HEATHCOTE STORMWATER INVESTIGATION REPORT

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PREPARED FOR

City of Greater Bendigo

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EXECUTIVE SUMMARY

The City of Greater Bendigo (CoGB) engaged Water Modelling Solutions to undertake a detailed stormwater investigation of Heathcote in central Victoria. The project involved identifying the presiding hydrologic system and hydraulic influences throughout the catchment. The primary aim of the project was to identify and design four (4) concept mitigation options to reduce stormwater risk in town.

Initially, prior modelling was assessed to determine "fit-for-purpose" use and to better understand the issues Council had found with the scale of inundation recorded. Following this assessment, a rainfall-on-grid (partial Ensemble analysis) modelling approach was conducted for design storm events (50% to 1% AEP). Sensitivity analysis was undertaken for a number of scenarios including drainage blockages, hydraulic roughness increase/decrease and climate change scenarios (RCP4.5 and RCP8.5) for the 10% AEP and 1% AEP events. The 1% AEP results were interrogated by Water Modelling Solutions, Dryside Engineering and Council to determine ten (10) integrated preliminary mitigation options.

Following discussions of these options, mitigation model scenarios were undertaken using TUFLOW hydraulic modelling suite to identify the proposed influences of each option upon flood behaviour within the township. After testing these scenarios, the options were modified to improve efficiency and overall functionality. These results were then presented to Council with the purpose of determining four preferred options for concept design and costing.

In development of the concept designs, some changes were made to improve the stability, feasibility, and effectiveness of the structures. Additional drainage infrastructure and upgraded stormwater systems were added to a few of the options to provide the highest net-benefit for the community and feasibility to construct.

The four (4) options identified include:

- **Option 1 – Possum Gully and Caledonian Gully Works**
- **Option 2 – Golden Gully Upstream Storage**
- **Option 3 – Barrack Street Upgrades**
- **Option 4 – Northern Zone Combined** Option

Each mitigation option focuses on a different location within the township, thus the preferred options collectively achieve benefit across the township. The hydraulic model runs conducted on each of the proposed mitigation options yielded consistent net-beneficial results for stormwater risk.

As such, the performance of the proposed mitigation infrastructure during a future feasibility assessment is expected to be high. Environmental and heritage impacts as well as damages and feasibility assessments were not included in the scope of this project however should be taken into consideration during future implementation of mitigation.

Water Modelling Solutions would like to acknowledge the Dja Dja Wurrung and the Taungurung people as part of the Kulin Nation as the Traditional Owners of the land on which this assessment was based and which site visits were conducted. We would like to pay our respects to Elders past, present and emerging.

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LIST OF ABBREVIATIONS

AEP	Annual Exceedance Probability
ARR	Australian Rainfall and Runoff
BoM	Bureau of Meteorology
CBD	Central Business District
CoGB	City of Greater Bendigo
DELWP	Department of Environment, Land, Water and Planning
DEM	Digital Elevation Model
DTM	Digital Terrain Model
FFA	Flood Frequency Analysis
GP	Grated Pit
HQ	Height/Flow Boundary
ISC	Index of Stream Condition
JP	Junction Pit
LiDAR	Light Detection and Ranging
NCCMA	North Central Catchment Management Authority
RCP	Representative Concentration Pathway
RF	Rainfall Boundary Condition
RFFE	Regional Flood Frequency Estimation
RoG	Rain-on-Grid
SA	Source-Area Boundary
SEP	Site Entry Pit
SES	State Emergency Services
URBS	Unified River Basin Simulator
WMS	Water Modelling Solutions

1 INTRODUCTION

1.1 BACKGROUND

The City of Greater Bendigo (CoGB) engaged Water Modelling Solutions to undertake a detailed stormwater investigation for the township of Heathcote in central Victoria. The project involved hydrological and hydraulic modelling of the study area to produced updated stormwater mapping and intelligence for a range of design events to better understand stormwater risk and help inform mitigation and planning decisions. The project largely focused on urban and local runoff as opposed to inundation from McIvor Creek inundation which was analysed in the previous BMT WMB modelling in 2015.

The key components of the study, as detailed in the project brief are:

- Review existing documentation and hydraulic models in relation to Heathcote;
- Identify data gaps and provide recommendations relate to the data gaps;
- Updating the model to the ARR2019 guidelines;
- Undertake survey to acquire the necessary data of the stormwater system;
- Run the existing models with the included data;
- Identify critical areas that require stormwater upgrades or measures to mitigate local flooding;
- Provide up to 10 options, recommendations or mitigation measures to reduce the impact of local flooding in Heathcote;
- Model each option to determine their potential benefits;
- Prepare existing and proposed conditions flood maps;
- Prepare concept designs of the proposed mitigation options;
- Prepare a report with the model modifications, results and recommendations;
- Provide a high-level cost for each option;
- Undertake a climate change sensitivity analysis; and,
- Undertake a sensitivity analysis for intensified development / changes in land use.

1.2 STUDY AREA

Heathcote, shown in Figure 2-1, is located approximately 110 km north-west from Melbourne's CBD and 40 km south-east of Bendigo CBD along the McIvor Highway, nestled between the McHag and McIvor Ranges. The Dja Dja Wurrung and the Taungurung people as part of the Kulin Nation are the traditional owners of the land. Prior to European settlement the region was known as Jaara Jaara country. The population of Heathcote is approximately 2,793 people (ABS Census, 2016). There are predominately long-standing residential properties in the township, however, the flourishing art, food and wine industry has seen a number of new residential developments in recent years.

McIvor Creek traverses the township and is fed by a number of tributaries including; Caledonia Gully, Possum Gully, Long Gully, Golden Gully, Dead Horse Gully and Parsons Gully. The Heathcote Flood Study, completed in 2016 by BMT WBM, outlined several mitigation options to improve flood risk, however, these predominately focused on riverine flooding impacts with recent community requests for stormwater mitigation infrastructure for local flooding. Debris is a major issue in rural communities during flash-flooding and stormwater events with localised stormwater systems unable to compensate for their effects.

The study area possesses environment, cultural, social, economic and recreational values that make the area a popular place for a wide variety of activities. It is important that the environmental, cultural and social impacts of any proposed mitigation options are considered as part of a thorough assessment prior to detailed design and construction.

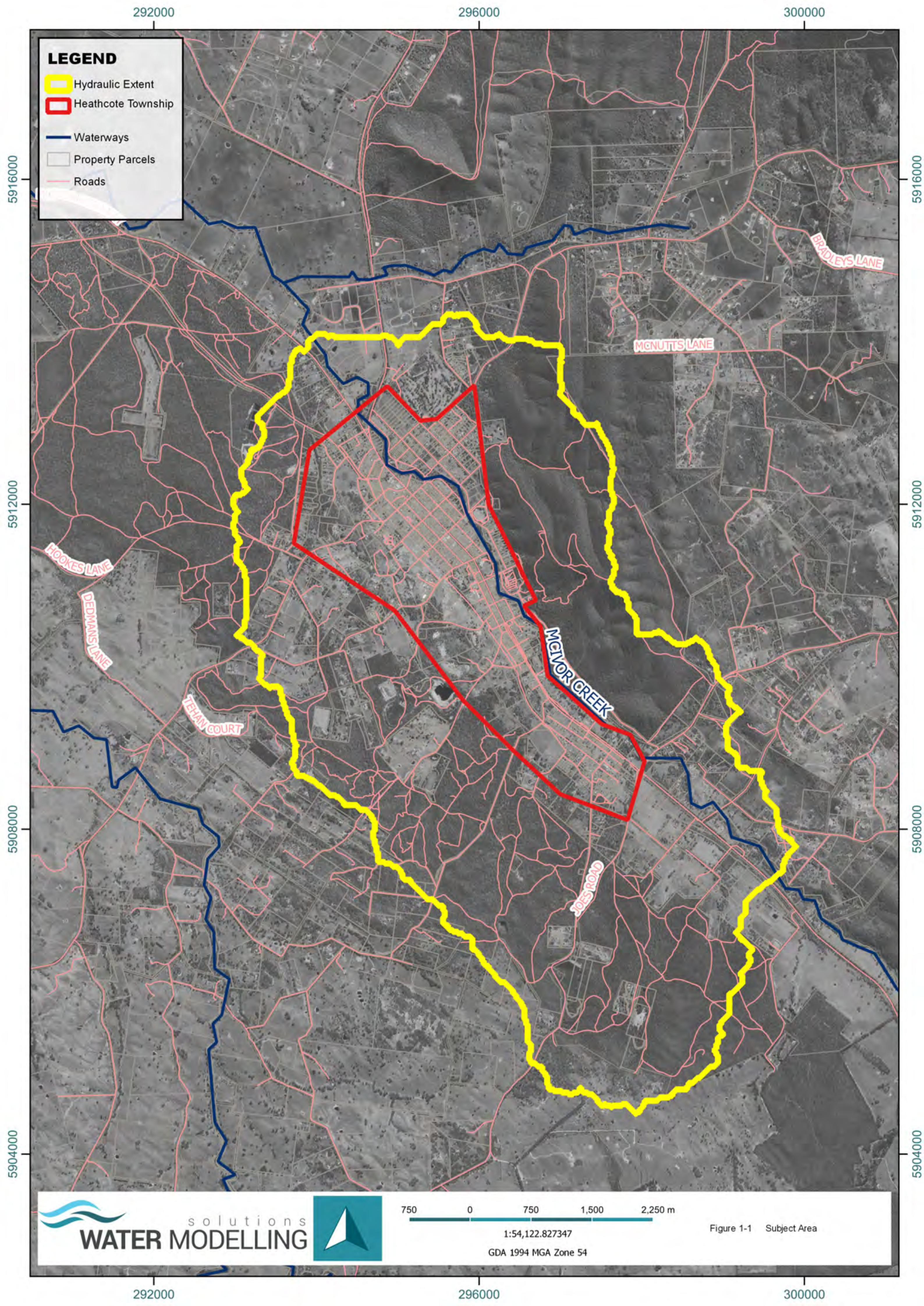


Figure 1-1 Subject Area

1.3 PREVIOUS INVESTIGATIONS

The project builds on the work undertaken by BMT WBM in 2016 for the riverine and stormwater investigations for the Heathcote Township. The previous work is summarised below:

- Flood mapping and flood-related planning controls developed in late 1990s and early 2000s.
- Two studies were developed by BMT WBM in 2015/16 as commissioned by the Department of Environment, Land, Water and Planning (DELWP), the North Central Catchment Management Authority (NCCMA) and the City of Greater Bendigo (CoGB) to update the existing flood mapping and flood-related planning controls of Heathcote and McIvors Creek.
  - The Heathcote Flood Study (BMT WBM 2016). The study was based on an URBS hydrological model in conjunction with a TUFLOW hydraulic model. This part of the study focussed on the riverine flooding component and identified flood depths, velocities, heights and extents along the McIvor Creek corridor. The aim of this study was to update the flood modelling and develop a baseline understanding of flooding in Heathcote. A few mitigation measures are mentioned in the reporting namely the use of an effective flood warning system.
  - The Heathcote Flood Study: Town Drainage Assessment (BMT WBM 2015) was modelled through a direct TUFLOW rain-on-grid approach. The purpose of this model is to improve the understanding of flood risk from local stormwater runoff as opposed to the riverine modelling described above. The modelling did not include a detailed assessment of the underground drainage system.

2 DATA REVIEW

2.1 HYDROLOGICAL DATA

The revised ARR2019 stormwater modelling was not calibrated to the below mentioned streamflow and rainfall gauges. Instead, the updated results were compared against the previously calibrated results for the purpose of verification. The proposed methodology was discussed in the inception report and presented in detail in the Hydrology and Hydraulic Reports.

2.1.1 Streamflow Data

There are two streamflow gauges nearby to Heathcote, Mount Ida Creek @ Derrinal (406226) and Wild Duck Creek @ Upstream of Heathcote Mia Mia Road, shown in Figure 2-1. Only the Mount Ida Creek @ Derrinal (406226) gauge downstream of the township is within the relevant catchment, however it is not located along McIvors Creek.

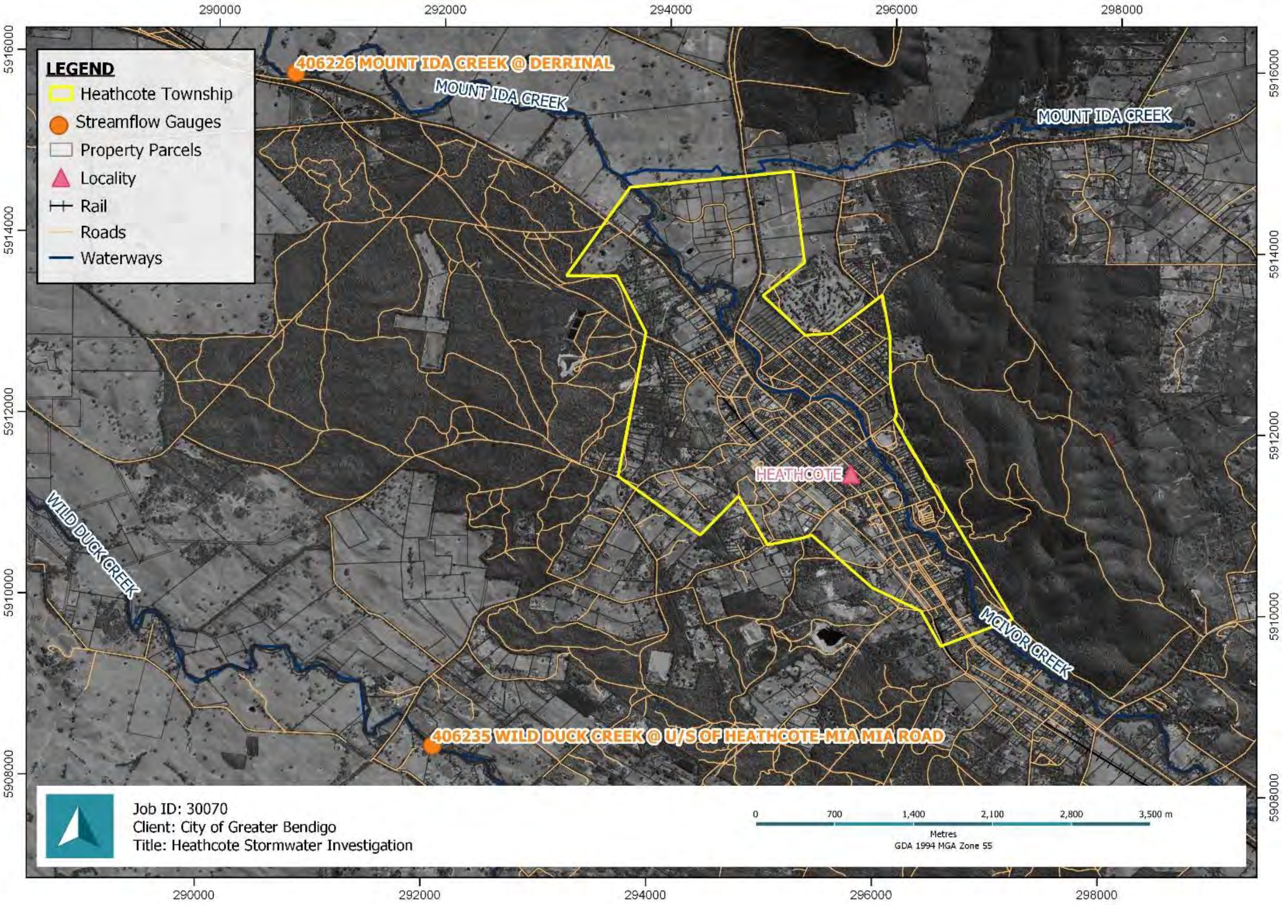


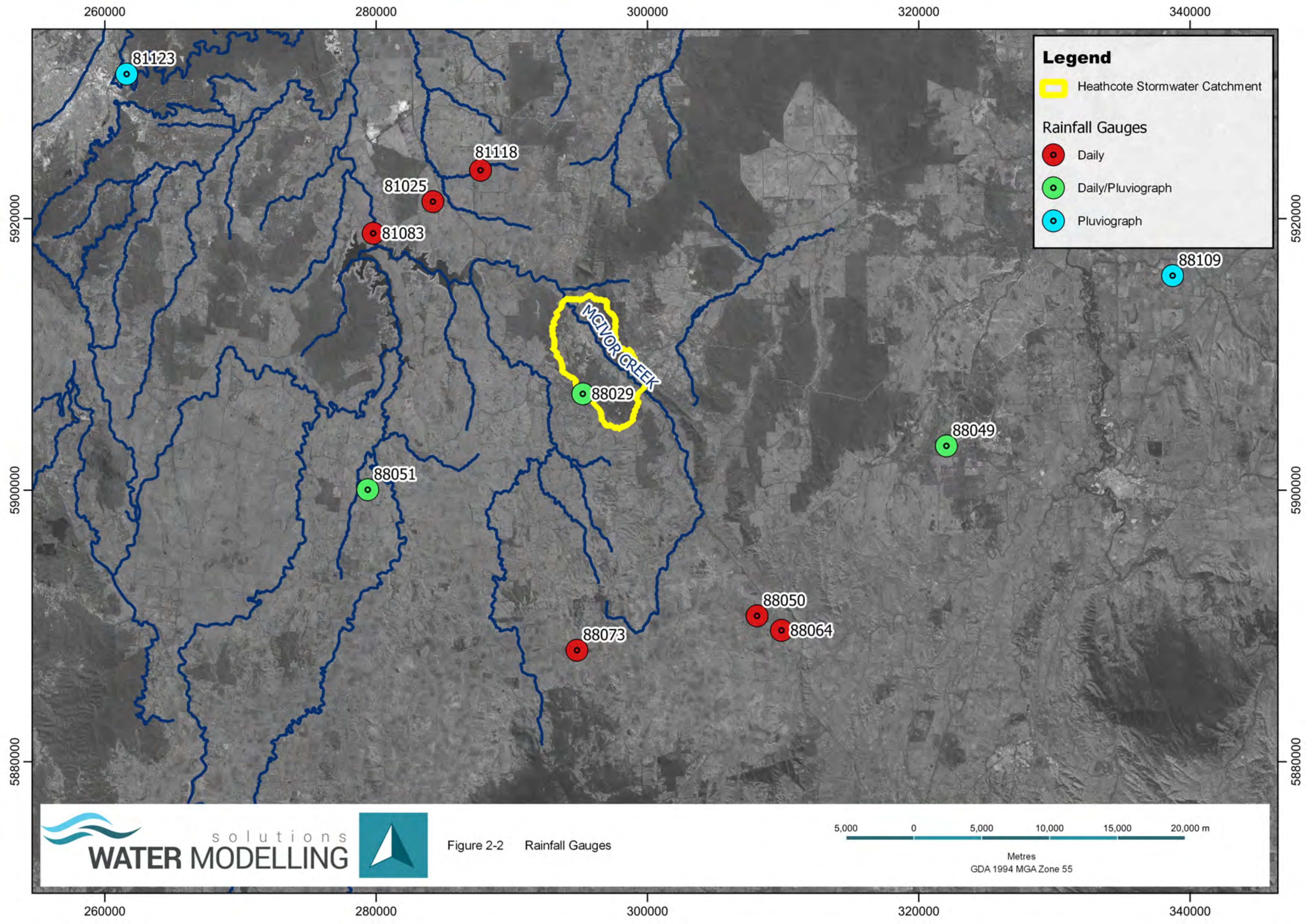
Figure 2-1 Local Streamflow Gauges

2.1.2 Rainfall Data

There were 12 daily, sub-daily and pluviograph rainfall gauges in and nearby to the Heathcote Township. These rainfall gauges were used in the previous investigation for calibration purposes and were still relevant for this investigation. Both daily and pluviograph data was obtained from the Bureau of Meteorology (BoM) historic rainfall data and the Department of Environment, Water, Land, and Planning (DELWP) Water Data website. The gauged station name, data type, active years and locations are represented below in Table 2-1 and Figure 2-2.

Table 2-1 Rainfall Data Gauges

Station No.	Station Name	Station Type	Start Year	End Year
81025	Knowsley Post Office	Daily	1905	1983
81083	Eppalock Reservoir	Daily	1965	2014
81118	Knowsley	Daily	1984	2014
81123	Bendigo Airport	Pluviograph	1993	2014
87029	Lancefield	Pluviograph	1929	1975
88029	Heathcote	Daily	1882	2014
		Pluviograph	1968	2013
88049	Puckapunyal	Daily	1899	1987
		Pluviograph	1968	1989
88050	Pyalong West (Caravan Park)	Daily	1900	2014
88051	Redesdale	Daily	1903	2014
		Pluviograph	1994	2014
88064	Mollisons Ck at Pyalong	Daily	2003	2014
88073	Baynton	Daily	1953	2014
88109	Mangalore Airport	Pluviograph	1993	2014



solutions WATER MODELLING

Figure 2-2 Rainfall Gauges

2.1.3 Historic Flood Records

Heathcote has a long history of riverine flooding stemming back to 1867, as identified in the previous investigation, however, sufficient information of many of these events is not accessible, instead recorded by newspaper articles. The largest riverine flood event occurred in 1974, which inundated many properties throughout the township. Heathcote was fortunate only to be mildly impacted during the largest known flood events in Northern Victoria in September 2010 and February 2011. The other known flood events occurred in 1870, 1883, 1899, 1906, 1916, 1930, 1939, and 1954.

This study focussed on the stormwater inundation of the township which has become a more regular occurrence due to land clearing, erosion and the increased rainfall intensities as a consequence of climate change. The largest stormwater known event occurred in 2000, through a localised short duration storm event. Smaller events have caused a number of SES calls in the more recent past.

2.2 PREVIOUS STUDY DATA

2.2.1 Hydrologic Model Data

Rainfall-runoff modelling was undertaken with the URBS hydrological modelling package. The model, built by BMT WBM, was provided by the City of Greater Bendigo. The input and output files provided include;

- Design Event (20%, 10%, 5%, 2% and 1% AEP for several durations);
- Probable Maximum Precipitation (PMP); and,
- Climate change (1% AEP Event).

The hydrologic model data was developed in accordance with the previous ARR1987 framework, and therefore requires an update predominately due to changes in rainfall intensities, rainfall losses, and temporal patterns. The project climate change outputs will also require an update to the Representative Concentration Pathways (RCP) 4.5 and 8.5, deem appropriate by ARR2019, for the mid to high changes in climate.

2.2.2 Hydraulic Model Data

The City of Greater Bendigo provided the TUFLOW model that was developed during the previous study by BMT WBM (2015/16). The model identifies key hydraulic structures and floodplain as 1D and 2D TUFLOW files. The design flood depths, velocities and heights for the 10% AEP and 1% AEP flood events were provided as outputs from the study. The hydrologic calibration data was not provided and as such the hydraulic extents will assist in verification of the riverine flows during short burst stormwater events.

2.3 CATCHMENT CHARACTERISTICS

2.3.1 Topographic and Physical Survey

The topographic data supplied were processed Digital Elevation Models (DEM) in .txt which were used during the previous modelling exercise, shown in Table 2-2. The datasets include a number of state and local topographic datasets that form the basis for the hydrologic and hydraulic modelling. There are two previous surveys undertaken onsite, though this data has not been provided and are only discussed in previous reporting. The ground survey undertaken by ThinkSpatial identified several locations in and around Heathcote for assessment. These survey points were compared against the 20m and 1m LiDAR datasets to determine their accuracy, outlined in Table 2-3. As the extent to the previous model is reduced to that of the Heathcote township, fortunately only the most accurate data LiDAR datasets are necessary.

The provided DEM extents cover the existing and proposed hydraulic model area.

