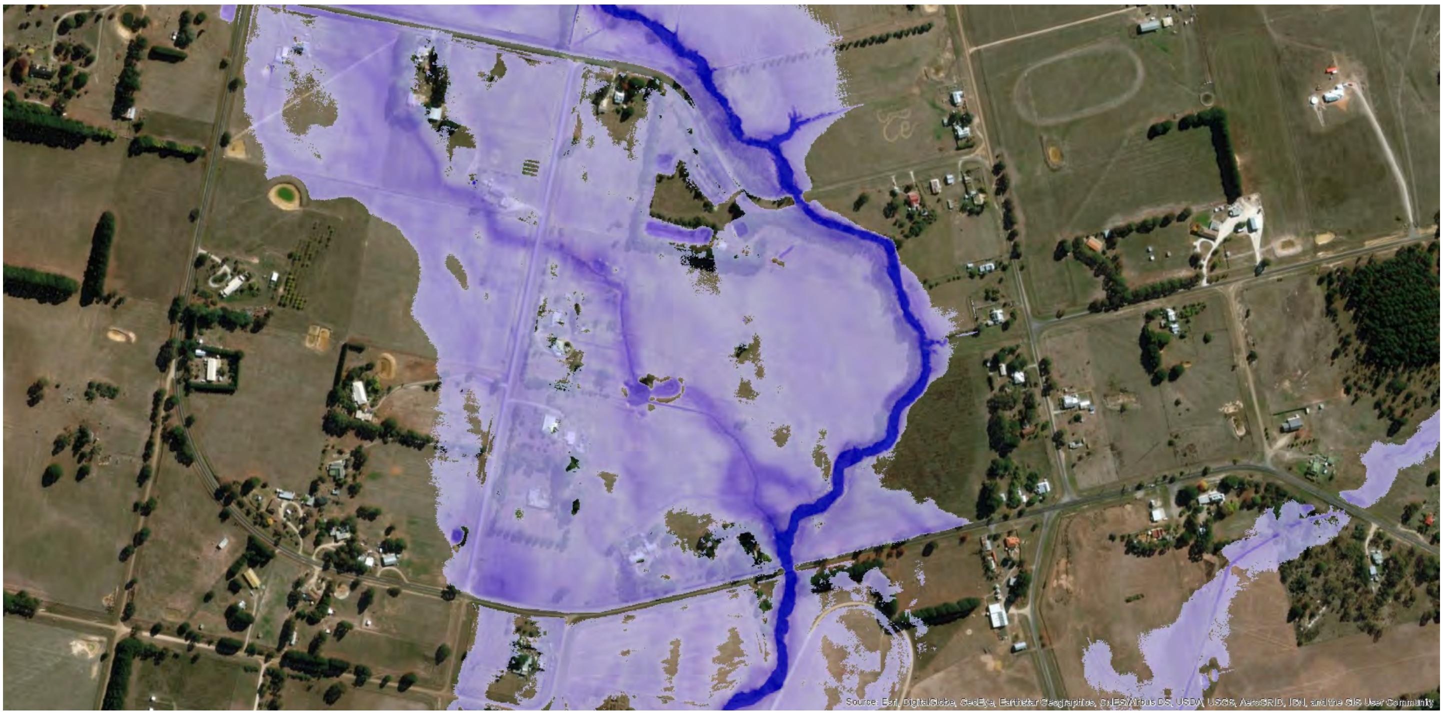


Raglan and Lexton

Preliminary Flood Study

Summary Report

Report

Prepared For

Pyrenees Shire Council

August 2018

HYDRO SPATIAL

utilis

1 Introduction

Pyrenees Shire Council (Council) has developed a Flood Planning Scoping document that sets out a strategic action plan for the Shire. The document includes a review of flood threats for the Shire and seeks to respond to the 2016 flood event (combined with the experience from the 2010 and 2011 floods). The 2016 experience highlighted the need to review the flood planning arrangements that are currently in place. A Flood Planning Committee has been established to oversee this task.

Utilis Consulting (supported by HydroSpatial) has been engaged to undertake preliminary flood investigations for Lexton, Raglan and Waubra. In June 2018, these initial investigations were completed. Further refinement for the flood models was completed in August 2018 for Lexton and Raglan.

The results of this further work is documented below.

2 Summary and Recommendations

The process followed for investigating each town is consistent for both and broadly includes:

- An overview of the study area and community consultation
- Identification of the available data and information used in the technical component
- Delineation of the catchment for the main waterways through the towns
- Development of the hydrological model using the RORB Software Package (v 6.31) and in line with the Australian Rainfall and Runoff (AR&R 2016) guidelines.
- A comparison of alternative hydrological methods
- Development of the hydraulic model using the HEC-RAS v5.03 software.
- A description of the model and its parameters
- An overview of the results of the modelling and description of flood behaviour
- An overview of flood planning and controls
- Summary and recommendations.

The investigation has applied this process consistently across both towns and is delivered in a stand-alone report for each. The key findings for each investigation and town specific recommendations include:

- Raglan has the highest number of properties that have a high likelihood of above floor flooding (AFF). This likelihood is determined by the modelling showing a depth of flooding >0.3m around the house in the 1% AEP flood scenario.
- Raglan has the highest uncertainty in flow estimation due to the significant variation in extent when the flow is varied in the model.
- Flood mitigation options appear plausible for Raglan and to test these and tighten the certainty around flood extent, depth and appropriate planning responses, **a flood study is recommended**.
- Lexton has less properties with high chance of AFF but more properties with some chance of AFF (as there is inundation around the house). When the flow is increased by 20% in the model, it increases the number of properties with a high likelihood of AFF.

Town	Properties with Above Ground Flooding	Properties with Chance of AFF	Properties with High Likelihood of AFF	Properties with High Likelihood of AFF if flows increased 20%	Recommendation
Raglan	29	11	4	4	Flood Study
Lexton	38	10	2	5	Progress to flood planning and response stages

3 Comparison with initial (simple) investigation

Raglan

Hydrology Changes

The main change to the hydrology model was to build a more complex model using additional sub-catchments and reaches to better represent the catchment. This brings the level of detail in the hydrological model to being line with what would be expected as part of a detailed flood investigation.

The update to the model had a fairly minimal impact of the critical duration, in both the simple and updated model the 6 and 12 hour events had a fairly similar distribution of peak flows. The 12 hour had a slightly greater mean and significantly greater maximum flow and therefore it was adopted as the critical duration.

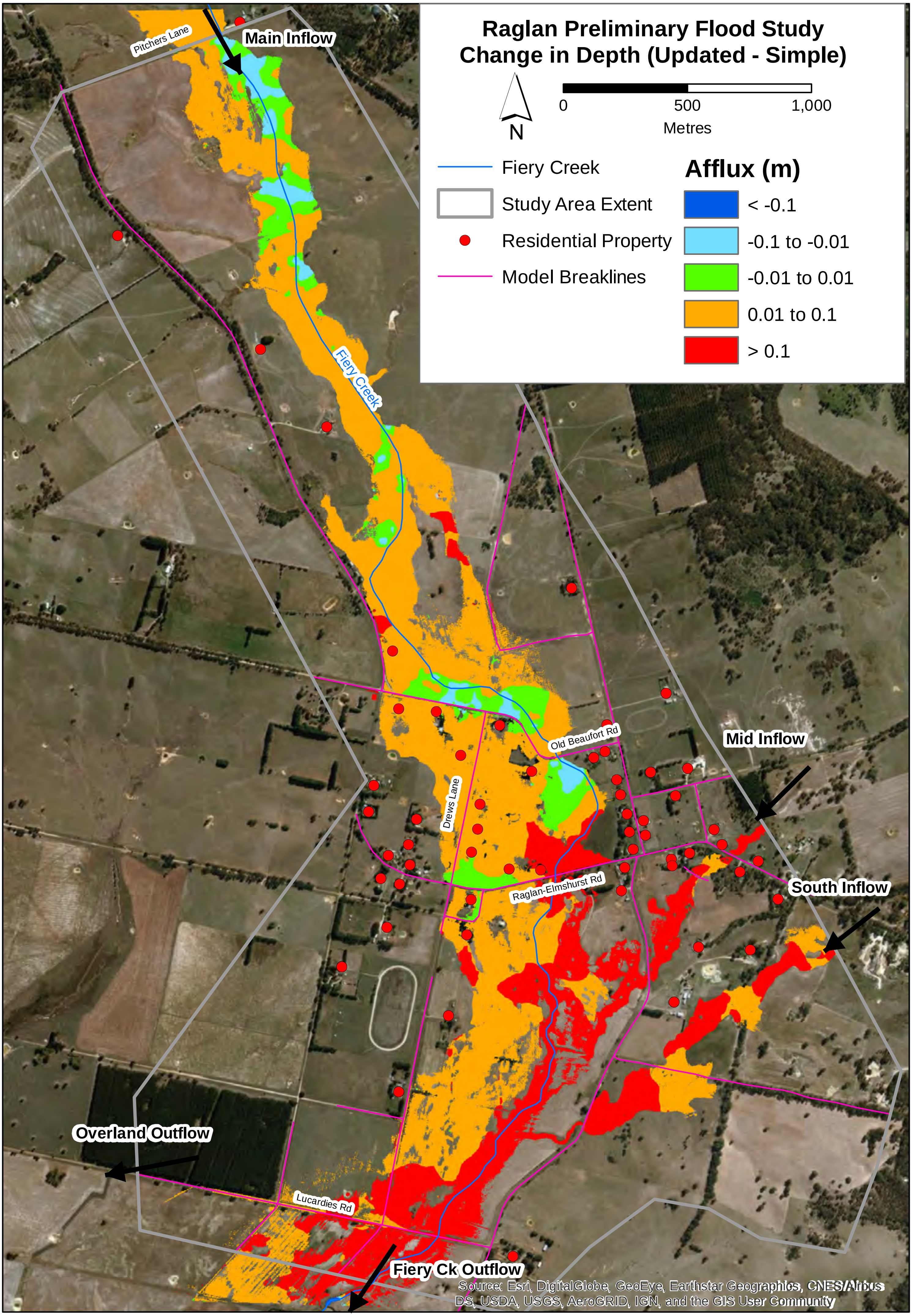
The update to the model had no impact on the chosen critical temporal pattern, with both models choosing the TP22 pattern[1].

Hydraulic Changes

The main changes to the hydraulic model were to implement structures as per measured dimensions as well as a spatially variable roughness. This brings the model in line with the standard of a detailed flood investigation.

These changes, along with the hydrological changes have had a significant impact on some locations in the model. Upstream of town, there is a variable impact on the main creek channel (with some locations increasing, and others decreasing). This is likely due to the variable roughness. Further downstream the changes are uniformly increasing. This is likely due to a combination of the structures, some changes to the tributary inflow hydrology and variable roughness. The following afflux map, where the simpler model values were subtracted from the updated model values, shows these significant changes.

[1] TP - temporal pattern generated from AR&R 2016)


Raglan Preliminary Flood Study
Change in Depth (Updated - Simple)
N
0
500
1,000
Metres
Fiery Creek
Study Area Extent
Residential Property
Model Breaklines
Afflux (m)
< -0.1
-0.1 to -0.01
-0.01 to 0.01
0.01 to 0.1
> 0.1
Pitchers Lane
Main Inflow
Fiery Creek
Old Beaufort Rd
Mid Inflow
Drews Lane
Raglan-Elmshurst Rd
South Inflow
Overland Outflow
Lucardies Rd
Fiery Ck Outflow
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Lexton

Hydrology Changes

The main change to the hydrology model was to build a more complex model using additional sub-catchments and reaches to better represent the catchment. This brings the level of detail in the hydrological model to that of a detailed flood investigation.

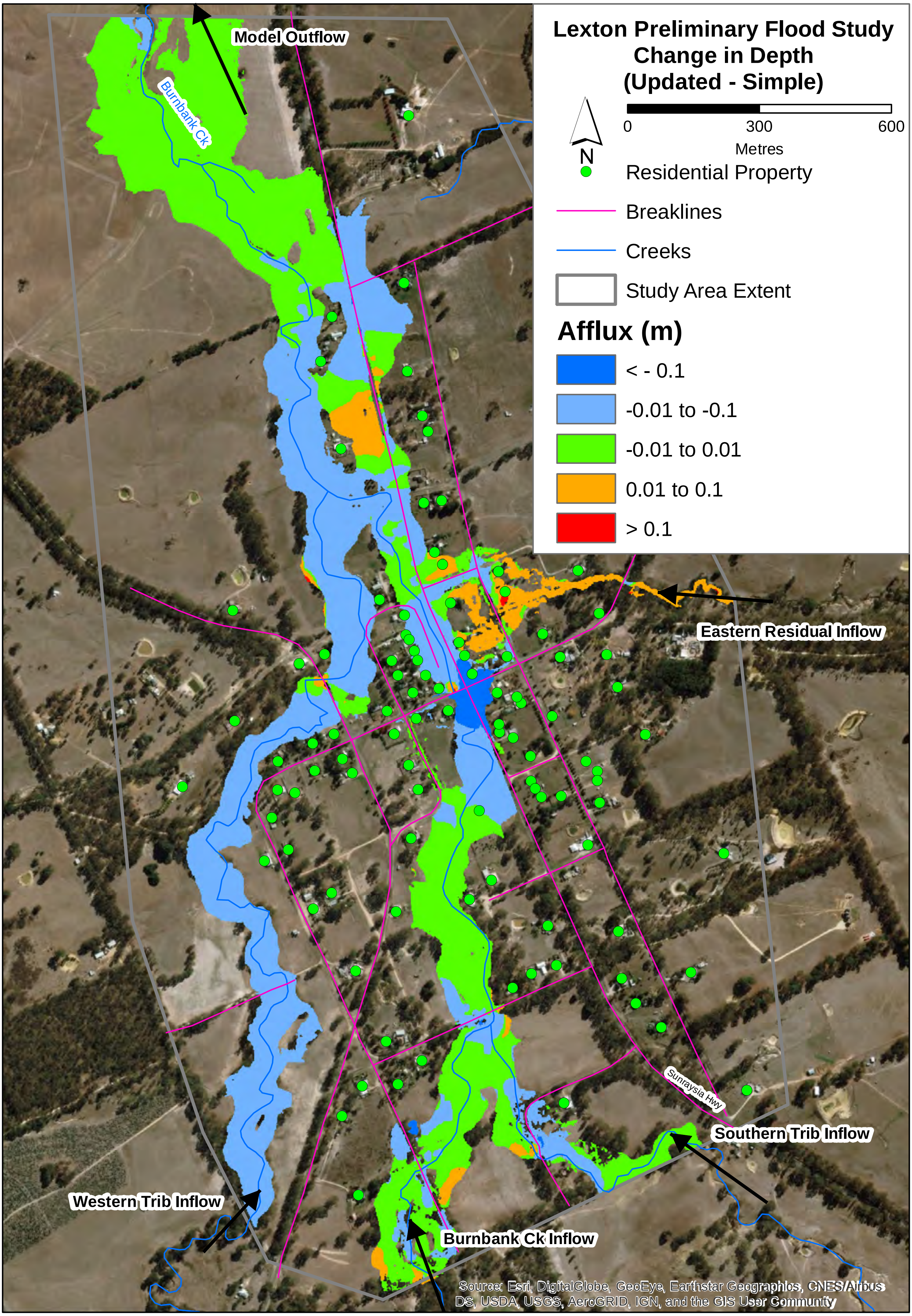
The update to the model had a fairly minimal impact on the critical duration. In both the simple and updated model the 6 and 12 hour events had a similar distribution of peak flows. The 12 hour had a slightly greater mean and significantly greater maximum flow and therefore it was adopted as the critical duration.

The update to the model changed the rainfall temporal pattern that was used as the critical pattern. In the simpler model, the critical pattern was TP22 while in the updated model it is TP28. This change has very little impact on the peak flows that are modelled, however it has a significant impact on the flood hydrograph.

Hydraulic Changes

The main changes to the hydraulic model were to implement structures as per measured dimensions as well as a spatially variable roughness. This brings the model to more in line with the standard for a detailed investigation.

These changes, along with the hydrological changes, had some impact on the overall flood depths for the 1% AEP design flood. The following afflux map where the simpler model values were subtracted from the updated model values, show that generally there has been little change in the flood depths. In many locations the change is less than 0.1m. The updated model tended to produce slightly lower depths than the simpler model with the exception of the eastern inflow.


Lexton Preliminary Flood Study
Change in Depth
(Updated - Simple)
0
300
600
Metres
N
Residential Property
Breaklines
Creeks
Study Area Extent
Afflux (m)
< - 0.1
-0.01 to -0.1
-0.01 to 0.01
0.01 to 0.1
> 0.1
Model Outflow
Burnbank Ck
Eastern Residual Inflow
Sunraysia Hwy
Southern Trib Inflow
Western Trib Inflow
Burnbank Ck Inflow
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Lexton
Preliminary Flood Study

Report

Prepared For

Pyrenees Shire Council

August 2018

HYDRO SPATIAL

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Project Details	Lexton Preliminary Flood Study
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Version	Type	Review	Release	Date
1	Draft	Brad Henderson	Utilis	14/09/2018

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1 Introduction

1.1 Study Background

Pyrenees Shire Council (Council) has a number of towns within its Local Government Area that are flood prone, including Lexton. The extent of the flooding and the associated flood risk is largely unknown and this creates difficulties for Council to assess proposed developments with respect to flood issues. As a result, Council is seeking to proceed through the floodplain risk management process (i.e. flood study, floodplain risk management study and plan, plan implementation). However, Council has limited resources and therefore needs to prioritise the towns that have the greatest flood risk.

Council has engaged Utilis and HydroSpatial to undertake a preliminary flood study to determine whether a full flood study is required as well as provide flood risk and flood planning advice for the town.

1.2 Study Objective

The main objectives of the study are to provide an overview of the flood risk within Lexton and determine whether a full flood study, or further improvements to the preliminary flood study are recommended.

