas at risk of flooding and the corresponding storm event (ARI) that this is likely to occur in. WSP also provided interpretation for the reasons as to why the flooding could be occurring (e.g., insufficient capacity of culvert and no overland flow path). These reports were the outputs for this work package and indicated areas of uncertainty and improvement and potential validation sites.

> Whilst the results from this project were not publicly published (as they were considered preliminary only), they gave Waipa some understanding of areas of risk and catchment areas where their maintenance/renewals could be focussed.

7.4.3 Model Build Notes / Assumptions

Key assumptions were made during the process of coupling the 1D model with 2D. These assumptions included:

- Schematisation
  - The model is 1D-2D network models built using InfoWorks ICM v7.0.
  - The modelled areas were extended, with new areas (i.e., outside of the 1D model sub-catchments) represented within the 2D zone.
  - Runoff is applied to the models both with sub-catchments loaded to specific nodes (typically urban areas) and rain on grid (surrounding less developed areas where no sub-catchments were present in the 1D models –i.e., MS2).
  - The model includes pipes (generally larger than 225mm), manholes, open channels (as 1D river reaches) and key hydraulic structures such as culverts. Most catchpits are included in the model, however private connections are not represented.
  - Representation of the secondary system represented by the 2D mesh surface, which is coupled both at nodes and open channel lateral boundaries.
  - Allowance has not been made for drainage infrastructure that was not included in the Waipa District Council asset register.
- Rainfall

- o Rainfall profiles are as per the 1D only version of the models, as described in MS2.
- o Rainfall scenarios were selected for the following reasons:
- o The 10-year design storm was used to support design requirements in the Regional Infrastructure Technical specification (RITS) (Waikato Local Authority, 2018)).
- o The 50-year design storm was used to support building code and RITS specification requirements.
- o The 100-year ARI design storm was used to support understanding of flood hazards.

- Hydrology
  - o Sub-catchments and associated hydrology were taken from the earlier 1D models (refer to MS2) and are predominantly based on property parcel boundaries.
  - o Sub-catchment percent impervious assumptions were maintained as per the baseline models (MS2). In this stage of the modelling, only the existing level of development was modelled.
- Tailwater Boundary
  - o The 2D zone boundary was modelled with Normal conditions.
  - o 1D outfalls were assumed to be 'free' outfalls as per MS2.
- Network Assumptions
  - o 2D surface representation of developments within the catchment is limited to December 2018
  - o Lid level of the nodes, manholes, and catch-pits were set to 0.3 m below the LiDAR/ground level to allow water from the surface to enter the network easily.
  - o Where values in the asset data were not known, they were interpolated based on the upstream and downstream network sizes and levels.

7.4.4 Deliverables

- Stage II – First Pass Model Development (Stormwater Model Build and System Performance Report – Cambridge) (Adjei-Sasu, Mills, & Boldero, 2019)
- Stage II – First Pass Model Development (Stormwater Model Build and System Performance Report – Te Awamutu) (Adjei-Sasu, Mills, & Boldero, 2019)
- Stage II – First Pass Model Development (Stormwater Model Build and System Performance Report – Pirongia) (Gangurde, Mills, & Boldero, 2019)
- Stage II – First Pass Model Development (Stormwater Model Build and System Performance Report – Ohaupo) (Gangurde, Mills, & Boldero, 2019)
- The model was run with 10-year, 50-year and 100-year rainfall. Two scenarios were run: the first was existing development scenario and the second was with infill.

7.4.5 External Peer Review

This work was subject to External peer review by AECOM.

7.5 (MS5) PSP 0213 / 19WA Waipa Masterplan Development Works

7.5.1 Introduction

WSP was engaged to support the development of three water masterplans for Waipa District Council. The purpose of this was to set up ultimate growth model scenarios and add in known committed project infrastructure for each stormwater scheme (Cambridge, Te Awamutu, Pirongia, and Ohaupo) to assist Council's strategic planning (in partnership with Beca Consultants) with regards to Council's growth projections and levels of service. Ultimate growth modelling and committed project modelling for Kihikihi was done during PSP 0655 / 20WA (MS7).

7.5.2 Summary of Scope

1 Committed Project Scenarios

Committed project (CP) model scenarios were created for Cambridge and Te Awamutu. These scenarios were set up based on the existing development model with all known future stormwater infrastructure projects to Year 2021 (i.e., the committed projects) added into the network.

Committed project scenarios were not created for the Pirongia and Ohaupo as, at the time, there were no known major future stormwater projects.

The details of the committed project modelling are presented in Appendix D.

2 Maximum Probable Development scenarios

Maximum probable development model scenarios were created for each of the four main towns: Cambridge, Te Awamutu, Pirongia, and Ohaupo. These scenarios were set up based on growth area and infill assumptions.

The growth area extents were supplied by Waipa District Council based on district plan 2050 growth cells and added into the model as sub-catchments. Only growth areas that contributed to the topographic catchment were added into the town stormwater models. This was done based on the assumption that future stormwater networks, in growth areas, would follow natural overland flow paths. Cambridge and Te Awamutu had growth areas and predicted infill while Pirongia and Ohaupo just had predicted infill.

The ultimate growth modelling used the below assumptions for the percentage impervious:

(a) Infill in existing residential areas was modelled as an increase of 7% for the impervious areas.

(b) Assumptions for new developments (future growth areas) impervious percentages were adopted based on the district plan land zoning Table 7-1.

Table 7-1. Percentage impervious used in the model.

Land Zoning	Percentage Impervious
Residential	70%
Commercial	80%
Industrial	90%

The details of the growth area modelling are in Appendix C.

Locations of growth area extents and committed projects in the Cambridge and Te Awamutu are shown in Figure 7-2 and Figure 7-3.