Table 2-2 Topographic Datasets

Dataset	Resolution	Originally Supplied
ISC Rivers LiDAR (2010)	1m	NCCMA
State-wide DEM	25m	NCCMA
2009-2010 Victorian State-Wide Floodplains LiDAR Project	1m	DELWP
VicMap Elevation DTM 2008	20m	DELWP
Previous Verification Datasets		
Permanent Survey Marks	N/A	DELWP
Ground Survey (2014)	N/A	ThinkSpatial

Table 2-3 LiDAR Comparison with Survey from Heathcote Flood Study: Final Report (BMT WBM, 2016)

Statistical Measure of Difference (m)	20m VicMap Elevation DTM 2008	1m Victorian State-Wide Floodplains LiDAR Project 2009-2010	1m ISC Rivers LiDAR 2010
Mean	2.56	-0.05	0.01
Median	2.50	-0.04	0.01
Standard Deviation	0.52	0.06	0.05
Lower Quantile	2.05	-0.09	-0.02
Upper Quantile	3.06	0.00	0.04

2.4 KEY HYDRAULIC STRUCTURES

Following discussion with Council during the site visit, it was understood that regular maintenance has occurred around the key hydraulic structures of Heathcote since 2016 due to the more significant stormwater risk determined in the previous study. Golden Gully, shown in Figure 3-3, is one of the key overland flow paths through the township and had recently been mowed and cleared of debris. A number of culverts upstream of the township, located in dense bush, had been cleared of debris to allow improved passage of flow, shown in Figure 3-2.

2.4.1 Missing structures

Following the data collation and review there were a number of missing culverts throughout the township. Further investigation was undertaken during the site visit where this missing infrastructure was assessed, and key dimensions gathered.

The key missing hydraulic structures were located along the old railway line which acts as a key hydraulic control for sheet flow during stormwater events.

2.5 OTHER DATA

2.5.1 Waterways

Waterway centreline data was obtained from Geosciences Australia. The waterlines provided from Geoscience Australia have been delineated on much coarser elevation data than necessary for a flood model and as such do not align completely with the provided DEM. The Geoscience Australia centrelines are useful for information purposes only, in particular with producing maps at a small scale. Centrelines will be digitized by WMS for use in township mapping and will be based on aerial imagery and the provided DEM.

2.5.2 Cadastre

Parcel and property data were obtained from the Victorian Spatial DataMart.

2.5.3 Road and Rail

Road and rail shapefiles were sourced from the Victorian Spatial DataMart. The road and rail data were reviewed against google maps and aerial imagery and appears complete and mostly aligns with the aerial imagery. The road and rail data were deemed fit for use in mapping.

2.5.4 SES and Council Reported Requests For Assistance (RFA)

The SES and Council reported a number of Requests For Assistance during stormwater and flooding events both above and below floor level, shown in Figure 2-3. The largest number of RFAs are located along High Street with 11 properties inundated. This information was useful for proposed future mitigation infrastructure.

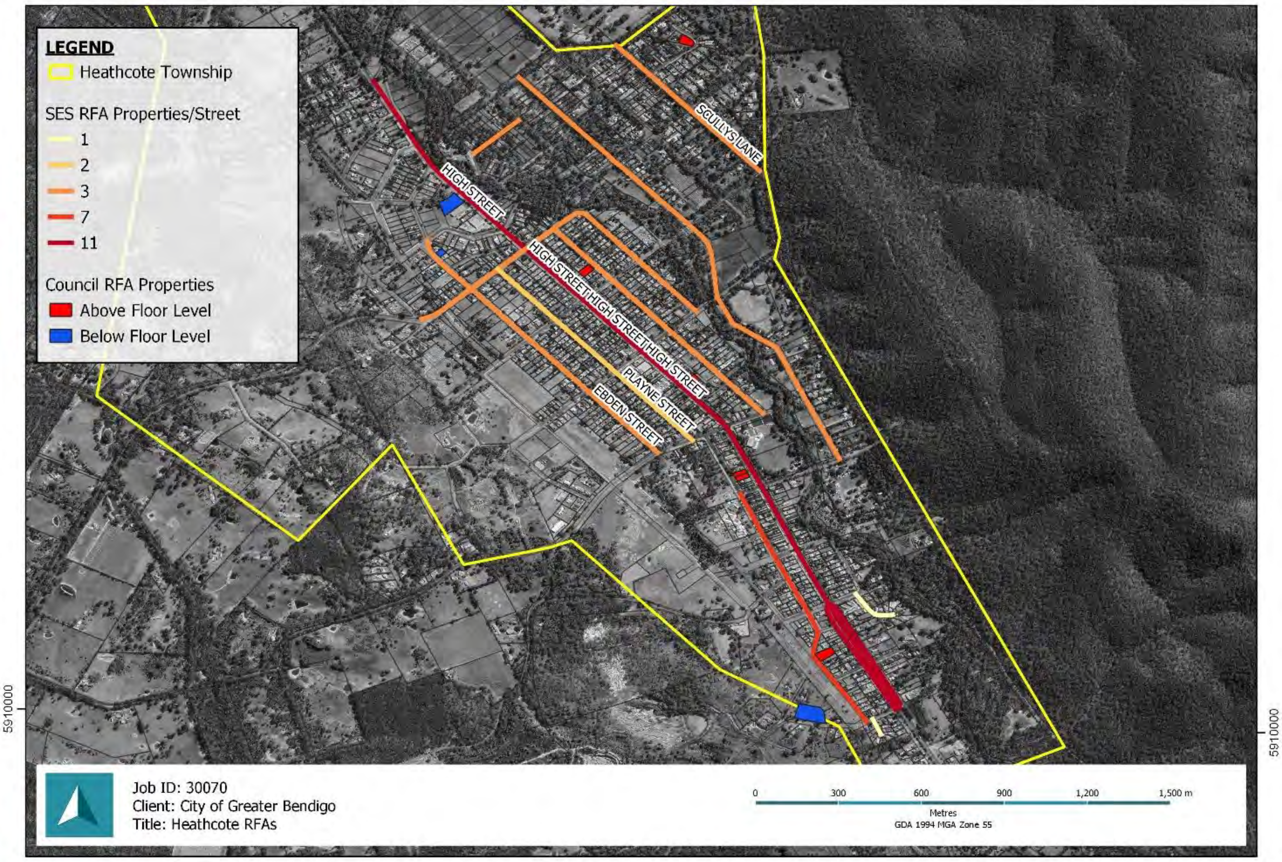


Figure 2-3 Locations of Requests For Assistance during Stormwater and Flooding Events from SES and Council

3 SITE VISIT

A site visit was undertaken by Water Modelling Solutions on the 7th December 2020 and covered all the key structures within the study area. Select images and details from the site visit are shown below.

Figure 3-1 Playne Street Channel and Culverts

Figure 3-2 Upstream Overland Flow Path and Cleared Culvert

Figure 3-3 High Street Newly Cleared Golden Gully and Culverts

Figure 3-4 Hanging Rock Swimming Hole and Naturalised Spillway

4 HYDROLOGY

4.1 OVERVIEW

The previous study *Heathcote Flood Study (2015)* provides a thorough hydrological assessment of the Heathcote region. The adopted process includes Regional Flood Frequency Estimation, At-site Flood Frequency Analysis, URBS rainfall-runoff modelling and TUFLOW Rain-on-Grid modelling for the township component. Each section of the previous hydrology was reviewed.

An URBS model was adopted from the previous *Heathcote Flood Study (2015)* built by WBM BMT. A preliminary stormwater investigation was undertaken following the 2015 study (*Heathcote Flood Study: Town Drainage Assessment*) and reviewed as part of this project. The URBS analysis was not included in the *Town Drainage Assessment* instead opting for direct Rain-on-Grid (RoG) modelling developed in TUFLOW with no external inflow included for McIvor Creek. It is important in the accurate assessment of the current conditions to model both TUFLOW Rain-on-Grid and URBS streamflow data to ensure tailwater conditions in McIvor Creek are accurately represent. The URBS model aims to represent the rainfall and runoff processes occurring along McIvor Creek upstream of the Heathcote Township.

The existing model was built using Australian Rainfall and Runoff (ARR87) guidelines and an older version of URBS. The URBS model was reviewed prior to implementation to determine whether the model was fit-for-purpose and in-line with the newest Australian Rainfall and Runoff (ARR2019) guidelines. The existing URBS model was calibrated and validated against many historic flood events. The comprehensive process achieved a positive calibration to each historic event.

The previous URBS model and key routing parameters were adopted for this study. The URBS model included multiple detailed inputs, to ensure accuracy, review and verification modelling was conducted, these inputs included;

- Sub-catchments and link delineation
- Fraction Impervious areas
- Rainfall losses

This study focused on the Heathcote Township stormwater inundation.

4.2 RAIN-ON-GRID MODEL REVIEW

The Rain-on-Grid files from the existing TUFLOW model were not available and consequently no Rain-on-Grid model files were reviewed or validated against. The previous Rain-on-Grid files were modelled using ARR1987 intensity-frequency-duration curves, and temporal patterns which are now considered obsolete except for verification and sensitivity purposes.

4.3 DESIGN HYDROLOGY

4.3.1 Overview

The design hydrology focused on Rain-on-Grid modelling using the Ensemble Event approach, consistent with the methods described in Australian Rainfall and Runoff guidelines 2019. Monte Carlo modelling was not used for two main reasons, primarily, as the model is Rain-on-Grid a median rainfall would not accurately represent front, mid and rear loaded rainfall events subsequently missing potential inundation of properties during these more burst events. The secondary reason is the sheer number of model runs required as the hydrology must be run in conjunction with the hydraulic model. The ensemble approach used was determining a range of representative temporal patterns and durations for each flood event based on identifying front, mid and back loaded temporal patterns. The existing URBS model was used to determine flows from McIvor Creek. These flows were determined using Australian Rainfall and Runoff 2019 design hydrology and calibrated losses from the previous study, see Appendix A.

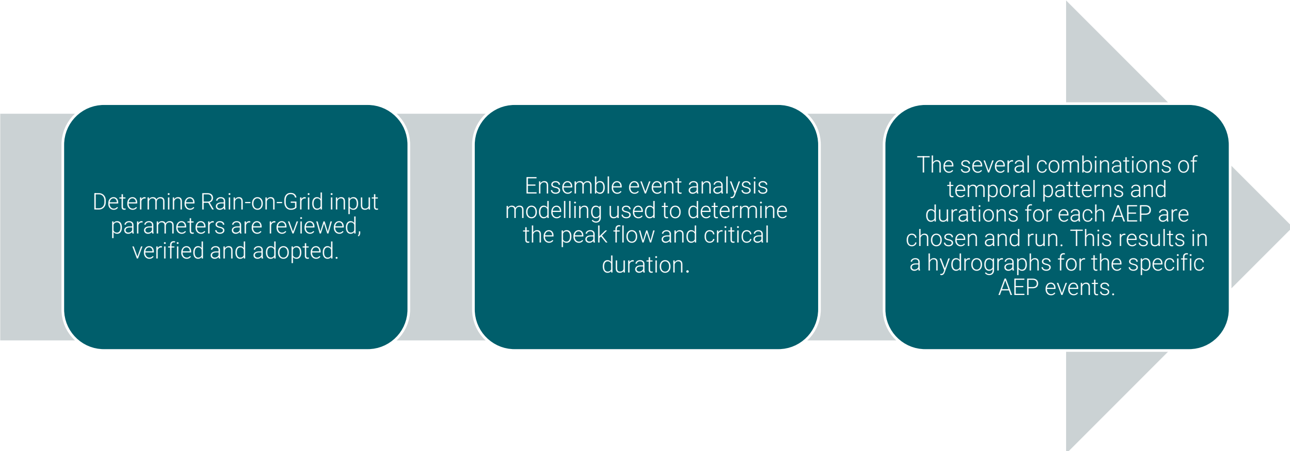


Figure 4-1 Design Ensemble Event Process Diagram

4.3.2 Rainfall Depths

Rainfall depths for the Heathcote township were extracted from ARR2019 Data Hub[1]. Areal Reduction Factors (ARFs) and temporal patterns were sourced from the ARR Data Hub via the TUFLOW Rain-on-Grid QGIS plugin. The Intensity-Frequency-Duration (IFD) depths were sourced from the Bureau of Meteorology (BoM) online IFD tool[2]. The datasets were based on the coordinates of the centroid of the catchment (-36.99, 144.74).

4.3.3 Rainfall Losses

The rainfall losses were separated based on the modelling approach used. The calibrated URBS model losses were applied to the URBS model for the McIvor Creek inflow, see Appendix A, whilst regional losses were extracted for the Rain-on-Grid modelling. Each rainfall loss method remained consistent with ARR2019 guidelines. The Rain-on-Grid model did not use the calibrated losses for a three main reasons:

- The calibrated rainfall losses are not applicable to the study area. The calibration data available is relevant to the broader McIvor Creek catchment (i.e. farmland and rural zones) however, these losses do not accurately apply to the ungauged urban stormwater catchment (i.e. residential properties, stormwater infrastructure and open concrete channels).
- Updates in hydraulic roughness. The catchment characteristics of the Heathcote Township vary significantly from the previous modelling, as shown in Table 4-4, particularly in the urbanised catchments. Recent development and changes in land-use have altered the existing hydraulic roughness.
- The newest application methods of impervious and pervious land-uses have been altered significantly from the previous ARR1987 guidelines. This involves the use of Effective Impervious Areas (EIA), Interconnected Impervious Areas (IPA) and Pervious Areas (PA).

The adopted losses for the RoG modelling were determined and shown in Table 4-1.

Table 4-1 ARR Data Hub Losses adopted for the Rain-on-Grid modelling

	Loss Values
Initial Loss (mm)	27.0
Continuing Loss (mm/day)	4.4

[1] http://data.arr-software.org/
[2] http://www.bom.gov.au/water/designRainfalls/revised-ifd?year=2016

4.3.4 Design Temporal Patterns

Design temporal patterns were sourced from the ARR2019 data hub. There are 30 design point temporal patterns relevant to the Heathcote Township. The temporal patterns fall into three categories: frequent (temporal patterns 1 – 10), intermediate (11 – 20) and rare (temporal patterns 21 – 30).

4.3.5 Design Event Modelling

4.3.5.1 Ensemble Event Analysis

In ARR2019, it is recommended to consider the variability of storm events and to run a range of different duration storms and temporal patterns. The ARR Data Hub provides ten temporal patterns for a given storm AEP and duration. The difference between riverine and direct-rainfall suggests a slightly different method based on each temporal pattern and storm event. An analysis was conducted to identify three representative temporal patterns consisting of front, mid and rear loaded temporal patterns. A temporal pattern with the majority of the flood in the first third of the duration, is considered front loaded. A temporal pattern which either has the majority of the flood in the middle third of the duration, or a pattern that is evenly spread across the full storm duration, is considered mid loaded. A temporal pattern with the majority of the flood at the last third of the duration, is considered rear loaded. Figure 4-2 shows examples of each of the temporal pattern types.

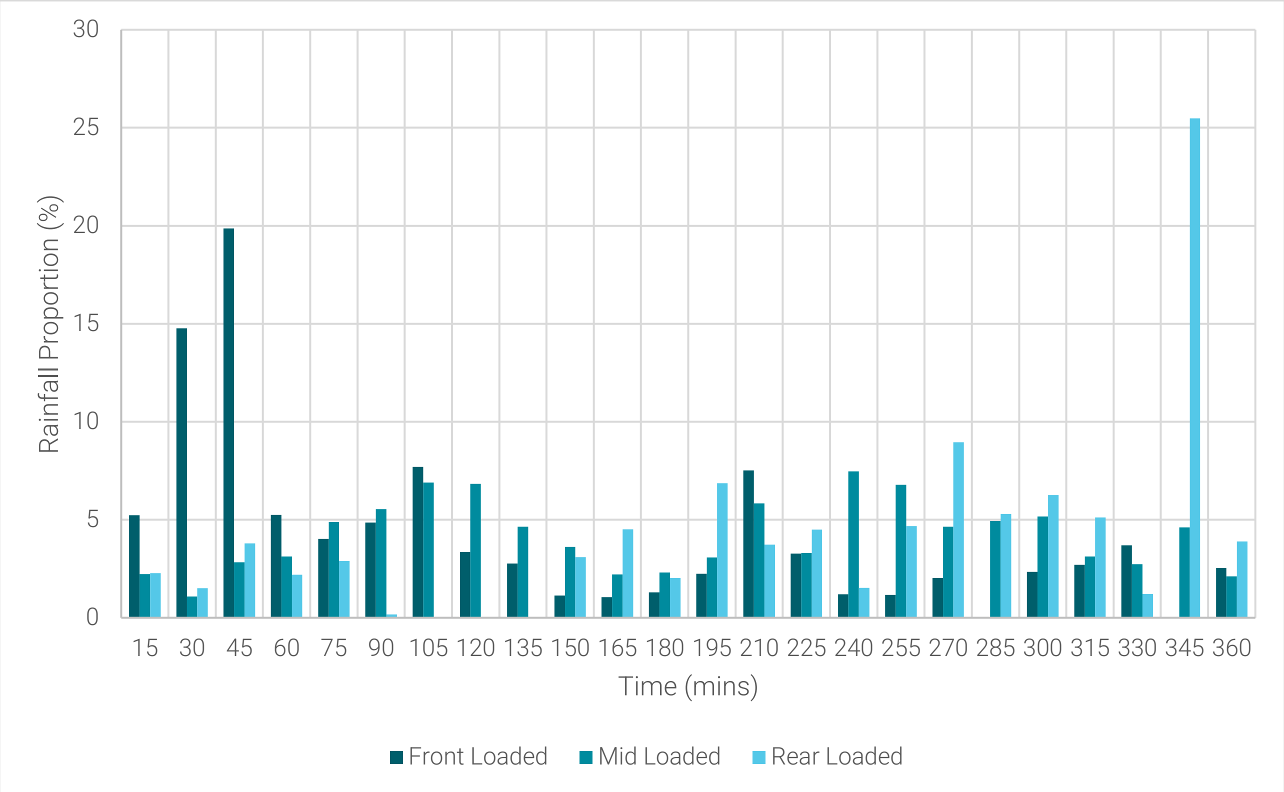


Figure 4-2 Sample temporal patterns

An analysis was undertaken to select representative patterns for the 50%, 20%, 10%, 5%, 2%, and 1% AEP flood events. The results showed several temporal patterns in combination with durations and design events to determine the front, mid and rear loaded temporal patterns. This approach was used to reduce the number of potential hydraulic runs, temporal patterns and durations were chosen to represent each AEP event.

The chosen Rain-on-Grid temporal patterns and durations will then be used in conjunction with the URBS model results, which provide a tailwater flow for McIvor Creek.

4.3.5.2 Temporal Pattern Summary

The chosen representative temporal patterns are shown in Table 4-2. These temporal patterns were selected for the 30 minute, 1 hour, 1.5 hour, 2 hour, 3 hour, and 6 hour durations over frequent, intermediate and rare AEP events based on analysis of the distribution of rainfall within all available temporal patterns. Shorter event durations have been selected given stormwater catchments are the focus of the study and a spread of durations between 30 minutes and 6 hours have been adopted. As mentioned in Section 8.5.5.1, the representative temporal patterns consist of front, mid and rear loaded temporal patterns. These temporal patterns discern where the majority of the rain falls over each duration and event. Table 4-2 shows that on average temporal pattern 2 represents front loaded temporal patterns, that there are no average temporal patterns for the mid loaded temporal patterns, and temporal pattern 10 represents the rear loaded temporal pattern where the majority of the rainfall falls in the last third of the duration. The chosen temporal patterns will result in 18 model runs for each AEP event which is considered manageable given the catchment size and project timeframes.

Table 4-2 Chosen Temporal Patterns for Front, Mid and Rear Loaded for each AEP event category

Duration (mins)	AEP Event Category	Front Loaded	Mid Loaded	Rear Loaded
30	frequent	3	5	6
30	intermediate	3	5	6
30	rare	5	4	10
60	frequent	4	9	10
60	intermediate	2	6	10
60	rare	4	8	9
90	frequent	2	9	10
90	intermediate	5	9	10
90	rare	4	1	9
120	frequent	2	5	10
120	intermediate	5	2	9
120	rare	2	5	10
180	frequent	2	8	9
180	intermediate	2	4	10
180	rare	4	1	2
360	frequent	2	4	10
360	intermediate	4	1	10
360	rare	6	3	10

4.3.6 Climate Analysis

ARR19 recommends climate change assessment scenarios using temperature and rainfall intensity projections, derived from the Australian Climate Futures Tool[3]. This tool is used to assess flood impacts based on the assumption that for every 1℃ increase in temperature there is a 5% increase in rainfall intensity. ARR19 recommends a mid-range scenario (RCP4.5) and high-range scenario (RCP8.5). This was modelled for the 1% AEP design event for 2090 projection temperature rise.

The ARR19 equation IP = IARR x 1.05Tm assists with the estimation of the increase in rainfall intensities for each climate change scenario

- Scenario 1 Scenario 1 – Australian Climate Futures Tool Mid-Range (RCP4.5) – 2090 Projection – 1.80C temperature increase = 9.2% increase in rainfall intensity
- Scenario 2 – Australian Climate Futures Tool High-Range (RCP8.5) – 2090 Projection – 3.77C temperature increase = 20.2% increase in rainfall intensity

Table 4.3 shows an example climate change scenario modelled in RORB using an increase of 9.2% rainfall intensity for the RCP4.5 and 20.2% for the RCP8.5 from the current climate scenario. This process was adopted throughout the abovementioned temporal patterns and durations.

Table 4.3 Climate Change Rainfall Increase Example

AEP (%)	Temporal Pattern	Duration (hours)	Current Climate	Climate Change (RCP4.5)	Climate Change (RCP8.5)
1	5	2	53.51	58.43	64.32

4.4 MCIVOR CREEK TAILWATER CONDITIONS

The URBS model developed for the *Heathcote Flood Study (2015)* and built by WBM BMT was adopted and updated to ARR2019 to provide inflows for McIvor Creek so ensure there are appropriate tailwater conditions for the stormwater modelling. A detailed review of the URBS model was undertaken to determine 'fit-for-purpose' use prior to adoption. The model was updated to ARR2019 guidelines including rainfall depths and temporal patterns and remained consistent with rainfall losses from the existing calibration.

Appendix A outlines all key hydrologic parameters for the URBS model.

4.4.1 URBS Model Review

4.4.1.1 Catchment Delineation

The catchment was originally delineated using CatchmentSIM software package based on the then available digital elevation datasets. The delineation separated the catchment into 11 sub-catchment areas of consistent size and shape to ensure sufficient routing upstream of the hydraulic extent. The *Boyd (1985)* calculation estimates a minimum of 9 sub-catchments are needed to extract flows. (See Equation 1). The URBS manual stipulates a minimum of five upstream sub-catchments are necessary got adequate definition of upstream catchments.

There are approximately 7 upstream catchments available to extract flows for the Heathcote township. Though this is less than the estimated minimum 9 stipulated by the *Boyd* equation it is acceptable as per the URBS manual and will therefore not be altered.

Equation 1 Boyd (1985) sub-catchment delineation calculations:

$S_{min} = 5.20\,(A)^{0.1} = 5.20(173.0)^{0.1} = 9$

[3] https://www.climatechangeinaustralia.gov.au/en/climate-projections/climate-futures-tool/introduction-climate-futures/

4.4.1.2 Node and Reaches

URBS models' route from node to sub-catchment boundary to node. The advantages of this system include;

- Additional calculation points are easily incorporated into the model without requiring crossing boundary routing paths to be split;
- Provides a better hydrograph shape by the addition of extra routing nodes; and,
- Allows the characteristics of each sub-catchment to be attached to each routing reach.

There is a factor or "fraction forested (F)" that affects the routing of each reach by increasing the lengths and therefore the catchment and channel storage capacity. The reach length factor was likely calibrated to best represent the catchment conditions during the historic events. The reach alignments accurately represent the catchment conditions and were therefore appropriate for the URBS model.

4.4.1.3 Fraction Impervious (FI)

The estimated proportion of impervious surface within each sub-catchment is usually determined using land use planning (zoning) maps which is then modified based on aerial imagery and land cover mapping. This was the method used during the previous study.

