Esk LFMP

Esk Local Floodplain Management Plan

Somerset Regional Council

13 November 2020

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1 INTRODUCTION

Flooding in Queensland during the summer of 2010/2011 affected more than 2.5million people with approximately 29,000 homes and businesses impacted. As a result, the Queensland Flood Commission of Inquiry (QFCI) was established in 2012 to recommend how state and local governments should manage flooding including future development, emergency response procedures, dam operations and structural mitigation.

Following the QFCI, the Queensland Government and local governments have committed to long-term floodplain management practices to reduce the impact of current and future flood risks, including the Brisbane River Flood Studies and Brisbane River Strategic Floodplain Management (SFMP)[1], led by the Queensland Reconstruction Authority (QRA). The Brisbane River Flood Study was released in May 2017 and is the largest ever undertaken in Australia and informed the development of the SFMP to better understand current and future flood risks and identify regionally consistent approaches to strengthen flood resilience across the Brisbane River floodplain. The outcome of the SFMP includes a Technical Evidence Report, recommendations for local floodplain management plans (LFMPs) and guidance material for amending planning schemes to align with State Planning Policy state interest for natural hazard risk and resilience. This LFMP establishes strategies to deliver sustainable management of flood risk in the long term for Esk, a township in the wider local government area (LGA) of Somerset.

Flooding in the Esk township occurs from Redbank and Sandy Creek which are catchments located between Lake Wivenhoe to the East and Esk National park and the Deongwar State Forest to the West. The catchment is shown in Figure 1-1. Sandy Creek and Redbank Creek flow in a west to east direction through the catchment. At the centre of town, the two creeks combine and continue downstream as Sandy Creek. To the north, Beer Creek confluences with Gallanani Creek (North Branch), and then with Gallanani Creek (South Branch) a few kilometres downstream from Esk. Gallanani Creek meets Sandy Creek just north of Esk Township, and collectively forms Esk Creek which flows into Lake Wivenhoe approximately 7km to the west.

The total contributing area of the Redbank and Sandy Creek catchment to the Esk Township is approximately 118.4 km^2. In terms of length, the catchment is approximately 34km measured from north to south and approximately 13km east to west.

The Redbank and Sandy Creek catchment is traversed by three (3) major roads as illustrated in Figure 1-1, these being The Brisbane Valley Highway, Esk Hampton Road and Gatton Esk Road. Brisbane Valley Highway traverses the catchment in the north through Esk town centre before exiting the catchment to the east. Esk Hampton Road comes in from the West through the Deongwar State Forest and meets with the Brisbane Valley Highway in the town centre. Esk Road comes from the south and meets the Brisbane Valley Highway about 400m after its junction with Esk Hampton Road.

Most of the existing development in the catchment is in the downstream areas and at the eastern portion of the catchment. The remainder of the catchment is primarily rural with some low-density residential areas. The upstream catchment areas extend to the Esk National Park and is predominately forested.

[1] BMT 2018, *Brisbane River Strategic Floodplain Management Plan Technical Evidence Report.* Available: (Online) https://cloudstor.aarnet.edu.au/plus/s/o7L0vJD0Uo5UO4B.

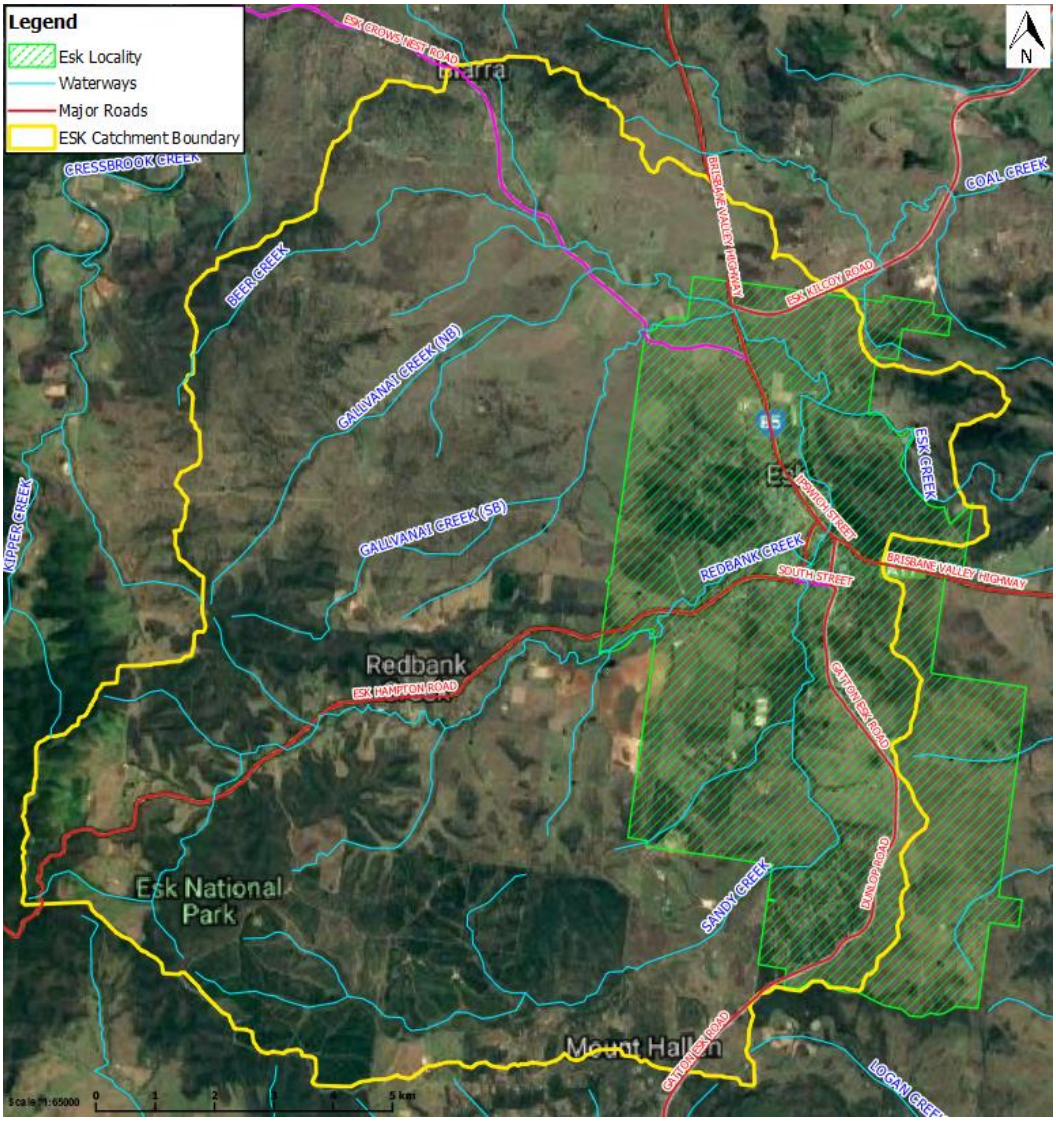

FIGURE 1-1 ESK CATCHMENT LOCALITY MAP

2 CURRENT FLOOD RISK

The following information provides an overview and understanding of the flood exposure and current flood risk within the Esk catchment area.

For further flood history of Esk and its catchments, the Somerset Flood Study Technical Report[2] should be consulted for a detailed breakdown of any historical flooding and catchment characteristics.

2.1 Flood Risk Assessment

2.1.1 Overview

The approach taken to identify, document and analyse flood risk in the Esk township for this Local Management Flood Plan (LFMP) follows the guidelines and strategic framework established in the Brisbane River Strategic Floodplain Management Plan (SFMP), which guides stakeholders to build flood resilience within the communities.

The risk assessment methodology established in the SFMP is in accordance with ISO 31000:2009 which summarises the process into four steps:

1) Risk identification
2) Risk analysis
3) Risk evaluation
4) Risk treatment

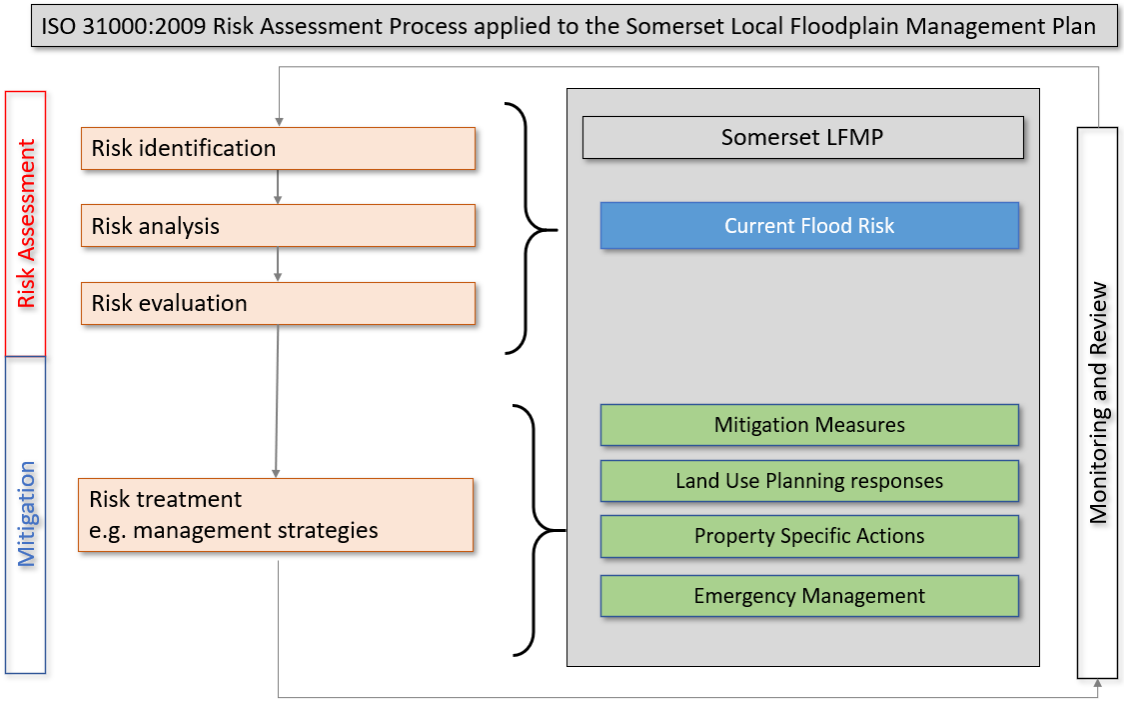

FIGURE 2-1 RISK ASSESSMENT PROCESS APPLIED TO THE LFMP

[2] *Water Technology, 2020 - Somerset Flood Study Technical Report*

2.1.2 Risk Identification

Whilst the above risk assessment process is reflective and driven by the SFMP framework, the identification of flood risk in the Somerset Catchments has been refined and evolved to suit locally specific conditions. i.e. the local risks are alike to the associated creek catchments and major tributaries of the Brisbane River Catchment.

Therefore, flood risk to the Somerset Local Government Area (LGA) has due consideration to the following:

- Potential Hydraulic Risk;
- Direct and indirect damages caused by flooding;
- Isolation caused by flood waters creating flood islands;
- Time to inundation of roads and buildings;
- Duration of inundation of roads and buildings.

The SFMP provides the baseline methodology for calculating the risk identification. However, where the LFMP has refined the methodology, this will be clearly stated in this document.

2.2 Risk Analysis

Risk is defined as a combination of **likelihood** and **consequence**.

Likelihood of flood risk has been kept consistent across all flood studies in the Somerset Floodplain Management Plans (LFMP) and is expressed as the hazard's Annual Exceedance Probability (AEP), representing the probability of a flood event to reach or exceed a given intensity in any year.

The following AEP events were considered when assessing risk:

- 1 in 10 (10% AEP)
- 1 in 20 (5% AEP)
- 1 in 50 (2% AEP)
- 1 in 100 (1% AEP)
- 1 in 500 (0.2% AEP)
- 1 in 2000 (0.05% AEP)
- PMF (Probable Maximum Flood)

It should be noted that the PMF ranges in flood likelihood across the Somerset LGA due to the local creek catchment variance. The Brisbane River Catchment adopts a consistent 1 in 100,000 likelihood for the PMF.

Consequence examines the impact to exposed elements resulted by a flood event. This is both the physical impact of the event on an asset, as well as the economic, social, and environmental impacts on the same asset.

Potential Hydraulic Risk has been used in the Brisbane River Flood Studies and SFMP to define a regionally consistent definition of consequence using Potential Hydraulic Risk derived from hazard characteristics identified in the Australian Institute of Disaster Resilience (AIDR) guideline. These six characteristics are defined in the graphic taken from AIDR in Figure 2-2 and represented in the map in Figure 2-3.

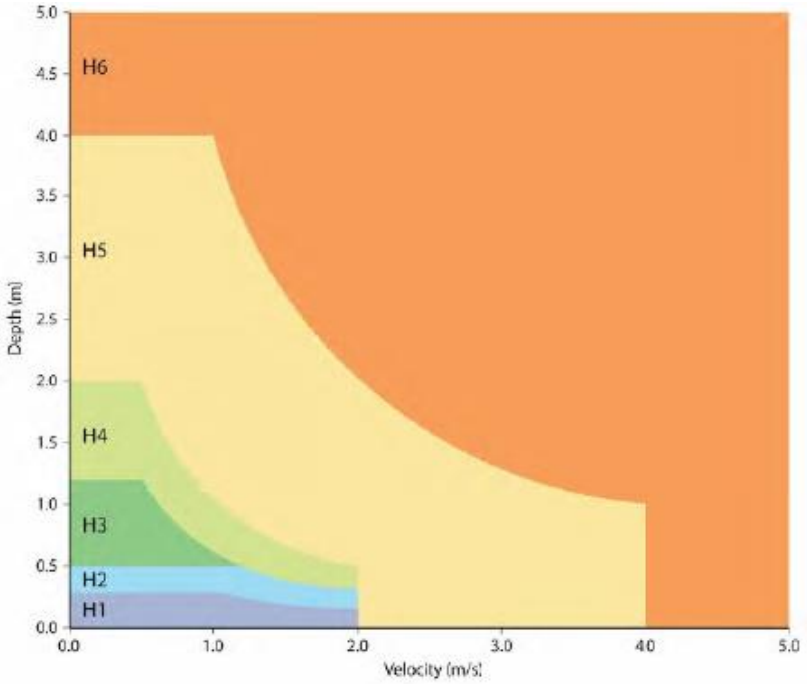

FIGURE 2-2 AIDR HAZARD CATEGORIES

These hazard categories are important component of defining flood risk and breaking down the hazard across the floodplain. Using different hazard categories across the catchment is helpful in designating appropriate flood risk management responses in areas exposed to hazard that is unsafe for children and the elderly; or on the other end of the scale, areas potentially exposed to hazard that threatens the structural integrity of buildings.

2.3 Hazard

Hazard is one of the most critical elements to defining overall flood risk. For the Esk area it enables assessment of particular hazards to different circumstances (risk to life, property and vehicles). The entire hazard output from the flood model is shown below and a close-up version of the Esk Township is shown for the 1 in 100 and 1 in 2000 AEP events.

The following is noted with regards to the township shown in Figure 2-4 and Figure 2-5:

- During the 1 in 100 AEP, the floodplain has broken out across the township from the south and caused widespread inundation. This inundation flows through properties and the central commercial areas; then crosses the Brisbane Valley Highway, further inundating residential properties;
- Some properties are exposed to life-threatening hazards (H3 and H4) and in some isolated cases there are properties exposed to H5 hazard which threatens structural damages of these premises;
- During the 1 in 2000 AEP event, the consequences of flooding increases dramatically with the entire township exposed to H3 and H4 flooding. There are also several houses exposed to the potential of structural damage encountering H5 hazards.