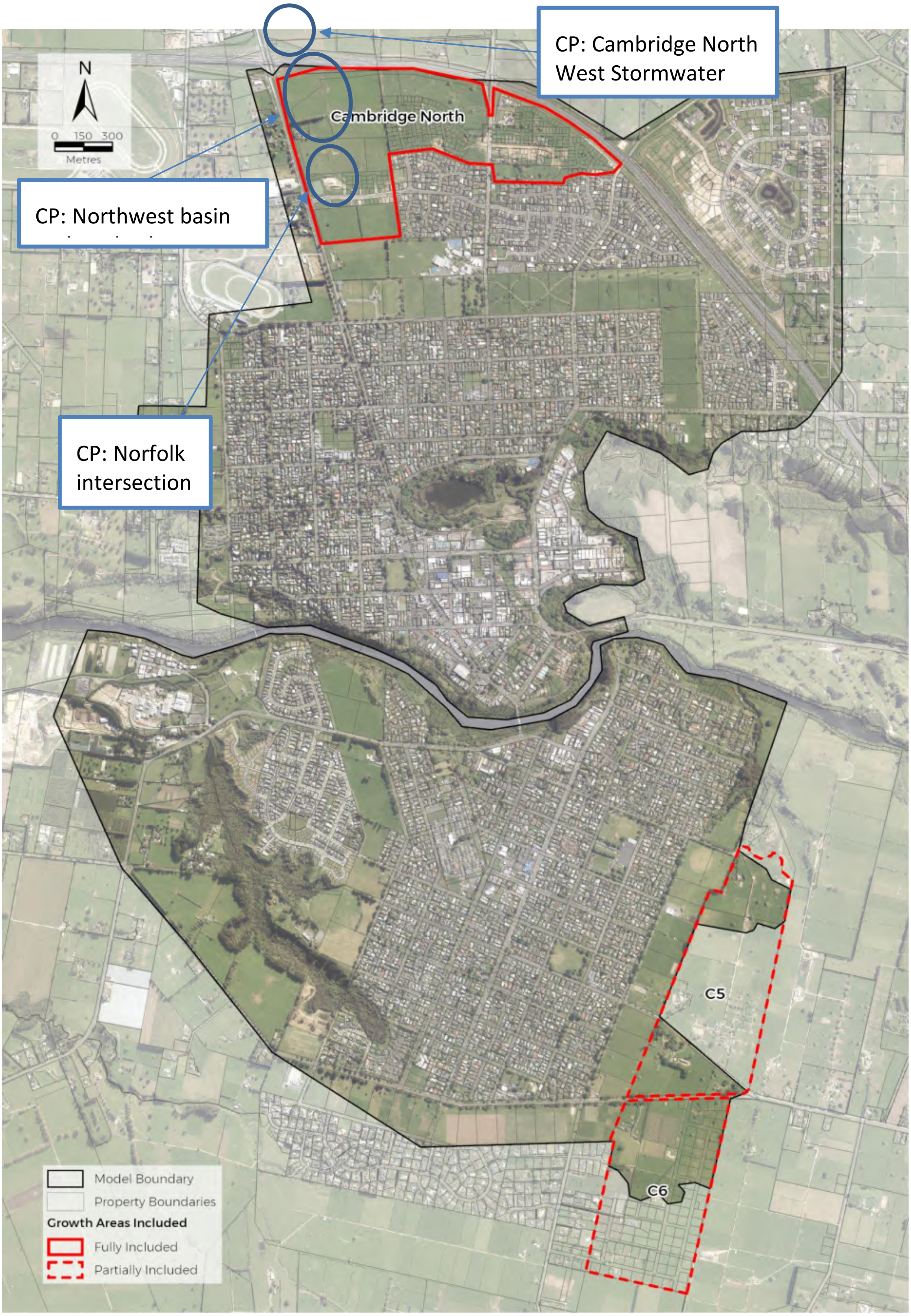


Figure 7-2 : Cambridge growth areas and committed projects included in the model.

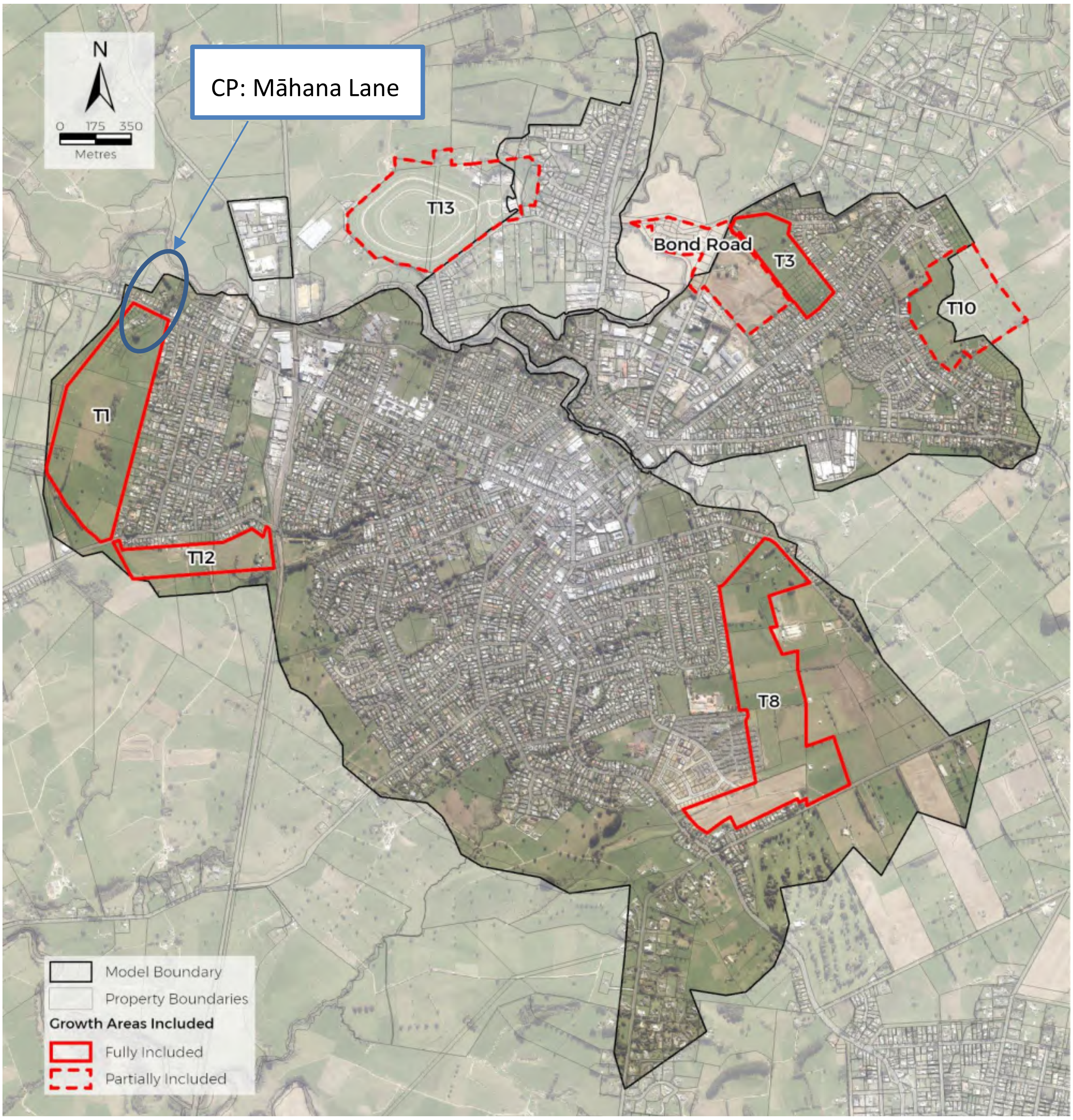


Figure 7-3 : Te Awamutu growth areas and committed projects included in the model.

7.5.3 Model Build Notes / Assumptions

- Schematisation
  - o The models are 1D-2D network models built using InfoWorks ICM v7.0 as per MS4 – this stage made no significant changes to the schema.
  - o Allowance has not been made for drainage infrastructure that is not included in the Waipa District Council asset register.
- Rainfall

  - As per MS4 rainfall was based on the PMP distribution and HIRDS v4 with climate change accounted for by RCP 6.0 2130.
- Hydrology
  - Sub-catchments were taken from previous modelling stage (MS4) and are predominantly based on property parcel boundaries.
  - A 7% increase in existing residential (and rural residential) areas for the maximum probable development scenario, with additional growth areas added.
- Tailwater Boundary
  - Tailwater Boundaries are as per MS4.
- Network
  - The committed project scenarios were based on all known infrastructure projects confirmed for construction by the end of 2021.

7.5.4 Deliverables

- Cambridge Stormwater Model – Committed Projects Update (Adjei-Sasu & Mills, 2019)
- Te Awamutu Stormwater Model - Committed Projects Update (Adjei-Sasu & Mills, 2019)
- Cambridge Stormwater Model – Growth Area Update (Adjei-Sasu & Mills, 2019)
- Te Awamutu Stormwater Model – Growth Area Update (Adjei-Sasu & Mills, 2019)
- Ohaupo Stormwater Model – Growth Area Update (Adjei-Sasu & Mills, 2019)
- Pirongia Stormwater Model – Growth Area Update (Adjei-Sasu & Mills, 2019)

7.6 (MS6) PSP 0318 / 20WA Masterplan Additional Stormwater Modelling

7.6.1 Introduction

WSP were engaged to:

- Updated the modelling methodology to follow the WRC Runoff modelling guidelines (Shaver, 2020) and
- Investigate options / upgrades to the network to meet the needs of future growth.

Specified options and scenarios to meet the needs of the baseline population and future growth based on Waipa District Council's levels of service were analysed in the Cambridge, Te Awamutu, Pirongia and Ohaupo models. Kihikihi was not included in these assessments.

7.6.2 Summary of Scope

The stormwater modelling analysis was carried out in several stages, broken down as follows:

1 Update of the stormwater 2D models to be compliant with WRC runoff guidelines.

(a) The additional modelling included updating the modelling methodology of the Cambridge, Te Awamutu, Pirongia and Ohaupo models to follow the *Waikato Regional Council Runoff Modelling Guidelines* (Shaver, 2020). This required the calculation of a curve number and time of concentration for each sub-catchment and development of new rainfall event profiles. For details on the methodology change see Appendix E.

2 Development of options to inform Master Plan.

(a) This work package also included modelling and investigating potential stormwater network improvements. Model scenarios were set up in the Cambridge, Te Awamutu, Pirongia and Ohaupo models to quantify upgrade effects. Options to assess were provided by Beca.