1.3 Study Area

Lexton is a small town in the Pyrenees Shire Council on the banks of Burnbank Creek. Lexton is primarily residential with no retail or government services. The main industry in Lexton is sheep grazing and associated support industries.

1.3.1 Physical Description

The study area extends along Burnbank Creek through the town and as far downstream as Butler St. The study area is shown in Figure 1. Burnbank Creek flows generally from south to north and is a “gaining” stream through the study area, with an upstream width of approximately 8 m to around 14 m at the downstream end. Burnbank Ck splits the town east and west and a number of small tributaries have the potential to further split the town into segments.

The floodplain is traversed by a number of roads, The Sunraysia is the most significant and sits on a raised embankment approximately 500 mm high. A number of other local roads cross the floodplain and are potentially hydraulic controls.

Development within the floodplain is primarily rural residential with relatively low set single storey houses, most properties have other significant infrastructure such as large rural sheds.

There is limited stormwater infrastructure within the town, with no clear stormwater detention or formalised stormwater network. The roads are drained using table drains.

Figure 1 Study Area Location

1.3.2 Study Area Community

Key community statistics have been extracted using the Lexton (SSC) area. At the 2016 census, the Lexton (SSC) covers the study area with some rural additional area. We estimate that approximately 75% of the Lexton (SSC) population is within the study area.

The community statistics provide information on the relative flood risk of the study area with respect to the average across Victoria. Table 1 shows the key statistics that have been extracted and from these it can be inferred that:

- Lexton has a lower population density (people per dwelling). This can present warning and evacuation difficulties. Particularly in single resident houses that may need assistance.
- Lexton has a greater proportion of residents that are elderly and would need assistance with evacuation and may not respond to more modern community consultation or warning techniques.
- Lexton has a lower proportion of rental properties as the rest of Victoria, who may leave the area or struggle to recover after a flood.
- Lexton has a much smaller proportion of non-English-speaking households who may need assistance interpreting warnings or flood study outputs.
- The average household income in Lexton is significantly lower than the rest of Victoria, indicating potential difficulty to financially recover from flood damage.
- There are a few households without any vehicles that may need assistance to evacuate.

Table 1: Key Community Statistics

Measure	Lexton	Rest of Victoria
Number of People	231	N/A
Average People per Dwelling	1.7	2.8
Percentage Elderly Population (> 65 years of age)	23.1	15.6
Percentage Very Young Population (< 5 years of age)	4.4	6.3
Percentage Young Population (5 – 14 Years of Age)	15.3	12.0
Percentage Rental Properties	11.7	28.7
Percentage Non-English-Speaking Households	3.7	27.8
Median Household Income ($/Week)	777	1,419
Number of Households with No Vehicles	3	N/A

1.4 Available Data

The following data was available for the risk assessment:

- LiDAR derived 2 m Digital Elevation Model, provided by Water Technology Pty Ltd.
- Aerial Photography of the site at a 50 cm pixel resolution captured, available as a basemap within ESRI ArcGIS.
- Cadastral Boundaries made available from the Victorian Spatial DataMart.
- Intensity-Frequency-Duration tables for the catchment area using BoM IFD2013, available from the Bureau of Meteorology.
- Recommended Hydrological Modelling parameters (loss values, temporal patterns etc). available through the AR&R 2016 Data Hub (2016_v1).
- Beaufort Flood Study (Water Technology, 2008).
- Shuttle Radar Topography Mission (SRTM) DEM available from Geoscience Australia.

2 Hydrological Modelling

This chapter outlines the hydrological modelling that has been undertaken. The modelling has been undertaken using the RORB Software Package (v 6.31) and in line with the Australian Rainfall and Runoff (AR&R 2016) guidelines.

Modelling has been undertaken of the 1% Annual Exceedance Probability (AEP) design flood, which is typically used to limit flood exposure and damage to development. 1% AEP means that a flood of this magnitude has a 1% chance of occurring in any given year. This means that in some years there may be two or more floods of this magnitude or alternatively, a thousand years could pass before a flood of this magnitude occurs. The 1% AEP is sometimes referred to as the 1 in 100 Year Average Recurrence Interval (ARI) flood, which does not mean that these floods only occur every 100 years.

2.1 Catchment Delineation

The catchment delineation has been undertaken using the hydrologically enforced SRTM DEM, which is a low (30m) resolution DEM covering all of Australia. The spatial location of the catchment is shown in Figure 4. The calculated catchment size is 44.4 km^2. The majority of which contributes to the Burnbank Ck upstream of town, with some smaller inflows contributing within the town. The catchment has been sub-divided into eight sub-catchments to improve the catchment routing and storage representation.

2.2 Model Development

2.2.1 Design Rainfall Estimation

The design rainfall parameters have been obtained using the AR&R Data Hub (Version 2016_v1) and Bureau of Meteorology using the coordinates of the centroid of the catchment (-37.302 south, 143.503 east).

2.2.2 Loss Parameters

The rainfall loss parameters have been extracted the AR&R (2016) as well as those parameters used in the Beaufort Flood Study (2008). The rainfall loss parameters are provided in Table 2. Both sets of loss parameters have been modelled. However, as the Beaufort Flood Study parameters are based on a calibrated model using a similar hydrological modelling approach we believe these parameters are likely to be more accurate and more appropriate to use than those of the AR&R 2016 Data Hub. Therefore, the Beaufort parameters were adopted.

Table 2 Rainfall Loss Parameters

Model Parameter	Data Hub Output	Beaufort Flood Study
Initial Loss (mm)	25	19.75
Continuing Loss (mm/hr)	4.6	1.0

2.2.3 Catchment Parameters

The catchment parameters have been applied using recommended values from the RORB User Manual (v 6.31). The catchment loss parameters are provided in Table 3. These align with the values in the Beaufort Flood Study.

Table 3 Catchment Parameters

Model Parameter	Value
Kc	5.74
M	0.8

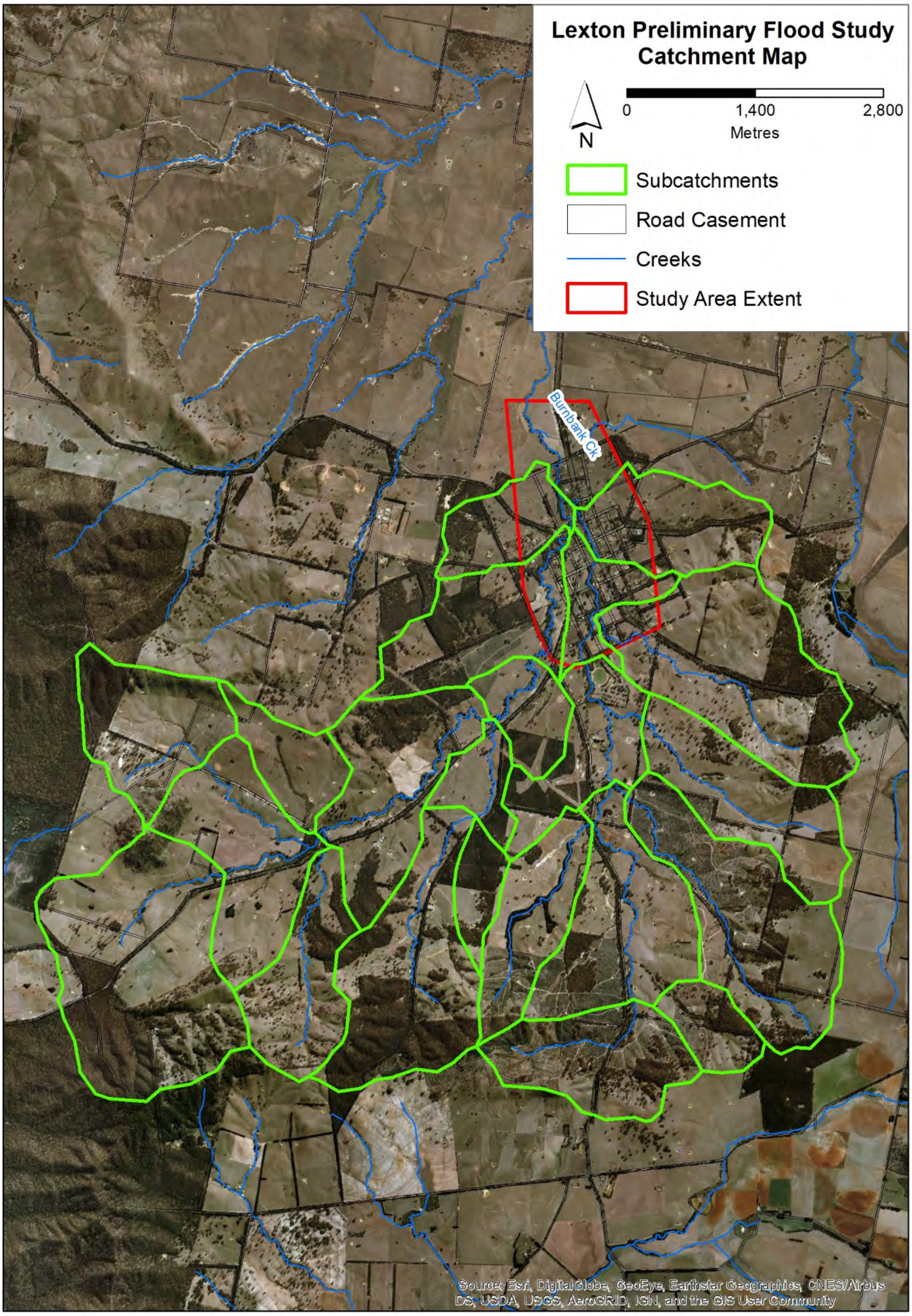


Figure 2 Burnbank Ck Catchment Map

2.3 Critical Duration

As per AR&R (2016) recommendations, an ensemble of 10 storms with varying temporal patterns was run through the RORB model with varying storm duration (between 15 minutes and 72 hours).

Figure 3 shows the peak flow comparison for the durations modelled, it can be seen that the 12 hour design storm is more critical than the other durations considered, with a higher mean, median flow than the other durations. The 6 hour duration is fairly similar, and a more detailed analysis may show that the 6 hour storm is more critical in some locations.

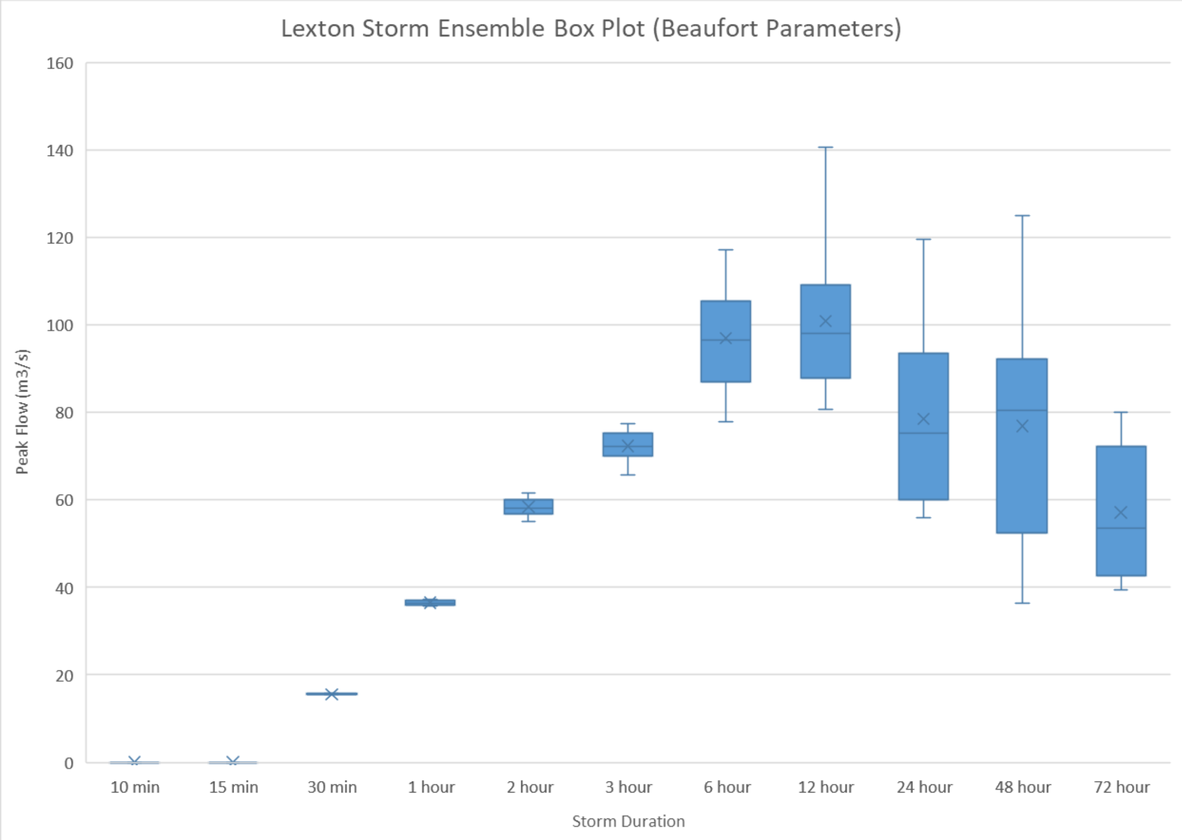


Figure 3 Ensemble Storm Box Plots

2.4 Adopted Design Storm

As recommended in Retallick (2017), the "Median" plus one temporal pattern was used for the critical duration design storm. The temporal pattern selected was ARR2016 Pattern 28, which produced a peak flow of 102.8 m^3/s (combined). The flow hydrograph, which is applied in the hydraulic modelling, is shown in Figure 4.

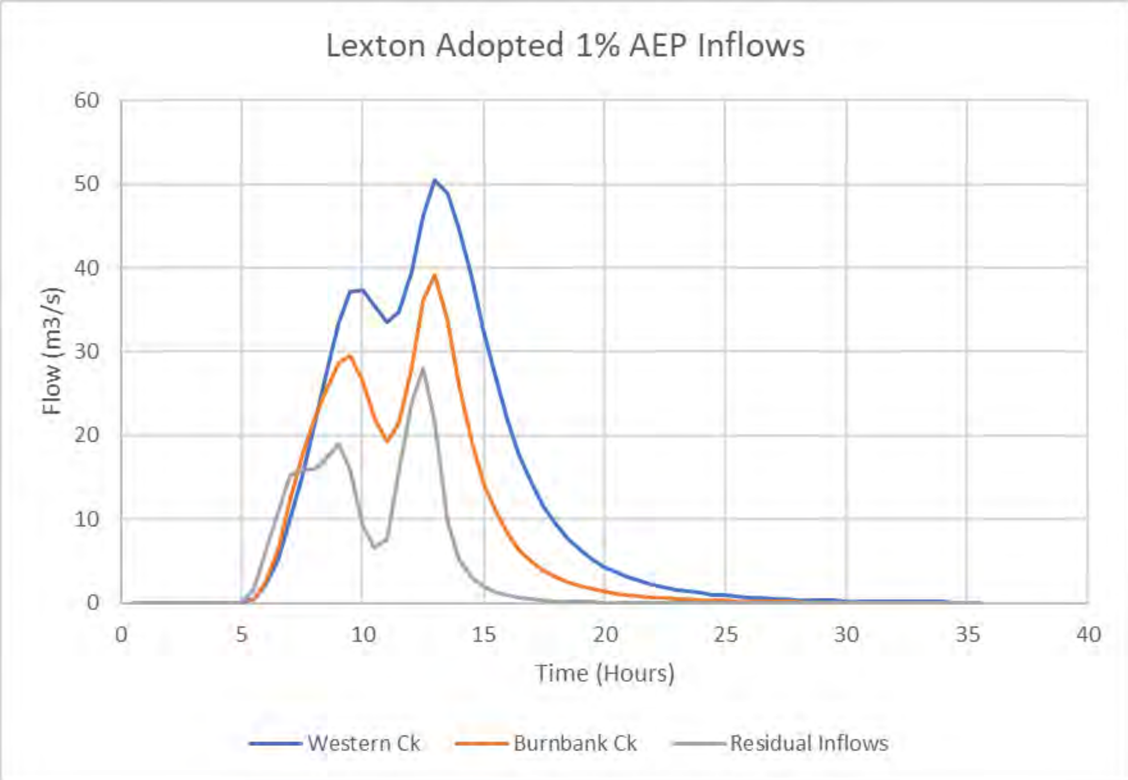


Figure 4 Adopted Design Storm Flow Hydrographs

2.5 Comparison to Regional Methods

Comparison has been made between the critical duration flows and alternative techniques, including:

- The same RORB model with the AR&R 2016 rainfall parameters.
- The same RORB model using the AR&R 1987 rainfall intensities and temporal patterns.
- The Regional Flood Frequency Estimation (RFFE) model, developed as part of AR&R 2016.
- The Probabilistic Rational Method, developed as part of AR&R87 and is replaced by the RFFE.

Table 4 shows the different estimation techniques and resulting peak flow in the 1% AEP event. There a range of results between each of the different calculation techniques. The RFFE has a significantly lower estimated flow than all other methods. Previous modelling in similar rural catchments show that RFFE is often inaccurate and therefore shouldn't be applied. Also, given that the AR&R2016 techniques are designed to replace the AR&R1987 techniques, it is recommended that the RORB model with Beaufort parameters remains as the adopted flow.

Table 4 Comparison of Flow Estimates

Estimation Technique	1% AEP Flow (m3/s)
RORB (Beaufort Parameters)	102.8
RORB (AR&R 2016 Parameters)	67.4
RORB (AR&R 1987 with Beaufort Parameters)	155.4
RFFE (AR&R 2016)*	50.6
Probabilistic Rational Method (AR&R 1987)	72.4

3 Hydraulic Modelling

The model for this study has been developed using the HEC-RAS v5.03 software. HEC-RAS is widely used both internationally and in Australia for similar projects.