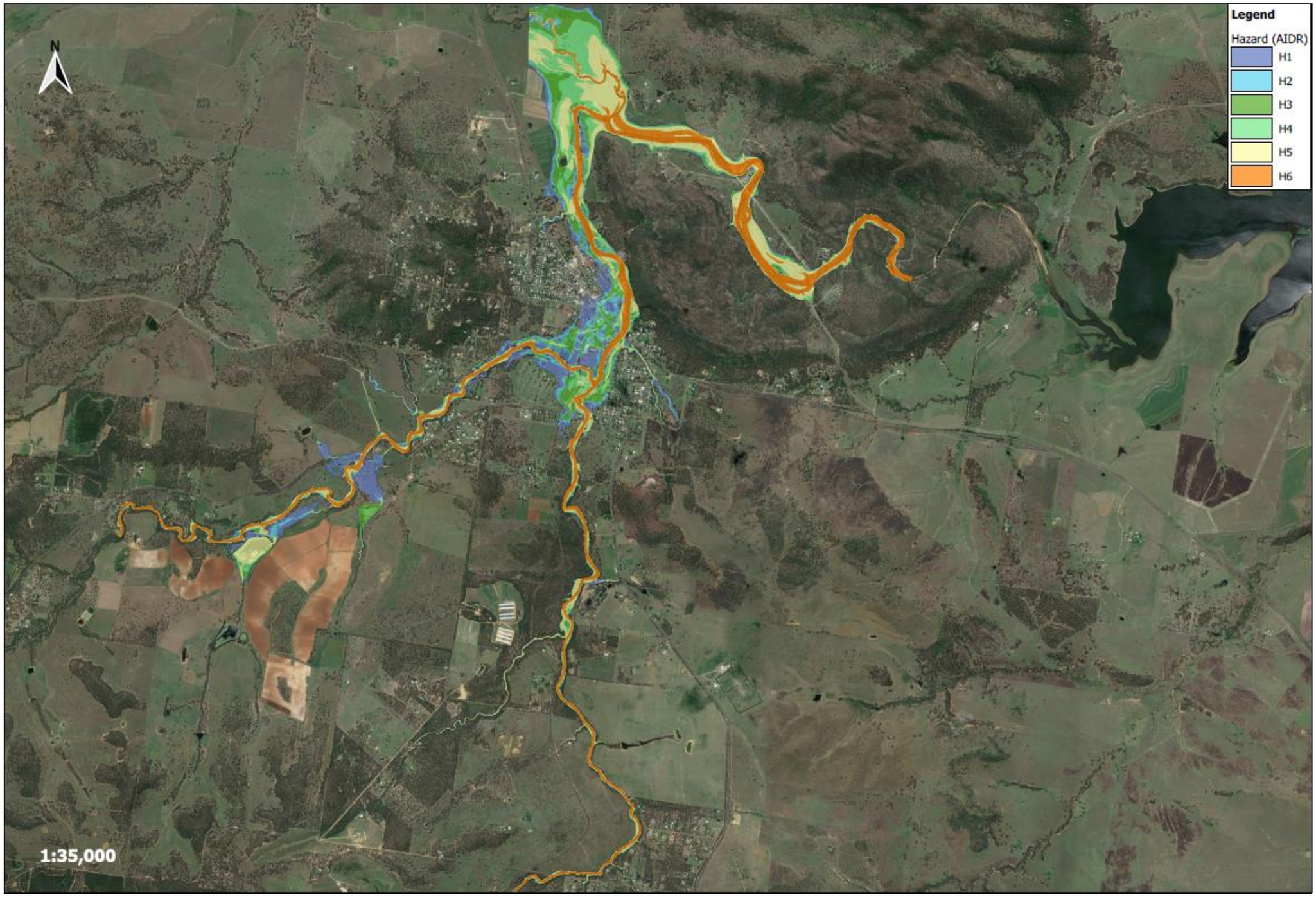

FIGURE 2-3 ESK 1 IN 100 AEP HAZARD

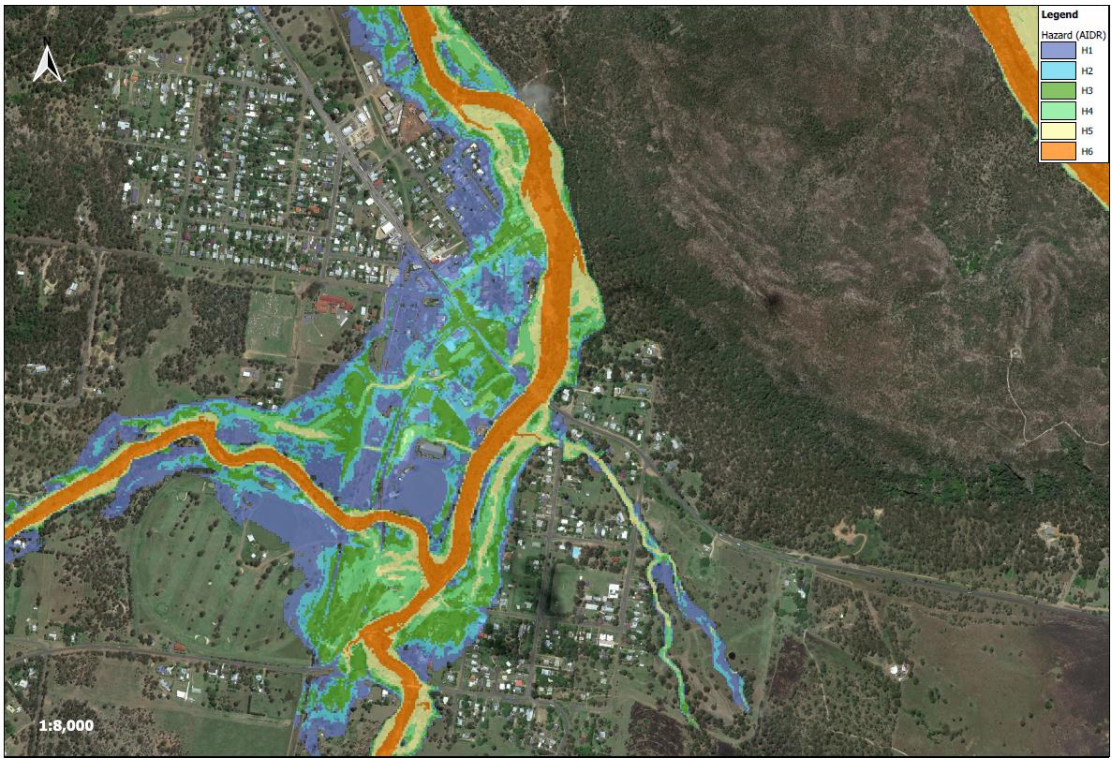

FIGURE 2-4 ESK TOWNSHIP 1 IN 100 AEP HAZARD

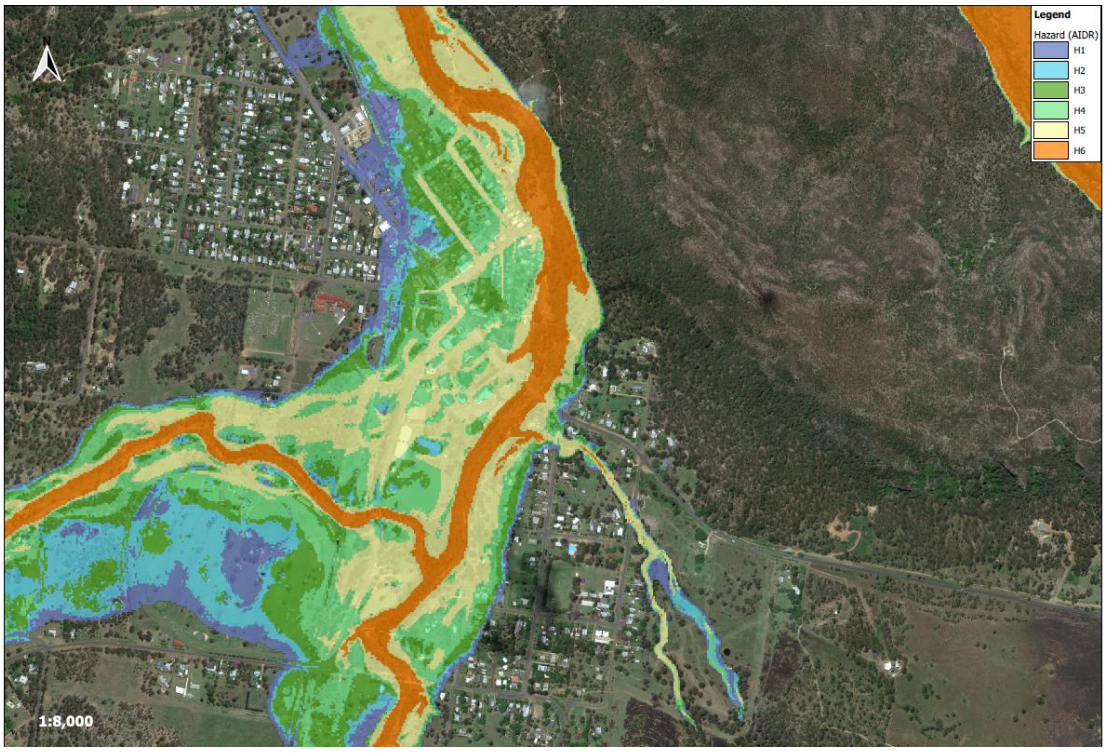

FIGURE 2-5 ESK TOWNSHIP 1 IN 2000 AEP HAZARD

2.4 Potential Hydraulic Risk

Potential hydraulic risk (PHR) represents the hydraulic behaviour of floods and their likelihood to occur in a given floodplain. PHR is a useful tool to distinguish between degrees of risk (i.e. from low and high risks). For example, higher frequency higher hazard flooding requires special consideration, due to the elevated risks of both characteristics.

The methodology in the SFMP applies potential hydraulic risk across seven likelihood AEP events, providing a gradation of risk across five risk definitions. The mapping is sufficiently granular to pick up different bands of risk areas across the floodplain regionally. The output is five bands of relative hydraulic risk, derived from a matrix combining seven flood events.

The SFMP HR matrix identifies five bands of risk (HR1-HR5), with HR1 being the highest hydraulic risk to HR5 being the lowest hydraulic risk.

This is intended to be used for regional riverine flooding, but it disproportionally overrepresents areas of higher hazard (HR1 and HR2) across local creek floodplains, due to the frequency of events mapped in these categories. Through project team workshops, it was determined that more refinement and detail was needed to distinguish between low likelihood and hazard. Examples of this include:

- Defining low likelihood flooding (1 in 10 AEP) that has low hazard (H2):
  - The SFMP method defines this as HR1 (the highest risk category being low likelihood).
  - While this is true, understanding why risk is so high is also important.
- Defining low likelihood flooding (1 in 10 AEP) with extreme hazard (H6):
  - The SFMP method defines this as HR1.

It is useful to distinguish between the two examples above, as the second situation has a much higher risk and should be mitigated against, in areas within this category. To differentiate between risk categories, a new matrix was adopted that provided a way to distinguish between floods driven by frequency and hazard.

Three broader subcategories are used, vertically splitting the matrix to align with the three consequence thresholds (AIDR hazard categories). This creates three sub-classifications within the HR1 to HR3 bands to reflect low hazard (H1), moderate hazard (H2-H4) and High hazard (H5-H6) within each HR band. The revised Hydraulic Risk matrix includes 10 discrete bands of risk with HR5, HR4, HR3 containing (a), (b) and (c) sub-categories, HR2 also containing (a), (b) and (c) sub-categories and HR1 containing only (b) and (c) subcategories.