(b) Modelled scenarios:

(i) Pipe upgrades:

I The pipes were initially upsized based on the results of the ultimate growth that showed the pipes that had no capacity and were surcharging.

II Following the upsizing of the upstream pipes, the downstream pipes were required to pass an increased volume of flow. In some cases, this resulted in the downstream pipe network to be predicted as undersized and under-capacity. If that occurred, the under-capacity pipes were upsized, and the models were rerun. This process was iterated until there were no under-capacity pipes left surcharging in the model.

(ii) Increased on-lot soakage:

I Soakage and water reuse were investigated as catchment wide solution to improve the performance of the SW network. It was assumed that there would be only 30% uptake across all sub-catchments, including the road sub-catchments. The method of applying this in the model varied between the 10% AEP rainfall event and the 1% AEP rainfall event. The methodology was as follows.

(a) Current catchments in the model were duplicated by splitting the pervious section of the catchments from the impervious sections.

(b) To simulate the potential 30% uptake in the retrofitting of the devices the percent imperviousness was decreased by 30%.

(c) The 10% AEP scenario assumed that for no runoff occurred for soakage catchments (i.e., soakage designed to cope with 10y AEP).

(d) The 100% AEP scenario assumed the runoff from the soakage areas would be equivalent to 1% AEP profile reduced by the 10% AEP rainfall depth.

(iii) Detention ponds in the public network

I Potential detention ponds were conceptually modelled at different locations in the network to identify where they would have the largest benefit on flooding.

7.6.3 Model Build Notes / Assumptions

- Schematisation
  - The models are 1D-2D network models built using InfoWorks ICM v7.0 as per MS4 – this stage made no significant changes to the overall schema.
  - Allowance has not been made for drainage infrastructure that was not included in the Waipa District Council asset register.
- Rainfall
  - The updated rainfall profile used the specified nested storm profile from the WRC modelling guidelines, with accumulated depths extracted from HIRDS.
  - The 10% and 1% AEP events were run.
- Hydrology
  - The loss method was updated to use the SCS curve number (CN) method as per Waikato Regional Council Runoff Modelling Guidelines (Shaver, 2020). From this time onwards, Horton's method was not used.
  - The hydrological soil groups used to define the CN were assumed based on previous model calibration.
  - Curve numbers were then assumed based on land cover and hydrological soil group (Shaver, 2020).
- Network
  - Detention basins were sized based on the maximum flow the downstream pipe has capacity for during the 10% AEP rainfall event. The depth of the basin was determined by the existing ground level and the existing inverts of the incoming and outgoing pipes. The basins were designed to retain the 10% AEP volume, and a check was undertaken to verify what would occur in the 1% AEP scenario.

7.6.4 Deliverables

- Waikato Regional Council Modelling Approach Memorandum (Adjei-Sasu & Mills, 2019)
- Gateway Approval for Waipa Stormwater Master Plan Options Development Memorandum (West & Mills, 2019)
- Waipa stormwater modelling result differences following the Waikato Regional Council Method Memorandum (West, 2019)
- Waipa Stormwater Alternative Options Modelling results Memorandum (West, Adjei-Sasu, & Mills, 2020)

- Maps and shapefiles of pipe upgrade results for Cambridge, Te Awamutu, Pirongia and Ohaupo.
- Detention model results for Cambridge and Te Awamutu for the 10-and 100-year ARI storm events with climate change with the estimated size of detention required.
- Soakage model results for Cambridge, Te Awamutu, Pirongia and Ohaupo for the 10- and 100-year ARI storm events with climate change.

7.7 (MS7) PSP 0655 / 20WA District Wide Stormwater Model Checks

7.7.1 Purpose

The purpose of this project was to update the model to improve representation of the network and the 2D surface, by undertaking additional rainfall scenarios, updates to Kihikihi models, and scoping additional survey across 4 of the towns.

7.7.2 Summary of Scope

The following key items were completed in this modelling stage scope:

1 The Kihikihi model updated to the same point as the other towns (refer to MS6), including updates to follow the Waikato Regional Council Runoff Modelling Guidelines (Shaver, 2020).

2 Analysis of additional (longer duration PMP rainfall profiles) model runs was undertaken to better understand the implications from using the Waikato Regional Council Modelling Guideline rather than the calibrated hydrology from the previous 1D model.

The comparative analysis was completed to verify the latest version of the models (which use WRC guidelines) against the original calibrated modelling methodology. The comparison highlighted the differences between the design (nested) storm and a more statistically derived storm event like the probable maximum precipitation (PMP) distribution.

3 Additional survey was scoped for Cambridge, Te Awamutu, Pirongia and Ohaupo to improve representation of flooding in the models (excluding Kihikihi as it had better survey coverage than the other towns).

To improve the representation of stormwater assets in the models, a survey brief was developed. Originally the survey was going to be undertaken in two stages. The first stage being key assets, which was undertaken as per the list below, and the second stage being floor levels and other large assets / unknowns. Following both stages of survey, sensitivity checks within the models were going to be undertaken. Before stage two of the survey was scoped, the modelling process was accelerated so stage two survey and sensitivity testing were not carried out.

The survey brief outlined the requirements and locations of the following infrastructure to be surveyed:

- drains,

- o rivers,
- o pipe diameters,
- o outlets,
- o inlets,
- o culverts,
- o bridges, and
- o ponds.

The specific assets that were requested to be surveyed are shown in Figure 7-4, Figure 7-5, Figure 7-6, and Figure 7-7.

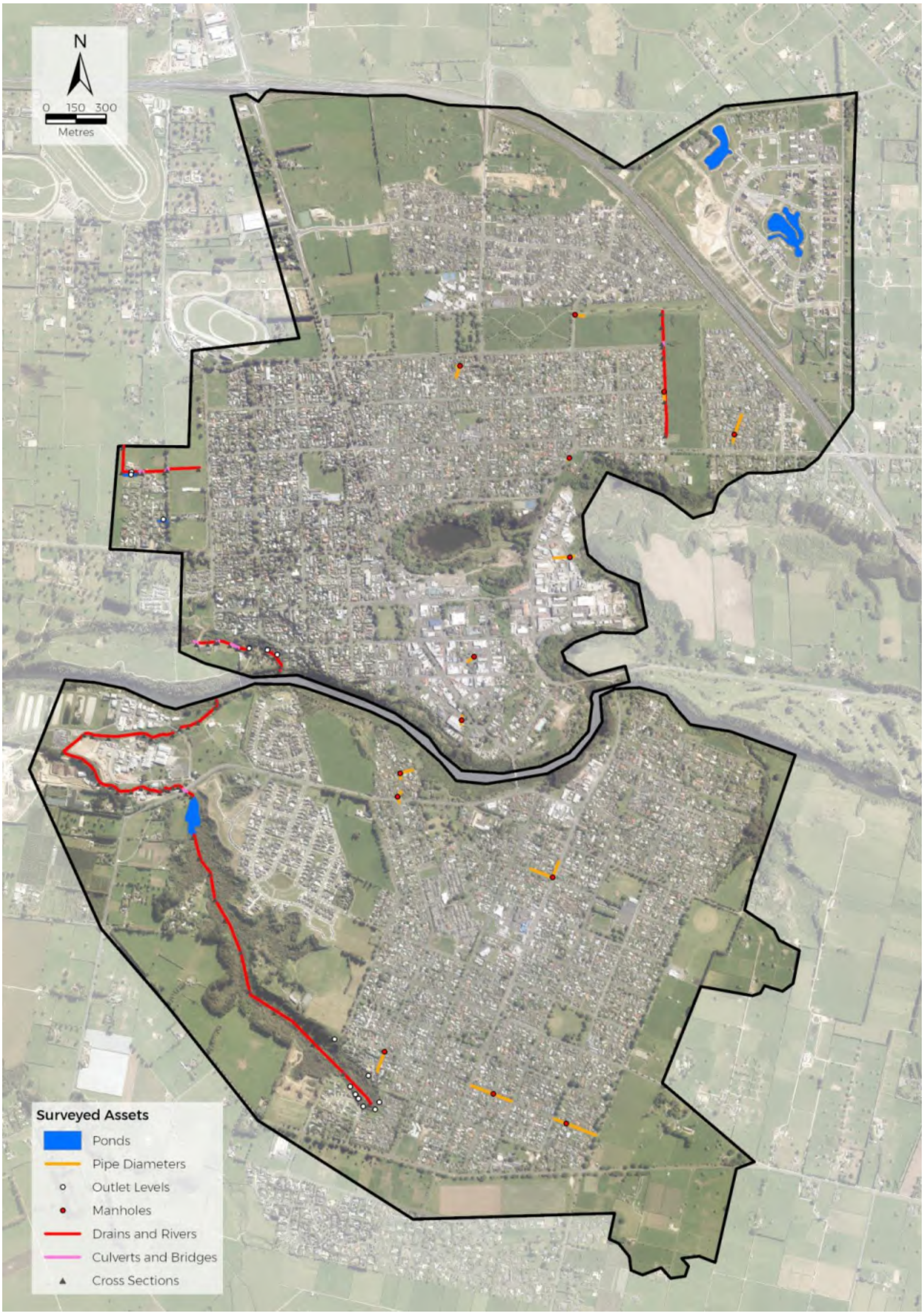


Figure 7-4 : Survey requested for Cambridge in February 2020.