Five sub-catchments were analysed, shown in Table 4-4, to compare the proposed values and the potential change in catchment characteristics. This assessment assists in the hydraulic modelling as changes in fraction imperviousness change correlate to changes in roughness of the hydraulic model. Three sub-catchments were selected upstream of the township; 3,5 and 6, the fraction impervious values closely reflect the updates estimates undertaken in the study. The area is predominately farmland and public conservation zones which have had limited alterations in the past 5 years. These closely matched results mean that the existing FI for the hydrological model will not be altered. Two sub-catchments were selected from the township; 8 and 11, the increased general residential and low density residential living zones of the township in the last 5 years is likely the reason for a discrepancy in final fraction imperviousness. As such, the hydraulic roughness's will be thoroughly reviewed in the township.

Table 4-4 Fraction Impervious Spot Checks

Sub-catchment IDs	Locations	Existing FI	Estimated FI
3	Rural Sub-catchment	0.007	0.007
5		0.016	0.021
6		0.011	0.013
8	Urban Sub-catchments	0.063	0.188
11		0.035	0.122

4.4.1.4 Regional Flood Frequency Analysis and At-Site FFA Sensitivity Analysis

A brief comparison was done of the URBS flows (both ARR1987 and ARR2019) compared to estimates from the RFFE tool. A sensitivity analysis was modelled to understand the differences in Regional Flood Frequency and At-Site Flood Frequency Analysis from the existing ARR1987 modelled data to the updated ARR2019 data. This analysis was conducted downstream of the Heathcote township at the outlet of the URBS hydrologic model.

Table 4-5 shows an increase of between 31 – 82% from the ARR87 RFFE results, however, the quantile probability limits are more extensive. It is noted that the RFFE flows were only used for comparison purposes, however, the significant increases in overall flow rate reveals the previous study design modelling may be revisited at some time in the future.

The at-site Flood Frequency Analysis results, recorded at 406226 Mount Ida Creek, better reflect the results found in the updated RFFE model. The 10% and 5% AEP flood event flows closely match and fall within the 90% confidence limits of the FFA. Though the FFA reveals larger flows during the 2% and 1% AEP events of 237.0m^3/s and 293m^3/s.

Table 4-5 RFFE Results Comparison ARR1987 vs ARR2019

AEP	Expected Quantile (m3/s)	90% Quantile Probability Limits (m3/s)		Expected Quantile (m3/s)	90% Quantile Probability Limits (m3/s)		Expected Quantile (m3/s)	90% Quantile Probability Limits (m3/s)		Diff ARR87 vs ARR19 (%)
	RFFE Estimate			Previous Study (ARR1987)			Updated Study (ARR2019)			
20%	76.0	57.0	102.0	57.0	24.0	137.0	104.0	37.6	288.0	**+82**
10%	119.0	90.0	161.0	83.0	34.0	201.0	130.0	46.5	369.0	**+57**
5%	167.0	125.0	229.0	109.0	44.0	269.0	158.0	54.4	459.0	**+45**
2%	237.0	176.0	331.0	145.0	58.0	364.0	195.0	64.3	601.0	**+34**
1%	293.0	215.0	419.0	172.0	67.0	436.0	226.0	70.8	724.0	**+31**

5 HYDRAULICS

5.1 OVERVIEW

The hydraulic modelling undertaken as part of the updated Heathcote Flood Study covers the township from the Heathcote-Nagambie Rd and North Highway intersection to Farley Road nearby Mt Ida Creek, shown in Figure 5-1.

A detailed 1D-2D hydraulic model was built consisting of the following components:

- One dimensional (1D) hydraulic model of key hydraulic structures (i.e. pipe and pit infrastructure); and,
- Two dimensional (2D) hydraulic model of some key structures (i.e. bridges), waterways and the broader floodplain.

The hydraulic modelling suite TUFLOW was used as it is the most widely used and suitable software package for the analysis of flood in urban areas, particularly the use of Rain-on-Grid modelling. TUFLOW consists of the five main inputs:

- Topography
- Drainage infrastructure data.
- Rainfall or Inflow data (based on catchment hydrology).
- Manning's Roughness; and,
- Boundary conditions.

This section of the report defines the hydraulic analysis, details the hydraulic model review, the hydraulic model construction, and discusses sensitivities in the modelling approach.

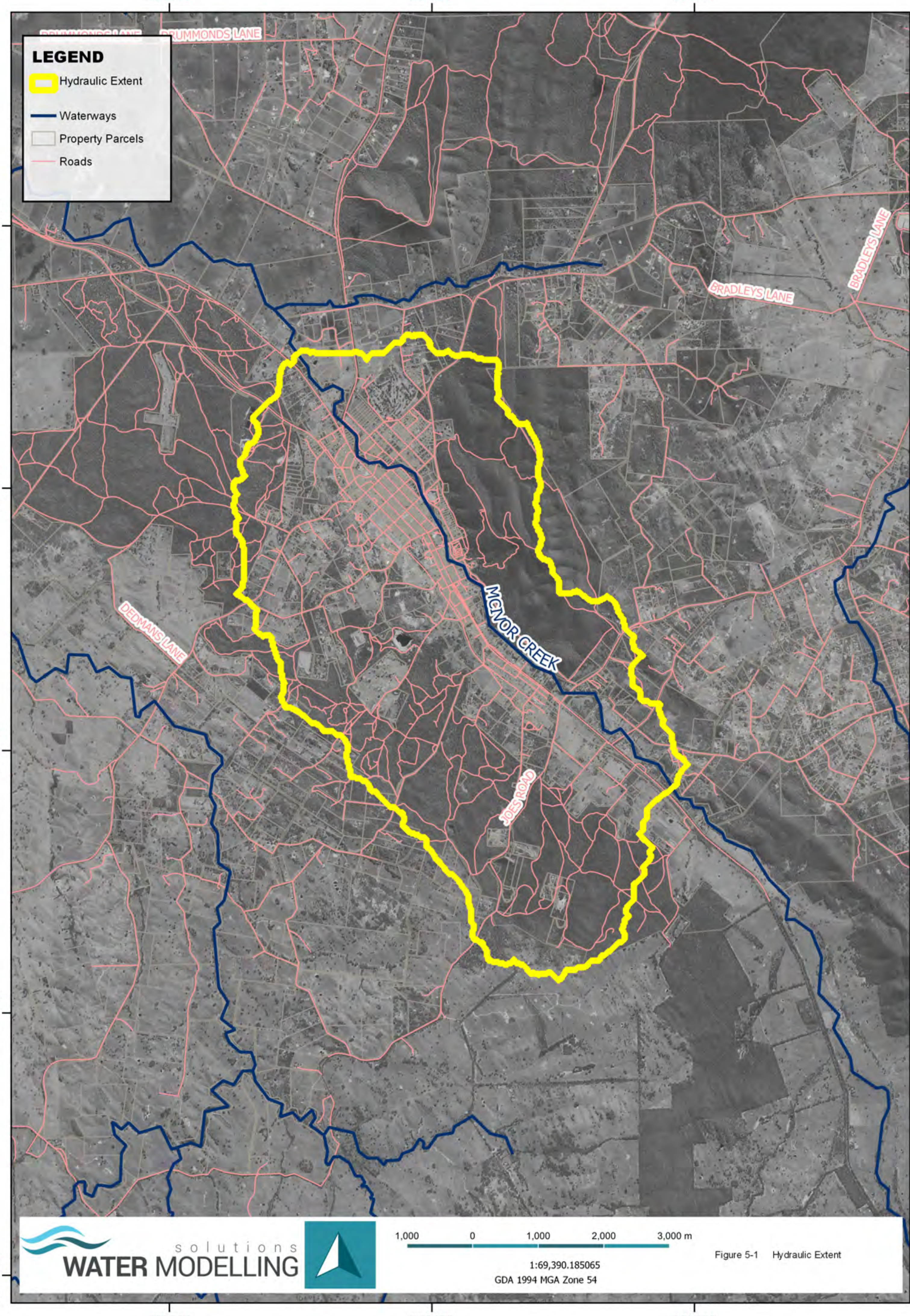


Figure 5-1 Hydraulic Extent

5.2 HYDRAULIC MODEL REVIEW

The hydraulic review consisted of the analysis of multiple control files and shape files relevant to the Heathcote Township Rain-on-Grid model developed by WBM BMT in 2016. From this hydraulic review there were two main issues with the previous modelling; the hydraulic roughness's and the hydraulic structures represented in the model.

5.2.1 Materials and Hydraulic Roughness

The previous reporting states that the best practice process of initially using the planning layers (as a general guide) followed by a modification based on land cover mapping and aerial imagery was followed. Upon further investigation the previous model does not thoroughly discern between differing levels of vegetation, nor does it accurately represent scattered vegetation with rural properties and the increase in development in the area.

To gain the best results the hydraulic model will require updating to better apply the hydraulic roughness and represent the new developments in the area. These updated roughness's will be in conjunction with the new losses that are necessary due to the missing material files, mentioned below in 9.2.3.

5.2.2 Key Hydraulic Structures

The hydraulic structures were represented as 1D and 2D structures depending on location, type and size.

The existing model was reviewed prior to adoption and a number of key hydraulic structures were noted to be missing and/or misrepresented. Though the structures may have had little consequence to the riverine flood model they will impact the Rain-on-Grid modelling and as such remodelled within the hydraulic extent.

The 1D network entry pits are modelled assuming to be 900mm wide and 150mm high kerb inlets. Though these parameters are adequate for some structures, or general purpose, pit inlet curves provide a more accurate representation of the inlet structures. They categorise the pits based on size and type i.e. SEP (Side Entry Pits), GP (Grated Pit) or JP (Junction Pit). A number of the drawings provided by council show specific details of the pit size and types in developments which should be included in the modelling.

Finally, hydraulic grades of the pipe network are slightly different from the survey. These results will require updating the drainage infrastructure to better represent the hydraulic grade of the system.

5.2.3 Rain-on-Grid Files

This study utilised the backbone hydraulic structure of the *Heathcote Flood Study: Town Drainage Assessment*, however, the Rain-on-grid files were not available and will be generated as part of the study.

Rain-on-Grid applies direct rainfall as rainfall hyetographs to active cells within the model boundary. The hyetographs (rainfall/time) replace the hydrographs (flow/time) as the inflow boundary. The process applies rainfall over the study area using RF files, followed by applying depth-varying roughness for the selected land-uses and finally applying the initial and continuing loss rainfall losses each using more complex material files.

5.3 BOUNDARY CONDITIONS

5.3.1 Model Inflow Boundaries

An Inflow boundary condition, representing baseflow of McIvor Creek, was extracted from the URBS model as a Source-Area (SA) boundary types whereby the inflow is applied across a polygon placed along the waterway. The 10% AEP baseflow was adopted for storm events >10% AEP and a 50% AEP baseflow was adopted for the 50% to 10% AEP storm events. The Rain-on-Grid (RF) boundary conditions were applied over the hydraulic extent. The hydraulic inflow locations are shown in Figure 5-2.

5.3.2 Model Outflow Boundaries

The outflow model boundary is located at the downstream boundary along McIvor Creek. The outflow is modelled as a Height/Discharge (HQ) boundary condition. This allows the model to determine a rating curve based on the model topography, slope, and roughness.

5.4 TOPOGRAPHY AND RESOLUTION

As discussed in the data review a number of topographic data sets were processed Digital Elevation Models. The LiDAR captured in 2010 from ISC Rivers LiDAR and in 2009-2010 from the Victoria Statewide Floodplains LiDAR project were converted to 2 metre grid resolutions, which was determined as an accurate size to represent the key hydraulic features (i.e. bridges and culverts) in the catchment. A key consideration for grid cell size is the representation of the capacity of any open channels and minor flowpaths in urban stormwater modelling. The 2 m grid is substantial to capture the McIvor Creek and the open drainage channels that exist throughout the township; however, Sub Grid Sampling (SGS) will be employed to better understand the stormwater infrastructure with a 0.5 to 1 metre grid adopted. The updated model DEM is shown in Figure 5-3.

5.5 HYDRAULIC ROUGHNESS

Hydraulic roughness was determined initially using planning layers and then modified based on land cover mapping and aerial imagery. Table 5-1 shows the Manning's 'n' roughness values adopted for each land use, with the values adopted in the hydraulic model are shown in Figure 5-4. The adopted roughness' were based on standard industry accepted values outlined in Australian Rainfall and Runoff.

Table 5-1 Manning's 'n' values for TUFLOW model build

Land type	Manning's 'n' value
Residential – Urban	0.300
Residential – Rural	0.150
Industrial – Commercial – Large buildings	0.300
Open Channels	0.025
Open Space or Waterway – minimal vegetation	0.040
Open Space or Waterway – moderate vegetation	0.060
Open Space or Waterway – Heavy vegetation	0.090
Open Water (with reedy vegetation)	0.060
Open Water (with submerged vegetation)	0.020
Dense Bush	0.100
Carpark – pavement – driveways – roads	0.020
Unpaved Roads	0.030

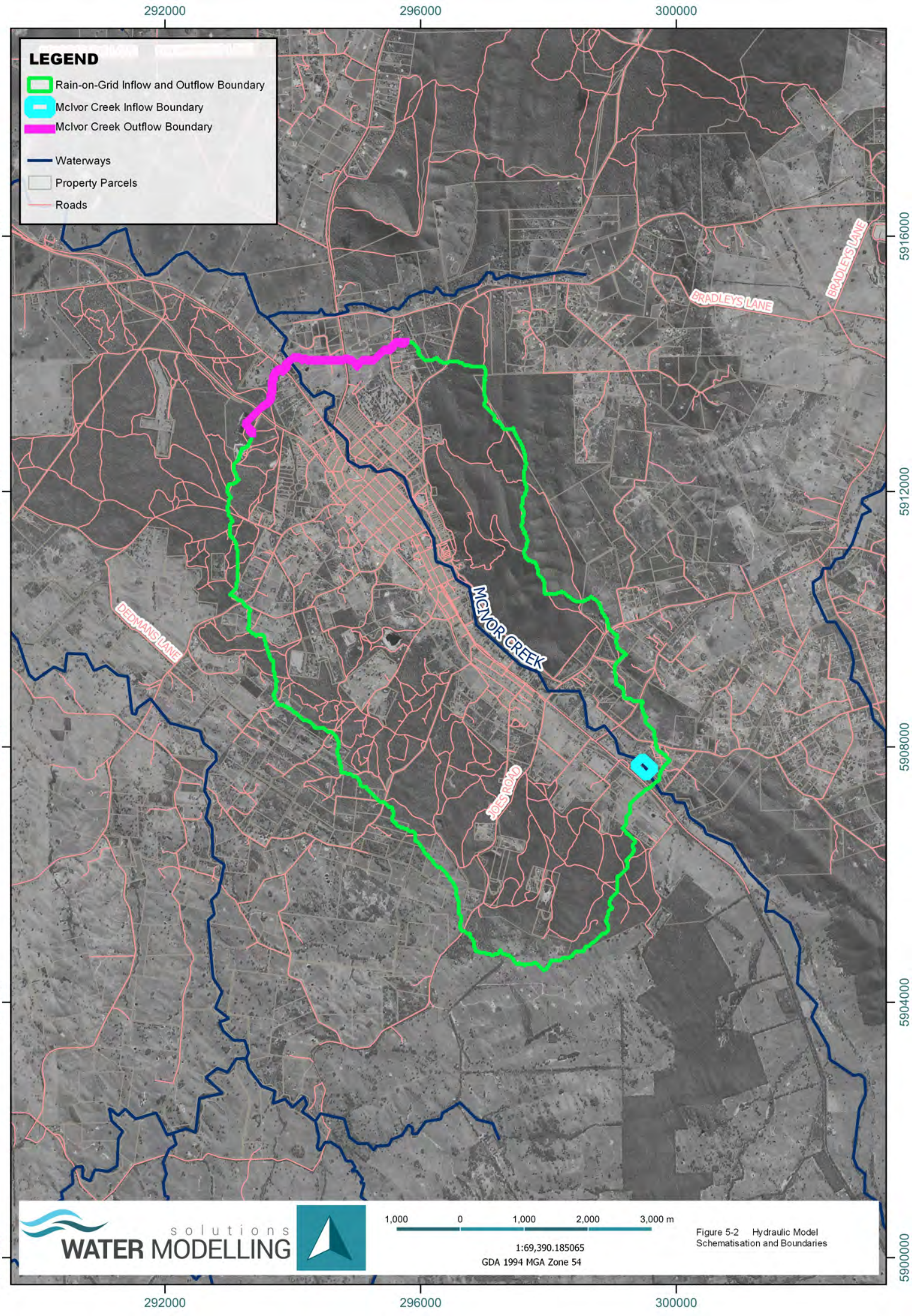


Figure 5-2 Hydraulic Model Schematisation and Boundaries

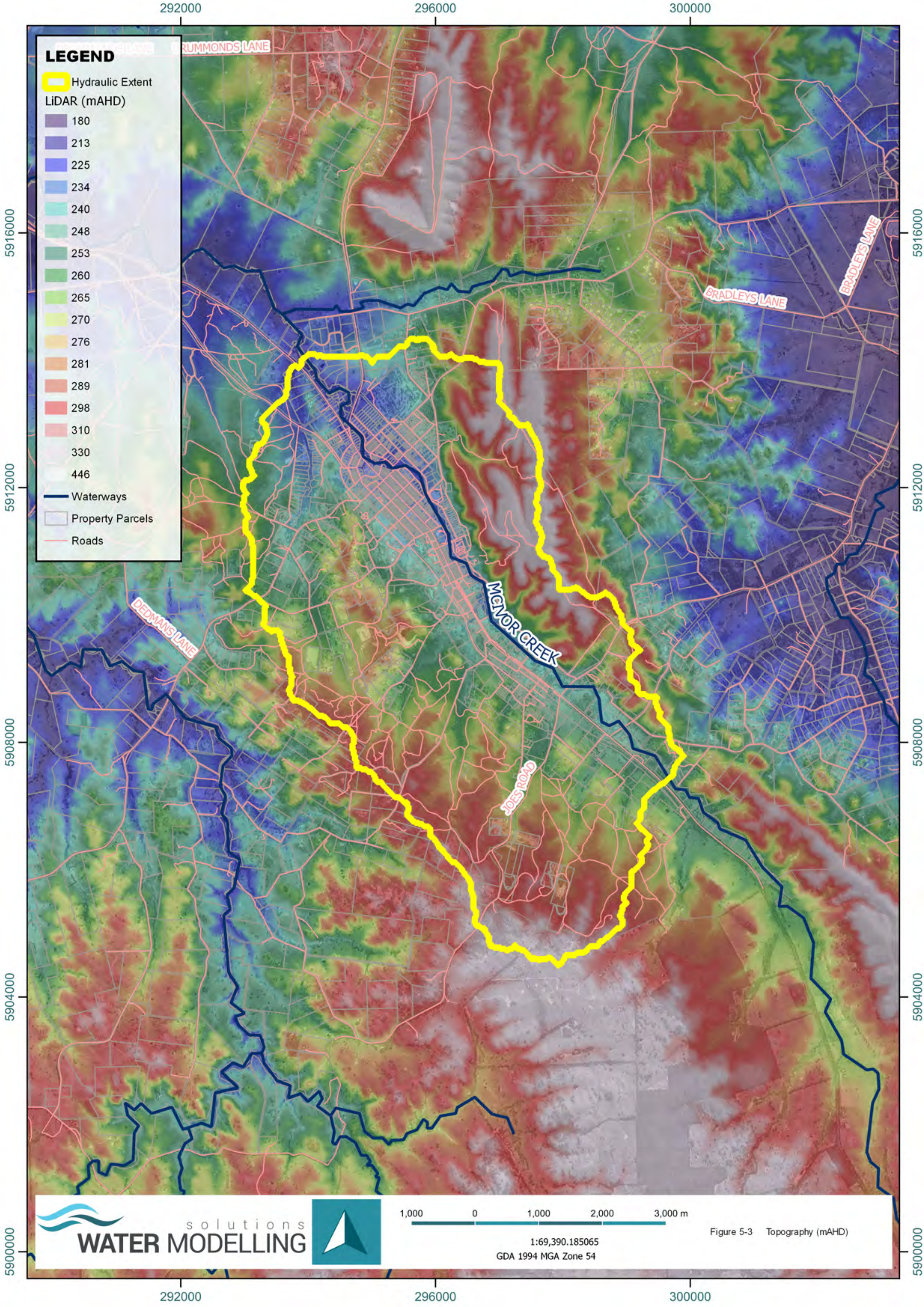


Figure 5-3 Topography (mAHD)

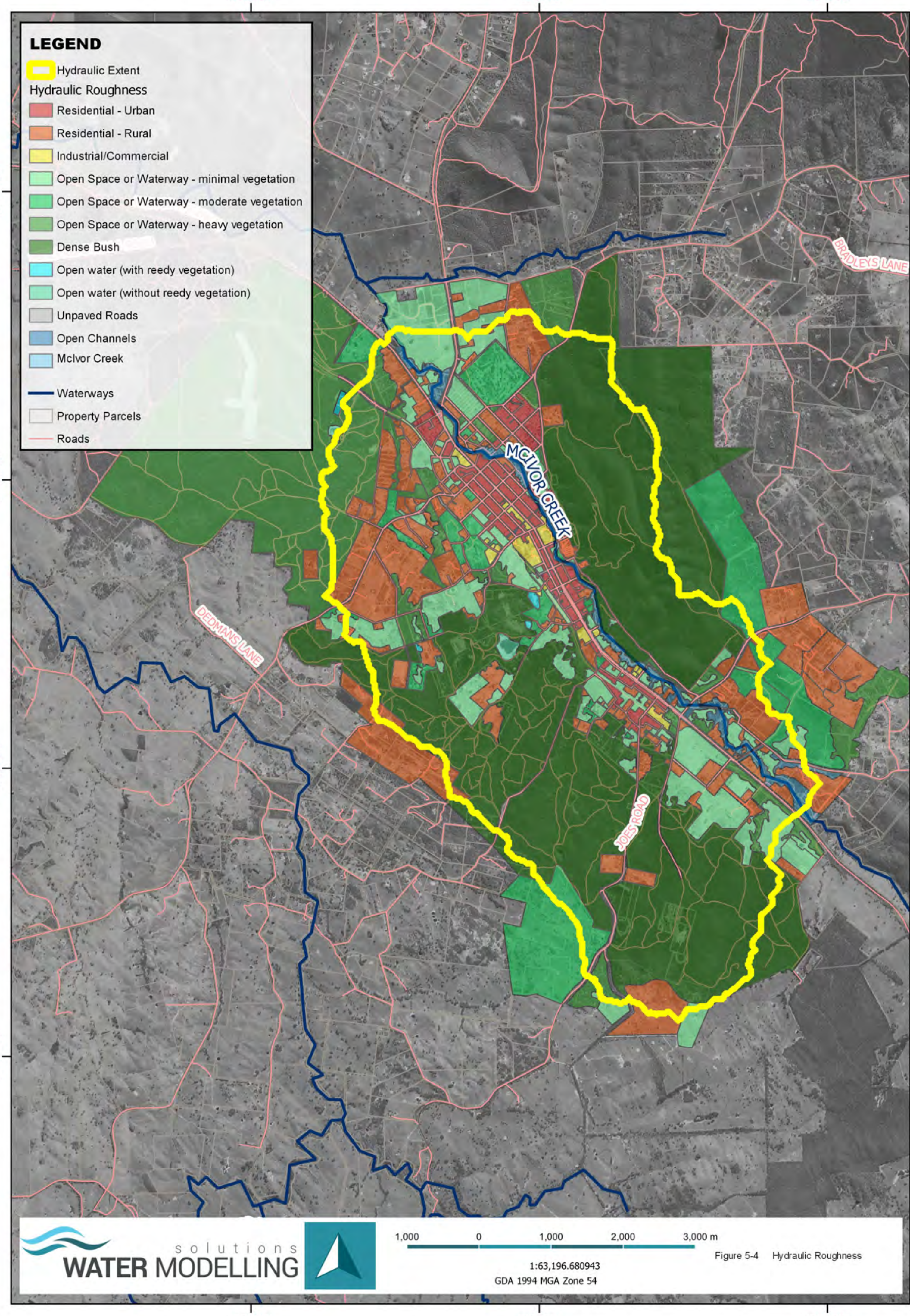


Figure 5-4 Hydraulic Roughness

6 EXISTING FLOOD RISK

The early stage of the investigation involved determining the existing level of flood risk through the township for the 50% to 1% AEP stormwater events. This included updating and modifying existing models to represent current conditions and to ensure consistency with current best practice. This process ensured the modelling complied with relevant guidelines included Australian Rainfall and Runoff 2019. Details of the models are outlined in Section 4: Hydrology and Section 5: Hydraulics.