HEC-RAS differs from traditional two-dimensional software in that rather than simply averaging the elevation within a computational cell, it calculates a storage vs elevation relationship from the terrain (DEM) as well as cross-sectional relationships along the face of each cell. The practical effect of this is that HEC-RAS can accurately represent features that are smaller than the grid size (e.g. a flow path that is 5 m wide in a 10 m resolution grid).

Recent benchmarking tests undertaken by HEC (the software developer) shows that its' two-dimensional flow solver is on par with other similar modelling software (TuFlow, MIKE Flood, ISIS etc) in terms of accuracy (US Army Corps of Engineers, 2016).

3.1 Model Schematisation

The model has been setup using a ten-metre resolution grid representing the catchment.

The model timestep is 1 minute timestep with up to 500 time slices (allowing for a minimum timestep of less than 0.001 minutes). Time slices effectively reduce the time step to ensure stability and maintain the mass balance.

Figure 5 shows the model schematic, boundaries and proposed development.

3.2 Model Roughness

Roughness, or Mannings 'n', has been applied variably across the model domain based on the land use observed in the aerial photo. Values in Table 5 below are based Table 10-1 of Institute of Engineers Australia (2012).

Table 5 Roughness Values

Land Use	Roughness (Manning's n)
Roads	0.03
Buildings	0.5
Channel	0.04
Land	0.05

3.3 Model Structures

In-channel structures such as bridges and culverts have been represented roughly using in field measurements and reducing this to AHD using LiDAR. Floodplain structures such as elevated roads and levees are represented by breaklines which force the cell boundaries on to the crest of the structure.

3.4 Model Boundaries

3.4.1 Initial Conditions

The model has been set with a “dry” initial condition.

3.4.2 Inflows

The main inflow has been applied at the upstream end of the study area on Burnbank Creek as well as smaller additional inflows from residual inflows within the town. The flow rates that have been applied are shown in Figure 4.

3.4.3 Outflows

There is a single model outflow located at the northern end of the model domain, the outflows has been applied using the “Normal Depth” boundary formulation in HEC-RAS which uses Mannings equation to derive a stage-discharge curve based on the assigned slope, which has been applied as 1% for these boundaries.

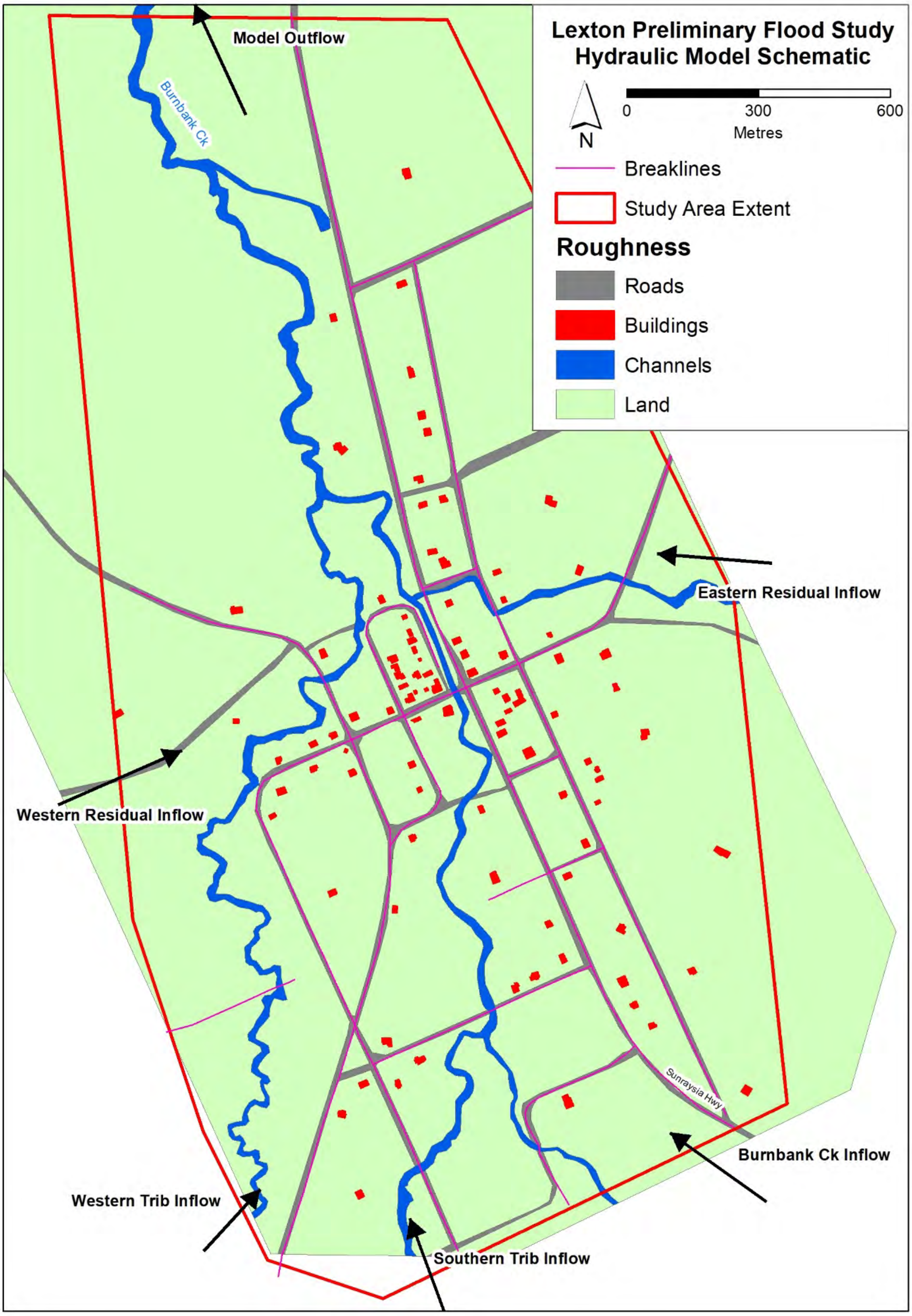


Figure 5 Hydraulic Model Schematic

4 Results

4.1 Model Calibration

Data for calibration was sought from Council and local residents (through limited door knocking). Calibration data was made available from residents for the September 2016 event.

The September event was modelled using the total rainfall depth from the Lexton daily rainfall gauge, disaggregated to hourly rainfall totals using the Ballarat Aerodrome pluviometer. This provided an hourly rainfall time series with the same rainfall depth as the town.

Given significant rainfall prior to the event, the initial loss component of the event was set to 0 mm, and so the only losses are the continuing 1 mm/hr loss.

The rainfall was then modelled through the RORB and HEC-RAS models and then compared to four locations with calibration evidence. These locations are shown in Figure 6.

Location 1 Goldsmith St
Location 1 was flooded to almost the air vent level beneath the house. At this location, the model shows around 0.1 – 0.15 m depth of flooding which is relatively close to the recorded flood level. The location is shown in Figure 7.

Location 2 Goldsmith St from Williamson St
Flood photo (Figure 8) shows the flood extent beginning just downstream of the intersection of Goldsmith St and Williamson St. This flood extent is matched closely by the model

Location 3 Sunraysia Highway upstream of Williamson St
Flood photo (Figure 9) shows flooding banking up around the south east corner of the intersection and almost crossing the Sunraysia Highway. The modelling shows some flooding of the highway although this is relatively shallow (less than 0.03 m). This suggests a close match and it is possible that the flood photo was not taken at the peak of the flood.

Location 4 Burnbank Ck from the Pyrenees Hotel
Flood photo (Figure 10) shows flooding at the deck level of the Williamson St bridge and minimal flooding on the left bank just upstream of the bridge. The model matches the flow patterns with some minimal over-deck flooding of the bridge. As with Location 3, this is of a minimal depth and it is possible that the flood photo was not taken at the peak of the flood.

Overall the model reproduces the 2016 flood relatively closely and is a good calibration.

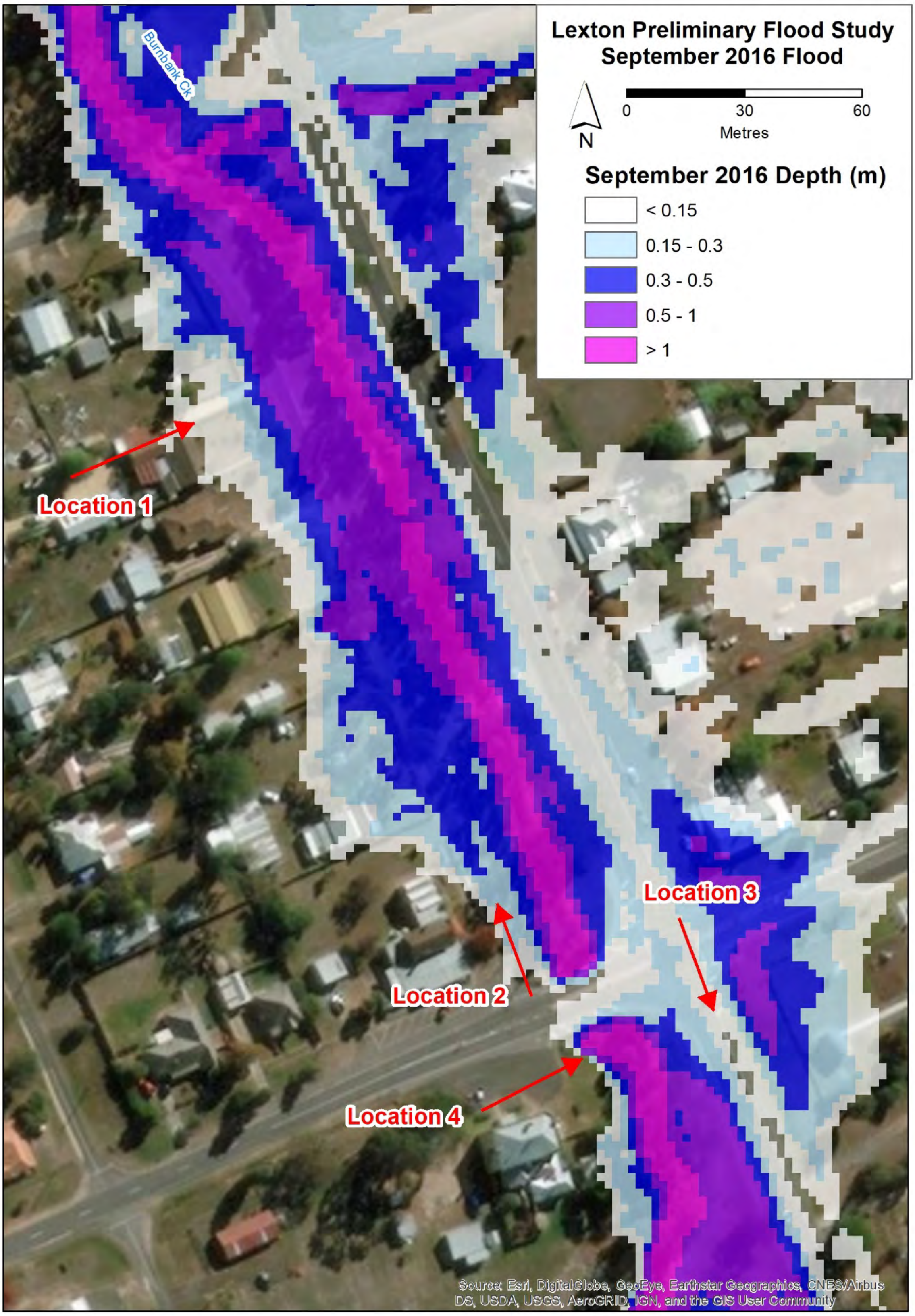


Figure 6 September 2016 Calibration Depth

Figure 7 Calibration Location 1

Figure 8 Calibration Location 2

Figure 9 Calibration Location 3

Figure 10 Calibration Location 4

4.2 Flood Behaviour

4.2.1 Flood Extent

The flood extent of the 1% AEP is shown in Figure 11. It can be seen that the flooding upstream of the main part of town is mostly constrained to a floodway around the Burnbank Creek Corridor and the Western Tributary Inflow Corridor.

As the creek approaches Williamson St there is a more widespread flooding that has the potential to inundate several residential properties along the local streets. This continues to just downstream of Anderson St.

To the west, the Western Tributary crosses the Lexton-Ararat Rd and isolates a number of properties between itself and Burnbank Creek until between the Lexton-Ararat Rd and Butler Rd.

In addition to the adopted 1% AEP design flood, the same flood using the AR&R 2016 rainfall loss parameters has also been modelled, as well as a sensitivity check by increasing the inflows by 20%. The floods extents have been layered such that the smaller flood is on top of the larger flood (i.e. the area inundated by the 20% increased flow includes the area of the design storm and the AR&R 2016 parameter runs.

It can be seen that by using the AR&R 2016 loss parameters, the flood extent is fairly similar, however as discussed these are likely to be less accurate than the adopted Beaufort Flood Study parameters in terms of depth and velocity. Without calibration it is difficult to determine the correct rainfall loss parameters.

The 20% increase in flow from the adopted design storm shows minimal increase in the flood extent. This suggests that the flood extent does not change between flows of a magnitude of the AR&R parameters (67 m^3/s) and flows 20% greater than the Beaufort Parameters (125 m^3/s).

4.2.2 Flood Depth

1% AEP Flood depths are shown in Figure 12. The figure shows that in general flood depths are greatest in Burnbank Creek and the Western Tributary (around 1 - 2 m and greater than 2 m in locations) and floodway along the creek (greater than 0.3 m). In the outer floodplain depths are generally lower than 0.3 m such as the widespread flooding around Williamson and Anderson St.

4.2.3 Flood Velocity

Similarly to depth, the highest velocities are generally in the floodway around the main channels. Significant velocities (> 1 m/s) are also in the flowpath coming from the eastern residual flow. Most floodplain areas exceed 0.5 m/s.

4.2.4 Flood Hazard (Hydraulic)

Hydraulic Flood Hazard (the product of depth and velocity) and it shown in Figure 9. The majority of the floodplain has relatively has a moderate hazard (0.2 - 0.4 m^2/s) while the flood fringe, including the eastern residual inflow is generally less than 0.2 m/s. There is a wide flowpath along both major channels that has a relatively high hazard (> 0.4 m^2/s).

Hydraulic hazard is a good indicator of where the most dangerous floodwaters are located as it highlights areas that are either fast flowing or deep or a combination of the two. The high hazard along the main channels would be largely obvious to most people and there are no locations where there is significant overland flow that is high hazard.

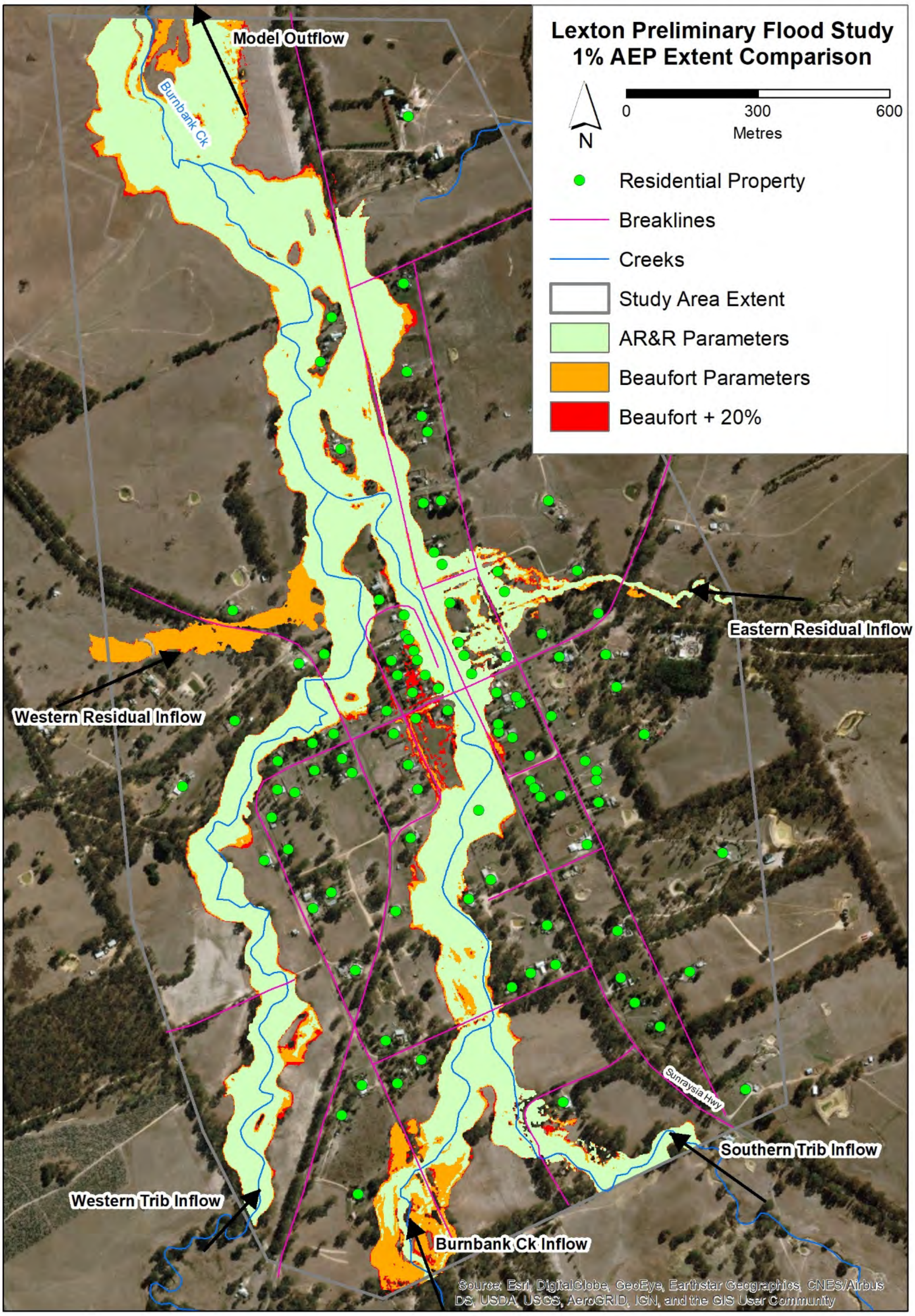


Figure 11 1% AEP Extent Comparison (AR&R 2016 vs Beaufort Parameters)