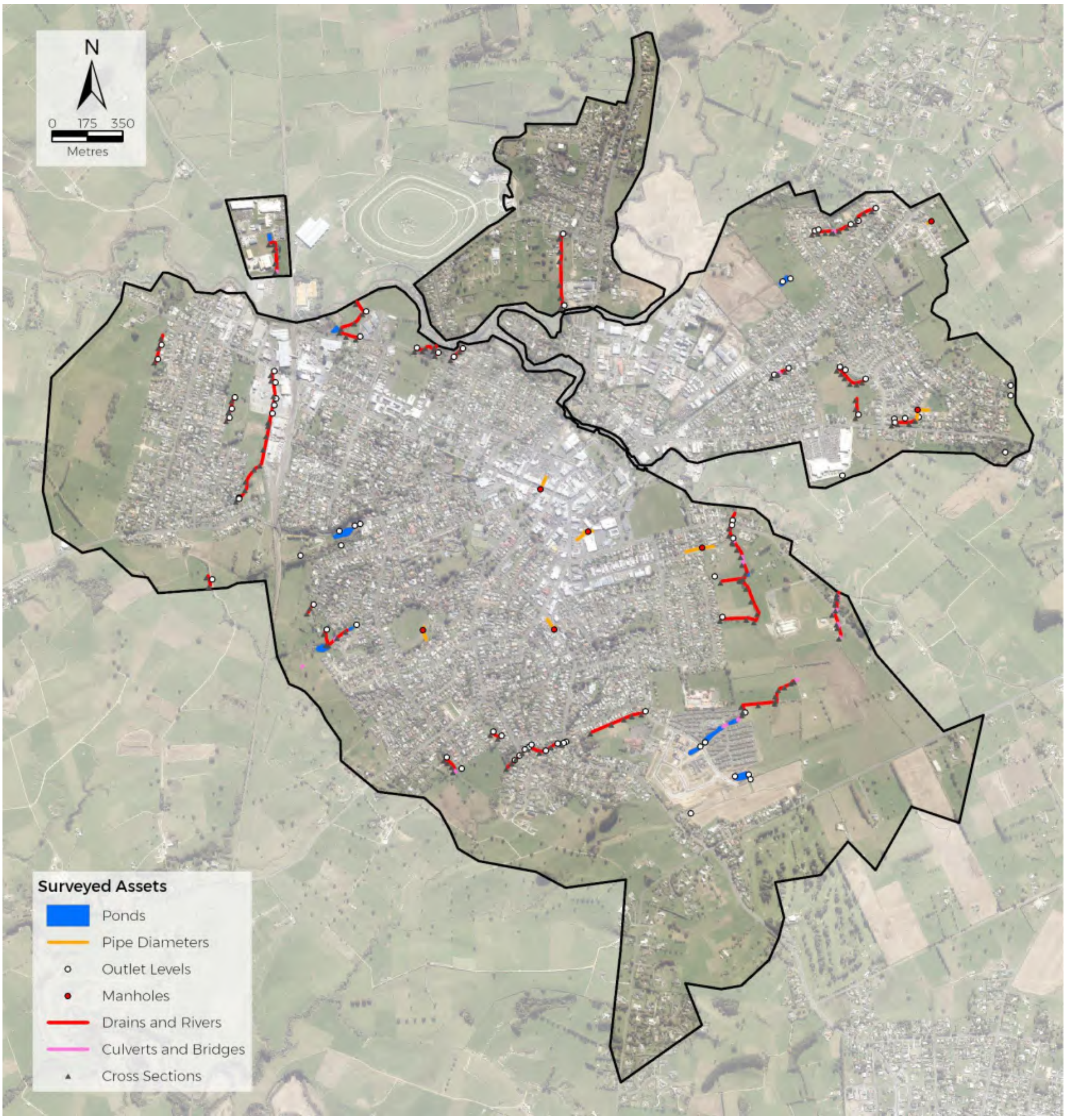


Figure 7-5 : Survey requested for Te Awamutu in February 2020.

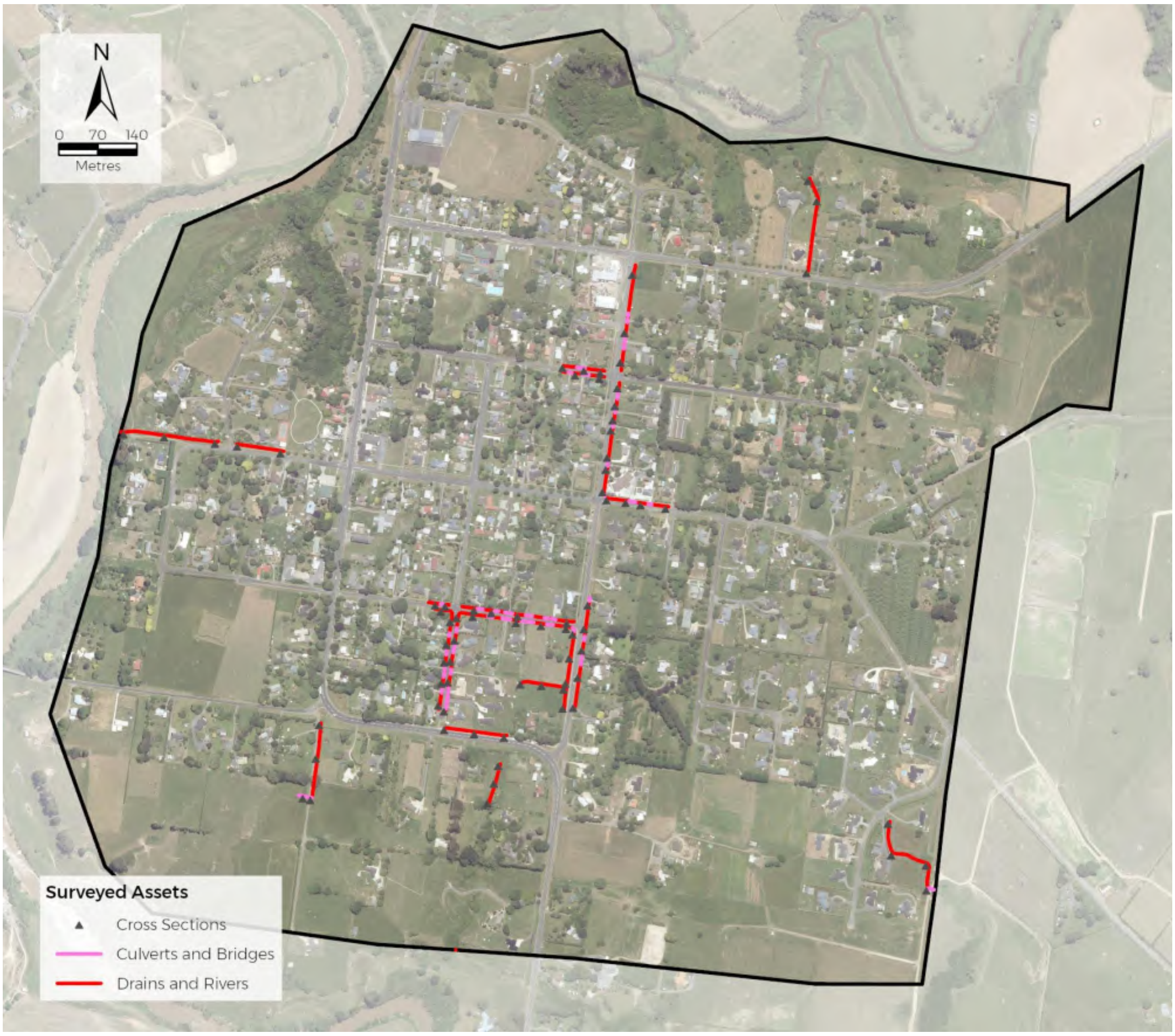


Figure 7-6 : Survey requested for Pirongia in February 2020.