The existing design event modelling identified a number of locations which are susceptible to stormwater inundation across a range of events. Table 6-1 shows the stormwater behaviours over each event from 50% to 1% AEP. The behaviours show similarities to historic event records identified by Council through community consultation. The above floor level inundation of residential properties is based on depths across the building footprint >150mm.

6.1 STORMWATER BEHAVIOUR ACROSS RANGE OF DESIGN EVENTS

The stormwater impacts across the range of modelled events (50% to 1% AEP) is presented below in Table 6-1.

Table 6-1 Summary of Flood Behaviour Across Design Events

Event	Flood Characteristics	Key roadways inundated
50% AEP	• Above floor flooding to 0 residential properties • McIvor Creek remains within its banks • Upstream storages (dams and mines) prevent much of the flow from impacting the township. • Overland flows contained within drainage assets throughout the Heathcote township • Largest velocities (>1.0m/s) contained within waterways (Caledonia Gully, Possum Gully, and McIvor Creek). • Flood heights reflect the underlying topography.	• No roads inundated.
20% AEP	• Above floor flooding to 2 residential properties along Marshall Crescent where nearby infrastructure reaches capacity • Tributaries to McIvor creek start to reach capacity with small breakouts along Caledonia Gully • Small breakouts along McIvor Creek which do not impact private property. • Overland flows contained within Golden Gully drainage assets. • Dead Horse Gully easement starts to reach capacity • Largest velocities remain within waterways. • Flood heights reflect the underlying topography.	• Minor flooding across Wattle Drive.

10% AEP	• Above floor flooding to more than 10 residential properties
	  – Mitchell Street / Playne Street
	  – Hunter Place
	  – Marshall Cresent
	  – Shakespere Street / Wattle Drive
	• Property parcel flooding to more than 20 residential properties
	• All tributaries to McIvor Creek running at capacity
	• Backwater occurring along Golden Gully at High Street
	• Breakouts occurring along Whites Gully, Long Gully and Parsons Gully
	• Flows no longer contained with drainage easement along Dead Horse Gully
	• All water storages (farm dams and mines) reaching capacity
	• Larger breakouts along McIvor Creek impacting residential properties
		• Minor flooding across Shakespere Street
		• Minor flooding across Bennett Street
		• Minor flooding across Mitchell Street, Marshall Crescent and Hunter Place.
		• Minor flooding across Jenning and Thomas Street
		• Medium flooding across McIvor Highway depths >350mm
		• Minor flooding across Northern Highway depths <350mm

Event	Flood Characteristics	Key roadways inundated
	• Multiple upstream flow paths forming • Increased flood velocities along road reserves i.e. Shakespere Street and Jennings Street of between 0.4 to >1.0m/s. • Flood heights for the most part reflect the underlying topography with some increases behind drainage infrastructure.	
5% AEP	• Above floor flooding to more than 18 residential properties – Mitchell Street / Playne Street – Hunter Place – Marshall Cresent – Shakespere Street / Wattle Drive • Breakouts occurring along Dead Horse Gully prior to entering township. • Flows sheeting from Wattle Drive across Scullys Lane toward McIvor Creek • Stormwater ponding behind Bennett Street causing depths greater than 350mm • Further backwater behind High Street along Golden Gully • Possum Gully/Kimore Road causing backwater into residential properties • Breakouts occurring at regular intervals along Long Gully • Stormwater spills from mine upstream of Hirds Road • Backwater occurring along Kilmore Road between Caledonia Gully and Possum Gully. • Stormwater pondage behind Caldwell Street at numerous locations.	• Minor flooding across High Street depths <300mm • Minor flooding across Chauncey Street • Medium flooding across Wattle Drive are <450mm • Medium flooding across Thomas Street depths <450mm • Medium flooding across Northern Highway depths >450mm. • Medium flooding across Hunter Place depths <500mm • High flooding across McIvor Highway depths >700mm
2% AEP	• Above floor flooding to more than 25 residential properties – Mitchell Street / Playne Street – Hunter Place – Marshall Cresent – Shakespere Street / Wattle Drive – Scullys Lane / Ross Street – Bennett Street – Ebden Street – Playne Street / High Street – Hospital Street – Kilmore Road • Dead Horse Gully sheets flow across numerous properties inundating a number of dwellings. • Depths between High Street and Playne Street increase to >350mm. • All tributaries to McIvor Creek cause property inundation via backwater and breakouts. • The bakery and properties nearby Barrack Street are inundated. • Stormwater ponds behind High Street at numerous locations • Breakouts occurring downstream of High Street along Golden Gully causing property inundation. • Stormwater ponds behind Beauchamp Street causing above floor level inundation. • Flood velocities increase along McIvor Creek to greater than 2m/s across the entire waterway. Velocities along road reserves increase as flows find their way to the Creek.	• Minor flooding across Ebden Street <350mm • Minor flooding across Pohlman Street <200mm • Minor flooding across Caldwell Street depths <150mm • Minor flooding across Ross Street <200mm • Minor flooding across Patterson Street depths <200mm • Minor flooding across Mitchell Street depths < 350mm • Medium flooding across Chauncey Street <450mm • Medium flooding across Wattle Drive depths >450mm • Medium flooding across Bennett Street depths >450mm • Medium flooding across Mears Lane >400mm • Medium flooding across Argyle Street depths >450mm

Event	Flood Characteristics	Key roadways inundated
	• Flood heights throughout the township reflect hydraulic controls causing ponding.	• Very high flooding across McIvor Highway depths >1250mm • Very high flooding across Northern Highway depths >1500mm
1% AEP	• Above floor flooding to more than 40 residential properties – Mitchell Street / Playne Street – Hunter Place – Marshall Cresent – Shakespere Street / Wattle Drive – Scullys Lane / Ross Street – Bennett Street – Ebden Street – Playne Street / High Street – Hospital Street – Kilmore Road • Depths between High Street and Playne Street increase to >450mm. • All tributaries to McIvor Creek cause increased property inundation via backwater and breakouts. • Substantial ponding behind Beauchamp Street, Wright Street, High Street and Kilmore Road • The bakery and properties nearby Barrack Street are further inundated. • Flood velocities increase along all road reserves causing dangerous passage to a number of roads. • Velocities along Shakespere Road increase to >1.0m/s along the entire roadway. • Velocities increase within all major and minor tributaries to McIvor Creek with these velocities causing a number of breakouts across the catchment. • Flood heights throughout the township reflect the hydraulic controls i.e. roads, pipes etc, however remain relatively consistent with topography in the rural catchment.	• Minor flooding across Routledge Street depths <200mm • Minor flooding across Caldwell Street depths <250mm • Minor flooding across Grant Street <350mm • Minor flooding across Joes Road <250mm • Minor flooding across Heathcote-North Costerfield Road depths <350mm • Medium flooding across Mitchell Street depths > 350mm • Medium flooding across Shakespere Street depths >350mm • Medium flooding across High Street depths <500mm • Medium flooding across Mears Street depths <350mm • Medium–High flooding across Hunter Place depths <600mm • Medium–High flooding across Wattle Drive depths <600mm • Medium–High flooding across Jennings Street depths <600mm

6.2 FLOOD BEHAVIOUR SENSITIVITY

The existing and the sensitivity scenario results for the 1% AEP flood event were analysed and compared to determine the impact of the catchment changes on existing stormwater heights. This comparison is calculated by subtracting the existing conditions from the sensitivity conditions.

'Developed Conditions – Existing Conditions = Difference comparison results"

Table 6-2 outlines the key changes in flood behaviour from each sensitivity scenario during the 1% AEP flood event.

See Appendix C, D and E for mapping.

Table 6-2 Summary of Flood Behaviour Sensitivity against the 1% AEP Flood Event

Event	Modelling Approach	Flood Characteristics
10% AEP Flood Event with RCP 4.5	• Rainfall increased by 9.2%	• Flood heights increase by between 0 – 250mm throughout McIvor Creek. • Long Gully, Parsons Gully, and Dead Horse Gully all experience increases in flood heights due to their being the largest sub-catchments in Heathcote. • All existing roads inundated during the 10% AEP increase in flood height by between 0 – 250mm. • Stormwater ponds behind Beauchamp and Pohlman Street increases by 150mm. • Flows increase across the drainage easement along Dead Horse Gully increasing inundation heights to dwellings.
1% AEP Flood Event with RCP 4.5	• Rainfall increased by 9.2%	• Increased flood heights across High Street along Golden Gully by <150mm • Increased flood heights across Wright Street, Beauchamp Street, Mitchell Street, Hunter Place, Pohlman Street, Playne Street and Ebden Street by <150mm. • High Street becomes a serious hydraulic control with backwater occurring throughout the township. • Increased breakouts across properties along Golden Gully • Numerous dwelling footprints experience increases in flood heights.
10% AEP Flood Event with RCP 8.5	• Rainfall increased by 20.2%	• Flood heights increase by between 0 – 500mm throughout McIvor Creek. • Flood heights within the property parcels located between High Street and Playne Street increase by 150mm. • Increases of flood heights behind High Street throughout the township. • Increased inundation of High Street by <150mm • Last Street and Jennings Street both experiences increase of inundation by <150mm • Flood heights behind Kilmore Road increase between Caledonia and Long Gully. • All tributaries experience increases in flood height by between 0 – 250mm.
1% AEP Flood Event with RCP 8.5	• Rainfall increased by 20.2%	• Stormwater ponds behind O'Keefe Rail Trail, causing heights to increase by >250mm. • Caledonian Gully spills across High Street and Kilmore Street with numerous breakouts causing above floor level inundation. • A number of breakouts occur along Golden Gully upstream and throughout the township, the increases in flood height across a number of dwellings between 50 – 150mm. • High Street and Norther Highway intersection experiences increases in flood height of between 350 – 500mm. • Stormwater spills across and along Wattle Drive inundating a number of properties prior to entering McIvor Creek. • Heights within McIvor Creek increase by between 150 – 500mm

Event	Modelling Approach	Flood Characteristics
1% AEP Flood Event with +25% Roughness	• Applied a 25% increase in hydraulic roughness across the catchment	• Flood heights along McIvor Creek increase by <150mm • Flood heights along all tributaries increase by <150mm • Flood heights across the Dead Horse Gully drainage easement increase by <150mm. • Flood heights across Scully Lane, Bennetts Street, Beauchamp Street, and Wright Street increase by <150mm
1% AEP Flood Event with -25% Roughness	• Applied a 25% decrease in hydraulic roughness across the catchment	• Flood heights reduce across all tributaries and along McIvor Creek of between 50 – 250mm. • Increased flow transport upstream causes a few tailwater events across drainage infrastructure. • Flood heights behind High Street between Pohlman Street and Hunter Place decrease by <10mm.
1% AEP Flood Event with 50% Blockage	• Increase the blockage factor of culverts and pipes to 50% • Increased the blockage factor of bridges to 15%	• Flood heights along McIvor Creek reduce due to the drainage infrastructure preventing flows from entering along major tributaries. • Increases in ponding occurs along High Street. • Minor flooding occurs across Herriot Street • Flows spill out of Golden Gully inundating several properties. • Flood heights increase between High Street and Playne Street area by <50mm • Minimal increased flooding along Dead Horse Gully.
1% AEP Flood Event with 100% Blockage	• Increase the blockage factor of culverts and pipes to 100% • Increased the blockage factor of bridges to 30%	• Flood heights along McIvor Creek reduce due to the drainage infrastructure preventing flows from entering along major tributaries • Increased breakouts along Golden Gully causing inundation across numerous properties to increase by between 50 – 250mm. • Wright Street, High Street, Chauncey Street, Pohlman Street, Herriot Street, Barrack Street, Morris Street, McMahon Street and Hospital Street all experience increased inundation. • Ponding behind O'Keefe Rail Trail increased in a number of locations of >550mm.

7 PRELIMINARY MITIGATION OPTIONS

7.1 OVERVIEW

An initial consultation was undertaken by Water Modelling Solutions with Dryside Engineering and the City of Greater Bendigo in May 2021 in which ten (10) preliminary mitigation options were collated and discussed.

Preliminary analysis was undertaken for the 10 mitigation options. Section 7.2 outlines the preliminary mitigation options that were not chosen for the concept design phase. This is largely due to their negligible stormwater risk benefits.

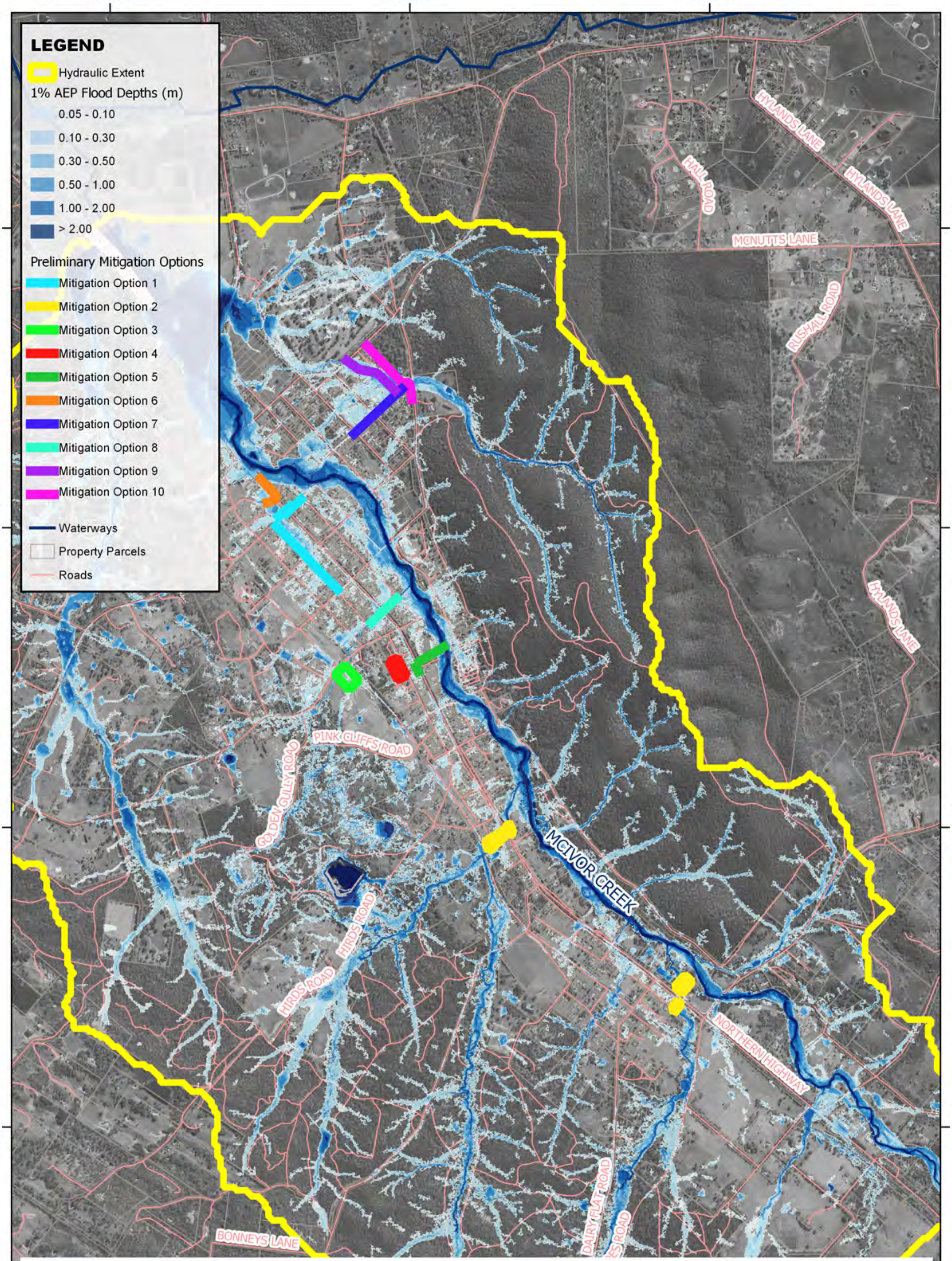
From the ten (10) preliminary options a refined list of 4 mitigation options were further investigated, outlined in Section 8: Detailed Mitigation Assessment. The selection criteria were be based on the level of flood risk benefit, adverse impacts and feasibility to construct.

7.2 PRELIMINARY MITIGATION OPTIONS ASSESSMENT

This section of the report presents the results of the preliminary modelling options that were not chosen for concept design assessment but were aimed at reducing the stormwater risk within the Heathcote. The preliminary mitigation option locations are shown below.

Each option was modelled for a full range of durations over the 1% AEP flood event. The impacts of the 1% AEP event are described below to understand the impact of each option on the flood behaviour.

Environmental and heritage impacts as well as damages and feasibility assessments were not included in the scope of this project however should be taken into consideration during future implementation of mitigation. However, the costings and concept plans will assist in these assessments of 4 mitigation options.



solutions WATER MODELLING

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GDA 1994 MGA Zone 54

Figure 7-1 Preliminary Mitigation Option Locations

294000 296000 298000

7.2.1 Option 1 – Playne Street and Mitchell Street Upgrades

7.2.1.1 Location and Description

Option 1 was recommended for preliminary assessment and involved increasing the capacity of existing stormwater infrastructure along Payne and Mitchell Streets, as well as new sections of pipe. During the 1% AEP storm event backwater occurs between Pohlman Street and Mitchell Street. This is further exacerbated by sheeting flow across Playne Street from Ebden Street and the rail trail. The increase in capacity and construction of new stormwater infrastructure in the area aims to increase the amount of sub-surface flow conveyed through the area and reduce surface water inundation to properties in this vicinity.

In the existing scenario over 20 properties experience inundation of between 100 – 550 mm at the rear of the parcels along an existing drainage line. The existing drainage is unable to compensate for the flows through the region causing storm water to pond in the depressions between High Street and Hunter Drive, Hunter Drive and Marshall Crescent, Marshall Crescent and Mitchell Street and Mitchell Street and Polman Street. It is possible that many of the properties in this area may experience above floor level inundation during the 1% AEP storm event however flood level survey is not available to confirm this.

For this mitigation scenario a series of 300 mm stormwater pipes and associated side entry pits (SEP) were modelled along Playne Street. These are designed to capture the sheeting flow limiting depths on the affected properties. The capacity of stormwater pipes along Mitchell Street were increased to between 525 to 600 mm. The pipes then run parallel to Mitchell Street, across High Street, allowing for stormwater to divert along Mitchell Street to the outfall at McIvor Creek earlier than the existing system.

7.2.1.2 Stormwater Impacts

The results represented no significant benefits or adverse impacts during the 1% design storm event. Stormwater heights showed between a 0 to 10 mm drop across the area. This is likely due to the upgrades not being significant enough to impact the 1% AEP stormwater event. Although proposed drainage replicates nearby infrastructure it is not sufficient to capture enough flow to cause any substantial impact. Therefore, option 1 was not a viable option.

7.2.2 Option 2 – Possum Gully and Caledonian Gully Works

Option 2 – Possum Gully and Caledonian Gully Works was selected for further concept design and is presented in Section 8.1

7.2.3 Option 3 – Golden Gully Upstream Storage

Option 3 – Golden Gully Upstream Storage was selected for further concept design and presented in Section 8.2.

7.2.4 Option 4 – Barrack Street Upstream Storage

7.2.4.1 Location and Description

Option 4 involves constructing a wetland or dam upstream of the Camp Street in the adjacent dog park to Barrack Street. This provides increased flood storage during the 1% AEP storm event. It is intended to restrict sheeting flow across Camp Street subsequently alleviating pressure on the stormwater system along Barrack Street near the Heathcote Bakery.

The existing results show an overland drainage line that flows from the upper catchment, through the dog park, and along Barrack Street. The storm water then ponds behind High Street causing inundation to a number of properties of between 200 – 400 mm deep. High Street acts as a hydraulic control in the area.

The chosen area used the existing topography and was dropped by 300 – 500 mm to replicate a wetland. The approximate volume of the wetland is 300m^3. The hydraulic roughness of the zone was altered to replicate a water storage with reedy vegetation.

7.2.4.2 Stormwater Impacts

Option 4 demonstrated a limited benefit to the proposed wetland works. Stormwater levels are reduced at the wetland and slightly north across Hospital Street and the adjacent property by between 0 – 50 mm, however this is the limit of the impacts. The properties inundated during the existing scenario remain inundated.

7.2.5 Option 5 – Barrack Street Upgrades

Option 5 – Barrack Street Upgrades was selected for further concept design and presented in Section 8.3.

7.2.6 Option 6 – Clouston Street Upgrades

7.2.6.1 Location and Description

Option 6 involves constructing stormwater infrastructure near Clouston Court across High Street which could assist with diverting flows away from properties into existing infrastructure downstream. The existing network runs at capacity during the 1% AEP event, therefore, allowing additional capacity may reduce inundation and impacts to properties.

As identified in Option 1, storm depths within the Coulston Street, Hunter Plance and Marshall Crescent area exceed 350 mm, the acceptable depth for residential properties footprints and access/egress from a flood hazard perspective. Stormwater depths on the north-eastern area along Clouston Street typically do not exceed 200 mm. The existing depths downstream provide a potential opportunity to allow flows to disperse further in this area.

The scenario was represented by a series of 600 mm pipes and associated SEPs along Hunter Place, Clouston Street and across High Street. The stormwater then discharges downstream into existing stormwater infrastructure releasing pressures on the system.

7.2.6.2 Stormwater Impacts

Flood levels, identified in Option 6, have been reduced across Hunter Place and the nearby service station; the proposed stormwater allows for increased capacity of existing infrastructure in the area. Flows across Hunter Place and Clouston Street reduce by 20 to 100 mm.

7.2.7 Option 7 – Shakespere Street Upgrades

A combination of Option 7, 9 and 10 were selected for further concept design and presented in Section 8.4.

7.2.8 Option 8 – Golden Gully Works

7.2.8.1 Location and Description

Option 8 involves the increase of the capacity downstream of High Street along Golden Gully. The existing concrete channel tapers along Morris Street. This causes a bottleneck, creating a backwater which inundates a number of nearby properties. By widening the channel larger flows can pass through the area, preventing breakouts along Wright Street.

Golden Gully consists of a relatively constricted channel, bounded on either side by fences and buildings. Flood depths within the channel exceed 2 metres prior to entering McIvor Creek but for much of the channel remain at approximately 600mm. The 1% AEP storm extent shows that instead of flows remaining within the channel, the water breaks out across a depression in the landscape, along and then across Wright Street causing further inundation to properties located along McIvor Creek.

The proposed mitigation option widens the channel therefore increasing the capacity. This modelled increase in channel width was approximately 2 – 3 metres wide along Morris Street.

7.2.8.2 Stormwater Impacts

Option 8 results identified a localised improvement with flood heights reducing by 60 to 600 mm, though the largest decreases are observed within the channel. Flood heights across nearby building footprints reduce by approximately 60 mm, and do not constitute a significant net benefit in the area. Currently the nearby vegetation, and topography changes continue to impact the area.

The benefits in the 1% AEP storm event are minimal.

7.2.9 Option 9 – Dead Horse Gully Works (Redefined Existing Easement)

A combination of Option 7, 9 and 10 were selected for further concept design and presented in Section 8.4.

7.2.10 Option 10 – Dead Horse Gully Works (Roadside bund and drainage line)

A combination of Option 7, 9 and 10 were selected for further concept design and presented in Section 8.4.

8 CONCEPT MITIGATION ASSESSMENT

This section presents results of the concept mitigation modelling of four (4) options aimed at reducing stormwater risk throughout Heathcote. The locations of the modelled options are shown in Figure 8-1.