The adopted Potential Hydraulic Risk Matrix is shown below.

TABLE 2-1 REVISED POTENTIAL HYDRAULIC RISK MATRIX

AEP	H1	H2	H3	H4	H5	H6
PMF	HR5	HR5	HR5	HR5	HR5	HR5
1 in 2000	HR5	HR5	HR4	HR4	HR4	HR4
1 in 500	HR5	HR4	HR4	HR3 (b)	HR3 (c)	HR3 (c)
1 in 100	HR4	HR4	HR3 (b)	HR2 (b)	HR2 (c)	HR2 (c)
1 in 50	HR4	HR3 (b)	HR2 (b)	HR2 (b)	HR1 (c)	HR1 (c)
1 in 20	HR3 (a)	HR2 (b)	HR2 (b)	HR1 (b)	HR1 (c)	HR1 (c)
1 in 10	HR2 (a)	HR1 (b)	HR1 (b)	HR1 (b)	HR1 (c)	HR1 (c)

The following can be derived from the new matrix:

- The (a) subcategories represent further distinction in catchments of a low hazard risk (i.e. of lesser consequence other than flood damage);
- The (b) subcategories represent the consequence range where there is risk to vehicles and life; and
- The (c) subcategories represent the consequence range where there is risk to structures.

It should be noted that hydraulic risk merely represents a portion of overall flood risk. Holistic flood risk includes a variety of other factors that are considered throughout the LFMP in conjunction with hydraulic risk.

The overview of the hydraulic risk output is shown below in Figure 2-6. In addition, the Esk Township is also shown in Figure 2-6 and the following is noted:

- There is some minor exposure to low hydraulic risk upstream of the Esk township;
- Within the township there is a mix of hydraulic risk. There is some HR3 (a) flooding which indicates generally frequent flow hazard flow. There is also HR4 flooding which can be associated with high hazard flooding in higher magnitude events (as expressed in the hazard overview);
- The township also has some isolated cases of HR2 (c) and HR3 (b) which is triggered with higher hazard flooding; and,
- The highest hydraulic risk property is exposed to HR1 (c). These properties are exposed to very high hazard and higher frequency which is of immediate concern from a PHR point of view. Put simply, these houses have a high probability that they will be structurally damaged rather frequently and require special consideration for this highest of hydraulic risk.

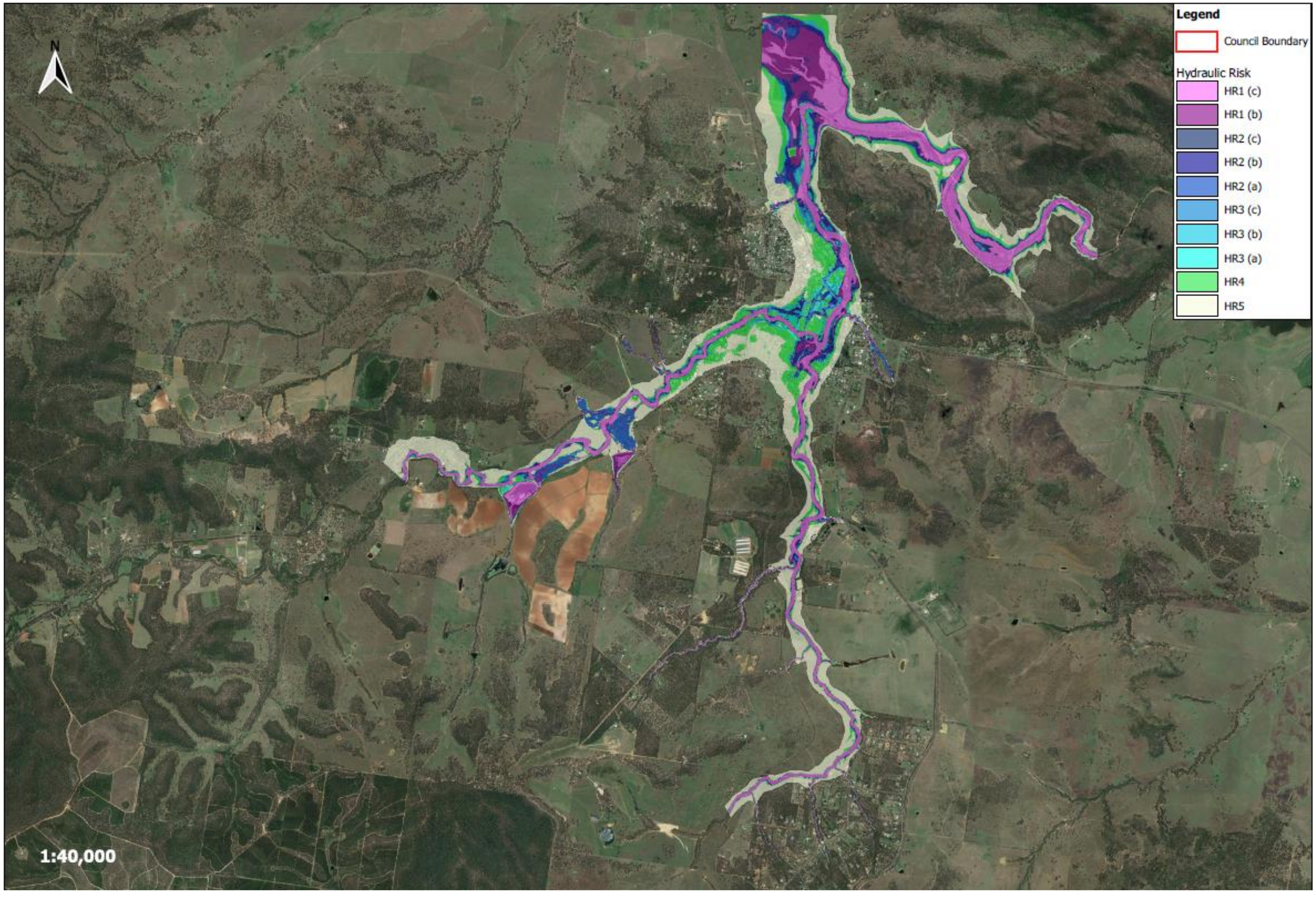

FIGURE 2-6 ESK HYDRAULIC RISK OUTPUT

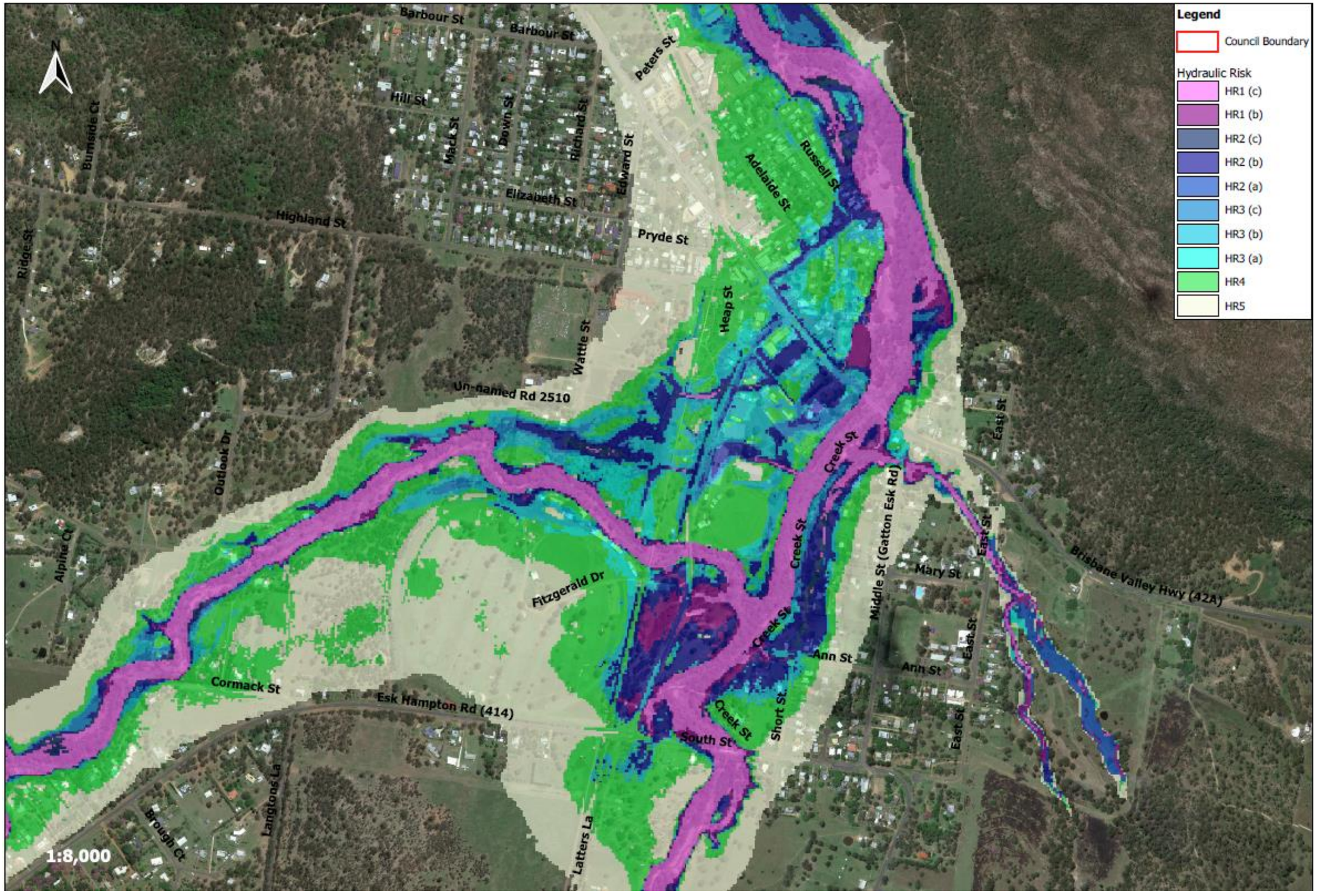

FIGURE 2-7 ESK TOWNSHIP HYDRAULIC RISK OUTPUT

2.5 Flooding and Climate Change in Esk

The following provides a summary of the current flood risk exposure in Esk:

- Inundation in the 1 in 100 AEP event generally affects residential dwellings on Russell St, Adelaide St, Creek St, Ann St and properties on the Brisbane Valley Highway near Sandy Creek and the SRC Offices;
- Several residences on Russell Street are inundated in the 1 in 10 AEP event;
- Flooding extents are sensitive to changes in rainfall intensities and flows;
- A large portion of the town is affected by the PMF extent;
- Brisbane Valley Highway is flood affected in the 1 in 20 AEP event.

The climate change scenario considered as part of the Somerset Flood Study assessed an increase in rainfall intensity which was assessed based on the 1 in 100 AEP. The climate change scenario was completed based on the guidance provided in Book 1, Chapter 6 of ARR2019. Specifically, this included a factored increase in rainfall intensity of 11.5% which is consistent with the 6.0 RCP to the year 2090. The difference between the 1 in 100 AEP in current conditions and the 1 in 100 AEP plus climate change modelling results are displayed in Figure 2-8 for Esk. Water levels increase up to approximately 300mm at the township. The flooding extent in the southern portion of the township is sensitive to increases in rainfall intensity and stream flows.

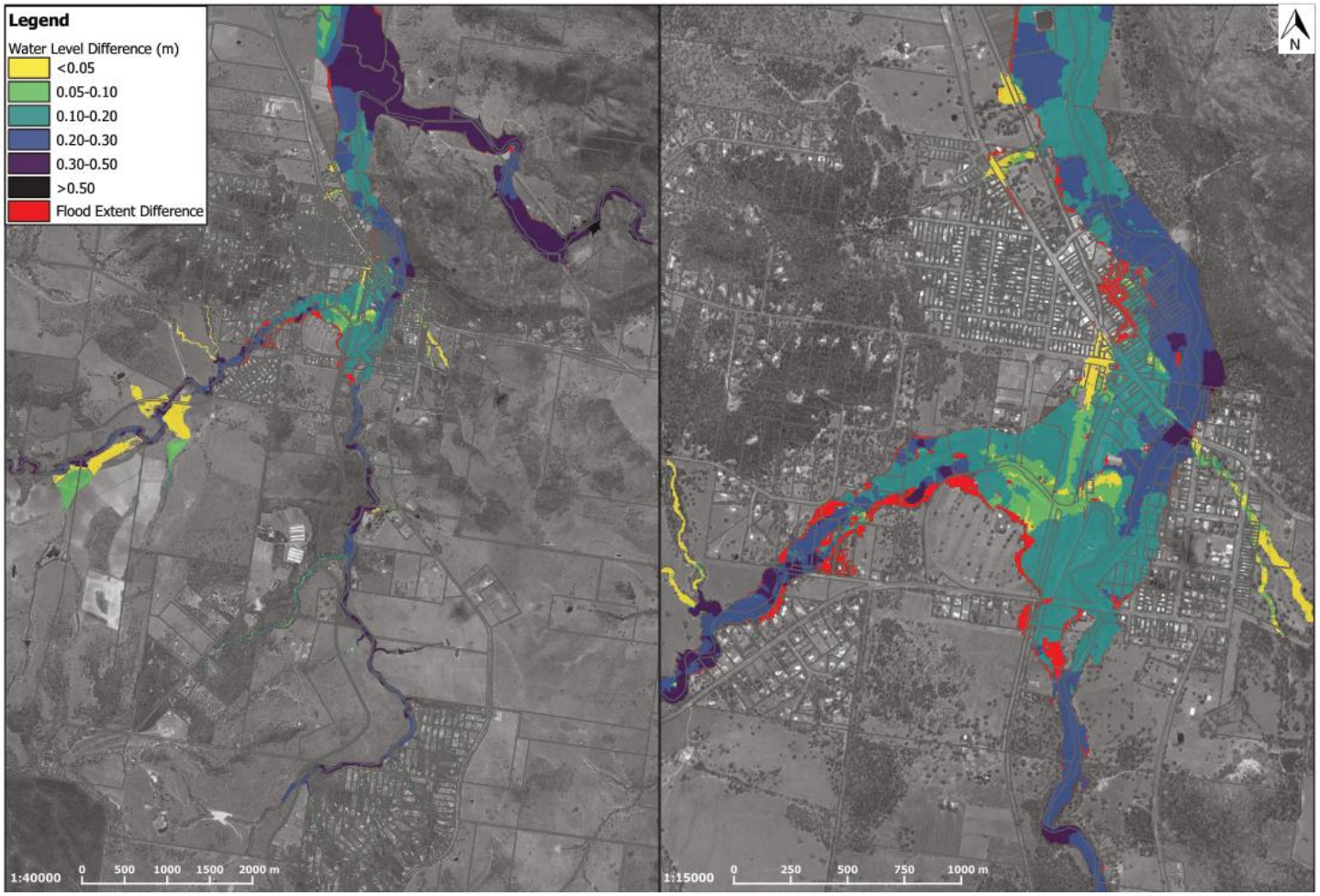

FIGURE 2-8 WATER LEVEL DIFFERENCE BETWEEN 1 IN 100 AEP AND 1 IN 100 AEP WITH CLIMATE CHANGE

2.6 Current Flood Exposure

Understanding the multi-faceted nature of vulnerability and exposure is a prerequisite for determining how weather and climate events contribute to the occurrence of disasters, and for designing and implementing effective risk management strategies (Cardona et al. 2012). Therefore, it is important to not only map assets, buildings, and services, but to also identify the community's vulnerability and exposure to flooding hazards.

This section explores the exposure of key built and community assets which are mapped within the floodplain, whereas later in the report, vulnerability of the community across the floodplain is summarised.

2.7 Building and Population Exposure

A spatial analysis of the land use zoning, buildings and flood information reveals the following exposure of existing land use across the Esk area.

2.7.1 Building Use Type Exposure Summary

An analysis of land use exposure, based upon planning scheme zonings, has been undertaken across the Esk Area and is shown in Table 2-2.

- The mapped extent of the floodplain reveals 120 detached residential buildings are exposed to flooding in the 1 in 100 AEP event;
- In a small event (1 in 2 AEP for example) there are very low numbers of ground level inundation in detached dwellings (2). This increases to 62 in the 1 in 20 AEP event as the floodplain engages within the Esk township; and
- A similar pattern also occurs in Community facilities impacted with substantial numbers inundated within this category.

TABLE 2-2 OVERALL ZONE EXPOSURE GROUND LEVEL FLOODING

AEP (1 in x)	Residential (Detached)	Residential (Multi-Dwelling)	Rural Living / Primary Production	Commercial / Business	Industrial	Community / Public Facilities	Public Utility (Critical or Sensitive)	Mining	Other (Mixed Use)	Vacant^
1	-	-	-	-	-	-	-	-	-	8
2	2	-	1	-	-	-	-	-	-	8
5	5	-	1	-	-	1	-	-	-	10
10	14	-	4	-	-	7	-	-	-	11
20	62	-	5	5	1	31	4	-	4	12
50	103	-	9	11	2	44	7	-	4	17
100	120	-	10	18	3	49	8	-	4	18
200	143	-	12	25	4	61	8	-	4	24
500	149	-	12	25	7	74	8	-	4	35
1000	155	-	13	28	13	78	8	-	4	40
2000	163	-	13	40	15	81	8	-	4	44

^ *Estimated by finding all lots zoned as Emerging Community, General Residential, Rural Residential or Township within the flood extent that do not have a house-sized building (>80sqm)*

In addition to the degree of flooding of buildings occurring at ground level, an assessment was undertaken of buildings flooded at floor level. As expected, this decreases the numbers of buildings triggered.

- The highest relative increase across all storm events is between the 1 in 10 and 1 in 20 AEP flood events which associated with the floodplain engaging into the Esk township.