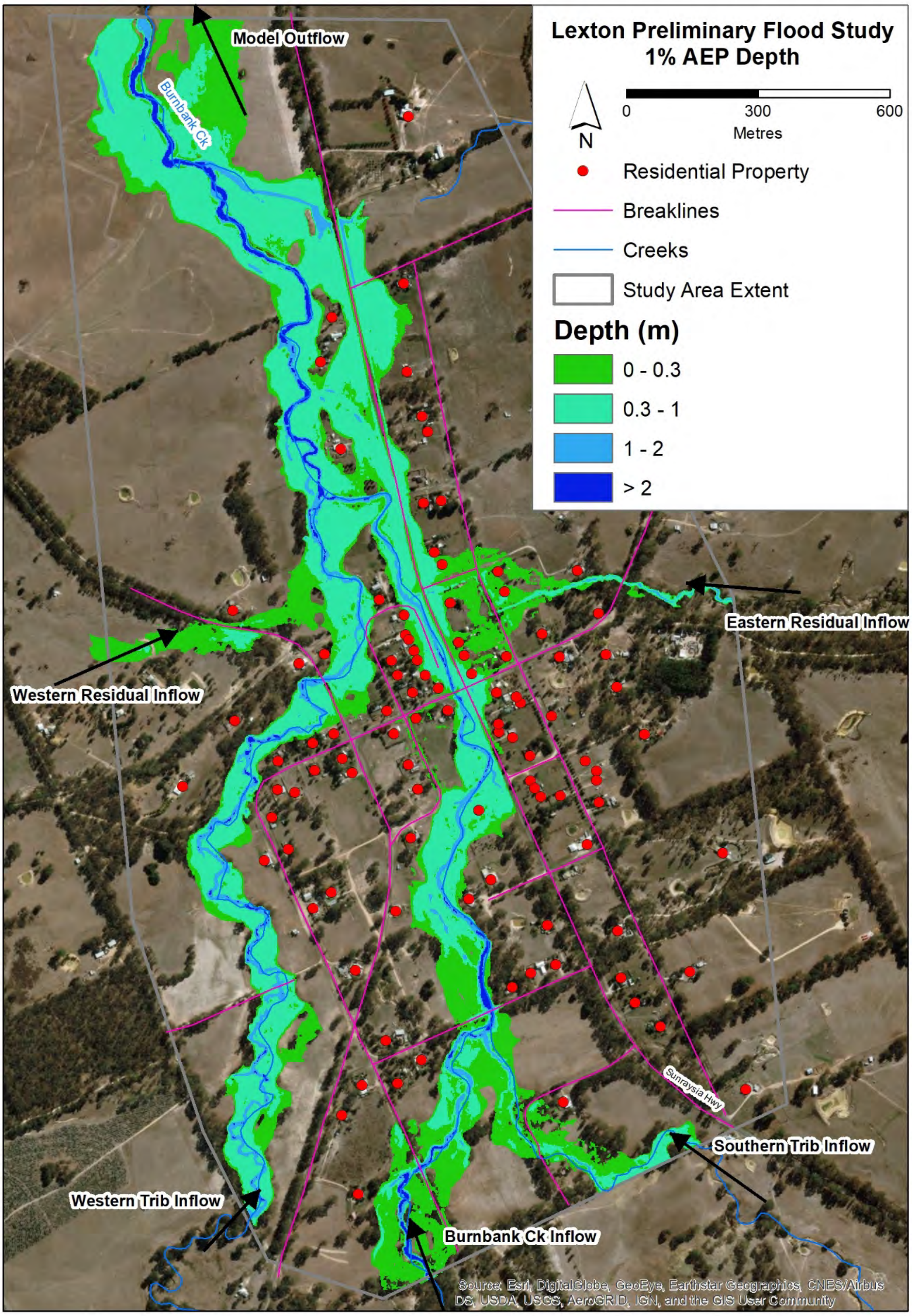


Figure 12 1% AEP Peak Depth

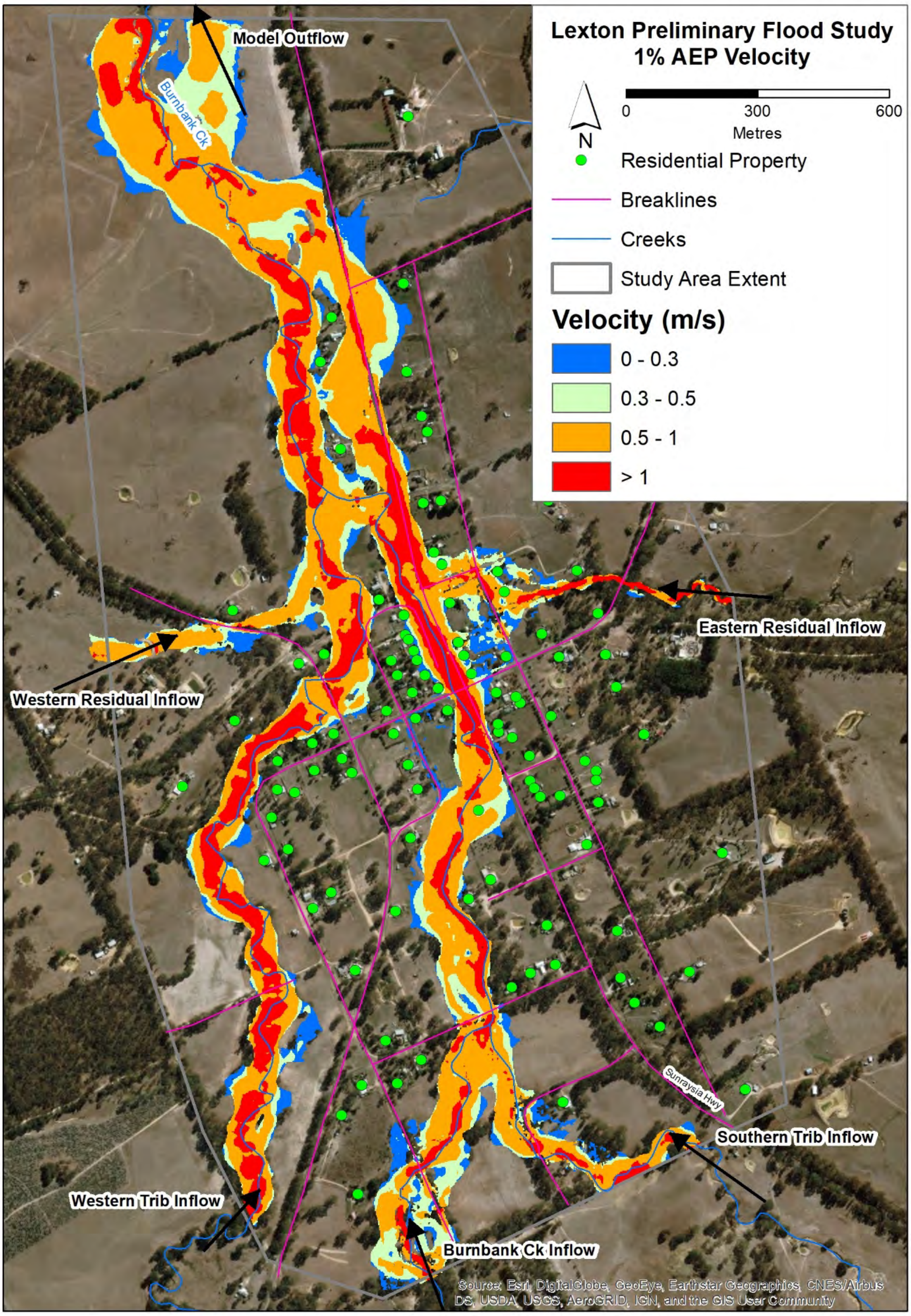


Figure 13 1% AEP Peak Velocity

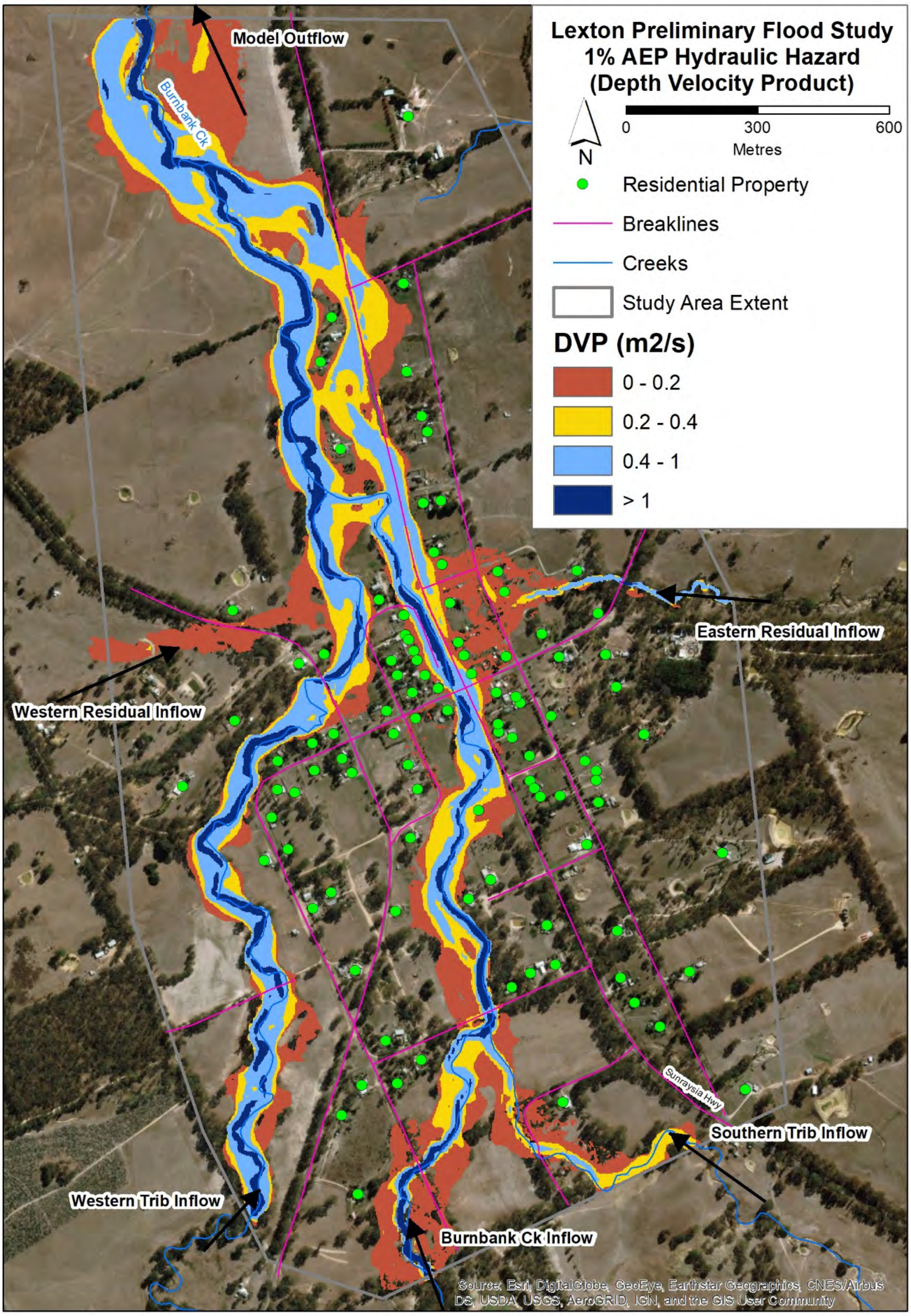


Figure 14 1% AEP Hydraulic Hazard

4.3 Flood Risk

4.3.1 Flood Risk to Life

The flood risk to life can be calculated from the Population at Risk (PAR). The PAR is estimated by taking the number of flood affected buildings and multiplying it by the average dwelling density (see Table 1). This is often calculated from the PMF, however in this case only the 1% AEP flood is available.

Table 6 shows the number of properties within the study area and the number of flood affected properties. It can be seen that using the Beaufort rainfall parameters significantly increases the PAR from around 53 people with the AR&R rainfall parameters to 61 people (properties with above ground flooding). As discussed in Section 2.5, the Beaufort parameters are likely to be more accurate. The higher risk PAR are located generally along closer to Burnbank Ck and the Sunraysia Hwy.

If flow is increased by 20% on top of the Beaufort Parameters run, then there is a corresponding increase in the PAR or as well as a number of properties that have an increased severity of flooding (i.e. move from above ground flooding to potential above floor flooding or move from potential to a higher likelihood of above floor flooding). The population at risk is shown spatially in Figure 14.

The PAR can also include people that may not be flood affected on their property but are potentially cut off from their homes or work places. There are a number of properties between Burnbank Ck and the Western Tributary that appear to be isolated during flooding, particularly north of Williamson St.

Given the size of the catchment and lack of gauging information, it is unlikely that any flood warning would be available and emergency services would need to mobilise prior to rainfall occurring.

Table 6 Flood Affected Residences

Residential Properties	Number of Properties (Beaufort Parameters)	Number of Properties (AR&R 2016 Parameters)	Number of Properties (Beaufort Parameters plus 20% flow)
Total Number of Residential Properties in Study Area	103	103	103
Properties with Above Ground Flooding	38	33	40
Properties with Potential Above Floor Flooding	10	8	17
Properties with Higher Likelihood of Above Floor Flooding (Depth => 0.3)	2	2	5

4.3.2 Commercial Flood Risk

In addition to the potential for residential properties to be inundated, the study areas have a significant number of sheds that would either be used for residential storage or commercial purposes (primarily agricultural). Inundation of these sheds would cause some financial loss.

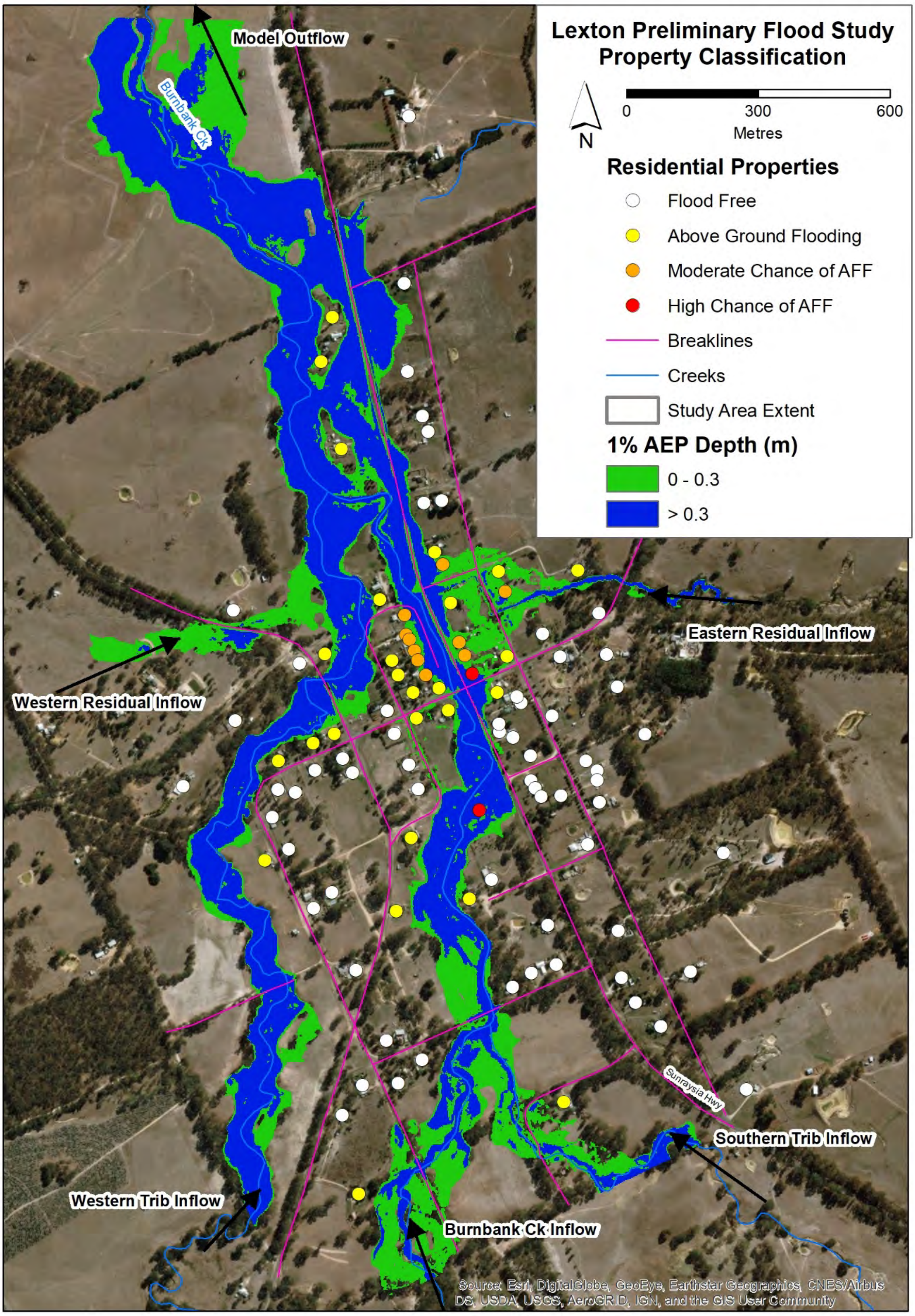


Figure 15 Lexton 1% AEP Population at Risk

4.4 Flood Planning

Floodway mapping has been undertaken in accordance with *Applying the Flood Provisions in Planning Scheme – Planning – Practice Note 12* (Victorian Department of Environment, Land Water and Planning, 2015). The floodway maps are shown in Figure 11.