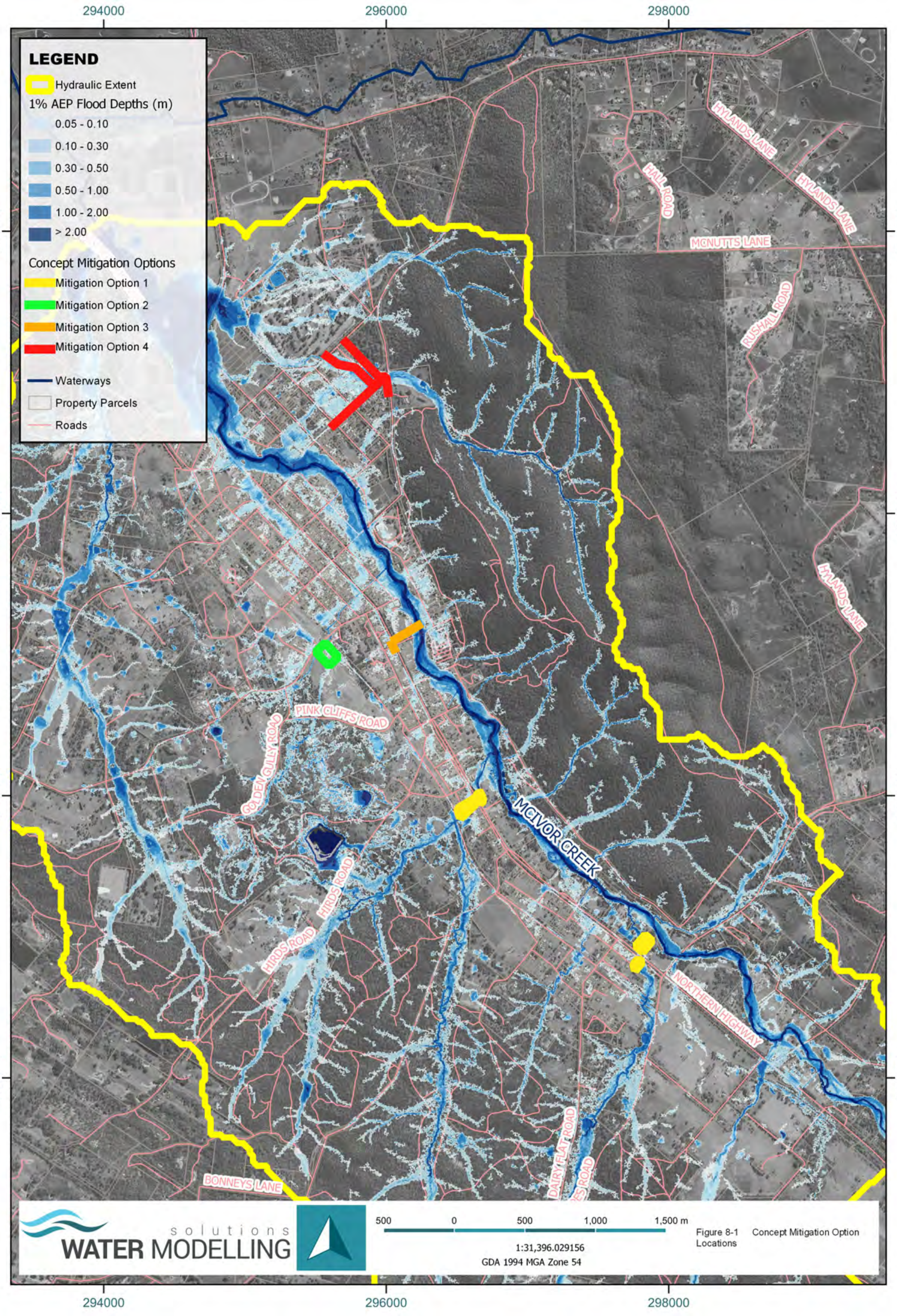

Figure 8-1 Concept Mitigation Option Locations

8.1 CONCEPT DESIGN OPTION 1 – POSSUM GULLY AND CALEDONIAN GULLY WORKS

8.1.1 Location and Description

Concept design 1 (Preliminary Assessment Option 2) involves the removal of exotic vegetation (elms, willows etc.) upstream and downstream of the Possum Gully and Caledonian Gully at High Street intersections.

Riparian vegetation can have an impact on stormwater and flood levels. Whilst native vegetation provides important waterway health and habitats, exotic vegetation is known to degrade waterways particularly through riparian zones. Exotic vegetation can constrict waterways during large storm events, including through vegetation and debris being swept into drainage infrastructure i.e. pipes, pits and in this case bridges, blocking the passage of floodwaters.

Flood extents in the area under existing conditions show a number of properties experiencing inundation. Though depths exceeding 350 mm are largely restricted to the waterway corridor, this option provides a relatively low-cost solution to reduce flood levels adjacent to these areas, and improve access to and from the township during events larger than a 1% AEP.

The hydraulic roughness of the local area, upstream and downstream of the gully intersecting the road has been reduced to replicate the removal of the exotic vegetation. This is intended to allow runoff to better traverse this section of waterway and through drainage structures, and reduce backwater impacts inundating properties and buildings.

8.1.2 Stormwater Impacts

Concept design 1 (Preliminary Assessment Option 2) was modelled for the 1% AEP design storm event. The impacts in the 1% AEP event are described below and mapped further below to understand the impact of this option on flood behaviour.

Figure F-1 shows the impacts of peak stormwater level. The results show a localised drop in stormwater levels upstream of between 50 to 100mm, and a slight increase downstream as flows are now able to traverse the structures more efficiently and effectively for both waterways. Stormwater levels decrease by <100 mm across a number of adjacent properties. Velocities increase, as mentioned above, due to the efficient and effective passage of stormwater.

The inadvertent impact of this option is the easier maintenance of the bridge and subsequent improved condition of the bridge structures.

8.1.3 Preliminary Costing

This option was not explicitly costed, as it is assumed the works can be achieved as part of ongoing Council's ongoing drainage maintenance program.

8.2 CONCEPT DESIGN OPTION 2 – GOLDEN GULLY UPSTREAM STORAGE

8.2.1 Location and Description

Concept design 2 (Preliminary Assessment Option 3) involves constructing a large multi-purpose detention basin along Golden Gully upstream of the O'Keefe Rail Trail. Within the proposed basin a small junior soccer pitch is proposed. This option provides increased flood storage during the 1% AEP storm event. It restricts flow and follow-on inundation downstream along Golden Gully, particularly to adjacent properties and building footprints along Ebden and Playne Streets.

Under existing conditions Golden Gully freely flows from the upper catchment, across Herriot Street eventually inundating a number of properties to depths of over 1 metre. 10 properties experience depths of between 100 – 300 mm between Playne Street and the Rail Trail during the 1% AEP storm event. Figure F-3 shows concept design drawings.

The chosen basin site was proposed by the City of Greater Bendigo. The underlying topography was used as the outlet level, the basin invert level was dropped by 300 – 500 mm to replicate a detention (depths in the centre are approximately 500 mm). The approximate volume of the basin is 1500m^3. The hydraulic roughness of the zone was altered to replicate open grassed land.

8.2.2 Stormwater Impacts

Figure F-2 demonstrates decreased storm levels throughout the drainage line of between 0 to 250 mm stemming from the proposed detention basin and along Golden Gully. Several properties along Ebden Street and Playne Street all experience reduced flood levels. A number of properties that were inundated become flood-free in this event.

This option is practical to construct, has a moderate cost and potentially creates some usable open space and a community recreational asset (e.g, Junior Soccer Oval) with a net benefit in storm water risk.

8.2.3 Preliminary Costings

A preliminary construction cost assessment has been undertaken to provide understanding on the feasibility of the proposed option. Table 8-1 shows an estimation of the costs associated with concept design option 2.

Table 8-1 Summary Costs of Concept Mitigation Option 2

Item	Description	Qty	Unit	Rate	Amount
1	**Preliminaries / Contractor's on Cost**				**$ 95,000.00**
1.1	**Site establishment / Preliminaries** Including establishment and implementation of all documents outlined in the contract and legislative requirements. Including, but not limited to, CMP, OH&S, QMS, Environmental Management, Insurances, Supervision costs and SWMS.	1	item	$ 25,000.00	$ 25,000.00
1.2	**Traffic management** Development and Implementation of council approved Traffic Management Plan inc. all necessary signage, VMS boards, lighting and barricading as required	1	item	$ 15,000.00	$ 15,000.00
1.3	**Survey & Service Location** Set Out Survey, Provision of "as constructed" set of plans, locate services and, where appropriate, depth, size and type of services, obtain any necessary permits to undertake the works.	1	item	$ 5,000.00	$ 5,000.00
1.4	**Design & Site Investigations** Feature Survey, Geotech and Detailed Design	1	item	$ 50,000.00	$ 50,000.00
2	**Bulk Earthworks**				**$568,990.00**
2.1	Stripping topsoil and vegetation (200mm) & stockpiling	13390	m^2	$ 3.50	$ 46,865.00
2.2	Cut to Dispose	17985	m^3	$ 25.00	$449,625.00
2.3	200mm Topsoil placement, raking and levelling from site stripped materials plus grass seeding	14500	m^2	$ 5.00	$ 72,500.00
3	**Drainage**				**$ 48,500.00**
3.1	Headwalls	4	item	$ 4,000.00	$ 16,000.00
3.2	Herriot Street Culverts	1	item	$ 25,000.00	$ 25,000.00
3.3	Spillway	1	item	$ 7,500.00	$ 7,500.00
4	**Miscellaneous**				**$ 12,500.00**
4.1	Signage	1	item	$ 2,500.00	$ 2,500.00
4.2	Sports Pitch Markings	1	item	$ 5,000.00	$ 5,000.00
4.3	Final Clean Up	1	item	$ 5,000.00	$ 5,000.00
	Estimate Total				**$724,990.00**
	Contingency Sum Allowance (30% of Lump Sum)		%	30%	$217,497.00
	Apparent Contract Total				**$942,487.00**

8.3 CONCEPT DESIGN OPTION 3 – BARRACK STREET UPGRADES

8.3.1 Location and Description

Concept design 3 outlines increasing the capacity and number of culverts around the Barrack Street / High Street intersection. The existing 600mm pipe across the oval was increased to a 1050mm pipe to allow flows to better funnel through the system from the nearby bakery and the development of another 1050mm pipe that flows from the southern intersection area, across High Street, along Barrack Street before discharging into McIvor Creek. Figure F-5 shows concept design drawings.

Under existing 1% AEP storm event conditions number of properties are inundated behind High Street and along Barrack Street. Depths in the area range from between 100 – 400 mm with building footprints subject to above floor level inundation.

8.3.2 Stormwater Impacts

Figure F-4 shows a reduction in flood extents and heights across Barrack Street and behind High Street of between 0 – 10 mm. Though these impacts are not significant the proposed infrastructure would limit inundation on the Bakery and properties along High Street.

8.3.3 Preliminary Costings

A preliminary construction cost assessment has been undertaken to provide understanding on the feasibility of the proposed option. Table 8-2 shows an estimation of the costs associated with concept design option 3.

Table 8-2 Summary Costs of Concept Mitigation Option 3

Item	Description	Qty	Unit	Rate	Amount
1	**Preliminaries / Contractor's on Cost**				**$100,000.00**
1.1	**Site establishment/Preliminaries** Including establishment and implementation of all documents outlined in the contract and legislative requirements. Including, but not limited to, CMP, OH&S, QMS, Environmental Management, Insurances, Supervision costs and SWMS.	1	item	$ 25,000.00	$ 25,000.00
1.2	**Traffic management** Development and Implementation of council approved Traffic Management Plan inc. all necessary signage, VMS boards, lighting and barricading as required	1	item	$ 30,000.00	$ 30,000.00
1.3	**Survey & Service Location** Set Out Survey, Provision of "as constructed" set of plans, locate services and, where appropriate, depth, size and type of services, obtain any necessary permits to undertake the works.	1	item	$ 5,000.00	$ 5,000.00
1.4	**Design & Site Investigations** Feature Survey, Geotech and Detailed Design	1	item	$ 40,000.00	$ 40,000.00
2	**Drainage**				**$242,800.00**
2.1	900mm x 1200mm GEP	3	item	$ 6,000.00	$ 18,000.00
2.2	1050mm Dia RCP Pipe Upgrade	222	Lm	$ 900.00	$199,800.00
2.3	1050mm Headwall incl. Rock Beaching	1	item	$ 5,000.00	$ 5,000.00
2.4	Highstreet Reinstatement	1	item	$ 5,000.00	$ 5,000.00
2.5	Connect existing Pipes	1	item	$ 5,000.00	$ 5,000.00
2.6	Allowance for working under NBN/Telstra	1	item	$ 10,000.00	$ 10,000.00
2.7	900mm x 1200mm GEP	3	item	$ 6,000.00	$ 18,000.00
	Estimate Total				**$342,800.00**

Item	Description	Qty	Unit	Rate	Amount
	Contingency Sum Allowance (30% of Lump Sum)		%	30%	$102,840.00
	Apparent Contract Total				**$445,640.00**

8.4 CONCEPT DESIGN OPTION 4 – NORTHERN ZONE (COMBINED OPTIONS)

8.4.1 Location and Description

Concept Design 4 includes the best features from the preliminary mitigation options 7, 8, and 9. Significant inundation occurs in and around Shakespere Street as outlined below. A combined approach was deemed appropriate when mitigating stormwater risk in the area. Figure F-8 shows concept design drawings.

The concept includes stormwater infrastructure along the arterial of Shakespere Street with a 1500mm pipe running northeast – southwest toward McIvor Creek. This comprises a series of side entry pits to capture flows within the road reserve. The existing twin 1500mm pipes along the easement have been extended to meet the proposed infrastructure and increased to 4 x 1500mm pipes along the entire easement. To encourage flows into this infrastructure a number of options are utilised including:

1. A series of road bumps (300mm high) are utilised along Shakespere Street.
2. Reductions in road level of 300mm at the easement and Shakespere Street and Wattle Drive intersections allow flows to funnel into the easement.
3. A series of 300mm bunds along the northern Shakespere Street Road Reserve and along each side of the easement continue to funnel flows away from nearby properties.
4. A 1800mm bund/fence along the fenceline of the properties along the Parks Victoria land parcel.

During the existing 1% AEP storm event 40 properties are impacted with above floor level inundation to approximately half of the properties inundated. These depths range from 100mm to >1.0m with the worst experienced west of Shakespere Street. Flows disperse upon crossing Shakespere Street and entering the drainage easement. Some flows run along the roadside toward McIvor creek, ranging in depths from 100 – 300mm, and others chart their own course around the existing easement. Dead Horse Gully enters the township without any clearly defined bed and banks, instead using a drainage easement characterised by a small patch of grass, and with a large catchment area, stormwater swells the existing drainage infrastructure and spills.

8.4.1.1 Stormwater Impacts

Figure F-7 shows a significant benefit to many properties, there are also some negative impacts, however these do not occur across building footprints. The 1% AEP stormwater extents reduce throughout the area with flood heights decreasing by between up to 1.2 metres. The increased capacity of the proposed drainage and defined channel allows many properties downstream to experience flood height decreases of between 20 to 400 mm. Flows along the Parks Victoria land increase by up to 1.3 metres and flood hieghts increase across Shakespere Street and Wattle Drive nearby the proposed lowering in road level and road bumps.

8.4.2 Preliminary Costings

A preliminary construction cost assessment has been undertaken to provide understanding on the feasibility of the proposed option. Table 8-3 shows an estimation of the costs associated with concept design option 4.

Table 8-3 Summary Costs of Concept Mitigation Option 4

Item	Description	Qty	Unit	Rate	Amount
1	**Preliminaries / Contractor's on Cost**				**$160,000.00**
1.1	**Site establishment / Preliminaries** Including establishment and implementation of all documents outlined in the contract and legislative requirements. Including, but not limited to, CMP, OH&S, QMS, Environmental Management, Insurances, Supervision costs and SWMS.	1	item	$ 50,000.00	$ 50,000.00

Item	Description	Qty	Unit	Rate	Amount
1.2	**Traffic management** Development and Implementation of council approved Traffic Management Plan inc. all necessary signage, VMS boards, lighting and barricading as required	1	item	$ 50,000.00	$ 50,000.00
1.3	**Survey & Service Location** Set Out Survey, Provision of "as constructed" set of plans, locate services and, where appropriate, depth, size and type of services, obtain any necessary permits to undertake the works.	1	item	$ 10,000.00	$ 10,000.00
1.4	**Design & Site Investigations** Feature Survey, Geotech and Detailed Design	1	item	$ 50,000.00	$ 50,000.00
2	Diversion Works				$103,300.00
2.1	Flood Bund	270	Lm	$ 200.00	$ 54,000.00
2.2	300mm Flat Topped Speed Hump	2	item	$ 7,500.00	$ 15,000.00
2.3	Shakespear Drive 300mm Bund	175	Lm	$ 50.00	$ 8,750.00
2.4	Formalisation of Easements Drain incl. 300mm bund	350	Lm	$ 65.00	$ 22,750.00
2.5	Grass Seeding Easement Drain	350	Lm	$ 8.00	$ 2,800.00
3	Drainage				$986,000.00
3.1	900mm x 900mm GEP	6	No.	$ 4,500.00	$ 27,000.00
3.2	900mm x 1800mm JP	7	No.	$ 6,000.00	$ 42,000.00
3.3	1500mm RCP Through Easement	115	Lm	$ 800.00	$ 92,000.00
3.4	1500mm RCP Shakespeare Drive	780	Lm	$ 1,000.00	$780,000.00
3.5	1500mm Headwall	2	No.	$ 5,000.00	$ 10,000.00
3.6	Allowance for working under NBN/Telstra	1	item	$ 20,000.00	$ 20,000.00
3.7	Shakespere Drive Asphalt Reinstatement	1	item	$ 15,000.00	$ 15,000.00
	Estimate Total				$1,249,300.00
	Contingency Sum Allowance (30% of Lump Sum)		%	30%	$ 374,790.00
	Apparent Contract Total				$1,624,090.00

9 SUMMARY AND RECOMMENDATIONS

This report details the hydrologic and hydraulic stormwater characteristics of Heathcote, Victoria. Water Modelling Solutions in collaboration with Dryside Engineering were engaged to assess stormwater risk throughout the township and recommend mitigation options to reduce stormwater risk.

Based on the findings above and consideration for the feedback from the City of Greater Bendigo Council, Water Modelling Solutions four (4) preferred mitigation options have been determine, with concept designs and costings prepared for them.

- **Option 1 (Possum Gully and Caledonian Gully Works)** is considered the most feasible option and is recommended to be undertaken as part of Council's ongoing drainage maintenance program. This option does not require extensive costs and can instead be undertaken by Council's works team. Although this option does not significantly benefit large portions of the town, the works will provide local benefit, and reduce blockage of key Council assets (bridges) during and following large storm events.
- **Option 2 (Golden Gully Upstream Storage)** was found to provide substantial reductions in stormwater inundation throughout the township. The option also creates a community asset in the form of a Junior Sporting Field. Given the works are on Council owned land it is recommended that further feasibility be conducted on this option.
- **Option 3 Barrack Street Upgrades** reduces stormwater risks around the Barrack Street/High Street intersection. The bakery, being a major community asset would stand to benefit from these proposed works. Given this option involves pipe upgrades and establishment it is recommended that Council consider this option as part of future drainage upgrades within its capital works program.
- **Option 4 Northern Zone Combined** is considered the greatest net benefit to the community residing near Dead Horse Gully, however, this option has a substantial cost as it involves, levee wall construction, road works, and the establishment and upgrading of drainage infrastructure. It is recommended that further investigation be undertaken to understand Community support for the option and assessment of social and environmental impacts.

10 REFERENCES

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APPENDIX A

URBS MODEL

A.1 URBS OVERVIEW

The URBS model was predominately adopted 'as-is' to determined inflows from the McIvor Creek catchment for the determined durations from the Rain-on-Grid design hydrology. The following are the hydrologic parameters used in the assessment for the model.

A.1.1 Rainfall Depths

Rainfall depths for the Heathcote township were extracted from ARR2019 Data Hub[4]. Areal Reduction Factors (ARFs) and temporal patterns were sourced from the ARR Data Hub for the URBS model update. The Intensity-Frequency-Duration (IFD) depths were sourced from the Bureau of Meteorology (BoM) online IFD tool[5]. The datasets were based on the coordinates of the centroid of the catchment (-36.99, 144.74).

A.1.2 Rainfall Losses

An initial and continuing loss URBS model was used to remain consistent with previous calibration to understand the riverine impacts from McIvor Creek on the township. The initial and continuing losses represented in Table A-1 show a changing loss model dependent on flood event for the initial losses.

Table A-1 Previously Calibrated URBS model Design Event Losses

Flood Events	Initial Losses (mm)	Continuing Loss (mm/day)
20%	35	0.3
10%	25	
5%	20	
2%	15	
1%	10	
0.5%, 0.2%, 0.1% and PMP	5	

A.1.3 URBS Parameters

The URBS parameters remained consistent with the previous design modelling, shown in Table A-2.