2.7.2 Residential Building Type

A building database for the entire Somerset LGA has been created for analysis for the Somerset LFMP. The database contains all building-scale information collated from Somerset Regional Council and the datasets from the Department of Natural Resources and Mines to calculate building floor level heights based on building classifications. The SFMP process for calculating floor level heights[3], has been applied to the buildings in the Somerset LGA. The building database documents building classification types, shown in Table 2-3.

TABLE 2-3 BUILDING CLASSIFICATION

Description	Category
Low set Single Story Slab on Ground	FDSS-SOG
Low set Single Story on stumps	FDSS - Stumps
Highset	FDHS
Low set Single Story (slab on ground)	FDDS
Single Storey	MUSS
Double or More Stories	MUDS

This database has been used in the Somerset LFMP for calculating existing and mitigated flood damages, screening properties potentially eligible for property specific actions, and prioritising properties for evacuation. The database will be provided to Council for use after completion of the LFMP project.

Further analysis of the residential building types as identified in Table 2-4, reveals minor differences in buildings affected in each flood event at ground level. For example:

- Between the lower magnitude events (1 in 1 to 1 in 10 AEP) there are only small numbers (up to 25) inundated in these more frequent events;
- Between the 1 in 10 and 1 in 20 AEP event there is a significant increase in inundation of over 127% more buildings. This is associated with the floodplain engaging across the township;
- There is also a fairly large increase from the 1 in 20 to 1 in 50 AEP event, again associated with more widespread inundation and depth of the floodplain; and
- The numbers increase steadily as magnitude increases, however there are no spikes in these numbers as the full floodplain is generally engaged during the 1 in 50 AEP event.

TABLE 2-4 RESIDENTIAL BUILDING TYPE EXPOSURE GROUND LEVEL

AEP (1 in X)	FDSS-SOG	FDSS-Stumps	FDHS	FDDS	MUSS	MUDS	Total
1	-	-	-	-	-	-	0
2	1	-	2	-	-	-	**3**
5	4	2	2	-	-	-	**8**
10	10	9	2	2	-	2	**25**

[3] As documented in the report Building Floor Level Heights – Brisbane Strategic Floodplain Management Plan – Brisbane LGA, Ipswich LGA, Somerset LGA and Lockyer Valley LGA dated 16/06/2017.

20	49	50	8	3	-	2	**112**
50	68	96	11	8	-	2	**185**
100	79	114	13	3	-	3	**212**
200	95	143	13	3	-	3	**257**
500	103	156	14	3	-	3	**279**
1000	110	166	16	4	-	3	**299**
2000	117	179	21	4	-	3	**324**
PMF	154	243	29	4	-	3	**433**

Note: Includes Rural Residential Buildings

Further analysis was undertaken to determine the number of and type of buildings with over-floor flooding. The results of this analysis are tabulated in Table 2-5.

- No properties are exposed to over the floor flooding in relatively frequent events such as the 1 in 2, and 1 in 5 AEPs. Only 3 properties are exposed during the 1 in 10 AEP.
- A sudden increase is seen however with over-floor flooding between 1 in 10 and 1 in 20 AEP events.

Low set Single Story Slab on Ground (FDSS-SOG) appears to exhibit the style of house predominately inundated up to the 1 in 20 AEP. Once reaching into flood events of greater magnitude, like the 1 in 50 AEP, FDSS-Stumps style homes become the most inundated style of building. This is most likely due to the age of the properties which were built to flood levels applicable at the time of construction, however have since been surpassed in flood classification.

TABLE 2-5 RESIDENTIAL BUILDING TYPE EXPOSURE OVERFLOOR FLOODING

AEP (1 in X)	FDSS-SOG	FDSS- Stumps	FDHS	FDDS	MUSS	MUDS	Total
1	-	-	-	-	-	-	0
2		-	-	-	-	-	0
5		-	-	-	-	-	0
10	2	-	-	-	-	1	3
20	11	3	-	-	-	1	15
50	23	12	-	1	-	2	38
100	29	17	-	2	-	2	50
200	41	25	1	2	-	3	72
500	50	39	4	2	-	3	98
1000	57	56	5	2	-	3	123
2000	60	71	5	2	-	3	141
PMF	92	132	9	2	-	3	238

Note: Includes Rural Residential Buildings

2.7.3 Building Use Type Hazard Exposure

As demonstrated in Table 2-6, Esk's exposure information has been further refined to present the number of buildings within the floodplain and their relevant hydraulic risk.

Key inferences and considerations to be drawn from this information include:

- There are quite significant numbers of residential properties (47) within high risk flood categories;
- There are 8 residential properties exposed to the highest flood risk; and
- A total of 228 residential properties is within the mapped extent of the floodplain which is considered a high proportion of the overall township.

TABLE 2-6 OVERALL BUILDING EXPOSURE

Building Type	HR1 (c)	HR1 (b)	HR2 (c)	HR2 (b)	HR2 (a)	HR3 (c)	HR3 (b)	HR 3(a)	HR4	HR5	TOTAL
Residential	8	3	3	33	-	-	24	4	73	80	228
Residential Multi-Dwelling	-	-	-	-	-	-	-	-	-	-	-
Commercial	-	-	-	3	-	-	4	-	14	19	40
Industrial	-	-	-	1	-	-	1	-	5	11	18
Community and Public Facilities	2	3	-	9	-	5	13	6	33	19	90
Agriculture	2	2	-	2	-	-	1	-	3	30	40
Other	-	-	-	2	-	-	1	1	-	1	5
TOTAL	12	8	3	50	-	5	44	11	128	160	421

2.7.4 Population Exposure

Information about the population within the floodplain has been derived from the Australian Bureau of Statistics (ABS) 2016 census data. The equivalent census data to reflect building information (9 August 2017 Census) indicates a total population in Esk of 1,698 people. For the exposure assessment, the existing residential building data is multiplied by the average equivalent residents per building for Esk (2.2), as identified in Table 2-7.This shows the exposure of residential population per hydraulic risk category. The analysis shows:

- Almost 585 residents are mapped with the extent of the floodplain which indicates approximately 35% of the Esk residents, are exposed to flooding of some nature;
- There are an estimated 113 residents in the highest five potential hydraulic risk categories of HR1(c) to HR2(a), with approximately 22 residents in the highest potential hydraulic risk category of HR1(c); and
- The spatial distribution of at-risk residents is like the distribution of residential properties.

Analysis of the vulnerability of the exposed community is undertaken in Section 4.

TABLE 2-7 RESIDENTIAL POPULATION EXPOSURE

Building Type	HR1 (c)	HR1 (b)	HR2 (c)	HR2 (b)	HR2 (a)	HR3 (c)	HR3 (b)	HR3 (a)	HR4	HR5	TOTAL
Residential Buildings (combined)	10	3	3	35	-	-	25	4	76	110	266
Average Population	22	7	7	77	-	-	55	9	167	242	585

2.8 Critical and Sensitive Infrastructure

2.8.1 Critical Infrastructure Exposure

Critical infrastructure is an important component of flood exposure as this infrastructure performs an important life supporting role in flood events. It is critical to have infrastructure operational before, during, and after flood events, as it increases operational preparedness, response, and recovery significantly. The exposure of these built assets as shown in Table 2-8 is based on the land use categories dataset. The analysis reveals:

- A total of 9 buildings associated with critical infrastructure are within the floodplain;
- Of the 9 buildings there are 3 buildings in the highest risk categories of HR1(c) to HR2 (a).

TABLE 2-8 CRITICAL INFRASTRUCTURE BUILDINGS EXPOSURE

Critical Infrastructure	HR1 (c)	HR1 (b)	HR2 (c)	HR2 (b)	HR2 (a)	HR3 (c)	HR3 (b)	HR3 (a)	HR4	HR5
Water infrastructure	2	-	-	1	-	-	3	1	1	1
Electricity and telecommunications	-	-	-	-	-	-	-	-	-	-
Total	**2**	**0**	**0**	**1**	**0**	**0**	**3**	**1**	**1**	**1**

2.8.2 Evacuation Centres

As identified in the figure below two of the three nominated evacuation centres in Esk, are affected by hydraulic Risk. The following assessment of both of these buildings includes:

- The Esk Showgrounds evacuation centre is covered with HR4 impact. There are also some sections of the showground including buildings affected by higher hydraulic risk such as H3 (b) where there is elevated hazards; and
- The Somerset Civic Centre generally has a higher flood risk with some of the buildings affected by HR 2(b).

Further assessment of the evacuation centres and their overall flood risk is undertaken in the emergency management chapter of this report.