Figure 7-7 : Survey requested for Ohaupo in February 2020.

7.7.3 Model Build Notes / Assumptions

- Schematisation
  - o The models are 1D-2D network models built using InfoWorks ICM v7.0 as per MS6 – this stage made no significant changes to the overall schema.
  - o Allowance has not been made for drainage infrastructure that was not included in the Waipa District Council asset register.
- Rainfall
  - o Two types of rainfall profiles were used for comparison.
    - – WRC nested storm (as per MS6)
    - – PMP rainfall profile (as per MS2)
- Hydrology
  - o The hydrology (for both rainfall profiles) is based on the WRC guidelines as per MS6.
- General
  - o Areas to survey that would increase model representation in key areas of uncertainty were chosen based on the previous model results and critical flooding locations.

7.7.4 Deliverables

- Waipa stormwater modelling result differences and sensitivity following the Waikato Regional Council method (West, Adjei-Sasu, & Mills, 2020).The details of this investigation are shown in Appendix F.
- Survey Brief to improve Waipa Stormwater Models (West & Mills, 2020)The survey brief memo is shown in Appendix G. Shapefiles were delivered with the memo showing requested survey locations. A survey of the Kihikihi assets was not included in the survey brief as a survey had been previously completed.
- BTW provided the survey as excel files with corresponding pictures.

7.8 (MS8) PSP 0688 / 20WA District Wide Stormwater Model Improvement

7.8.1 Introduction

The purpose of this modelling stage was to update the Cambridge, Te Awamutu, Pirongia and Ohaupo stormwater models to improve representation of the network and the 2D surface.

This involved the updating the models with survey results (as scoped in MS7) and as-built data received from Council. Kerb shapefiles supplied by Waipa District Council were also added into the Cambridge, Te Awamutu, Pirongia and Ohaupo models as break lines.

7.8.2 Summary of Scope

The following data was incorporated into the model:

- Surveyed levels and sizes of hard infrastructure (pipes and nodes). Where culvert inlets and outlets were updated in the model, the coefficients were determined based on photos of the inlet / outlet structures.
- Kerb lines were added into the 2D mesh and used as break lines for the delineation of the 2D mesh cells.
- To build the river reaches in the model, surveyed cross-section points were added as cross-sections and the river reaches were built based on these with inline banks connecting them to the ground surface.

All updated data was flagged as SV20 in the ICM modelling software to show the source was surveyed in 2020.

Following the model updates, 2-year, 10-year, and 100-year designs storms for each level of development were run with and without climate change to test model stability. However, it is noted that no results were delivered during this stage.

7.8.3 Model Build Notes / Assumptions

- Schematisation
  - The models are 1D-2D network models built using InfoWorks ICM v7.0 as per MS6 – this stage made no significant changes to the overall schema.
  - Allowance has not been made for drainage infrastructure that was not included in the Waipa District Council asset register.
- Rainfall
  - All rainfall was based on WRC guidelines a per MS6.
- Hydrology
  - The hydrology is based on the WRC guidelines as per MS6.
- Network
  - It is noted that while the addition of kerb-lines as break-lines are likely to improve the alignment of and add consistency to the 2D Mesh elements within the road, that kerb and channel profiles are not explicitly represented. It is expected that the conveyance capacity maybe under-represented in some road areas.
  - The kerb shapefiles were simplified to minimise the number of vertices so that the mesh triangle size around the kerb corners was not too small. This was because small triangles within the mesh significantly increase the model run time, without a corresponding increase in accuracy.
  - In some cases, limited information was available regarding connections between the newly surveyed assets and the existing assets. In these cases, engineering judgement was applied to assume a 'best guess' connection. This may result in additional flow (or less flow) being applied to certain pipelines, which may overpredict or underpredict pipe capacity in localised areas.

7.8.4 Deliverables

The existing model build reports (refer MS4) were updated to reflect the model updates completed in this modelling stage, including the representation of structures in the model, the assumptions, and the limitations. See Appendix H for the full Draft Model Build reports.

7.8.5 Model Build Reports:

- Stage III – District Wide Stormwater Model Improvement (Stormwater Model Build and System Performance Report – Cambridge) (Adjei-Sasu & Mills, 2021)
- Stage III – District Wide Stormwater Model Improvement (Stormwater Model Build and System Performance Report – Te Awamutu) (Adjei-Sasu & Mills, 2021)
- Stage III – District Wide Stormwater Model Improvement (Stormwater Model Build and System Performance Report – Pirongia) (Adjei-Sasu & Mills, 2021)
- Stage III – District Wide Stormwater Model Improvement (Stormwater Model Build and System Performance Report – Ohaupo) (Adjei-Sasu & Mills, 2021)

7.9 (MS9) PSP 0755 / 20WA Stormwater Model Peer Review Engagement

WSP provided the modelling data (networks, rainfall, and results) in model files (icmt's) and survey shapefiles, to AECOM for them to carry out the peer review of the Cambridge, Te Awamutu, Pirongia and Ohaupo Stormwater models. WSP collaborated with AECOM to discuss model set up and finalise peer review response tables.

The peer review identified recommended areas of improvement within the model, this included identification of areas to survey, refining roughness values, and sub-catchment delineation. The peer review also generated good discussion and rationalisation between Waipa District Council, AECOM and WSP of modelling decisions and best practise approaches, to ensure a best for Waipa result.

7.10 (MS10) PSP 0800 / 21WA Stormwater Models Final Peer Review Updates and Responses

7.10.1 Introduction

This purpose of this project was to facilitate the closeout of the peer review stage. This included WSP providing responses to specific comments from the Peer Reviewer (AECOM), undertaking additional checks, and completing model updates identified during the peer review process.

7.10.2 Summary of scope

The model updates were communicated with the peer reviewer (AECOM) and Waipa District Council. Once the changes were made the models were peer reviewed once again, to confirm if the updates had resolved previously identified areas for improvement.

Updates and checks to the models included:

- Additional runs to compare head losses on steep pipes to understand the impact of the chosen coefficients. Three values were compared:
    - FHWA: Value calculated based on the Federal Highway Administration (FHWA) Inlet and Access Hole Energy loss method (Brown, Stein, & Warner, 2001),
    - Normal: Headloss that is calculated using a built-in headloss curve,
    - None: No headloss.
- Updating PVC pipe loss parameters.
- Checking and identifying issues causing empty flow conduits in the Pirongia model.
- Updating 1D channel banks to ensure smooth transition from the survey data to the LiDAR.
- Review and update of time of concentration values for the catchments to ensure they are appropriate for the catchment size.
- Review and update of roughness parameters in 1D channels to ensure they vary across the panel.
- Check of how catchment delineation based on parcels differs from the topographical catchments.
- Performance of a sensitivity check parcel catchment vs. hydrological catchments to demonstrates.
- Highlight negative gradient pipes and changing as proposed in the peer review comments.
- Investigation of high peak velocities to see if the high values were justifiable and if not, the model set up was amended.

7.10.3 Additional model updates

Following the PSP 290135 Rain on Grid Stormwater Model Validation it was identified that sub-catchments in Cambridge and Te Awamutu could be reallocated and / or re-delineated to improve the representation of the existing topographic drainage directions. The model updates were done under a variation for SP 0800 / 21WA Stormwater Models Final Peer Review Updates and Responses.