Table A-2 Adopted URBS Parameters

	α	m	β
AEP Flood Event	0.19	0.80	2.0

[4] http://data.arr-software.org/
[5] http://www.bom.gov.au/water/designRainfalls/revised-ifd?year=2016

APPENDIX B

1% AEP EXISTING FLOOD MAPS

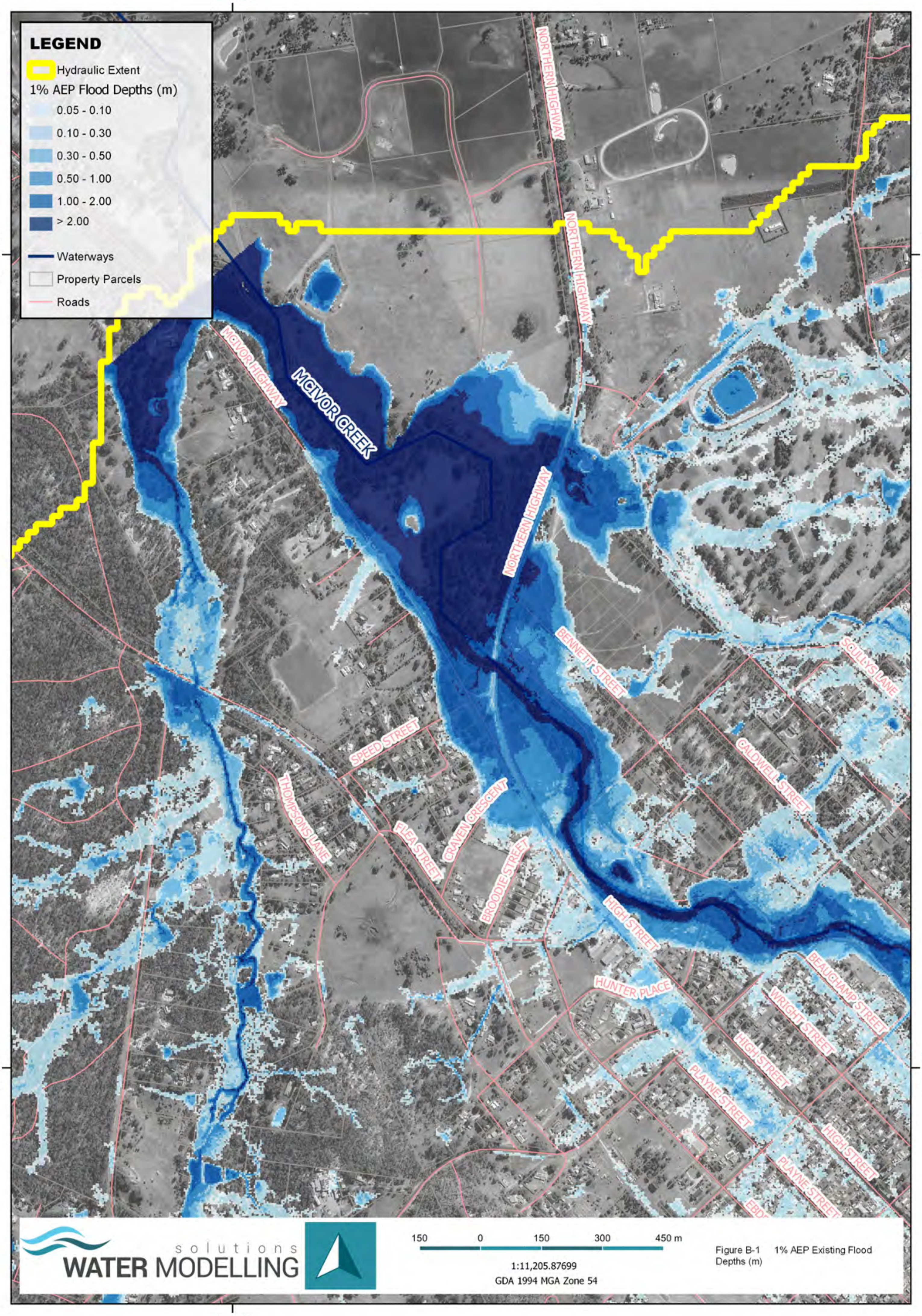

Figure B-1 1% AEP Existing Flood Depths (m)

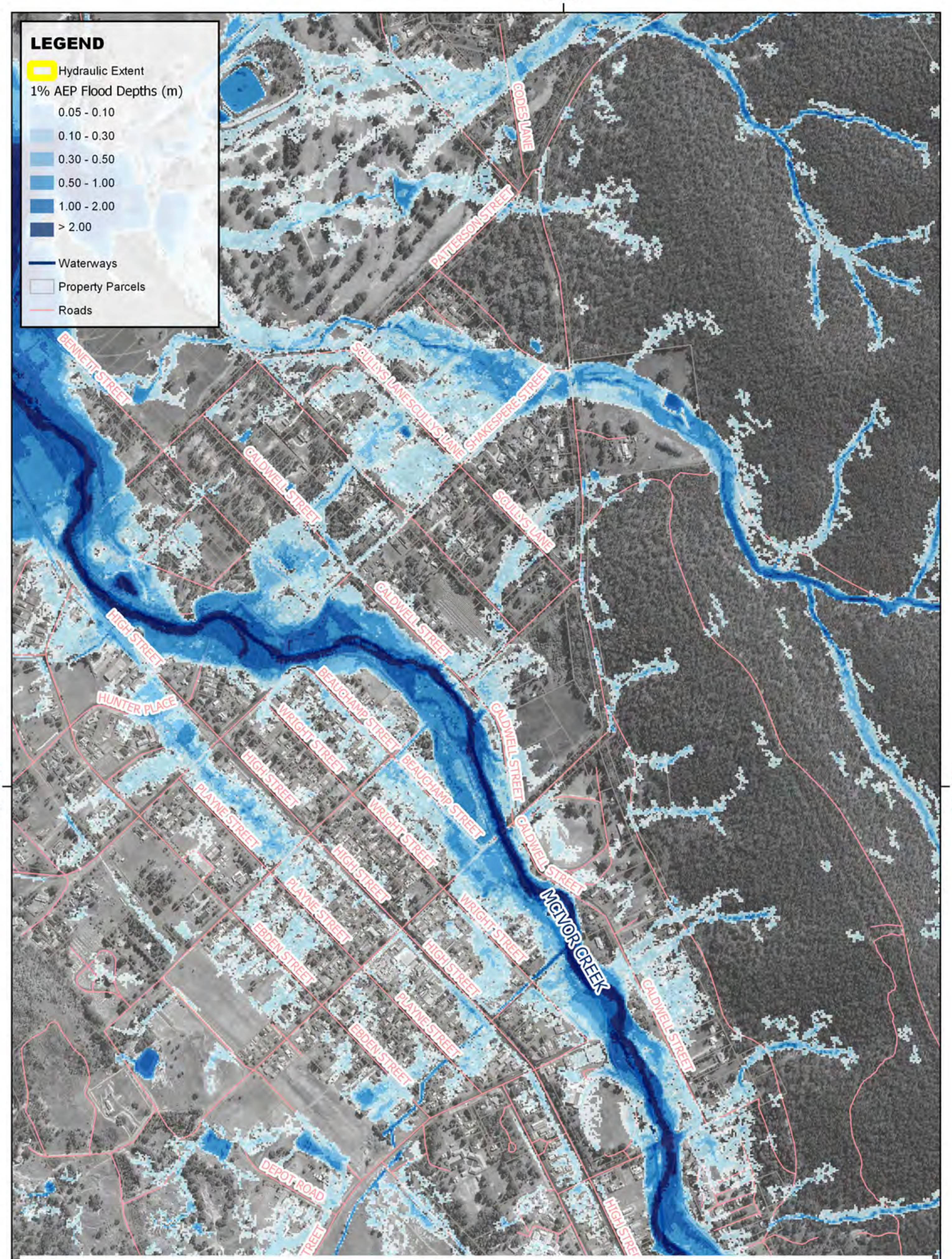

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Figure B-2 1% AEP Existing Flood Depths (m)

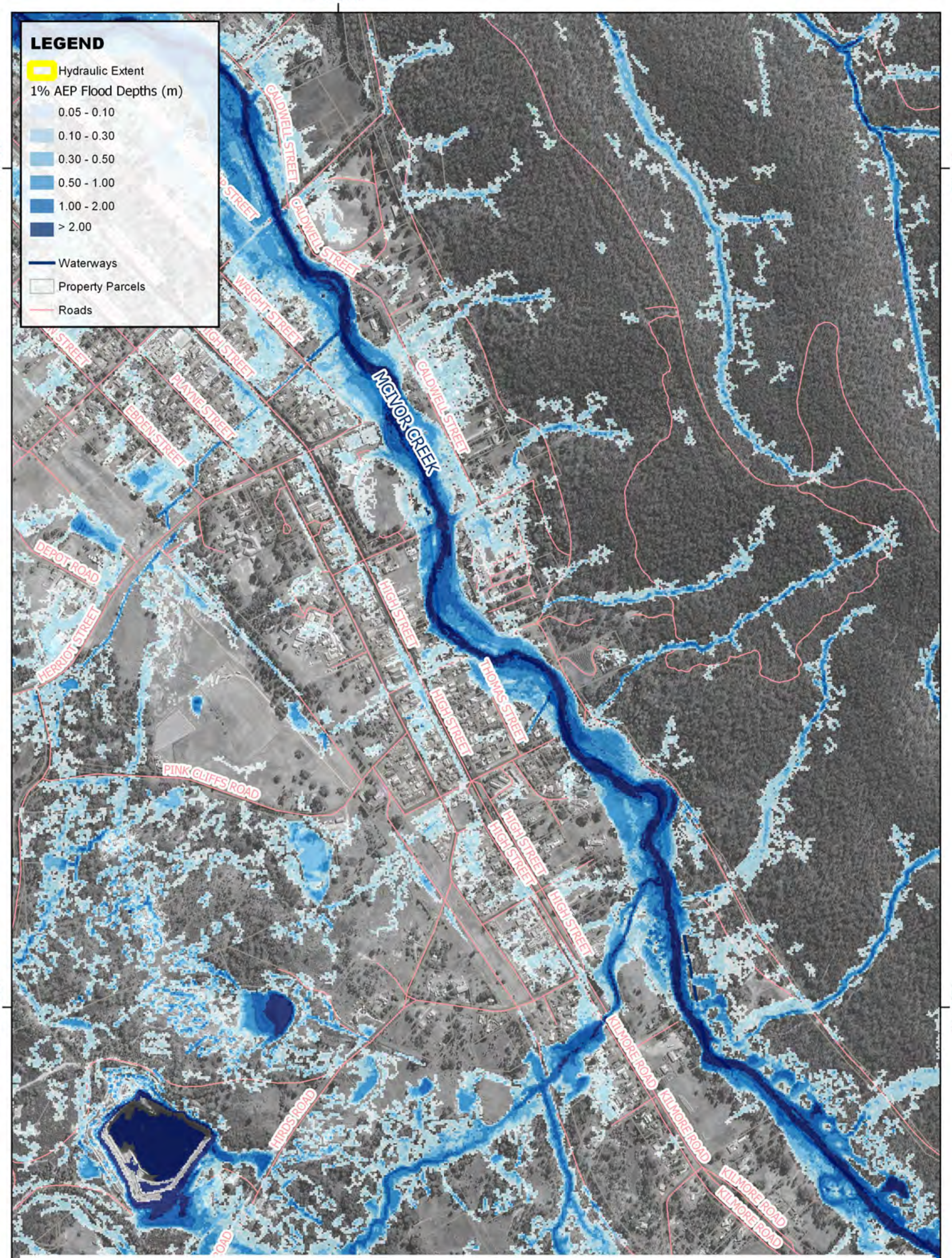

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Figure B-3 1% AEP Existing Flood Depths (m)

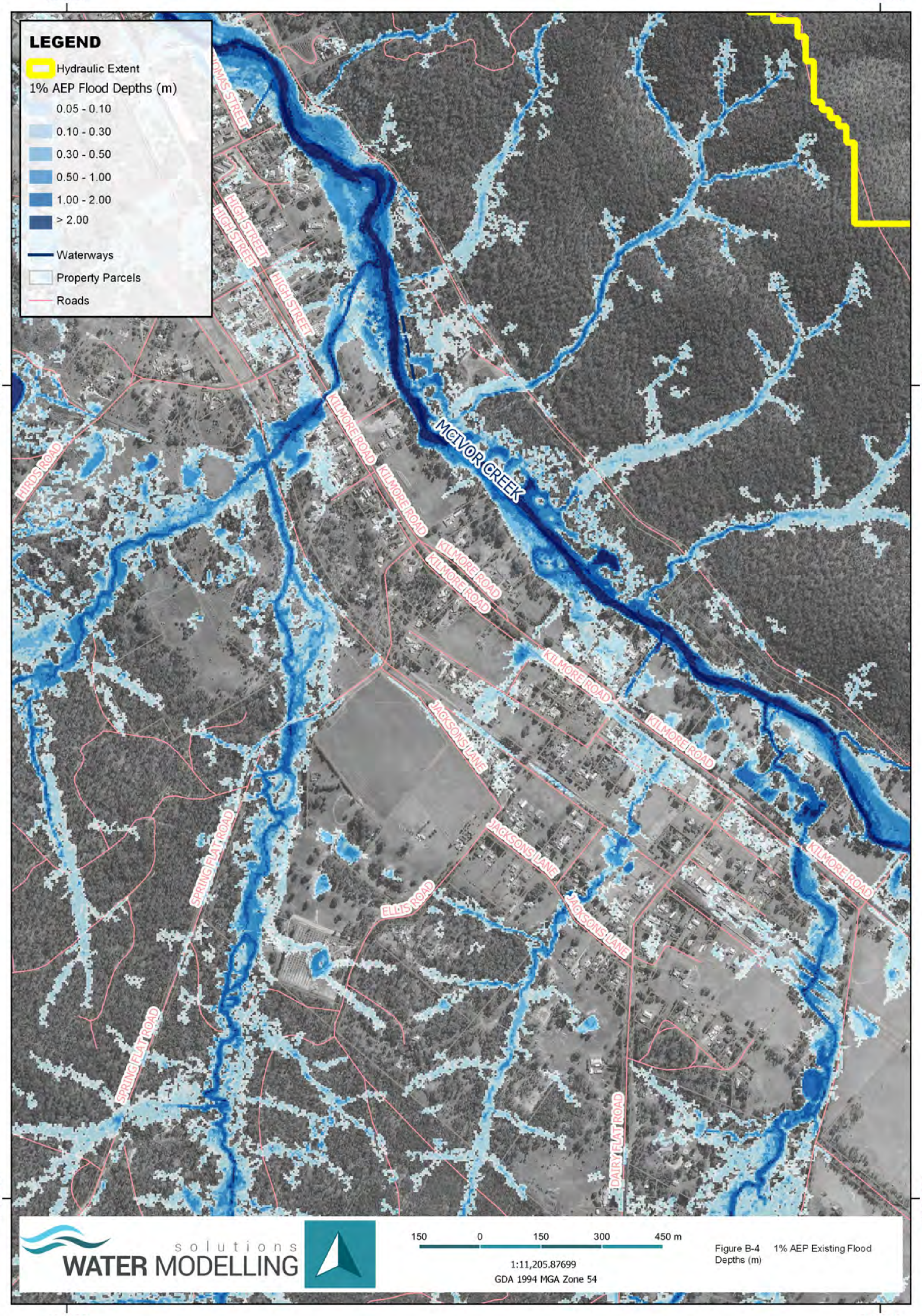

Figure B-4 1% AEP Existing Flood Depths (m)

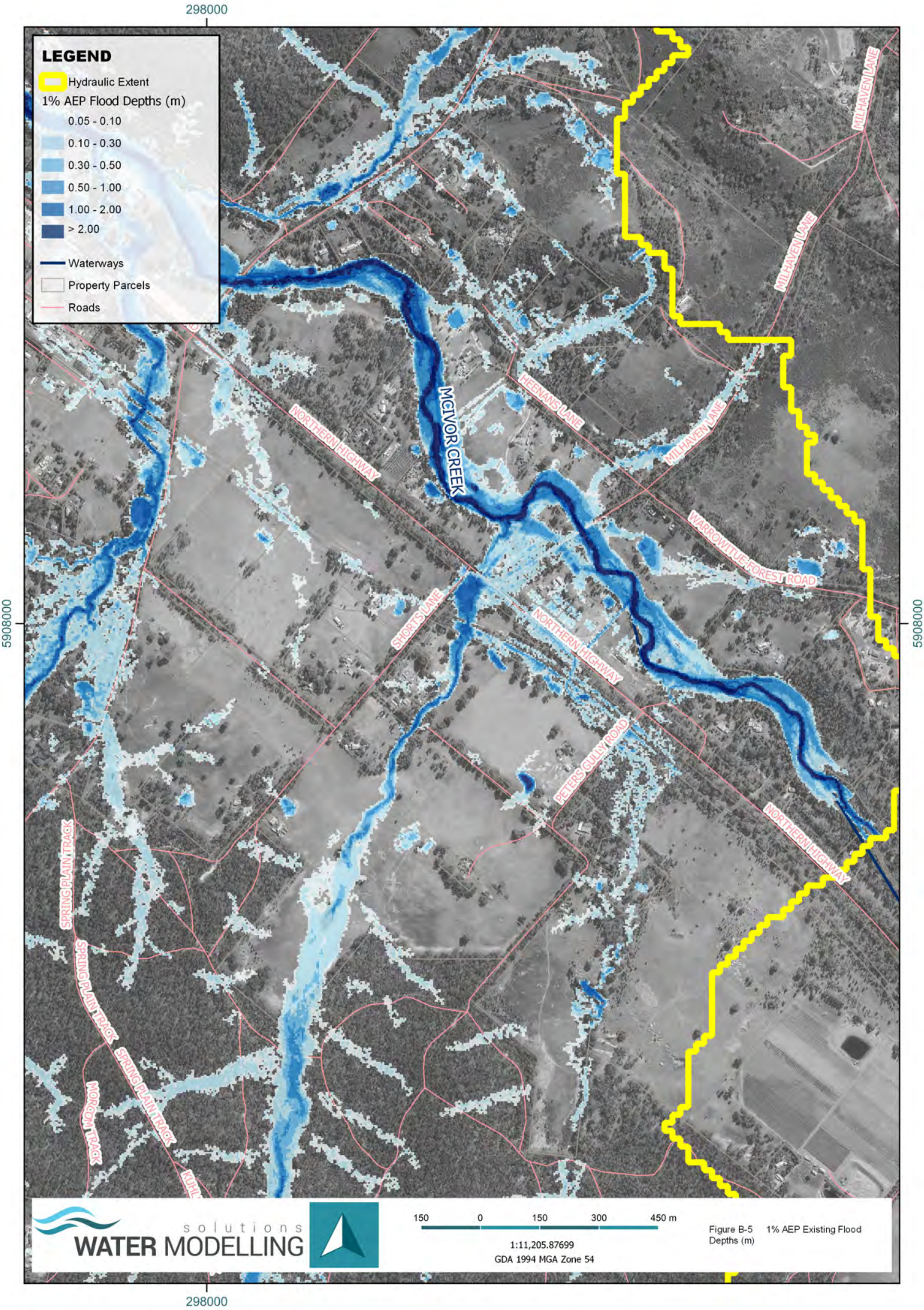

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Figure B-5 1% AEP Existing Flood Depths (m)