The figure shows the extent of the Floodway Overlay (FO) which is defined as areas of high depth and velocity and is generally used to delineate land that should not be developed. The Land Subject to Inundation Overlay (LSIO) is also shown, which is the extent of the 1% AEP (defined flood event) and would be used to limit development to appropriate uses.

Also shown on Figure 16 is the cadastral lots that are potentially subject to flooding (i.e. intersect with the LSIO). These delineations of LSIO and FO are considered preliminary and could be used to guide flood risk assessments for future development proposals.

To progress the preliminary mapping towards a planning scheme amendment, tasks include the development of draft amendment maps, ordinance and the consideration of a Local Floodplain Development Plan for Lexton. Community consultation will also be a key body of work to deliver prior to commencing the formal amendment process.

The mapping produced in this investigation also provides guidance to the Municipal Emergency Management Plan. In particular, the properties and buildings identified to be at risk may be included in flood response planning.

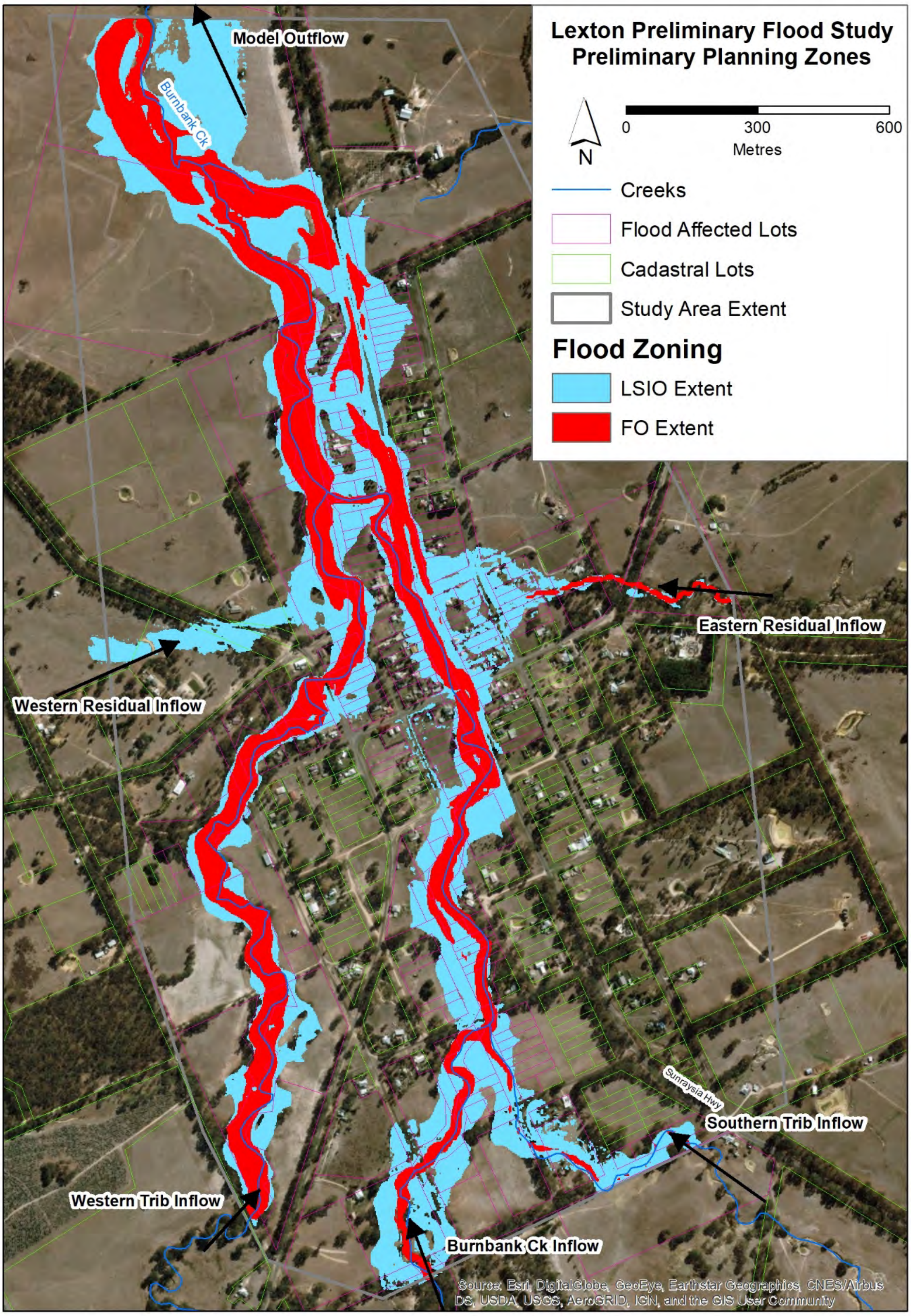


Figure 16 Preliminary Planning Zones

5 Summary and Recommendations

5.1 Summary

A hydrologic and hydraulic model have been setup to provide a preliminary estimate of the flood impacts within Lexton. The results show that flooding upstream of the main part of town is mostly constrained around the two main channels through town (Burnbank Ck and the Western Tributary).

Based on the results, there is a relatively minor risk to property, with two properties with a high likelihood of above floor flooding in the 1% AEP and an additional three properties with above floor flooding if flows were 20% higher.

There appears to be limited scope for flood mitigation works within the town, although flood detention basins upstream of the town could potentially reduce flooding.

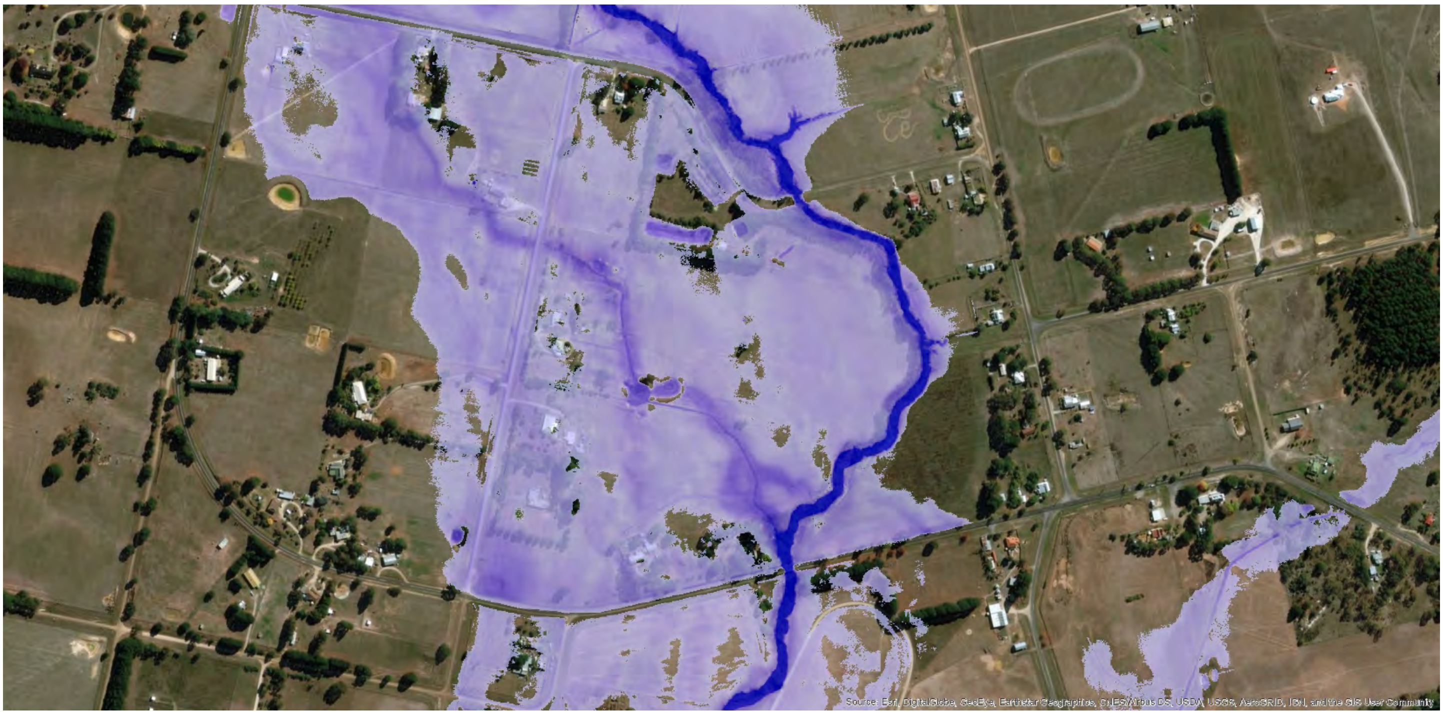
5.2 Recommendation

It is recommended that Pyrenees Shire use the preliminary flood investigation results to progress further work to amend the Planning Scheme and Municipal Emergency Management Plan.

6 References

Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors), 2016, Australian Rainfall and Runoff: A Guide to Flood Estimation, Commonwealth of Australia

Institute of Engineers Australia, 2012, Australian Rainfall and Runoff Revision Project 15 – Two Dimensional Modelling in Urban and Rural Floodplains.



Raglan
Preliminary Flood Study

Report
Prepared For
Pyrenees Shire Council
August 2018

HYDRO SPATIAL

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Project Details	Raglan Preliminary Flood Study
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1 Introduction

1.1 Study Background

Pyrenees Shire Council (Council) has a number of towns within its Local Government Area that are flood prone, including Raglan. The extent of the flooding and the associated flood risk is largely unknown and this creates difficulties for Council to assess proposed developments with respect to flood issues. As a result, Council is seeking to proceed through the floodplain risk management process (i.e. flood study, floodplain risk management study and plan, plan implementation). However, Council has limited resources and therefore needs to prioritise the towns that have the greatest flood risk.

Council has engaged Utilis and HydroSpatial to undertake a preliminary flood study to determine whether a full flood study is required as well as provide flood risk and flood planning advice for the town.

1.2 Study Objective

The main objectives of the study are to provide an overview of the flood risk within Raglan and determine whether a full flood study, or further improvements to the preliminary flood study are required.

1.3 Study Area

Raglan is a small town in the Pyrenees Shire Council on the banks of Fiery Creek. Raglan is primarily residential with no retail or government services. The main industry in Raglan is sheep grazing and associated support industries.

1.3.1 Physical Description

The study area extends along Fiery Creek from Pitchers Lane through the town and as far downstream as Lucardines Rd. The study area is shown in Figure 1. Fiery Creek flows generally from north to south and is a “gaining” stream through the study area, with an upstream width of approximately 6 m to around 20 m at the downstream end. Fiery Creek splits the town east and west and a number of small tributaries have the potential to further split the town into segments.

The floodplain is traversed by a number of roads, The Raglan-Elmhurst Road is the most significant and sits on a raised embankment approximately 300 mm high. The Old Beaufort Rd also crosses the floodplain at the northern end of town but appears to be closed at the Creek, however the road embankment has the potential to act as a hydraulic control.

Development within the floodplain is primarily rural residential with relatively low set single storey houses, most properties have other significant infrastructure such as large rural sheds.

There is limited stormwater infrastructure within the town, with no clear stormwater detention or formalised stormwater network. The roads drained using table drains.

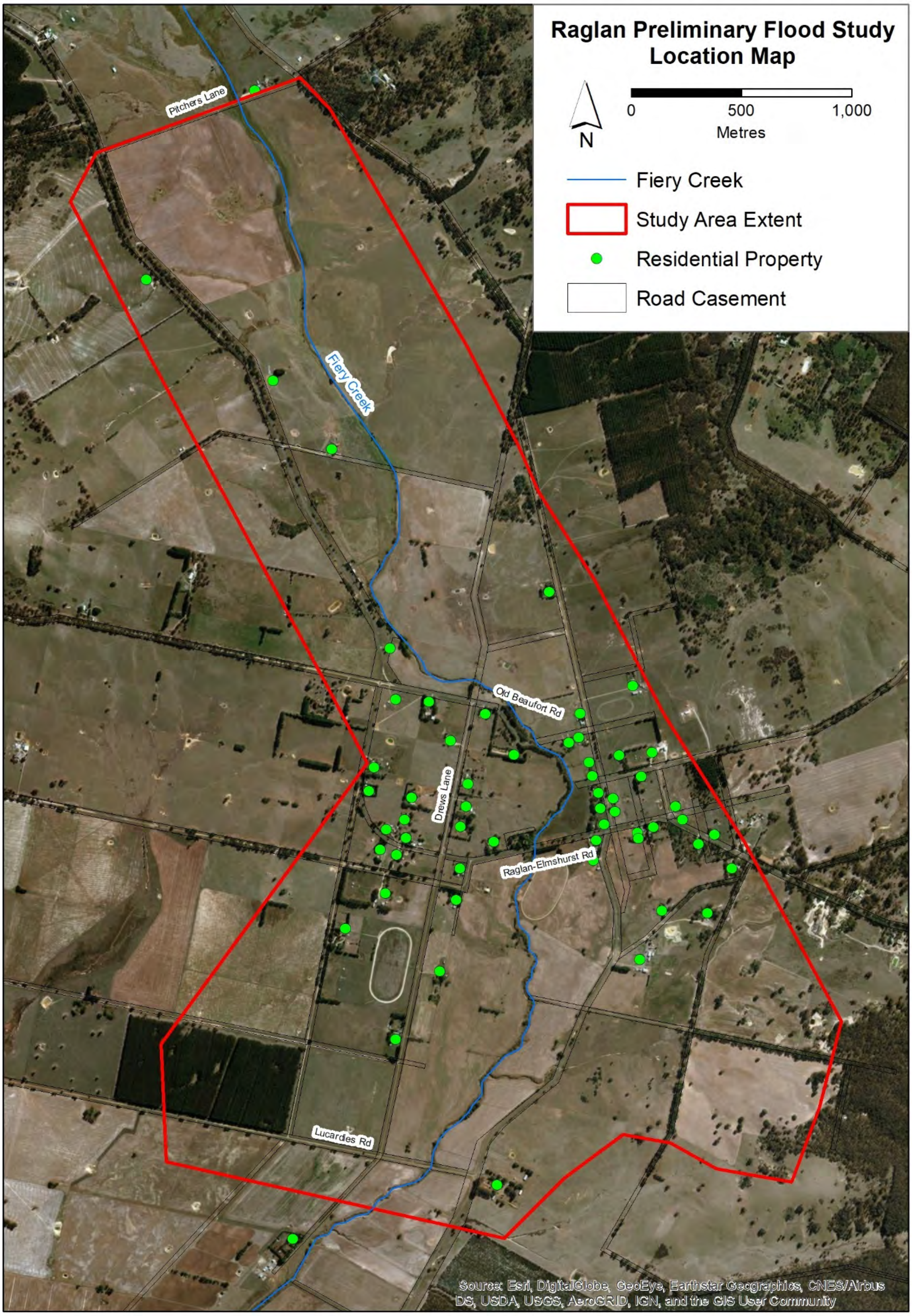

Figure 1 Study Area Location

1.3.2 Study Area Community

Key community statistics have been extracted using the Raglan (SSC) area. At the 2016 census, the Raglan (SSC) covers the study area with some rural additional area. We estimate that approximately 50% of the Raglan (SSC) population is within the study area.

The community statistics provide information on the relative flood risk of the study area with respect to the average across Victoria. Table 1 shows the key statistics that have been extracted and from these it can be inferred that:

- Raglan has a lower population density (people per dwelling). This can present warning and evacuation difficulties. Particularly in single resident houses that may need assistance.
- Raglan has a much greater proportion of residents that are elderly and would need assistance with evacuation and may not respond to more modern community consultation or warning techniques.
- Raglan has a similar proportion of children and rental properties as the rest of Victoria.
- Raglan has a much smaller proportion of non-English-speaking households who may need assistance interpreting warnings or flood study outputs.
- The average household income in Raglan is significantly lower than the rest of Victoria, indicating potential difficulty to financially recover from flood damage.
- There are no households without any vehicles that may need assistance to evacuate.

Table 1: Key Community Statistics

Measure	Raglan	Rest of Victoria
Number of People	231	N/A
Average People per Dwelling	2.1	2.8
Percentage Elderly Population (> 65 years of age)	27.3	15.6
Percentage Very Young Population (< 5 years of age)	6.3	6.3
Percentage Young Population (5 – 14 Years of Age)	10.5	12.0
Percentage Rental Properties	10.3	28.7
Percentage Non-English-Speaking Households	6.1	27.8
Median Household Income ($/Week)	820	1,419
Number of Households with No Vehicles	0	N/A

1.4 Available Data

The following data was available for the risk assessment:

- LiDAR derived 1 m Digital Elevation Model, available from Glenelg Hopkins Catchment Management Authority.
- Aerial Photography of the site at a 50 cm pixel resolution captured, available as a basemap within ESRI ArcGIS.
- Cadastral Boundaries made available from the Victorian Spatial DataMart.
- Intensity-Frequency-Duration tables for the catchment area using BoM IFD2013, available from the Bureau of Meteorology.
- Recommended Hydrological Modelling parameters (loss values, temporal patterns etc) available through the AR&R 2016 Data Hub (2016_v1).
- Beaufort Flood Study (Water Technology, 2008).

- Shuttle Radar Topography Mission (SRTM) DEM available from Geoscience Australia).

2 Hydrological Modelling

This chapter outlines the hydrological modelling that has been undertaken. The modelling has been undertaken using the RORB Software Package (v 6.31) and in line with the Australian Rainfall and Runoff (AR&R 2016) guidelines.