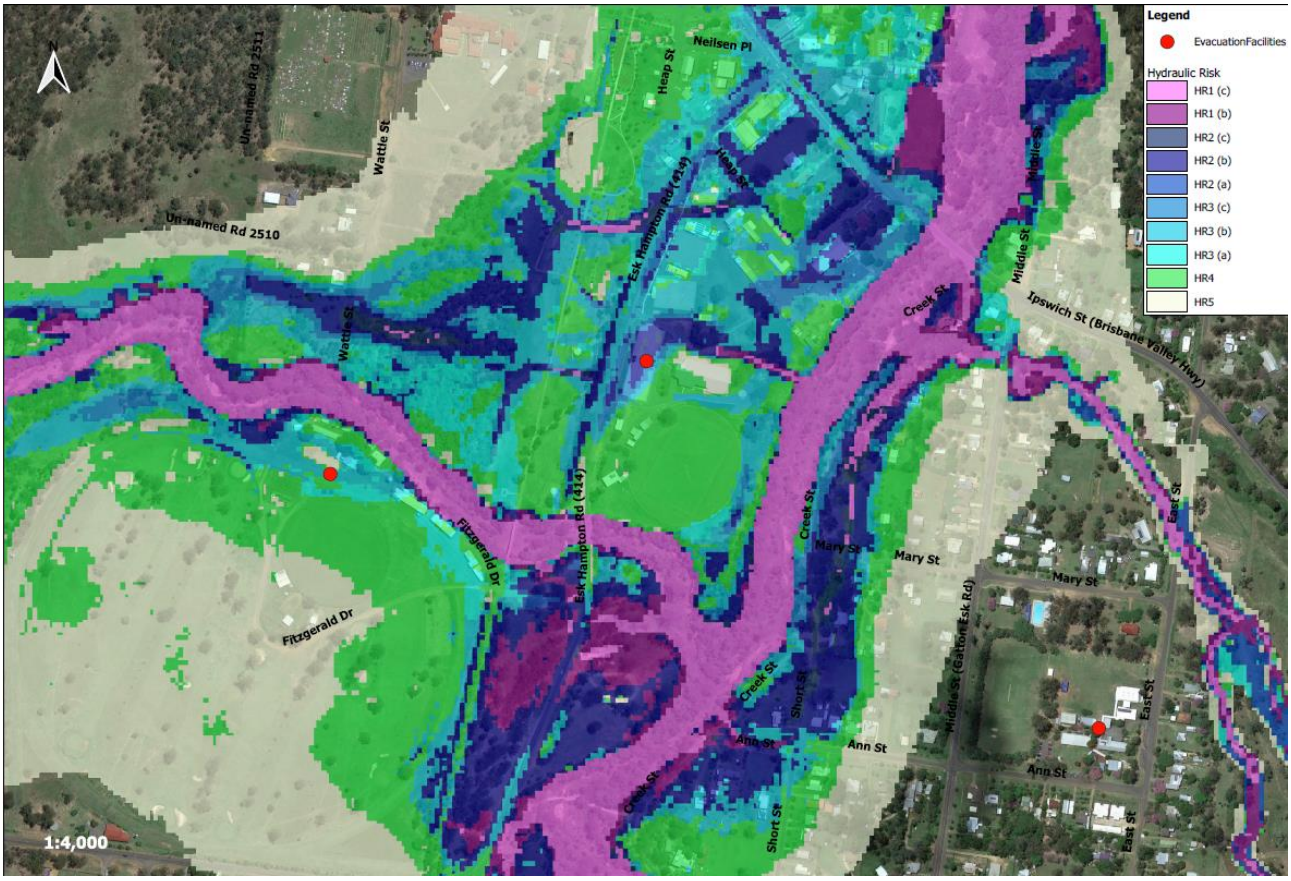

FIGURE 2-9 EVACUATION CENTRES

2.8.3 Sensitive Infrastructure

Uses that are 'sensitive' are considered as such due to the heightened risk associated with the inherent vulnerability of the occupants associated with that particular land use. For example, educational and childcare facilities are considered a sensitive use due to the vulnerability of children and elderly persons in flood events who may need assistance or emergency services to support evacuation. As identified in Table 2-9, there are only 3 community protection centres located in the lowest level of flood risk.

TABLE 2-9 SENSITIVE USE EXPOSURE

Sensitive Use	HR1 (c)	HR1 (b)	HR2 (c)	HR2 (b)	HR2 (a)	HR3 (c)	HR3 (b)	HR3 (a)	HR4	HR5
Childcare	-	-	-	-	-	-	-	-	-	-
Educational	-	-	-	-	-	-	-	-	-	-
Community Protection	-	-	-	-	-	-	-	-	-	3
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**3**

3 FLOOD ISOLATION

Isolation caused by floodwaters can be a major risk, especially when isolation occurs for long periods, or where critical services are cut-off. This can be exacerbated if the isolated dwelling's occupants are in need emergency assistance and/or evacuation. Areas of isolation are an important element of overall flood risk that should have due consideration. The LFMP has undertaken an analysis of isolation to provide flood intelligence to plan for pre-emptive evacuations during flooding, resupply operations, strategic land use planning responses and for community education and awareness. Isolation can be used in combination with other flood risk factors to prioritise for flood risk management treatment, and to ensure suitable future land uses are commensurate with the risk. This section describes the process of identifying flood islands, time to inundation and duration of inundation.

3.1.1 Flooded Road Immunity

The analysis of flooded roads identifies the first event in which the road is inundated. An overview map of the flood immunity is presented in Figure 3-1. The flooded road immunity shows locations across the Esk area which may be affected by poor road flood immunity. An example location is presented in Figure 3-1.

FIGURE 3-1 FLOODED ROAD IMMUNITY

An example of a close-up view of an area with low road immunity is shown below. This output can be extremely useful at a high level for identifying drainage infrastructure that is below immunity standard and for evacuation considerations (i.e. where key routes may require further investigation for upgrade).

FIGURE 3-2 ESK TOWNSHIP ROAD IMMUNITY

3.2 Time to Flood Inundation Information

The earliest time a road, building, or asset is inundated with floodwaters is known as Time to Inundation (TTI). The data informs several outputs that contributes to the picture of flood risk across the Esk area. The mapping produced uses TTI information for a high-level understanding across each catchment, TTI for buildings flooded above floor level, and TTI for roads flooded above low points.

TTI information is particularly useful to provide another factor in flood risk in areas such as evacuation, isolation, and community awareness. TTI helps Council to understand exposed road assets and the need for earlier action on road closures. When coupled with other flood risk outputs TTI is an incredibly important factor in determining flood risk. TTI information can and should also be used in future land use planning and strategic decisions regarding the appropriateness of settlement and designation of uses.

The emergency management chapter of the LFMP will explore the findings of this analysis. For example, flood intelligence could be used to develop and refine flood forecasting systems.