7.10.4 Model Build Notes / Assumptions

- Schematisation
    - The models are 1D-2D network models built using InfoWorks ICM v7.0 as per MS8 – this stage made no significant changes to the overall schema.
    - Allowance has not been made for drainage that was not included in the Waipa District Council asset register.
- Rainfall
    - All rainfall was based on the nested storm distribution and HIRDS v4 with climate change accounted for by RCP 6.0 2130 as per MS8.
- Hydrology

- o The hydrology was based on the SCS curve number method as per MS8.
- o The Cambridge and Te Awamutu model updates were focused on areas where the rain on grid modelling indicated that the sub-catchment allocation and delineation had potential to impact on the 100y ARI predicted model results. Therefore, while high level checks of sub-catchment delineation and allocation against topography were undertaken across the wider catchment, this updated does not cover an exhaustive update of all sub-catchments within the model.

- Network
  - o Refer to updates / changes listed in section 7.10.4 above.

7.10.5 Deliverables

- Model results were delivered for Cambridge, Te Awamutu, Pirongia, and Ohaupo for the below scenarios:
  - o Maximum probable development with climate change
  - o Maximum probable development without climate change
- Cambridge Stormwater Hydraulic and Hydrological Model Review Draft (AECOM, WSP and Waipa District Council, 2021)
- Te Awamutu Stormwater Hydraulic and Hydrological Model Review Draft (AECOM, WSP and Waipa District Council, 2021)
- Pirongia Stormwater Hydraulic and Hydrological Model Review Draft (AECOM, WSP and Waipa District Council, 2021)
- Ohaupo Stormwater Hydraulic and Hydrological Model Review Draft (AECOM, WSP and Waipa District Council, 2021)

To see the full peer review response tables, see Appendix I.

7.11 (MS11) PSP 290032 Stormwater Models Existing Development Results

7.11.1 Introduction

This purpose of this modelling stage was to re-run the 'committed projects' and 'existing development' scenarios using the updated model network (i.e., as per the outcomes of the previous modelling stages (including the peer review).

This work was done to support Council's flood plain mapping project and ongoing catchment management planning.

7.11.2 Summary of Scope

The previous existing development and committed project scenarios were rerun as part of MS5 (i.e., did not align with the WRC guidelines, or incorporate subsequent model refinements).

To bring these models up to the same level as the Maximum Probable Development model (i.e., MS10), the scenarios were converted to use the Waikato Regional Council methodology for hydrology. The models were subsequently rerun, and the results were provided to Waipa District Council.

7.11.3 Model Build Notes / Assumptions

- Schematisation
  - The models are 1D-2D network models built using InfoWorks ICM v7.0 as per MS8 – this stage made no significant changes to the overall schema.
  - Allowance has not been made for drainage that was not included in the Waipa District Council asset register.
- Rainfall
  - As per MS8 rainfall was based on the nested storm distribution and HIRDS v4 with climate change accounted for by RCP 6.0 2130.
- Hydrology
  - As per MS8 the hydrology was based on the SCS curve number method.
  - The maximum probable development WRC hydrology model scenarios for each town were used as the starting point, development assumptions (infill impervious percentage increase and growth area sub-catchments) were then rolled back to represent existing levels of development.
- Network
  - The infrastructure projects that had been previously confirmed as committed projects in 2019 (to be constructed by 2021) were left in the Te Awamutu and Cambridge committed project scenarios.
  - No committed projects were previously supplied for Pirongia, Ohaupo or Kihikihi; no additional runs were undertaken.

7.11.4 Deliverables

The run results provided for this work package with the model files (icmm containing network, rainfall and results) are provided below in Table 7-2.

Table 7-2. Model Runs.

Model	2-,10-, and 100-year Existing Development with and without climate change	2-,10-, and 100-year Committed Projects with and without climate change	2-,10-, and 100-year Maximum Probable Development with and without climate change
Ohaupo	Yes	N/A	Yes
Kihikihi	Yes	N/A	Yes
Te Awamutu	Yes	Yes	Yes
Pirongia	Yes	N/A	Yes
Cambridge	Yes	Yes	Yes

7.12 (MS12) PSP 290135 Rain on Grid Stormwater Model Validation

7.12.1 Purpose

The purpose of this study was to use rain on grid (ROG) modelling for Cambridge, Te Awamutu, Pirongia, Ohaupo, and Kihikihi to:

- Identify areas where the model sub-catchment delineation and assignment were not consistent with the topographic drainage direction (LiDAR), and
- Determine if any sub-catchment limitations identified (as per 1 above) are likely to have a significant impact on the predicted 100-year ARI max flooding.
- Provide recommendations for potential changes to the 1D-2D models.

This study allowed Waipa to make an informed decision on whether updates to the sub-catchments in the 1D-2D models were required.

7.12.2 Summary of Scope

The following points summarise the main scope / modelling activities undertaken for this modelling stage:

- Development of rain on grid models for 5 towns, using the current 2D extents as the domain.

  This included:

  - Removal of sub-catchments from the models.
  - Creation of effective rainfall profiles for the 100y ARI event (existing climate) using WRC hydrology.
  - Runs were completed for both with and with-out prefilled depression areas within the 2D surface.

- Completion of 'difference maps' for the ROG vs original sub-catchment models.
  The rain on grid model results were subtracted from the sub-catchment results to see where the largest differences were located within each of the towns.
- Interpretation of results identifying areas where the sub-catchment delineations differed from the topographic drainage areas, and the impact of these on predicted downstream floodplains.
- Provide recommendations on the potential need for sub-catchment refinement in the 1D-2D models.

7.12.3 Summary of Findings

Following the comparison of modelling results, the following recommendations were made:

- Cambridge:
  - It was identified that a number of sub-catchments were non- consistent with the topographic drainage directions generated from the LiDAR. It was recommended that an assessment of the potential reallocation and reshaping of other sub-catchments within the model should be undertaken to better reflect the topographic drainage directions.
- Te Awamutu:
  - It was identified that a number of sub-catchments were non- consistent with the topographic drainage directions generated from the LiDAR. It was recommended that an assessment of the potential reallocation and reshaping of other sub-catchments within the model should be undertaken to better reflect the topographic drainage directions.
- Pirongia:
  - The rain on grid modelling highlighted a number of limitations with the use of sub-catchment style approach, particularly related to the lack of formal connection between private properties and the Public Stormwater Network. Further, it was noted that a number of sub-catchments were identified where the sub-catchment delineation and allocation was not consistent with the latest LiDAR.
  - It was recommended that the hydrology of the Pirongia model should be updated to utilise a partial rain on grid approach to improve the representation of potential flooding within the relatively flat property areas of the township (i.e., the headwaters of the catchment).
- Ohaupo:
  - Based on the difference results, revision of the current sub-catchment allocation and delineation is not expected to have a significant impact on the predicted floodplain extents.
- Kihikihi:

- The rain on grid model indicates that the current predicted flood extents from the sub-catchment model have a reasonable level of confidence. However, there are some areas where the rain on grid results predicts additional overland flow and / or ponding compared to the existing sub-catchment model (particularly upstream of sub-catchment loading locations). Potential review of the inletting assumptions and sub-catchment allocation is recommended for these specific areas to ensure that the risk is captured appropriately.

7.12.4 Model Build Notes / Assumptions

This section summarised the key assumptions and limitations from this modelling stage. This not considered to be an exhaustive list. For additional detail please refer to the relevant report.