APPENDIX C

AFFLUX MAPS OF CLIMATE CHANGE SCENARIO

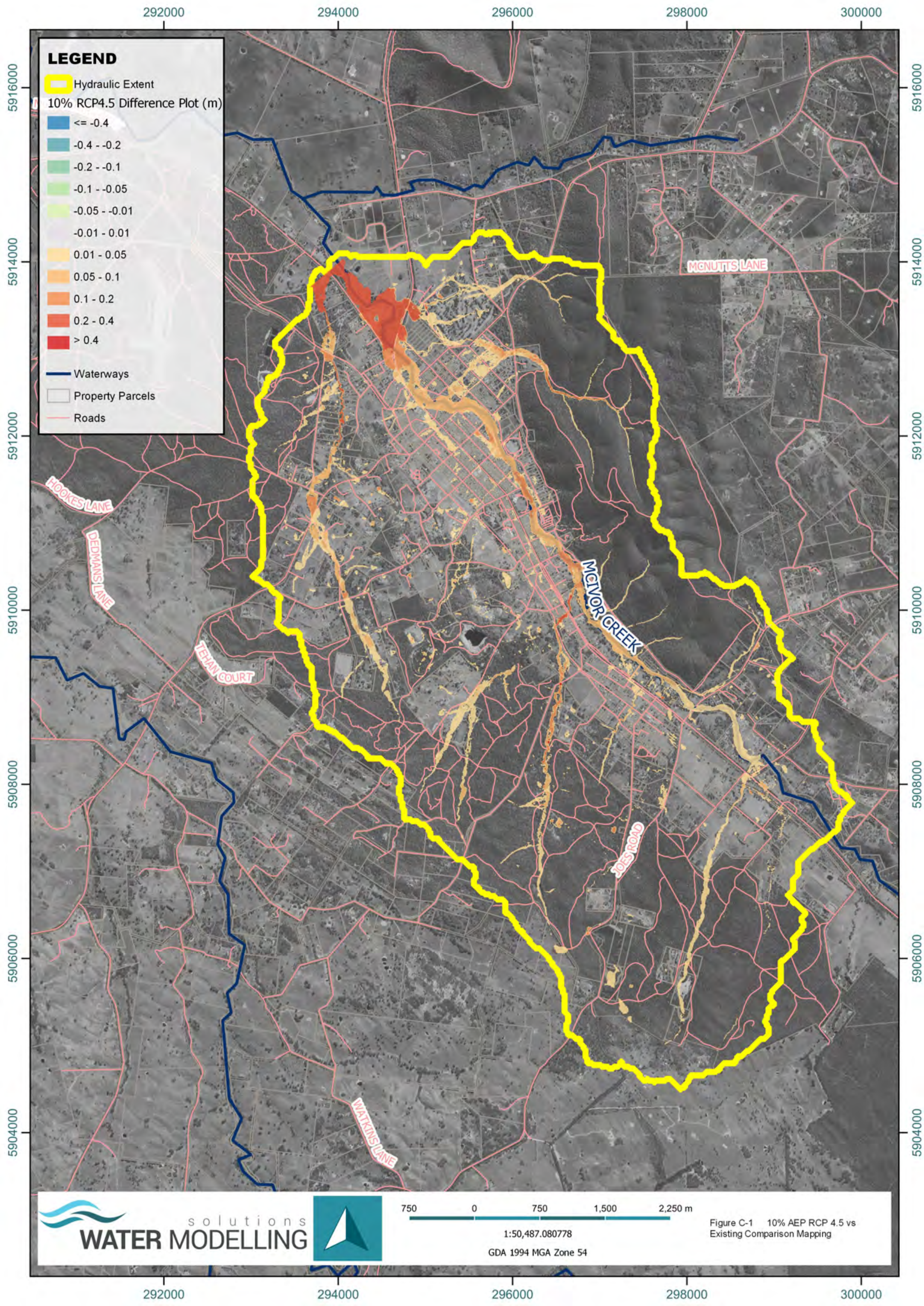

Figure C-1 10% AEP RCP 4.5 vs Existing Comparison Mapping

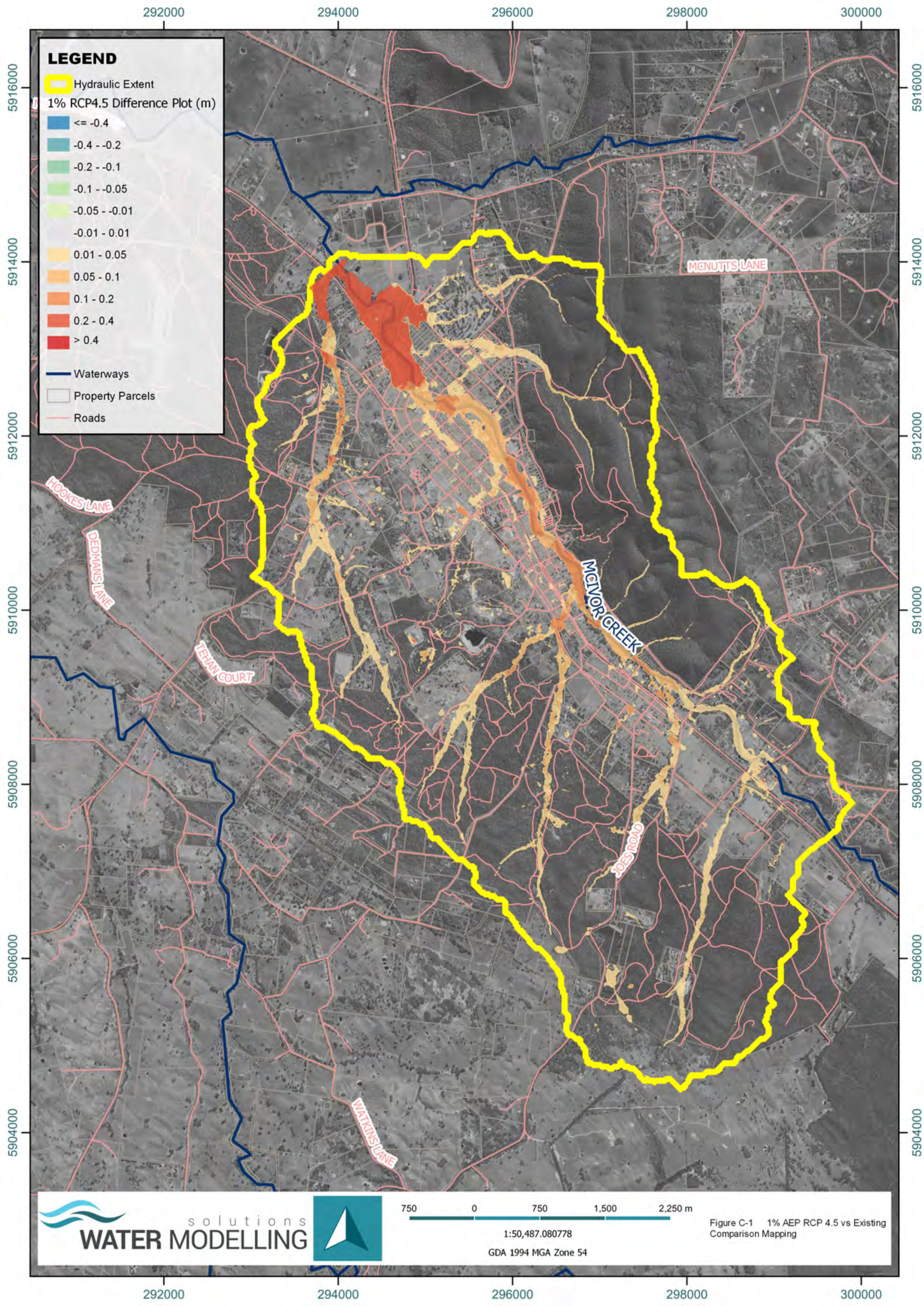

Figure C-1 1% AEP RCP 4.5 vs Existing Comparison Mapping

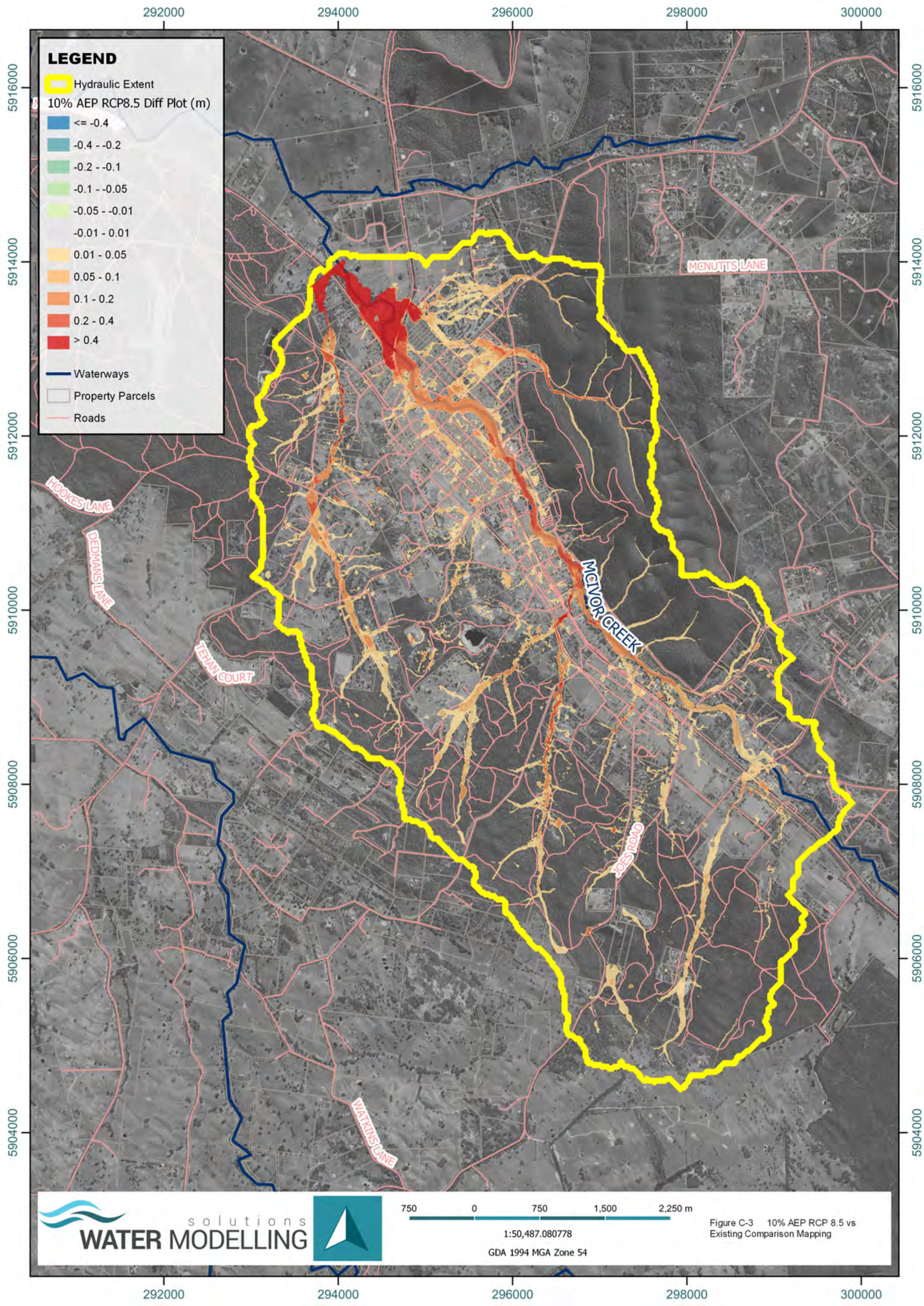

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Figure C-3 10% AEP RCP 8.5 vs Existing Comparison Mapping

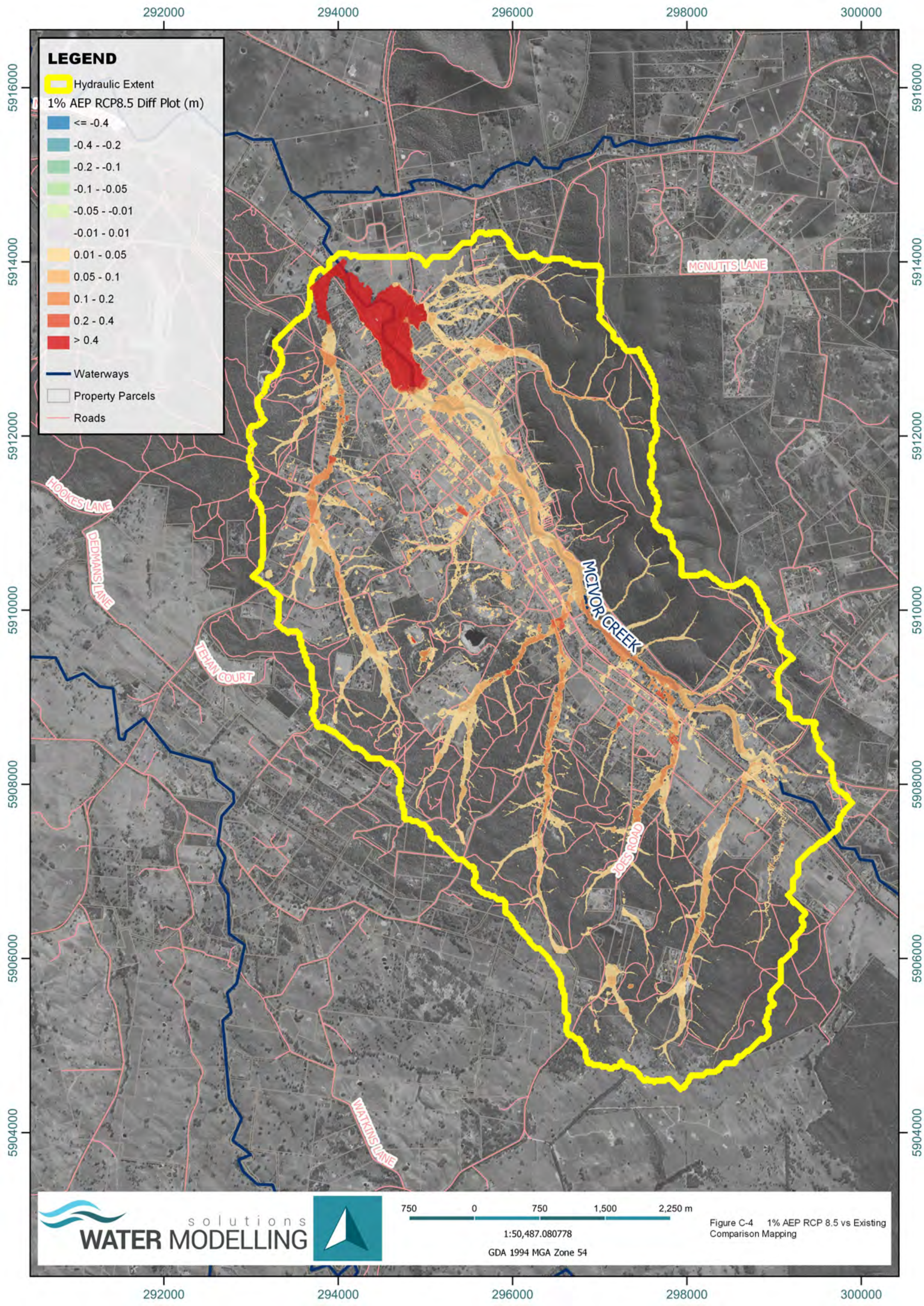

Figure C-4 1% AEP RCP 8.5 vs Existing Comparison Mapping

APPENDIX D

AFFLUX MAPS OF ROUGHNESS

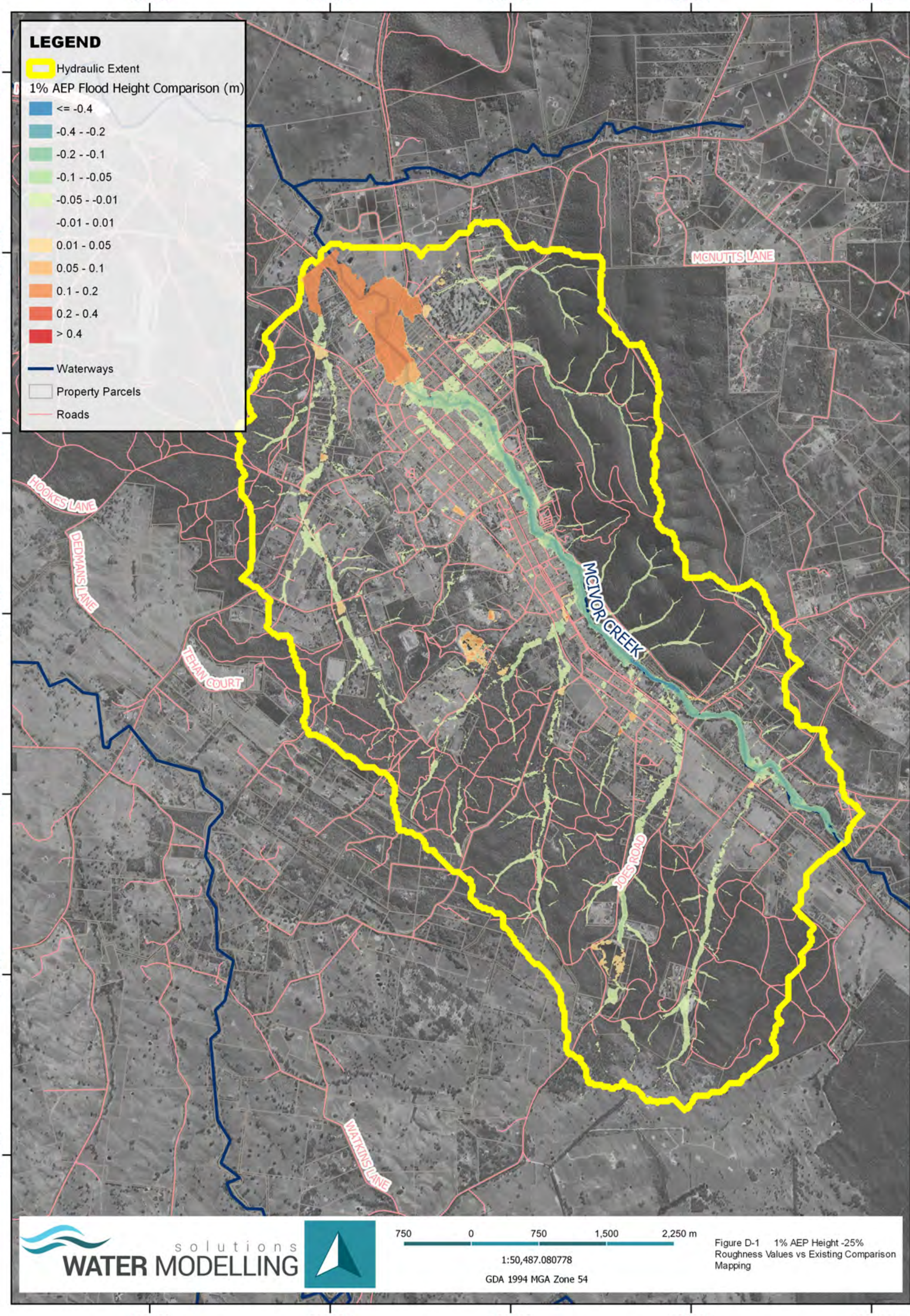

Figure D-1 1% AEP Height -25% Roughness Values vs Existing Comparison Mapping

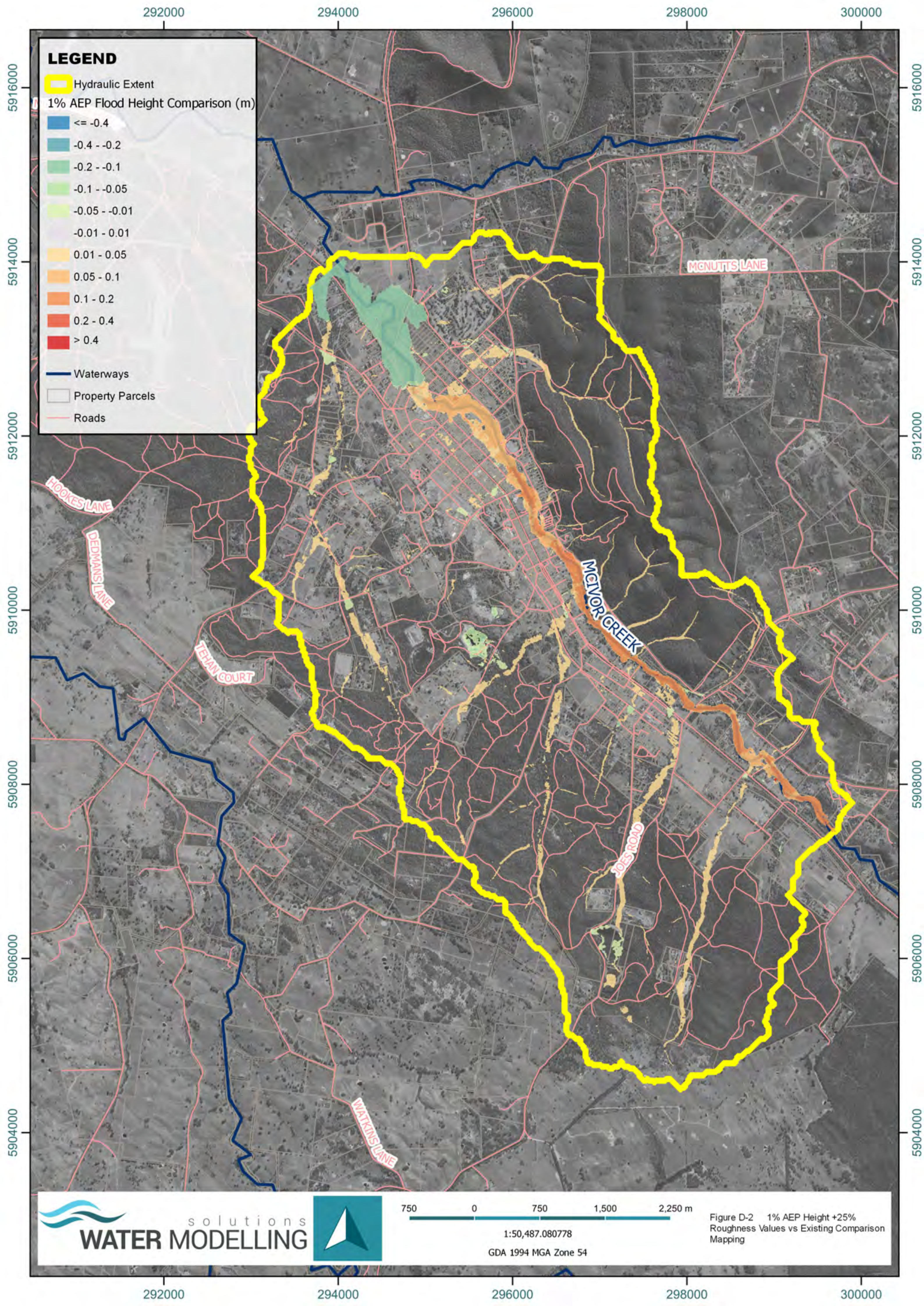

Figure D-2 1% AEP Height +25% Roughness Values vs Existing Comparison Mapping

APPENDIX E

AFFLUX MAPS OF BLOCKAGES SCENARIOS

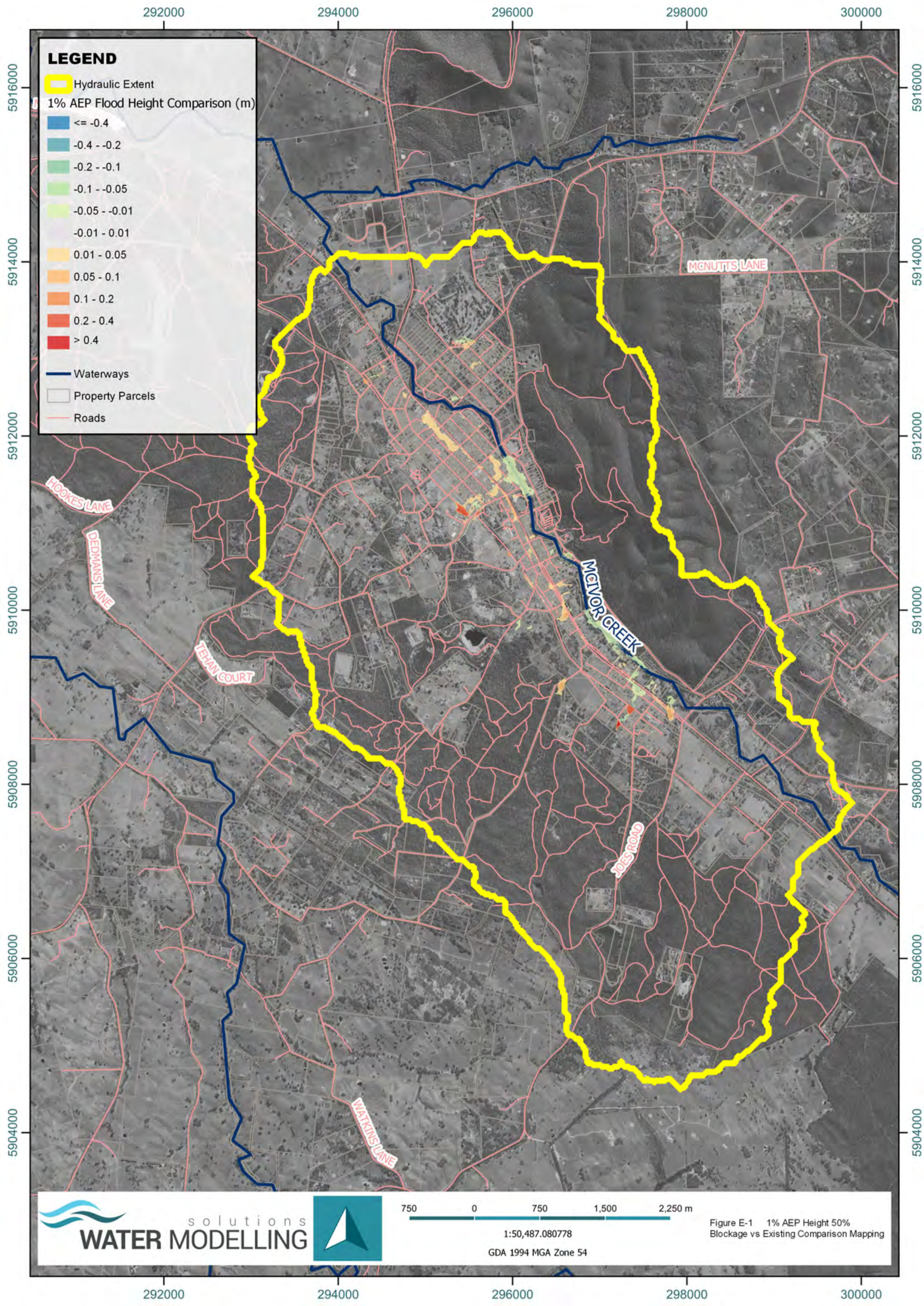

Figure E-1 1% AEP Height 50% Blockage vs Existing Comparison Mapping

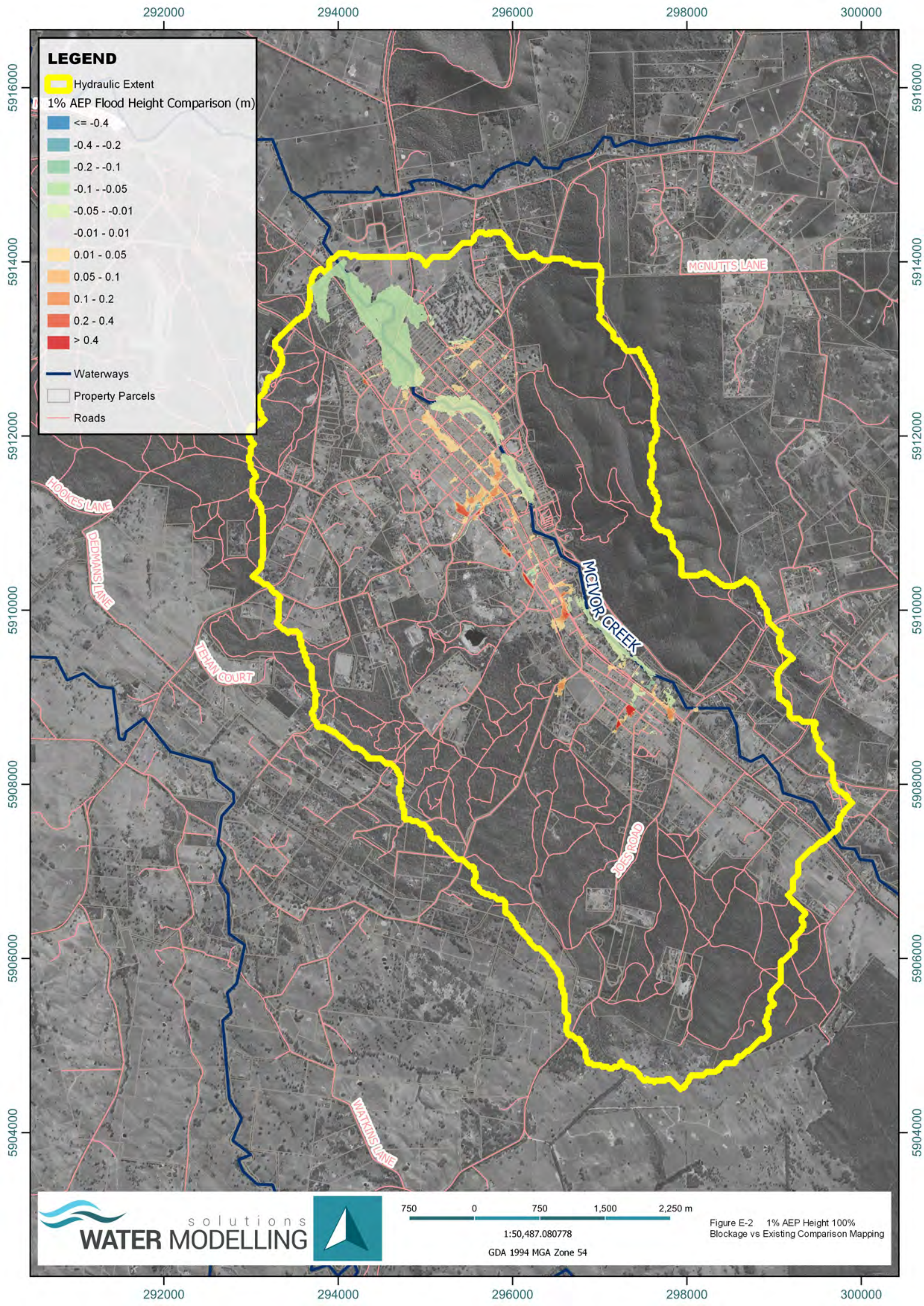

Figure E-2 1% AEP Height 100% Blockage vs Existing Comparison Mapping

APPENDIX F

DETAILED MITIGATION OPTIONS MAPS

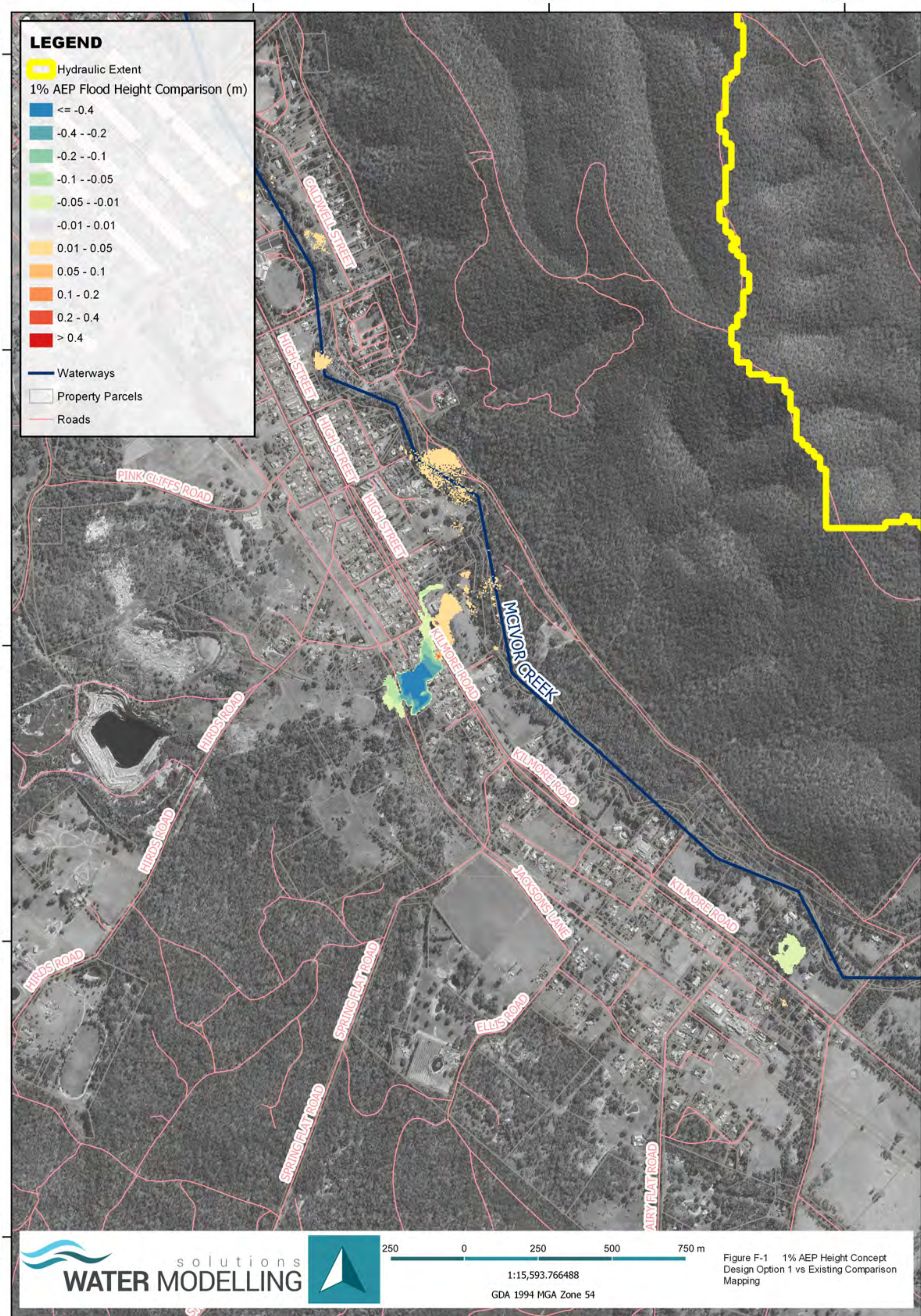

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Figure F-1 1% AEP Height Concept Design Option 1 vs Existing Comparison Mapping