Modelling has been undertaken of the 1% Annual Exceedance Probability (AEP) design flood, which is typically used to limit flood exposure and damage to development. 1% AEP means that a flood of this magnitude has a 1% chance of occurring in any given year. This means that in some years there may be two or more floods of this magnitude or alternatively, a thousand years could pass before a flood of this magnitude occurs. The 1% AEP is sometimes referred to as the 1 in 100 Year Average Recurrence Interval (ARI) flood, which does not mean that these floods only occur every 100 years.

2.1 Catchment Delineation

The catchment delineation has been undertaken using the hydrologically enforced SRTM DEM, which is a low (30m) resolution DEM covering all of Australia. The spatial location of the catchment is shown in Figure 4. The calculated catchment size is 60.1 km^2. The majority of which contributes to the Fiery Creek upstream of town, with some smaller inflows contributing within the town. The catchment has been sub-divided into twenty two sub-catchments to improve the catchment routing and storage representation.

2.2 Model Development

2.2.1 Design Rainfall Estimation

The design rainfall parameters have been obtained using the AR&R Data Hub (Version 2016_v1) and Bureau of Meteorology using the coordinates of the centroid of the catchment (-37.326 south, 143.31 east).

2.2.2 Loss Parameters

The rainfall loss parameters have been extracted the AR&R (2016) as well as those parameters used in the Beaufort Flood Study (2008). The rainfall loss parameters are provided in Table 2. Both sets of loss parameters have been modelled. However, as the Beaufort Flood Study parameters are based on a calibrated model using a similar hydrological modelling approach we believe these parameters are likely to be more accurate and more appropriate to use than those of the AR&R 2016 Data Hub. Therefore the Beaufort parameters were adopted.

Table 2 Rainfall Loss Parameters

Model Parameter	Data Hub Output	Beaufort Flood Study
Initial Loss (mm)	25	19.75
Continuing Loss (mm/hr)	4.6	1.0

2.2.3 Catchment Parameters

The catchment parameters have been applied using recommended values from the RORB User Manual (v 6.31). The catchment loss parameters are provided in Table 3. These align with the values in the Beaufort Flood Study.

Table 3 Catchment Parameters

Model Parameter	Value
Kc	7.02
M	0.8

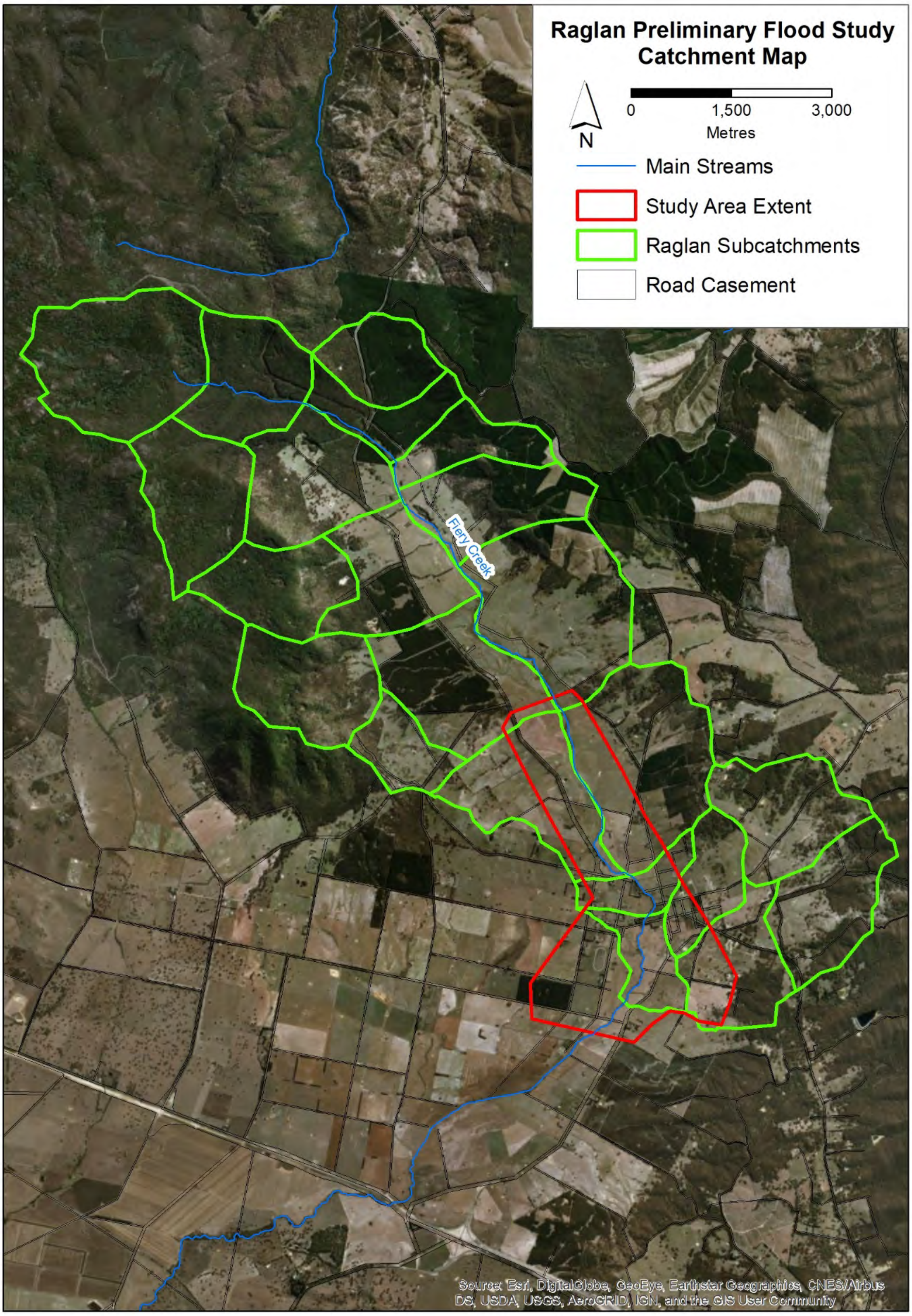

Figure 2 Fiery Ck Catchment Map

2.3 Critical Duration

As per AR&R (2016) recommendations, an ensemble of 10 storms with varying temporal patterns was run through the RORB model with varying storm duration (between 15 minutes and 72 hours).

Figure 3 shows the peak flow comparison for the durations modelled, it can be seen that the 12 hour design storm is more critical than the other durations considered, with a higher mean, median and upper flow than the other durations.

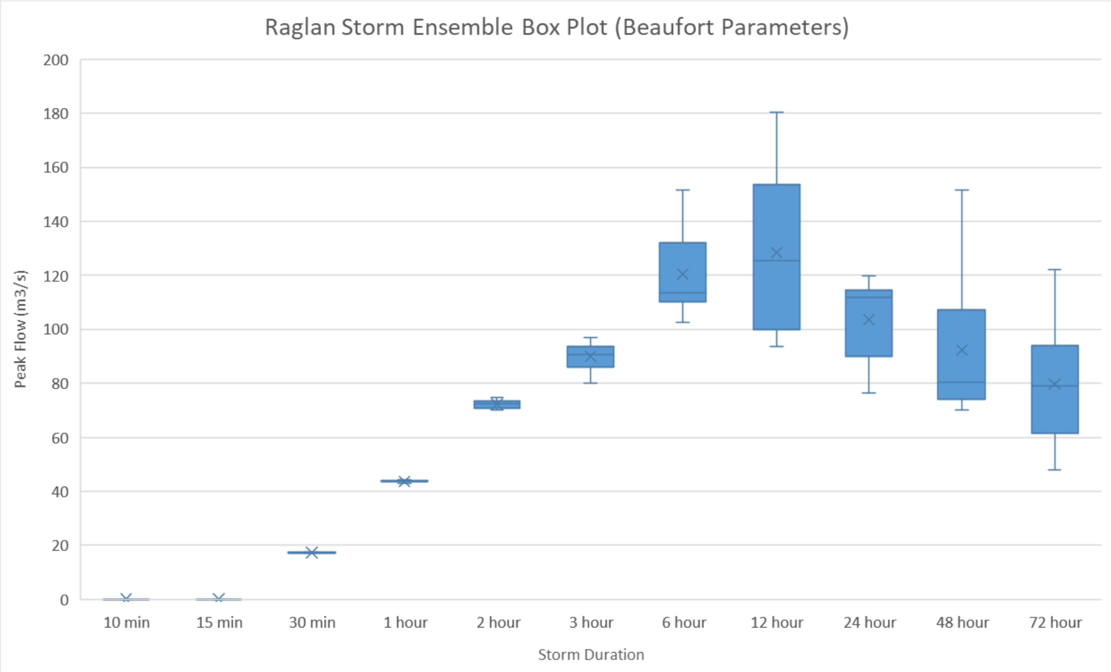

Figure 3 Ensemble Storm Box Plots

2.4 Adopted Design Storm

As recommended in Retallick (2017), the "Median" plus one temporal pattern was used for the critical duration design storm. The temporal pattern selected was ARR2016 Pattern 22, which produced a peak flow of 127.3 m^3/s (combined). The flow hydrograph, which is applied in the hydraulic modelling, is shown in Figure 4.

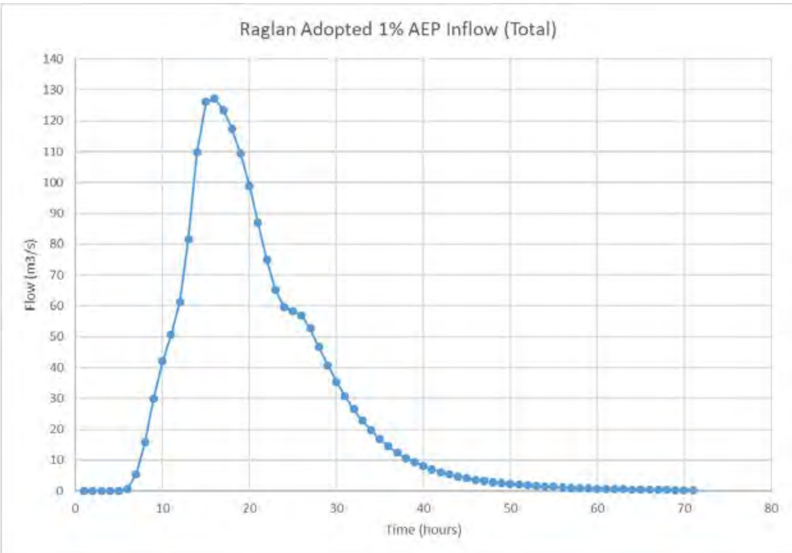

Figure 4 Adopted Design Storm Flow Hydrographs

2.5 Comparison to Regional Methods

Comparison has been made between the critical duration flows and alternative techniques, including:

- The same RORB model with the AR&R 2016 rainfall parameters.
- The same RORB model using the AR&R 1987 rainfall intensities and temporal patterns.
- The Regional Flood Frequency Estimation (RFFE) model, developed as part of AR&R 2016.
- The Probabilistic Rational Method, developed as part of AR&R87 and is replaced by the RFFE.

Table 4 shows the different estimation techniques and resulting peak flow in the 1% AEP event. There a range of results between each of the different calculation techniques. The RFFE has a significantly lower estimated flow than all other methods, however when the catchment parameters were input into the RFFE web-based tool, a warning was generated suggesting that the catchment shape is irregular. This may explain the significant difference in results.

Previous modelling in similar rural catchments show that RFFE is often inaccurate and therefore shouldn't be applied. Also, given that the AR&R2016 techniques are designed to replace the AR&R1987 techniques, it is recommended that the RORB model with Beaufort parameters remains as the adopted flow.

Table 4 Comparison of Flow Estimates

Estimation Technique	1% AEP Flow (m3/s)
RORB (Beaufort Parameters)	127.3
RORB (AR&R 2016 Parameters)	70.3
RORB (AR&R 1987 with Beaufort Parameters)	200.7
RFFE (AR&R 2016)*	26.7
Probabilistic Rational Method (AR&R 1987)	98.0

*Note that when using RFFE the web page produced a warning that the catchment shape was irregular and results may be inaccurate.

3 Hydraulic Modelling

The model for this study has been developed using the HEC-RAS v5.03 software. HEC-RAS is widely used both internationally and in Australia for similar projects.

HEC-RAS differs from traditional two-dimensional software in that rather than simply averaging the elevation within a computational cell, it calculates a storage vs elevation relationship from the terrain (DEM) as well as cross-sectional relationships along the face of each cell. The practical effect of this is that HEC-RAS can accurately represent features that are smaller than the grid size (e.g. a flow path that is 5 m wide in a 10 m resolution grid).

Recent benchmarking tests undertaken by HEC (the software developer) shows that its' two-dimensional flow solver is on par with other similar modelling software (TuFlow, MIKE Flood, ISIS etc) in terms of accuracy (US Army Corps of Engineers, 2016).

3.1 Model Schematisation

The model has been setup using a ten-metre resolution grid representing the catchment.

The model timestep is 1 minute timestep with up to 500 time slices (allowing for a minimum timestep of less than 0.001 minutes). Time slices reduce the time step to ensure stability and mass balance. Figure 5 shows the model schematic, boundaries and proposed development.

3.2 Model Roughness

Roughness, or Mannings 'n', has been applied variably across the model domain based on the land use observed in the aerial photo. Values in Table 5 below are based Table 10-1 of Institute of Engineers Australia (2012).

Table 5 Roughness Values

Land Use	Roughness (Manning's n)
Roads	0.03
Buildings	0.5
Channel	0.04
Land	0.05

3.3 Model Structures

In-channel structures such as bridges and culverts have been represented roughly using in field measurements and reducing this to AHD using LiDAR. Floodplain structures such as elevated roads and levees are represented by breaklines which force the cell boundaries on to the crest of the structure.

3.4 Model Boundaries

3.4.1 Initial Conditions

The model has been set with a “dry” initial condition.

3.4.2 Inflows

The main inflow has been applied at the upstream end of the study area on Fiery Creek as well as two smaller additional inflows from sub-catchments to the east. The flow rates that have been applied are shown in Figure 5.

3.4.3 Outflows

There are several model outflows located at the southern end of the model domain, the outflows has been applied using the “Normal Depth” boundary formulation in HEC-RAS which uses Mannings equation to derive a stage-discharge curve based on the assigned slope, which has been applied as 1% for these boundaries.

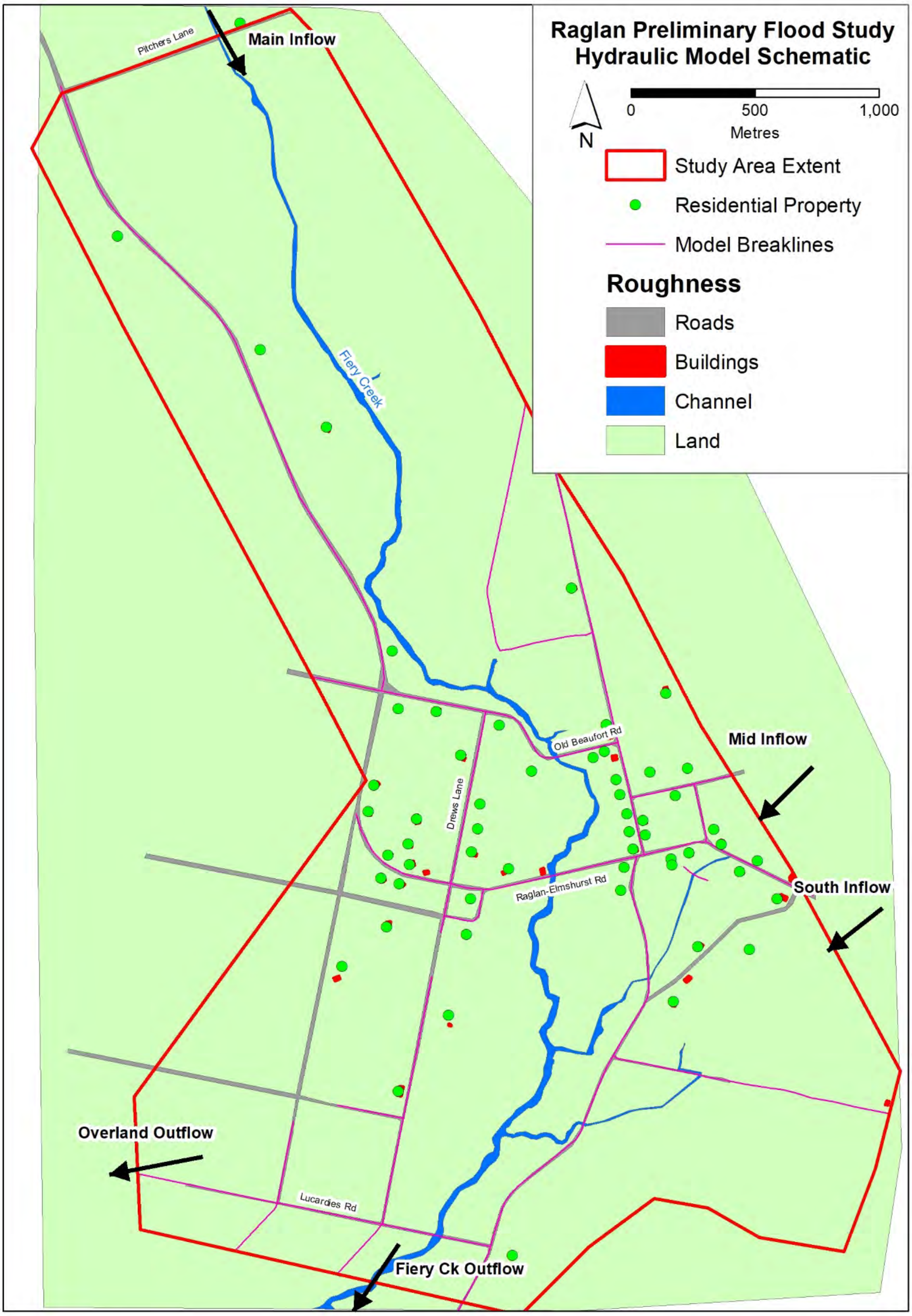

Figure 5 Hydraulic Model Schematic

4 Results

4.1 Model Calibration

Data for calibration was sought from Council and local residents (through limited door knocking). Unfortunately, the only calibration data available within the study area was a single flood mark on Drews Lane near the downstream end of the model. The information associated with the flood mark suggests above floor flooding of around 0.15 m.