- Rainfall
  - Rainfall profiles for each town using the WRC temporal pattern, with rainfall depths taken from HIRDS v4, as per the 1D-2D model.
  - Effective rainfall applied as 'rain-on-grid' to the sub-catchments zones was calculated using average CN and percent impervious values across all sub-catchments. This is expected to impact volumes and peak flow where land use within a sub-catchment significantly deviates from the 'average' percent impervious.
- Hydrology
  - Effective rainfall (i.e., runoff depth profile) was calculated using weighted average curve numbers, to subtract the soil infiltration from the rainfall profile.
  - Weighted curve numbers were calculated using the average of sub-catchment Curve numbers.
  - The effective rainfall was then applied directly to the 2D surface.
  - No infiltration losses are applied to the 2D surface.
  - Rain-on-grid modelling may result in different time of concentration compared to the routing methodology applied in the sub-catchment model and may hence impact the peak predicted flows at some locations.
- Network / Hydraulics
  - The hydraulic setup of the model (i.e., the 1D network, 2D surface and coupling parameters, were left as per the 1D – 2D models (refer to MS8)
  - It is noted that the capture of surface water into the stormwater network in a rain on grid model will differ when compared to the sub-catchment model. In a sub-catchment model runoff is loaded directly into the network, whereas in a ROG model the runoff must flow overland and onto specific points to enter the network. This relies on appropriate and accurate inlet representation, which has not been assessed for this exercise. A rain on grid model is typically expected to result in a higher proportion of overland flow and a lower proportion of network flow. The connectivity of depression areas to the public

stormwater network is not expected to be accurately represented. Private drainage or open channels that were not well captured in the 2D surface could not discharge water to the public network in the water.
  - Rain-on-grid modelling may result in different time of concentration compared to the routing methodology applied in the sub-catchment model and may hence impact on the peak predicted flows at some locations.
  - The connectivity of depression areas to the public stormwater network is not expected to be accurately represented. No allowance is made for private drainage, or open channels which may not be well captured in the 2D surface, that pass water to the public network.

- Other Limitations
  - These models were intended to provide context for the existing 1D-2D models and are not expected to provide a sensible representation of the network in all locations.
  - The scope of this works is limited to providing context for the existing sub-catchment by assessing sensitivity of sub-catchment delineation to the predicted 100-year ED (assumed 2019 baseline) flood results. This work is not intended to provide advice on the criteria for publication of floodplain results to the public domain. The ROG model results are not recommended for use for flood hazard mapping.

7.12.5 Deliverables

- Waipa Rain on Grid Modelling Assumptions (West & Nikkel, 2021)
- Kihikihi rain on grid sensitivity analysis results (West & Nikkel, 2021)
- Ohaupo rain on grid sensitivity analysis results (West & Nikkel, 2021)
- Pirongia rain on grid sensitivity analysis results (West & Nikkel, 2021)
- Cambridge rain on grid sensitivity analysis results (West & Nikkel, 2021)
- Te Awamutu rain on grid sensitivity analysis results (West & Nikkel, 2021)
- The 100-year rain on grid and sub-catchment existing development model results were provided.

See Appendix J for the memorandums relating to this work.

7.12.6 External Peer Review

This work was subject to External peer review by AECOM.

7.13 (MS13) PSP 290183 Pirongia Rain on Grid Modelling Updates

7.13.1 Introduction

WSP updated the Pirongia model schematisation, based on the recommendations of modelling stage 12, to better reflect surface water behaviour within the catchment, particularly within depression areas in private properties.

Topographically, Pirongia is relatively flat with no major flow paths, which results in many ponding locations within property boundaries. Due to this, as well as the lack of connectivity between ponding areas and the network, it is challenging to use a sub-catchment model to appropriately distribute runoff across the 2D surface.

7.13.2 Summary of Scope

- All sub-catchments representing non-road reserve were removed.
  Road reserve sub-catchments were retained, as unlike property catchments, the runoff from the road corridor directly enters the network through catchpits and other inlet structures. Where sub-catchments were removed in Pirongia, the model was set up as rain on grid.
- Rain Gauge Polygons were developed to allow different runoff volumes within different areas of the rain on grid area, based on the percent impervious assumptions from the modelled sub-catchments. This allowed for spatial distribution of runoff characteristics, to ensure that runoff volumes were appropriate for different land use types across the catchment. Figure 7-8 summarises the assumed percent impervious areas.

Figure 7-8. Percentage Impervious assumed in Pirongia.

7.13.3 Model Build Notes / Assumptions

- Schematisation
  - Schematisation was a mix of rain on grid and sub-catchments delineated based on land parcels and topography.
  - Rain-on-grid modelling may result in different time of concentration compared to the routing methodology applied in the previous sub-catchment model and may hence impact on the peak predicted flows at some locations.
  - It is noted that the schematisation applied in this model, may not be suitable for representation of future development scenarios, as these may result in significant re-grading of the topography, and or the direct connection of impervious surfaces to the public drainage system.
  - Allowance has not been made for the drainage that was not included in the Waipa District Council asset register.
- Rainfall
  - Rainfall was based on the nested storm distribution and HIRDS v4 with climate change accounted for by RCP 6.0 2130.
- Hydrology
  - The hydrology was based on the SCS curve number method (in line with the WRC modelling guidelines).
  - The curve numbers were determined based on the percentage impervious which was assumed based on the land use and aerial photos.
  - Rain-on-grid modelling may result in different time of concentration compared to the routing methodology applied in the sub-catchment model and may hence impact on the peak predicted flows at some locations.
- Tailwater Conditions
  - The model boundary was modelled with Normal conditions.
- Hydraulics
  - Several additional drainage channels were identified in discussion with WDC were and added to the model by using mesh zones to adjust the 2D mesh levels.
  - Capture of surface water into the public SW network in a ROG model may be under-represented in some cases. This is due to the limitations of the 2D grid to accurately represented surface drainage structures (i.e., kerb and channel) at a catch-pit scale.
  - Predicted flooding with properties is limited by the accuracy of the 2D mesh and uncertainty regarding private drainage location and performance. In some cases, shallow ponding, or flow paths may be shown in locations that would otherwise be diverted or drained by site structures (e.g., retaining wall, kerbs or small

drainage channels). Care should be taken when reviewing predicted results within depressions.

- o The connectivity of some depression areas to the public stormwater network may not be accurately represented (i.e., private drainage, or small open channels connections to the SW network, which may not be well captured in the 2D surface).
- o No specific soakage devices have been included in the model schematisation, as agreed with Waipa Council. This is expected to result in conservative results in some locations.
- o No initial conditions were applied to the model.
- o This work has been completed specifically for the 100-year ARI (existing development, existing climate) scenario.

7.13.4 Deliverables

- Pirongia Rain on Grid Modelling Updates Memorandum (West & Nikkel, 2021)
- Model results were provided for the 100-year existing development scenario.

See Appendix K for the Memorandum detailing this work.

7.13.5 External Peer Review

This work was subject to External peer review by AECOM.

7.14 (MS14) PSP 290372 Stormwater Modelling Completion Tasks

7.14.1 Purpose

To support the finalisation of Waipa District Councils flood hazard modelling and catchment management planning (to support the District Wide Stormwater Consent Renewal), WSP finalised model changes and ran the model scenarios shown in Table 7-3.

Table 7-3. Stormwater Modelling Completion modelling runs.

Model	100-year Existing Development (ED)* with existing climate	2- and 10-year Existing Development (ED)* with existing climate (Priority 7)	2, 10 and 100 year Committed Projects (CP)** with future climate.	2-, 10- and 100-year Maximum Probable Development (MPD)*** with future climate
Ohaupo	Complete with PSP 290032	This IFS PSP 290372	This was undertaken already – no change in catchments from “Peer Reviewed” model”	This was undertaken already – no change in catchments from “Peer Reviewed” model
Kihikihi	Complete with PSP 290032	This IFS PSP 290372	This was undertaken already – no change in catchments from “Peer Reviewed” model	This was undertaken already – no change in catchments from “Peer Reviewed” model
Te Awamutu	Complete with PSP 0800 / 21WA	This IFS PSP 290372	This IFS PSP 290372	This IFS PSP 290372
Pirongia	Complete with PSP 290183	This IFS PSP 290372	This IFS PSP 290372	This IFS PSP 290372
Cambridge	Complete with PSP 0800 / 21WA	This IFS PSP 290372	This IFS PSP 290372	This IFS PSP 290372
Karapiro	N/A	N/A	N/A	N/A
Hautapu	Others	Others	Others	Others

7.14.2 Scope Summary

The updates that were completed as part of the variation for SP 0800 / 21WA Stormwater Models Final Peer Review Updates and Responses and PSP 290183 Pirongia Rain on Grid Modelling Updates were applied to the Maximum Probable Development and Committed Projects Development scenarios where applicable.

Additional runs were also completed for additional rainfall and climate scenarios.