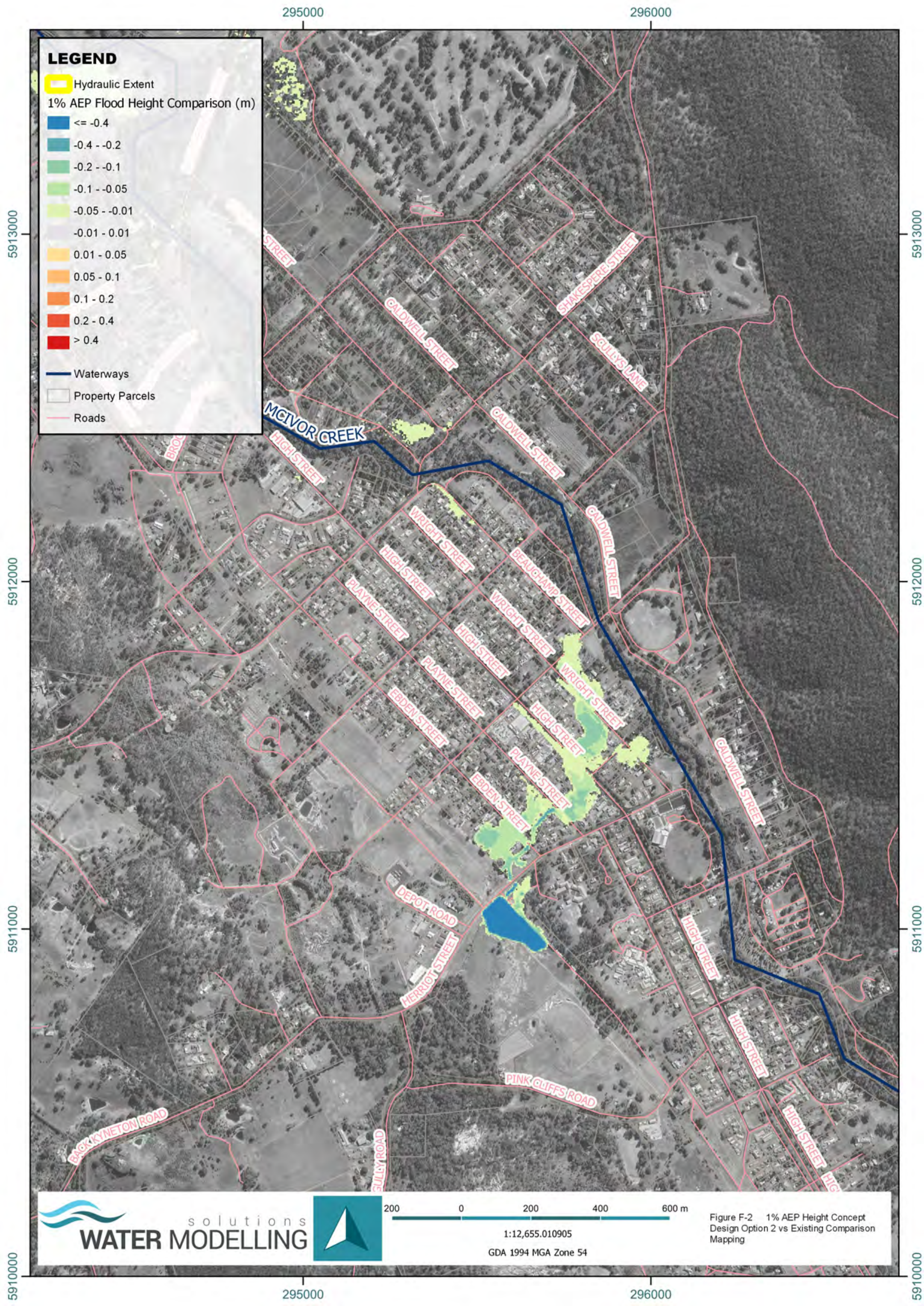
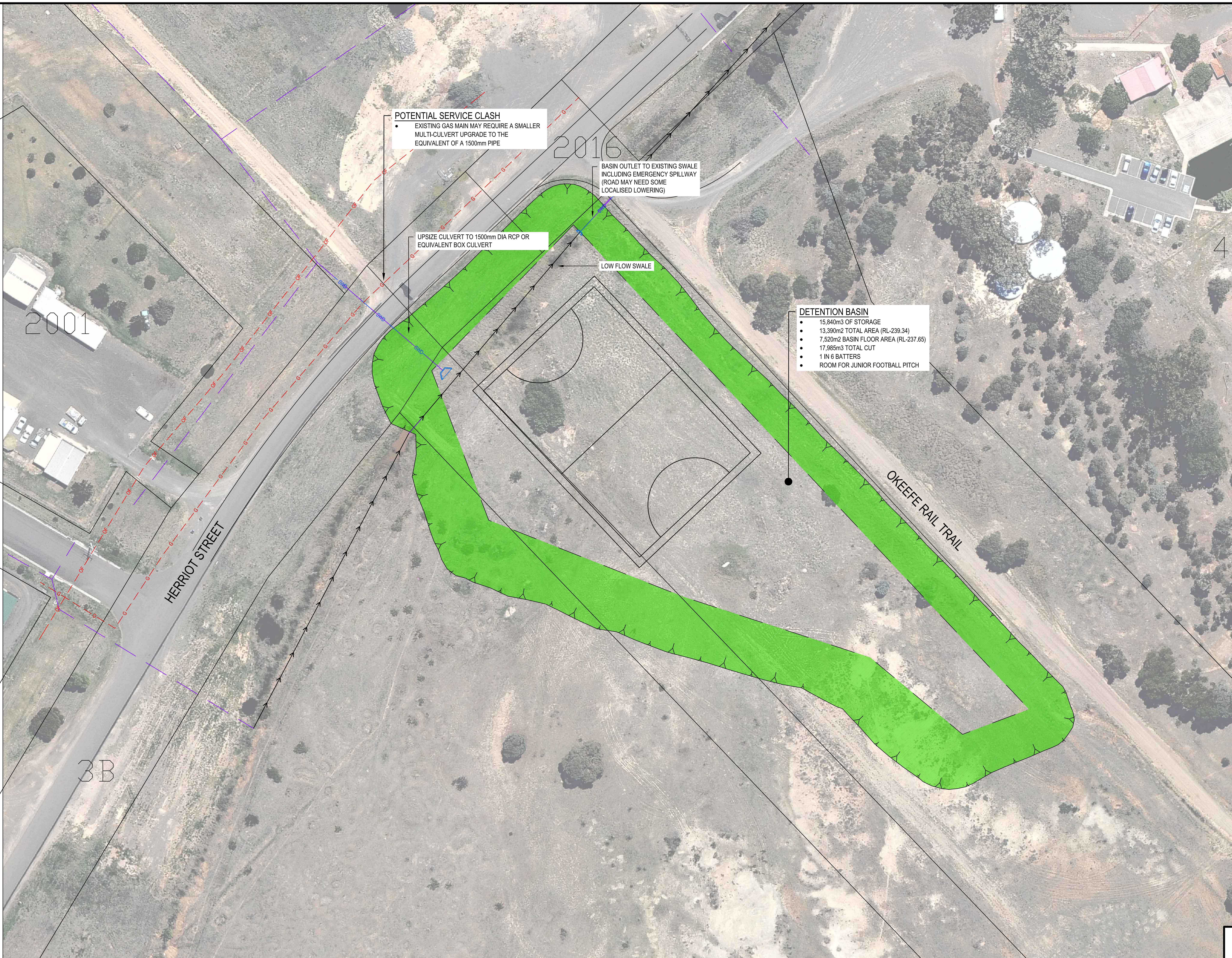


Figure F-2 1% AEP Height Concept Design Option 2 vs Existing Comparison Mapping

DATE PLOTTED: 25 August 2021 2:42 PM BY : ED HENTY



LEGEND

	FEATURE SURVEY
— 235.0 —	EXISTING CONTOURS MAJOR & LABEL MINOR & LABEL
SWD	PROPOSED DRAINAGE PIPE & PIT
SWD	EXISTING DRAINAGE
OF	EXISTING OPTIC FIBRE
S	EXISTING SEWER
W	EXISTING POTABLE WATER
G	EXISTING GAS
T	EXISTING TELECOMMUNICATIONS

WARNING

BEWARE OF UNDERGROUND SERVICES

THE LOCATION OF UNDERGROUND SERVICES ARE APPROXIMATE ONLY AND THEIR EXACT POSITION SHOULD BE PROVEN ON SITE. NO GUARANTEE IS GIVEN THAT ALL EXISTING SERVICES ARE SHOWN.

CONTRACTOR TO VERIFY EXISTING SERVICES CONNECTION LEVELS PRIOR TO CONSTRUCTION. ANY DISCREPANCIES MUST BE IMMEDIATELY IDENTIFIED AND THE SUPERINTENDENT NOTIFIED PRIOR TO CONSTRUCTION COMMENCING.

CONCEPT DESIGN
NOT TO BE USED FOR CONSTRUCTION PURPOSES

REV	DATE	DESCRIPTION	DES	VER	APP
-	-	-	-	-	-

Figure F-3

NORTH

0 10 20m
SCALE 1:500 @A1

DRYSIDE ENGINEERING
www.dryside.com.au
ABN:45639039839

CHECKED
ED HENTY AUG 2021
APPROVED
ED HENTY AUG 2021

CITY OF BALLARAT
HEATHCOTE FLOOD MITIGATION
HEATHCOTE - JAARA JAARA COUNTRY
VIC 3523
HERRIOT STREET
DETENTION BASIN

DRAWN	DATE	SCALE	DATUM
ED HENTY	AUG 2021	1:500	MGA
DESIGNED	DATE	PROJECTION	SHEET SIZE
ED HENTY	AUG 2021	GDA94	A1

DSE21008-1102 | 1

CAD File: C:\Users\ed\Dryside Engineering Dropbox\Dryside1. Jobs\DSE21008_Heathcote_Flood_Mitigation\4 ENGINEERING\2 Drawings\DSE21008-1100-1102.dwg

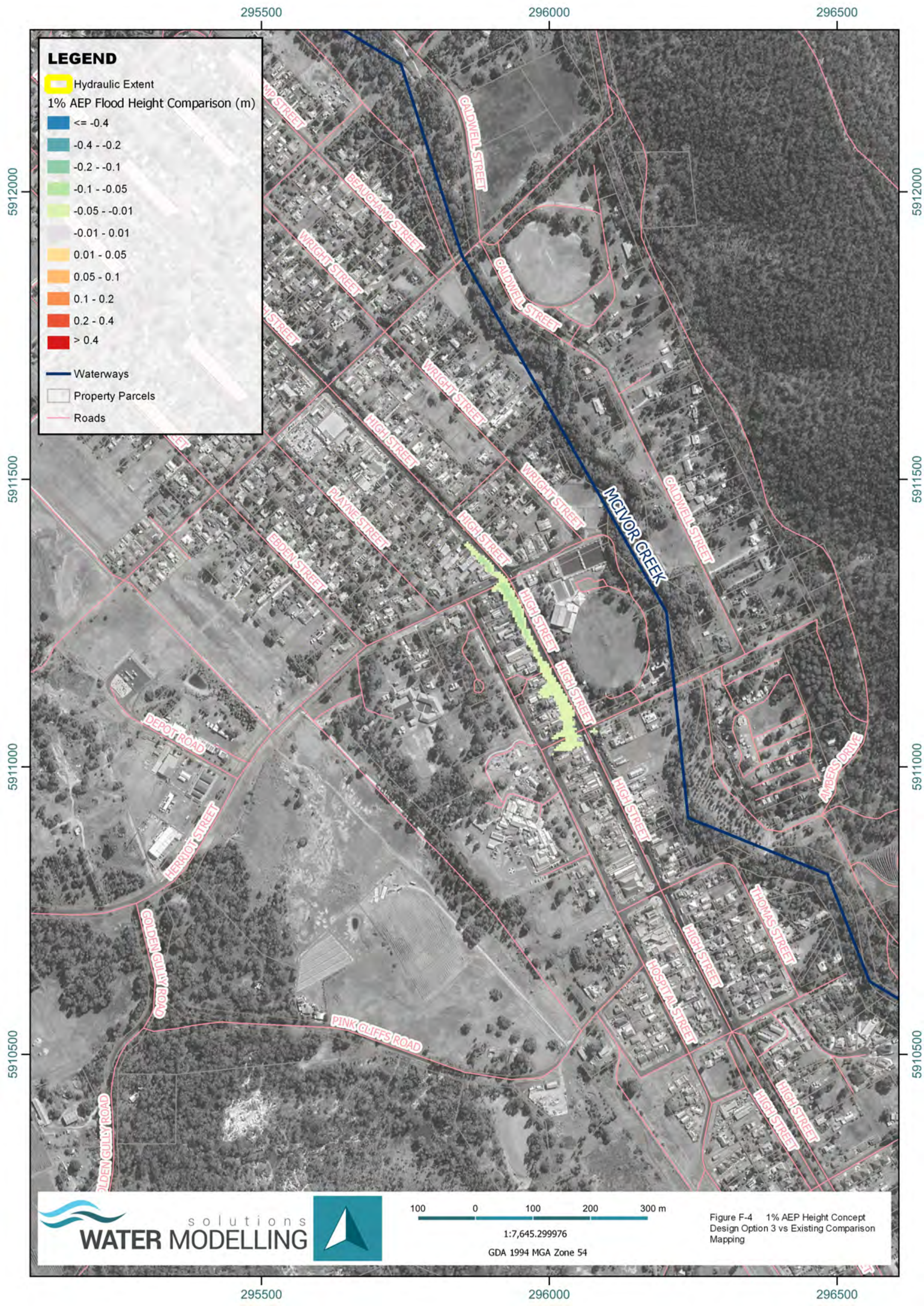


Figure F-4 1% AEP Height Concept Design Option 3 vs Existing Comparison Mapping

LEGEND

	FEATURE SURVEY
– 235.0 – / – 235.0 –	EXISTING CONTOURS MAJOR & LABEL MINOR & LABEL
SWD	PROPOSED DRAINAGE PIPE & PIT
SWD	EXISTING DRAINAGE
OF	EXISTING OPTIC FIBRE
S	EXISTING SEWER
W	EXISTING POTABLE WATER
G	EXISTING GAS
T	EXISTING TELECOMMUNICATIONS

WARNING

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CONTRACTOR TO VERIFY EXISTING SERVICES CONNECTION LEVELS PRIOR TO CONSTRUCTION. ANY DISCREPANCIES MUST BE IMMEDIATELY IDENTIFIED AND THE SUPERINTENDENT NOTIFIED PRIOR TO CONSTRUCTION COMMENCING.

CONCEPT DESIGN

NOT TO BE USED FOR CONSTRUCTION PURPOSES

REV	DATE	DESCRIPTION	DES	VER	APP
-	-	-	-	-	-

Figure F-5

NORTH

0 10 20m

SCALE 1:500 @A1

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CITY OF BALLARAT

HEATHCOTE FLOOD MITIGATION
HEATHCOTE - JAARA JAARA COUNTRY
VIC 3523

BARRACK STREET
FLOOD MITIGATION

DRAWN	DATE	SCALE	DATUM
ED HENTY	AUG 2021	1:500	MGA
DESIGNED	**DATE**	**PROJECTION**	**SHEET SIZE**
ED HENTY	AUG 2021	GDA94	A1

DSE21008-1100 | 1

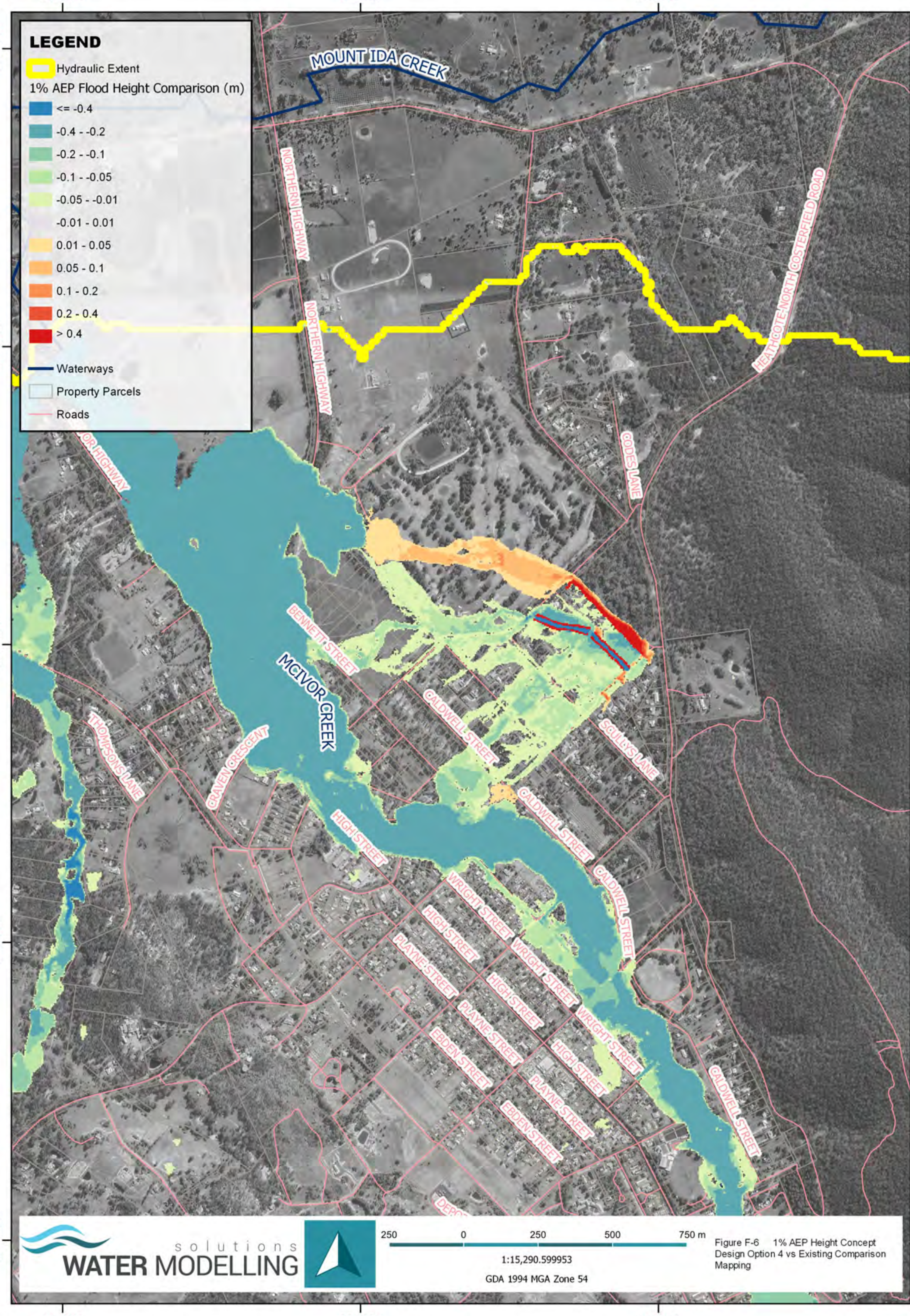

Figure F-6 1% AEP Height Concept Design Option 4 vs Existing Comparison Mapping

LEGEND

	FEATURE SURVEY
— 235.0 —	EXISTING CONTOURS MAJOR & LABEL MINOR & LABEL
SWD	PROPOSED DRAINAGE PIPE & PIT
SWD	EXISTING DRAINAGE
OF	EXISTING OPTIC FIBRE
S	EXISTING SEWER
W	EXISTING POTABLE WATER
G	EXISTING GAS
T	EXISTING TELECOMMUNICATIONS

WARNING

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CONTRACTOR TO VERIFY EXISTING SERVICES CONNECTION LEVELS PRIOR TO CONSTRUCTION. ANY DISCREPANCIES MUST BE IMMEDIATELY IDENTIFIED AND THE SUPERINTENDENT NOTIFIED PRIOR TO CONSTRUCTION COMMENCING.

CONCEPT DESIGN
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REV	DATE	DESCRIPTION	DES	VER	APP
-	-	-	-	-	-

Figure F-7

SCALE 1:1000 @A1 (0 20 40m)

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CITY OF BALLARAT
HEATHCOTE FLOOD MITIGATION
HEATHCOTE - JAARA JAARA COUNTRY
VIC 3523
SHAKESPEARE DRIVE
FLOOD MITIGATION

DRAWN	DATE	SCALE	DATUM
ED HENTY	AUG 2021	1:1000	MGA
DESIGNED	DATE	PROJECTION	SHEET SIZE
ED HENTY	AUG 2021	GDA94	A1

DSE21008-1101 | 1