The January 2011 event was modelled using the total rainfall depth from the Raglan daily rainfall gauge, disaggregated to hourly rainfall totals using the Ballarat Aerodrome pluviometer. This provided an hourly rainfall time series with the same rainfall depth as the town.

Given significant rainfall prior to the event, the initial loss component of the event was set to 0 mm, and so the only losses are the continuing 1 mm/hr loss.

The rainfall was then modelled through the RORB and HEC-RAS models and produced a significantly lower amount of flow than required to inundate the property. The flood extents of the 1% AEP and 1% AEP with 20% increased flow were then compared to the flood mark (see Figure 6). These events also produced significantly lower inundation at the site than the flood mark would suggest.

Given that the 1% AEP with 20% increased flow is a significantly larger event than the January 2011 event (111 mm rain vs 67 mm rain) it is unlikely that the model is this far out of calibration. Therefore it is likely that either the flood mark is erroneous or it is flooded due to other factors such as local runoff rather than the creek flooding.

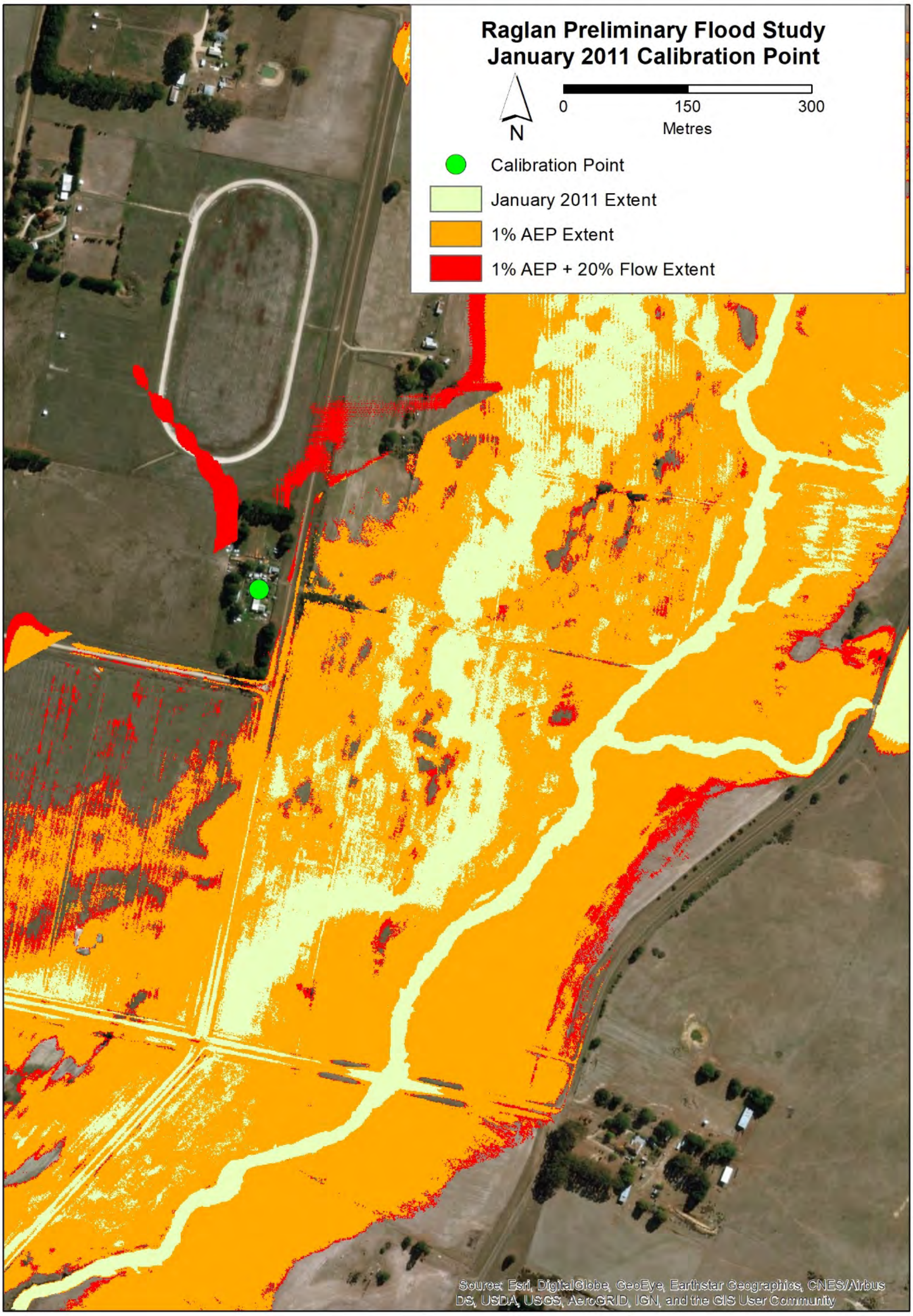

Figure 6 January 2011 Event Extent

4.2 Flood Behaviour

4.2.1 Flood Extent

The flood extent of the 1% AEP is shown in Figure 7. It can be seen that the flooding upstream of the main part of town is mostly constrained to a floodway around the Fiery Creek corridor, with some small breakouts across rural properties.

As the creek approaches Old Beaufort Road there is a significant break out that occurs on the right (west) bank and has the potential to inundate several residential properties along Dawes Lane. This flowpath continues downstream of the Raglan-Elmshurst Rd, flowing alongside the Fiery Creek floodway.

To the east there are a number of flowpaths that join Fiery Creek after crossing Eurabeen-Raglan Rd, these are generally constrained.

In addition to the adopted 1% AEP design flood, the same flood using the AR&R 2016 rainfall loss parameters has also been modelled, as well as a sensitivity check by increasing the inflows by 20%. The floods extents have been layered such that the smaller flood is on top of the larger flood (i.e. the area inundated by the 20% increased flow includes the area of the design storm and the AR&R 2016 parameter runs.

It can be seen that by using the AR&R 2016 loss parameters, the flood extent is significantly reduced, however as discussed these are likely to be less accurate than the adopted Beaufort Flood Study parameters. Without calibration it is difficult to determine the correct rainfall loss parameters.

The 20% increase in flow from the adopted design storm shows minimal increase in the flood extent. This suggests that if the estimated flows are within 20%, then the flood impacts are unlikely to be significantly different.

4.2.2 Flood Depth

1% AEP Flood depths are shown in Figure 8. The figure shows that in general flood depths are greatest in Fiery Creek (greater than 2 m) and floodway along the creek (greater than 0.3 m). In the outer floodplain depths are generally lower than 0.3 m such as the breakout to the west upstream of Old Beaufort Rd and downstream of Raglan-Elmshurst Rd. The area between Old Beaufort Rd and Raglan-Elmshurst Rd has a mix of deeper (0.3 - 1 m) and shallower (< 0.3 m) areas.

4.2.3 Flood Velocity

Similarly to depth, the highest velocities are generally in the floodway on either side of Fiery Creek. Significant velocities (> 0.5 m/s) are also in the flowpath between the western side of Old Beaufort Rd and along Dawes Lane. Other floodplains areas, such as the south of Raglan-Elmshurst Rd are generally slower, with velocities generally less than 0.5 m/s.

4.2.4 Flood Hazard (Hydraulic)

Hydraulic Flood Hazard (the product of depth and velocity) and it shown in Figure 10. The majority of the floodplain has relatively low hazard (< 0.2 m^2/s) with the exception of the area adjacent to Fiery Creek and also the floodway through Dawes Lane, where hazard exceeds 0.4 m^2/s along much of its length.

Hydraulic hazard is a good indicator of where the most dangerous floodwaters are located as it highlights areas that are either fast flowing or deep or a combination of the two. The high hazard along Fiery Creek would be largely obvious to most people, however the high hazard floodway along Dawes Lane may be less clear to residents and those travelling through the town.

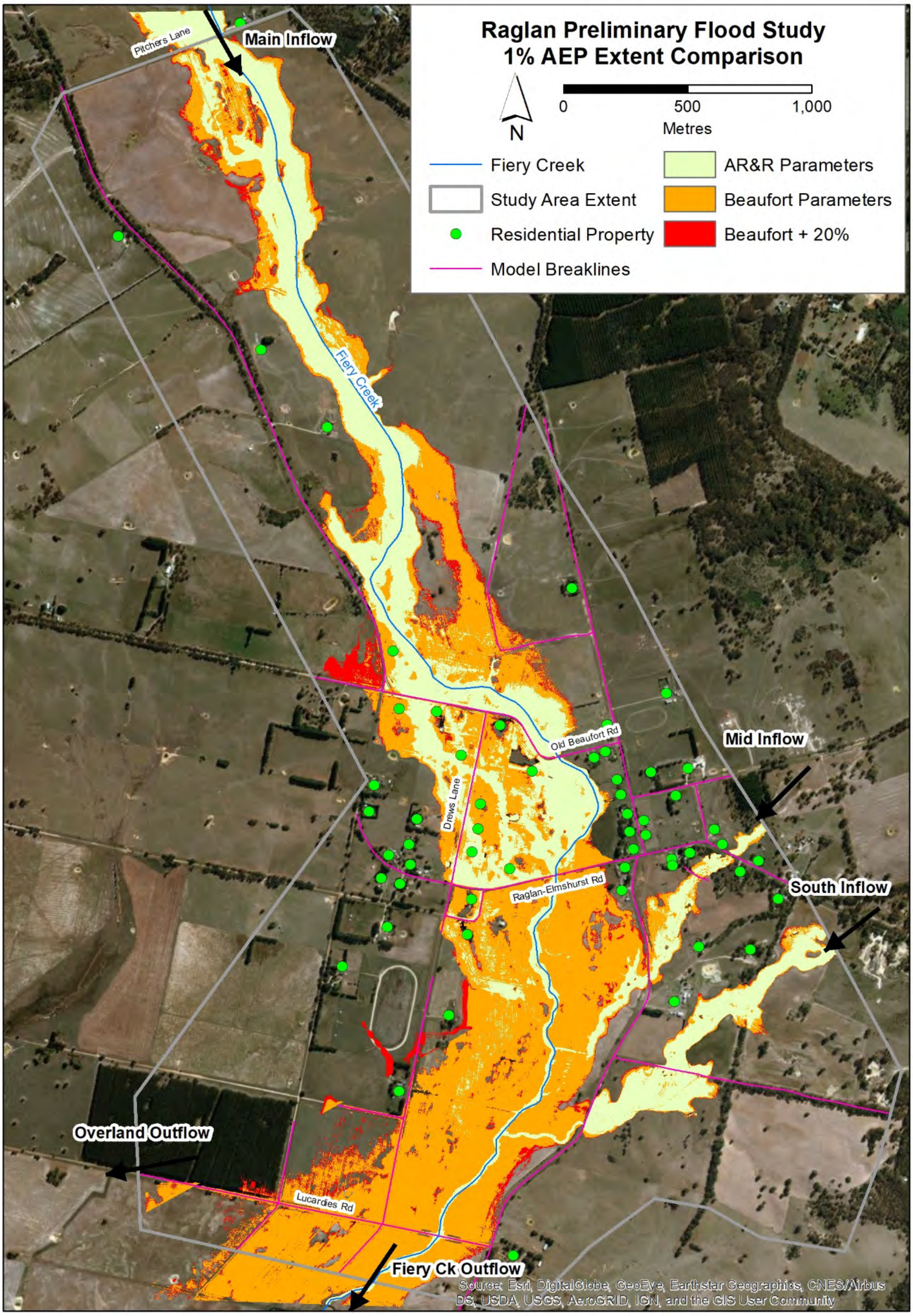

Figure 7 1% AEP Extent Comparison (AR&R 2016 vs Beaufort Parameters)