7.14.3 Model Build Notes / Assumptions

- Schematisation
  - Schematisation was a mix of rain on grid and sub-catchments delineated based on land parcels and topography.
    - Pirongia as per MS13.
    - Ohaupo and Kihikihi as per MS8.
    - Cambridge and Te Awamutu as per MS10.
  - Allowance has not been made for the drainage that was not included in the Waipa District Council asset register.
- Rainfall
  - Rainfall was based on the WRC nested storm distribution and accumulated depths taken from HIRDS v4. Climate change is accounted for by use of HIRDS RCP 6.0 2130.
- Hydrology
  - WRC hydrology as per previous modelling stages (MS8-10 for the towns of Ohaupo, Kihikihi, Cambridge and Te Awamutu, and MS13 for Pirongia).

7.14.4 Deliverables

- For all scenarios in Table 7-3 the following were provided:
  - Wetted extents boundary shape files (using raw model outputs, with an agreed min depth criteria of 100 mm).
  - b. Pipe capacity shape files.
  - 0.5 x 0.5 m - TIF and shapefile of depth (with 100 mm removed), peak velocity and peak water surface elevations.
  - Model results and ICM model files including the full-time series suitable for V x D mapping.
  - Maps of:
    - Pipe capacity for the 2-year and 10-year
    - Depth for 100-year
    - Velocity for 2-year
- This report summarising Waipa Stormwater model development.
- Model logs and register for all the five towns.

PART 8 - **MODEL LIMITATIONS**

8.1 General Modelling Assumptions and limitations

The assumptions and limitations presented here are intended to provide an overview of applicable key assumptions and limitations relevant to the modelling stages presented in PART 7 - The list below is focused on the most recent 1D-2D models (mostly applicable to MS11 onwards). This is not intended to be an exhaustive list of limitations and does not supersede those presented in the relevant deliverables and reports associated with each modelling stage.

8.1.1 General

- All models discussed in this report are catchment scale models, which are intended to provide an overview of predicted system performance and in some cases surface flooding within the catchments. The models may not be representative of the stormwater system at a property scale in all cases. Site specific investigations to confirm modelling assumptions are recommended when undertaking a detailed analysis of specific locations.
- Rainfall
  - The stormwater models use rainfall based on synthetic temporal patterns (i.e., the WRC nested storm profile combines multiple predicted intensity, frequency, duration profiles for a given AEP). This is not necessarily representative of an actual recorded rainfall event.
  - Singular rainfall events have been simulated for the 2-, 10-, and 100-year ARI events with and without climate change. It is possible that back-to-back events could cause an increase in the maximum predicted water levels.
- Hydrology
  - Effective rainfall has been applied as 'rain-on-grid' (ROG) to areas outside the urban sub-catchment zones. The percent impervious assumption used to develop the effective rainfall was calculated using the averaged land use for all ROG areas. This could result in differences to the maximum predicted runoff in locations where the actual percent impervious does not align with the average. The Exception to this is the recent stages of the Pirongia model (refer to section 7.12 for details)
  - No areal reduction factors or spatial distribution of rainfall has been applied. A single rainfall intensity hyetograph has been simulated and was assumed to occur simultaneously over the entire modelled catchment.
  - The sub-catchments within the models have been predominantly developed by delineating along parcel boundary approach, rather than a purely topographic approach. The use of parcel boundaries is normally considered to be most appropriate for design events (i.e., the primary or piped drainage network). For events where runoff is greater than the piped capacity, the direction of surface flow may (in some cases) diverge from the direction of pipe flow (i.e., the loading

points in some areas may be less valid for very large events, where part of the runoff may be diverted by the ground slope).

- Model sub-catchments use single weighted curve numbers to cover both pervious and impervious areas as previously agreed with Waipa District Council (where the SCS curve number is used). It is noted that this can result in lower runoff compared to models which represent separate curve numbers for impervious and pervious areas separately, although the largest differences are observed for smaller, more frequent storm events.
- Baseflow has been added as a constant inflow for areas where this was recorded in the flow monitoring period. Realistically there will be some seasonal variation, however overall, the observed baseflow is considered to be insignificant in comparison to design storm runoff.

- Boundary Conditions
  - A normal boundary condition is assumed for the 2D zones, meaning there are no large restrictions or backwater impacts from any downstream systems. The Infoworks ICM v7.0 model does not reflect the flooding due to rivers and streams outside of the model boundary, and it is assumed there is no hydraulic restrictions at the downstream model boundary.

- Network / Hydraulics
  - 2D floodplain element elevations are derived from the specified LiDAR datasets (using an average of the elevation at the element vertices). Detailed topographic features such as kerb and channel, retaining walls, narrow channels are not expected to be represented in this model. This may result in different predicted flow directions (especially for lower flows) than observed during actual flooding events. No blockages have been included in pipes or catch-pits.
  - LiDAR accuracy is reduced in areas of dense vegetation and around buildings.
  - The streams, open channels and ponds have been represented in the 1D based on surveyed cross-sections or as storage nodes based on as-built data.
  - Model network nodes have their ground level inferred from LiDAR, to ensure smooth link between 1D elements and 2D surface.
  - No threshold has been set for minimum pipe lengths to exclude from model. In some cases, this can lead to instabilities in the model results.
  - Several pipes did not have nodes in the council dataset so were added in the model automatically by Infoworks ICM v7.0 to enable it to run. These node names are started with XXXX-
  - No public or private soakage devices are included in the models either explicitly or implicitly. This is considered to be a conservative approach which may result in a higher volume of runoff than reality in some locations. The actual magnitude of

increased flow is dependent on the type and condition of soakage devices, which is expected to vary.

- The connectivity of some depression areas to the public stormwater network may not be accurately represented (i.e., private drainage, or small open channels connections to the SW network, which may not be well captured in the 2D surface).
- No initial conditions were applied to the model.
- Predicted flooding within properties is limited by the accuracy of the 2D mesh and uncertainty regarding private drainage location and performance. In some cases, shallow ponding or flow paths may be shown in locations that would otherwise be diverted or drained by site structures (e.g., retaining wall, kerbs or small drainage channels). Care should be taken when reviewing predicted results within depressions, private properties, and upper catchment areas.
- The updated models have not been subject to calibration of hydrological or hydraulic parameters and has not been validated against actual flooding events.

PART 9 - **RECOMMENDED FUTURE UPDATES**

Table 9-1. Recommended maintenance for the Waipa Stormwater Models.

Number	Maintenance
1	Adding new stormwater infrastructure and upgrades into the model network, based on most recent asset data.
2	Adding in new sub-divisions and proposed growth areas into the model.
3	Incorporating new LiDAR data as it becomes available.

Table 9-2. Recommended future updates to the Waipa Stormwater Models.

Number	Future updates
1	Validation of flood levels based on field survey of significant flood event. This would help refine and confirm appropriate curve numbers are used.
2	Soakage parameters validation through on-site soakage tests
3	Back-to-back rainfall event simulation to understand effects of longer duration events on stormwater system
4	Sensitivity testing of boundary conditions by applying water level to outfalls. If Waipa District Council could provide time varying levels that would be preferable over a constant level.
5	Additional topography survey for the open channels where flooding is predicted, and water is spilling out of the open channel affecting properties.
6	Sensitivity to difference climate change scenarios could be assessed.
7	Sensitivity testing of asset blockages to determine criticality of maintaining specific assets.
8	Update model versions from Infoworks ICM v7.0 to the latest Infoworks ICM version (at the time of this report it was v2021).
9	Extend the Cambridge model to include the Mangaone Stream as a backwater condition.

Table 9-3. Recommended maintenance for the Waipa Flood Hazard Mapping.

Number	Maintenance
1	On completion of any model update due to LiDAR, the Flood Hazard Mapping exercise should be repeated to update the flood viewer and to determine if the dwellings at risk have changed. If changes occur, appropriate communication to update owners should be undertaken.
2	Should Waikato Regional Council provide better river flood height data for boundary conditions incorporate this into the flood viewer and to determine if the dwellings at risk have changed. If changes occur, appropriate communications to update owners should be undertaken.
3	Should Waipa District Council undertake rural flood hazard mapping incorporate this into the flood viewer and to determine if the dwellings at risk have changed. If changes occur, appropriate communications to update owners should be undertaken.

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