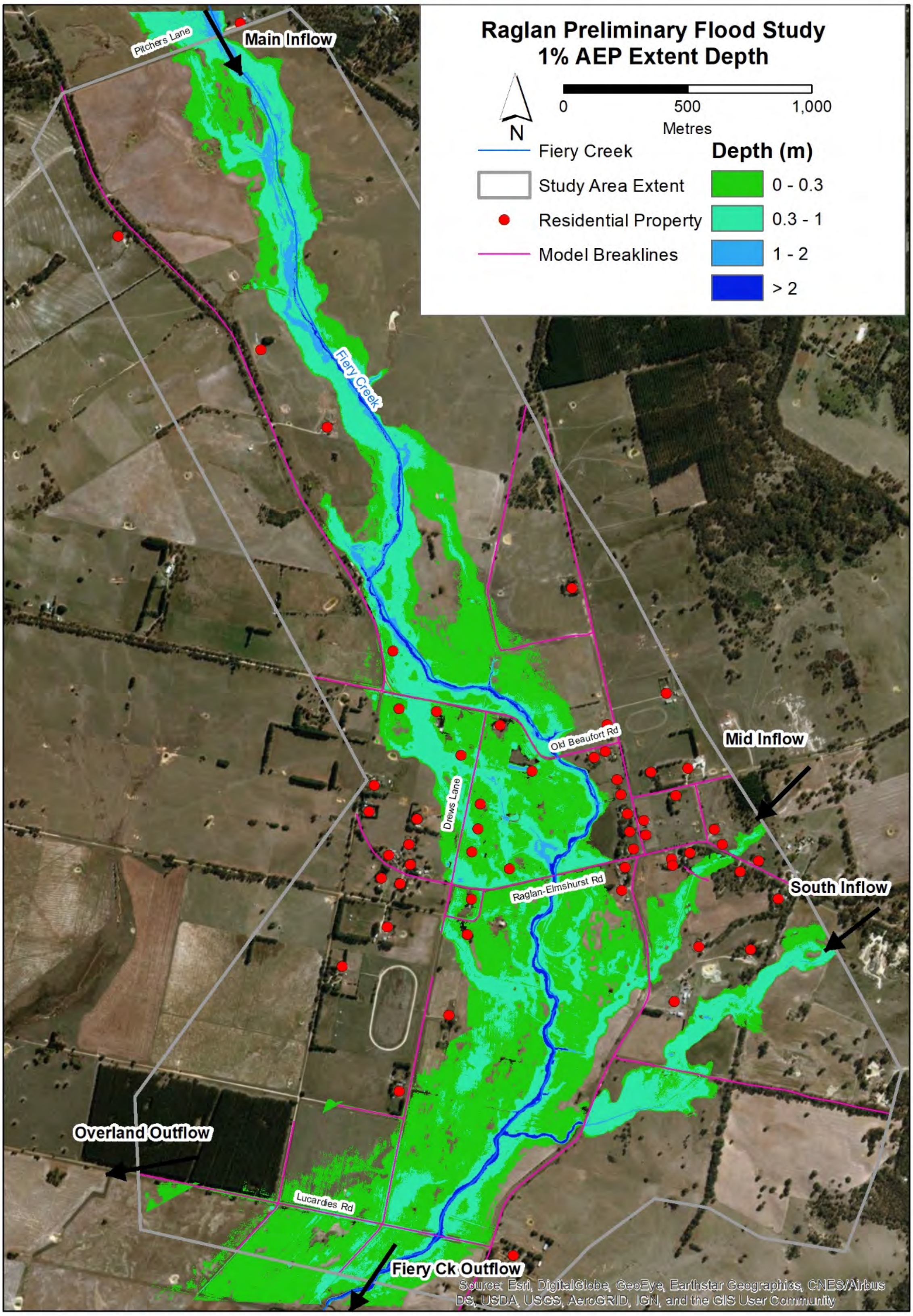

Figure 8 1% AEP Peak Depth

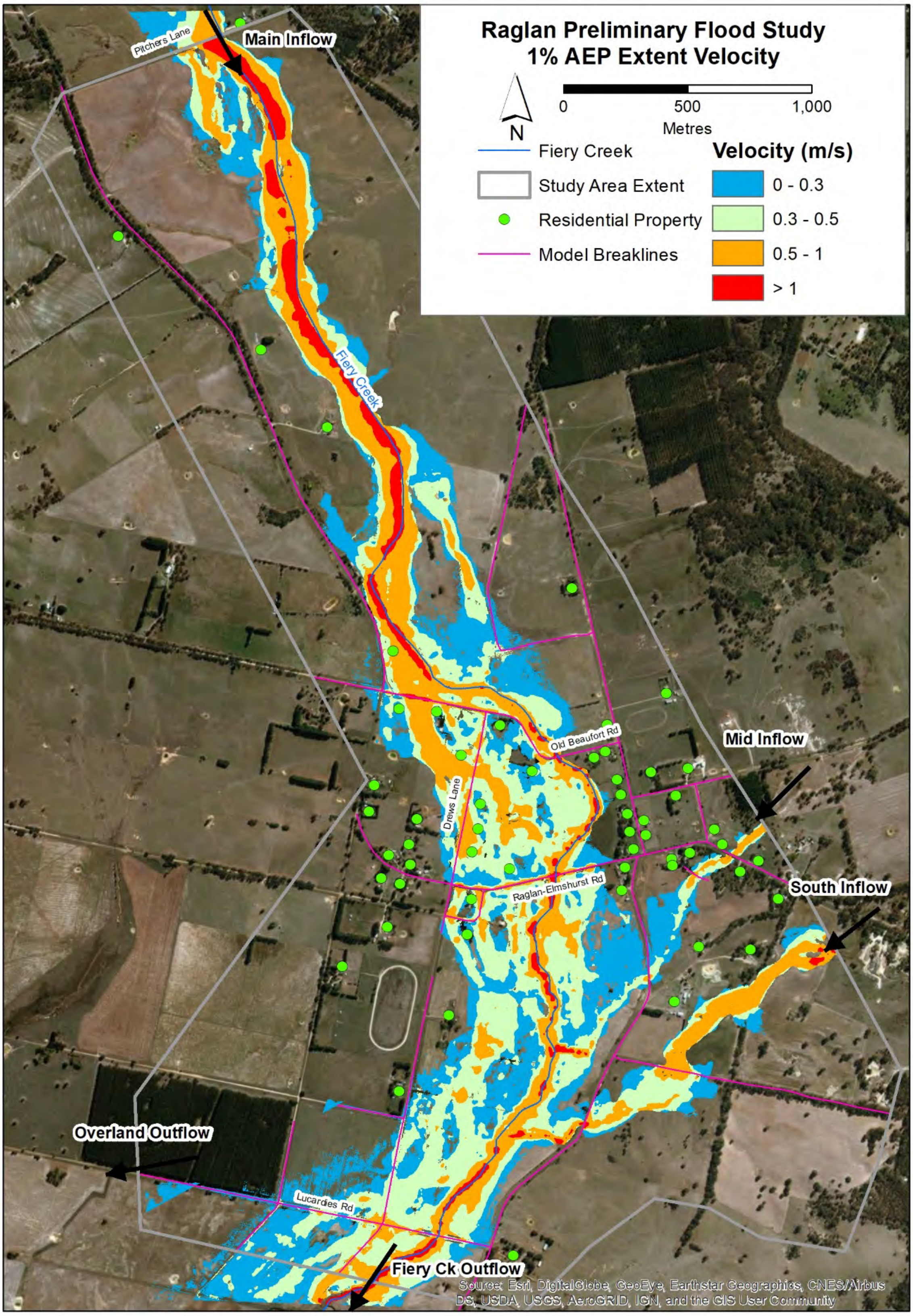

Figure 9 1% AEP Peak Velocity

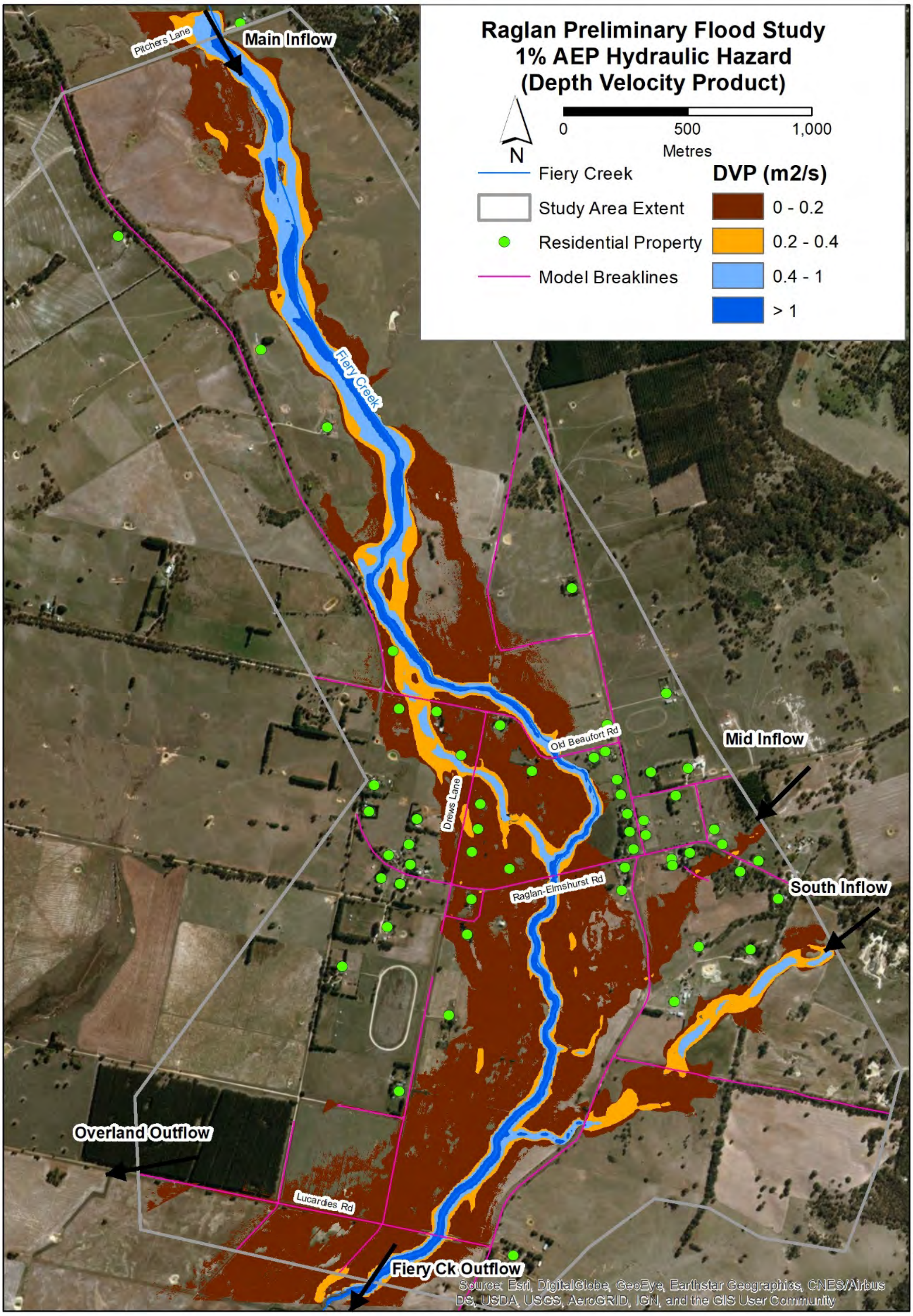

Figure 10 1% AEP Hydraulic Hazard

4.3 Flood Risk

4.3.1 Flood Risk to Life

The flood risk to life can be calculated from the Population at Risk (PAR). The PAR is estimated by taking the number of flood affected buildings and multiplying it by the average dwelling density (see Table 1). This is often calculated from the PMF, however in this case only the 1% AEP flood is available.

Table 6 shows the number of properties within the study area and the number of flood affected properties. It can be seen that using the Beaufort rainfall parameters significantly increases the PAR from around 32 people with the AR&R rainfall parameters to 61 people (properties with above ground flooding). As discussed in Section 2.5, the Beaufort parameters are likely to be more accurate. The higher risk PAR are located generally along Drews Lane. The PAR is shown spatially in Figure 11.

If flow is increased by 20% on top of the Beaufort Parameters run, then there is no corresponding increase in the PAR or severity of properties affected.

The PAR can also include people that may not be flood affected on their property but are potentially cut off from their homes or work places. It appears as though Raglan-Elmhurst Rd is not cut while other local roads such as Drews Lane, Lucardies Rd and Old Beaufort Rd are cut. However, more detailed modelling may show that the Raglan-Elmhurst Rd does get cut.

Given the size of the catchment and lack of gauging information, it is unlikely that any flood warning would be available and emergency services would need to mobilise prior to rainfall occurring.

Table 6 Flood Affected Residences

Residential Properties	Number of Properties (Beaufort Parameters)	Number of Properties (AR&R 2016 Parameters)	Number of Properties (Beaufort Parameters plus 20% flow)
Total Number of Residential Properties in Study Area	58	58	58
Properties with Above Ground Flooding (AGF)	29	15	29
Properties with Potential Above Floor Flooding (AFF)	11	4	11
Properties with Higher Likelihood of Above Floor Flooding (Depth => 0.3)	4	0	4

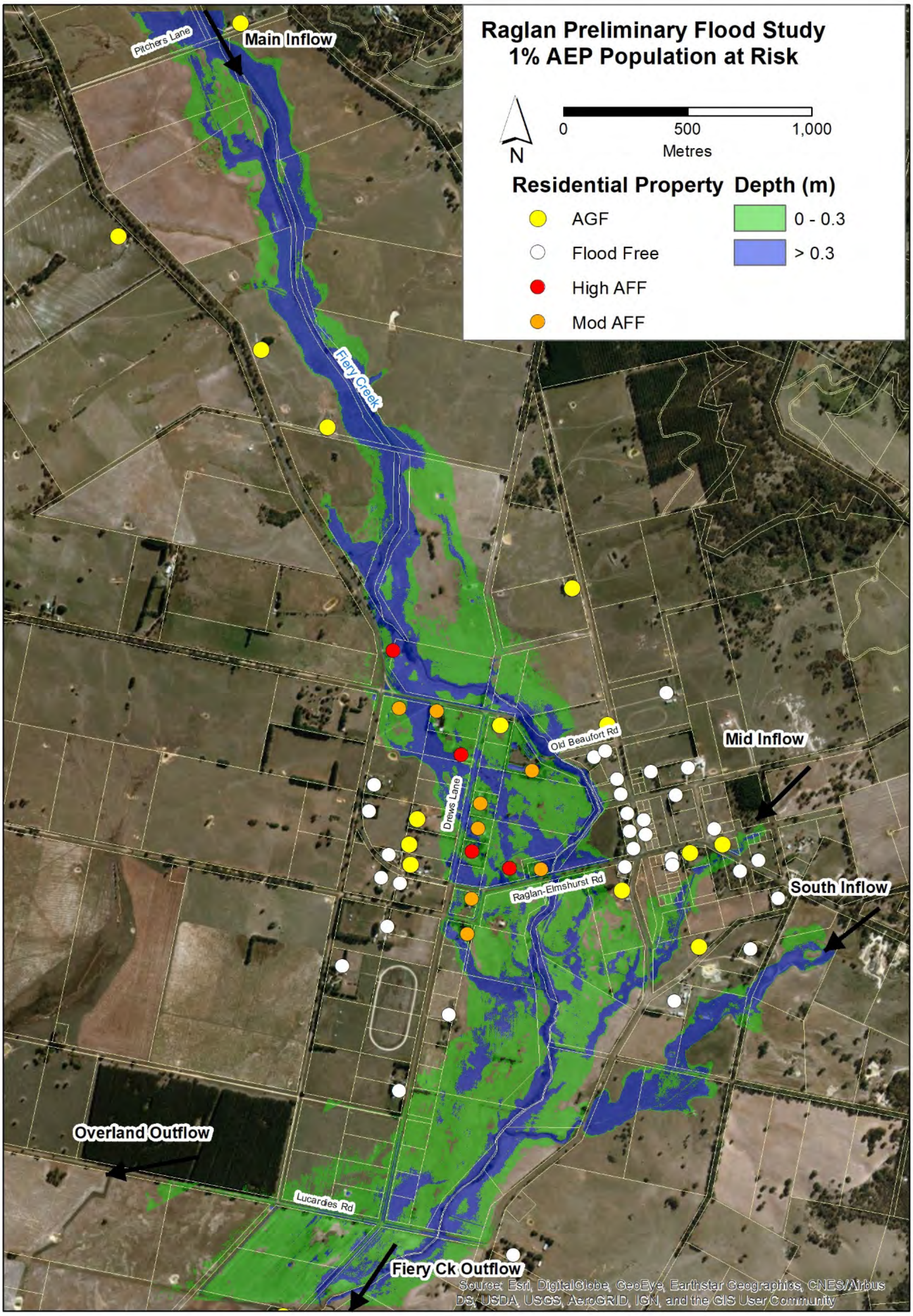

Figure 11 Raglan 1% AEP Population at Risk

4.3.2 Commercial Flood Risk

In addition to the potential for residential properties to be inundated, the study areas have a significant number of sheds that would either be used for residential storage or commercial purposes (primarily agricultural). Inundation of these sheds would cause some financial loss.

4.4 Flood Planning

Floodway mapping has been undertaken in accordance with *Applying the Flood Provisions in Planning Scheme – Planning – Practice Note 12* (Victorian Department of Environment, Land Water and Planning, 2015). The floodway maps are shown in Figure 12.

The figure shows the extent of the Floodway Overlay (FO) which is defined as areas of high depth and velocity and is generally used to delineate land that should not be developed. The Land Subject to Inundation Overlay (LSIO) is also shown, which is the extent of the 1% AEP (defined flood event) and would be used to limit development to appropriate uses.

Also shown on Figure 12 is the cadastral lots that are potentially subject to flooding (i.e. intersect with the LSIO). These delineations of LSIO and FO are considered preliminary and could be used to guide flood risk assessments for future development proposals.

To progress the preliminary mapping towards a planning scheme amendment, a full flood investigation should be considered to enable the mapping to refined to the DELWP and Glenelg Hopkins CMA standards. It will also provide for the amendment ordinance to be developed along with consideration of a Local Floodplain Development Plan for Raglan. A full flood investigation will also provide necessary peer review of this preliminary work and to seek additional calibration and validation data for the flood model.

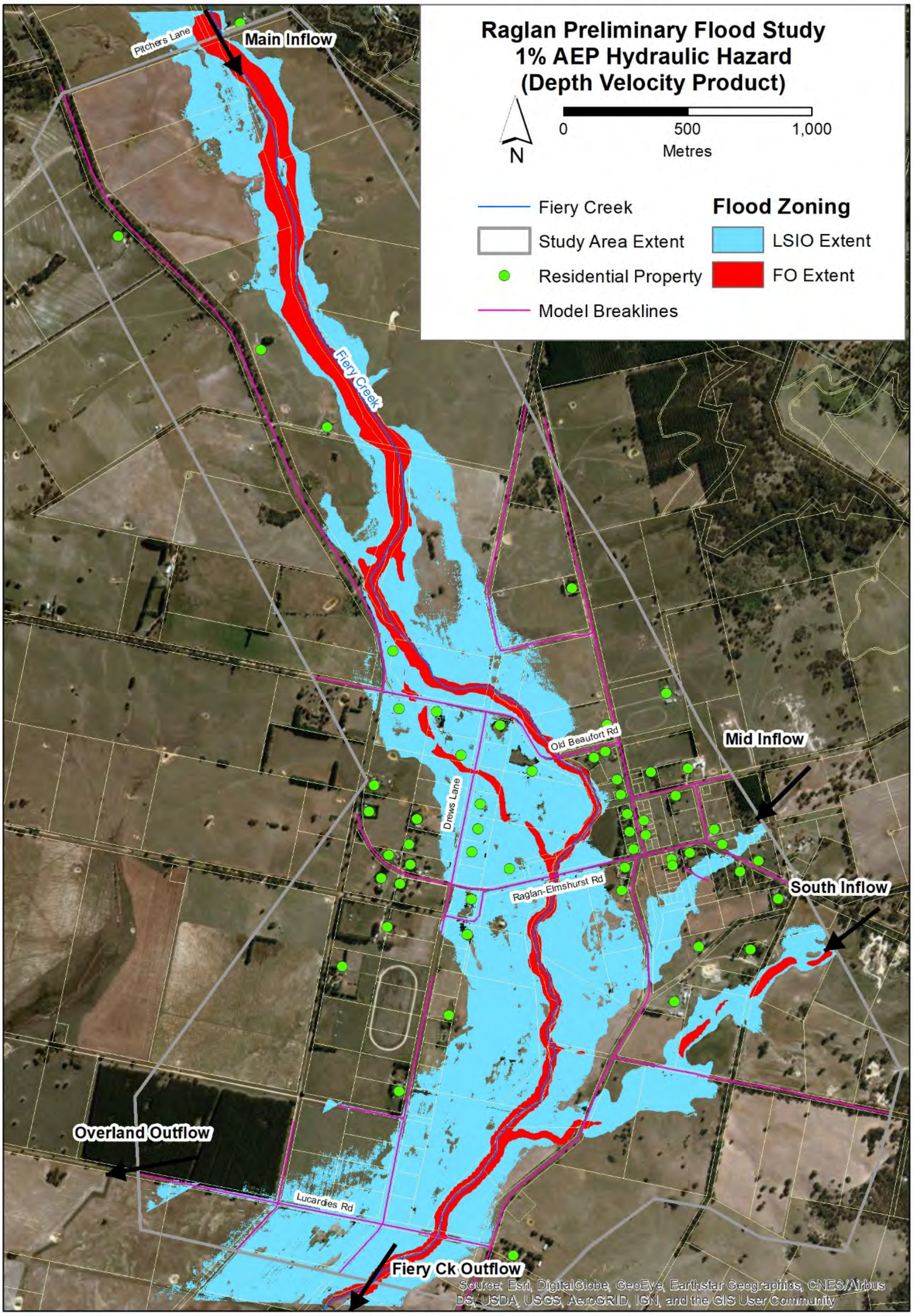

Figure 12 Preliminary Planning Overlays

5 Summary and Recommendations

5.1 Summary

A hydrologic and hydraulic model have been setup to provide a preliminary estimate of the flood impacts within Raglan. The results show that flooding upstream of the main part of town is constrained to a floodway around the Fiery Creek corridor. As the creek approaches Old Beaufort Road there is a significant break out that occurs on the right (west) bank and has the potential to inundate several residential properties along Dawes Lane. This flow path has high enough hydraulic hazard to be categorised as a floodway and it has the potential to cut some properties off from assistance.

Based on the results, there is a relatively significant risk to property, with four properties with a high likelihood of above floor flooding in the 1% AEP and an additional seven properties with some chance of above floor flooding. In our view the flood impact would warrant a full flood investigation. However, this should be weighed up against funding availability and the results of other preliminary flood studies.

If a full flood investigation is not undertaken, these results can be used to guide the future development of Raglan.

The most significant area of risk, along Dawes Lane, could potentially be mitigated by constructing a levee along running along the northern side of the Raglan-Elmshurst Rd just upstream of Dawes Lane.

5.2 Recommendations

It is recommended that Council investigate opportunities to resource a full flood investigation for Raglan.

6 References

Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors), 2016, Australian Rainfall and Runoff: A Guide to Flood Estimation, Commonwealth of Australia

Institute of Engineers Australia, 2012, Australian Rainfall and Runoff Revision Project 15 – Two Dimensional Modelling in Urban and Rural Floodplains.