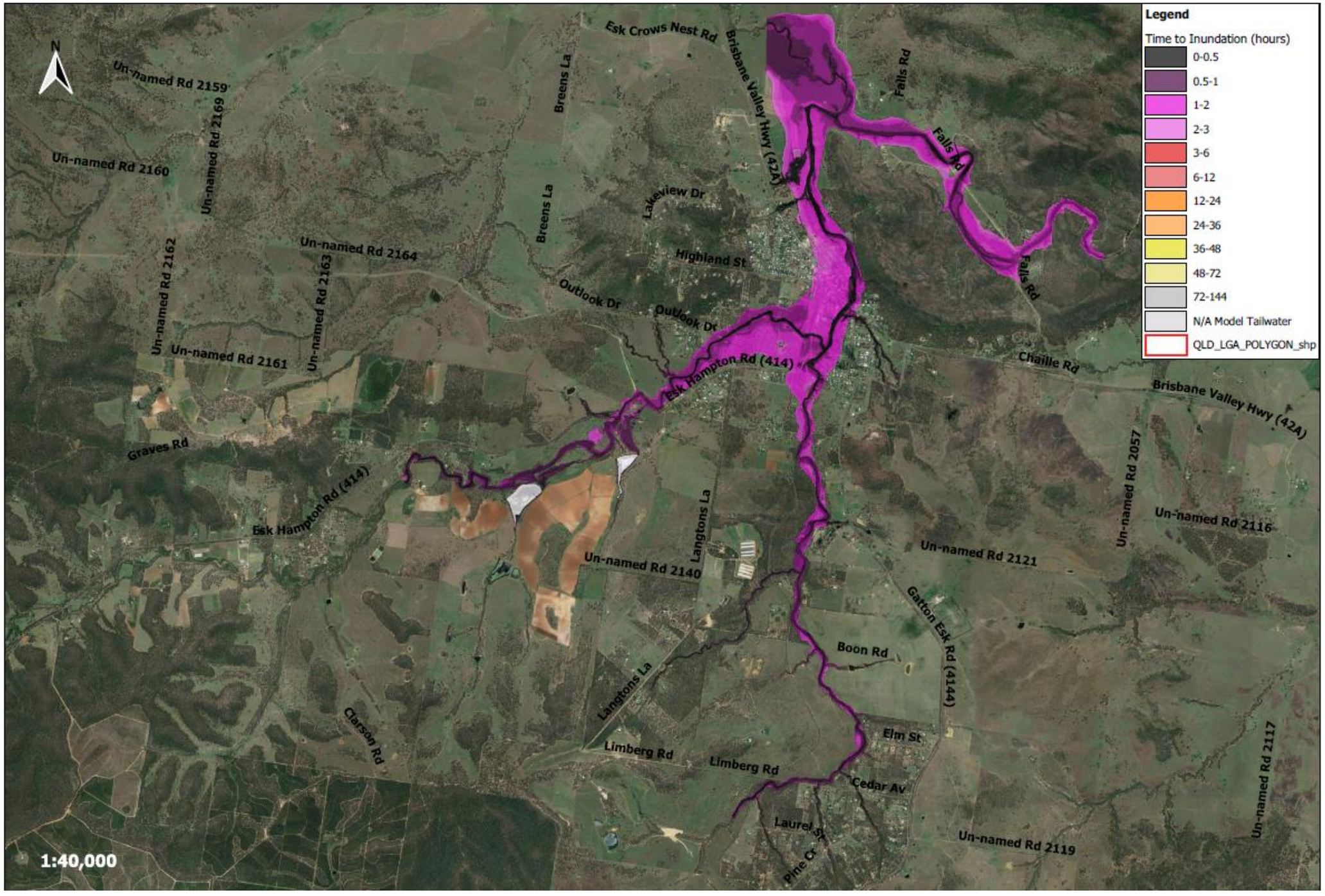

FIGURE 3-3 TIME TO INUNDATION (1 IN 2000 AEP) GROUND SURFACE

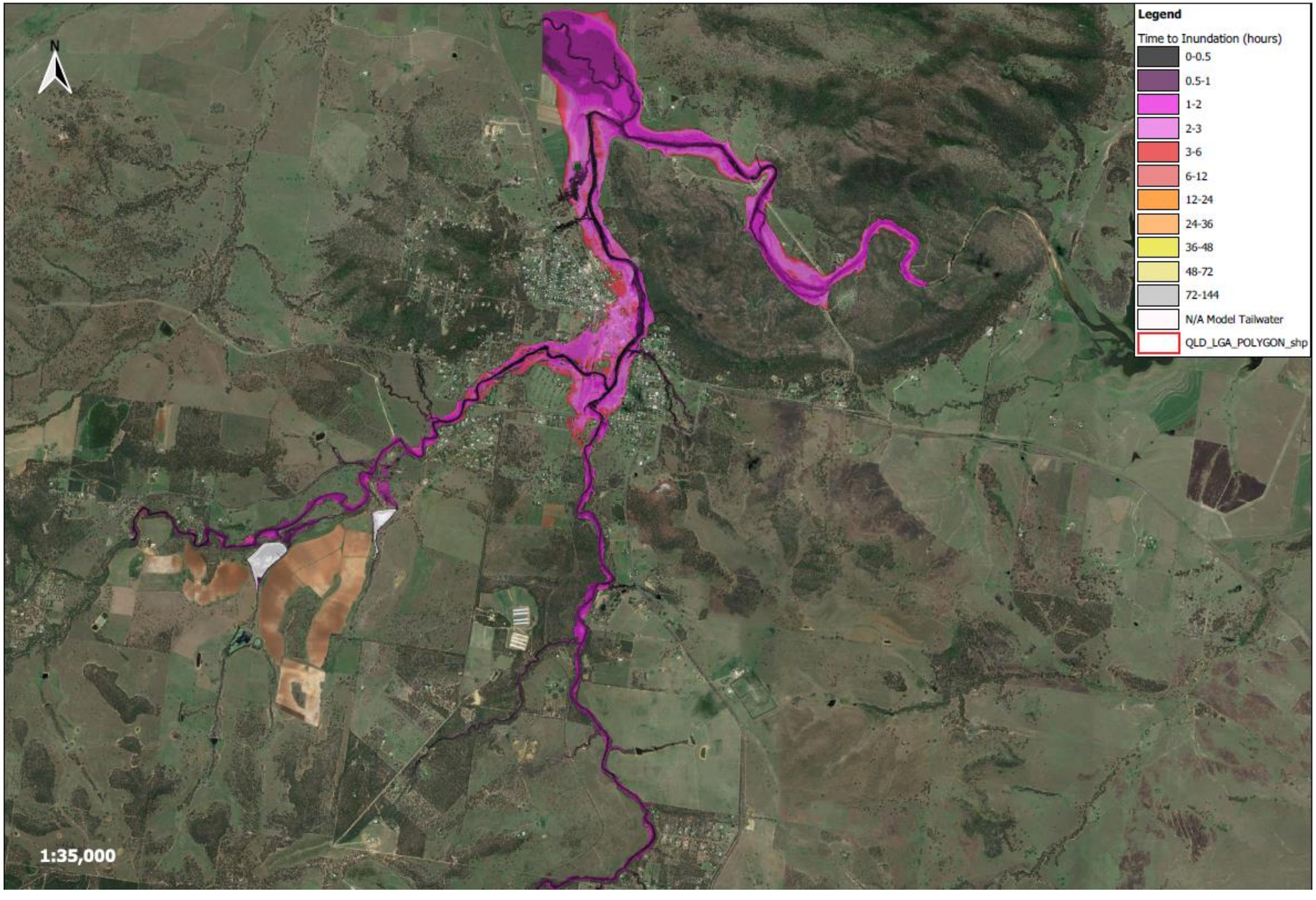

FIGURE 3-4 TIME TO INUNDATION (1 IN 100 AEP) GROUND SURFACE

As it can be seen from the Figure 3-3, TTI varies across the catchment dependent on:

- If the flood source is riverine, creek or overland flow/urban flooding;
- The location of the TTI (whether at the up or downstream sections of the catchment); and
- Interactions between multiple sources of flooding.

For the purpose of emergency management planning a 1 in 2000 AEP can be considered the “worst case” TTI. The speed of inundation differs significantly to the 1 in 100 and 1 in 2000 AEP, primarily due to flood storage being depleted faster, less resistance because of lower roughness values on floodplains, and an increase in velocity overall.

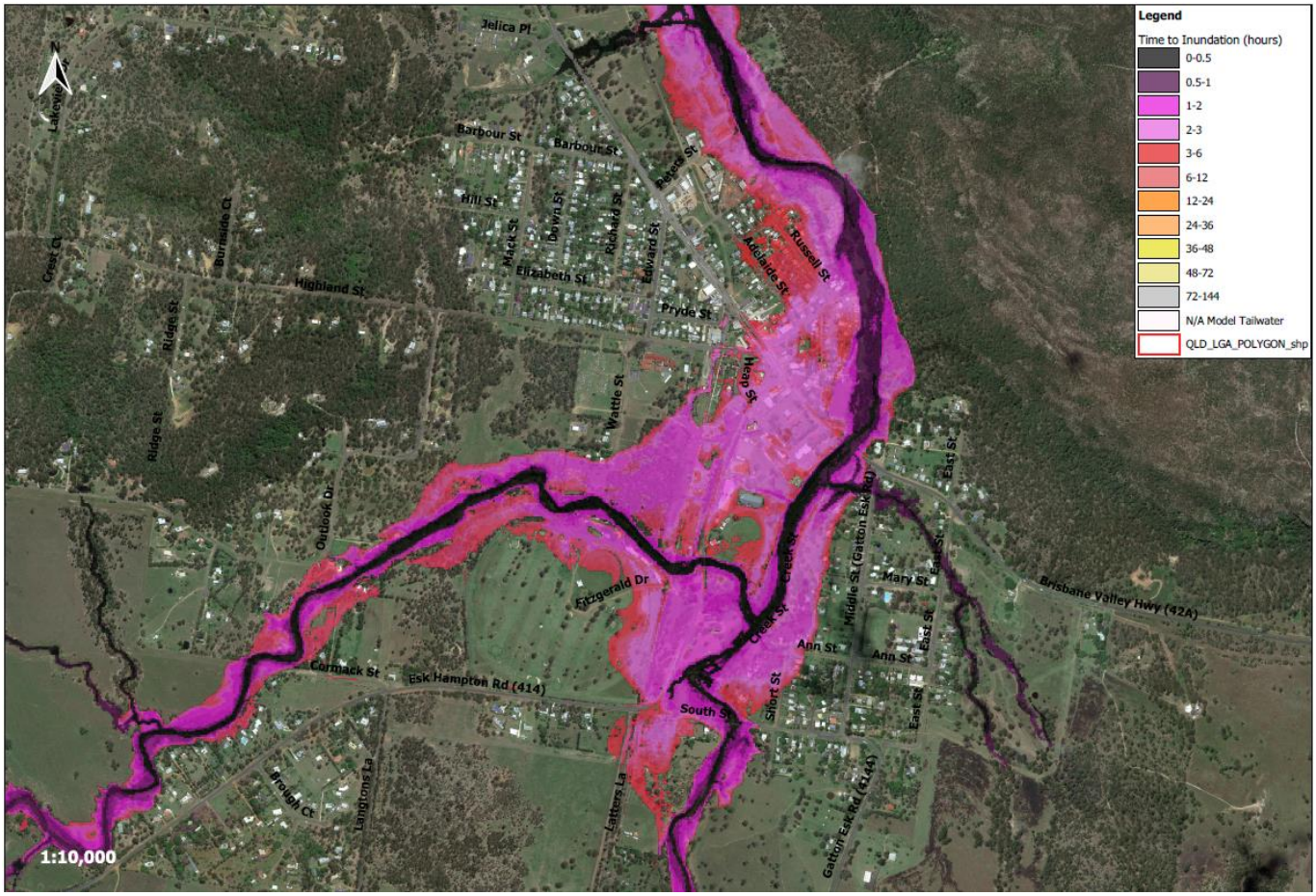

FIGURE 3-5 ESK TOWNSHIP CATCHMENT TIME TO INUNDATION (1 IN 100 AEP)

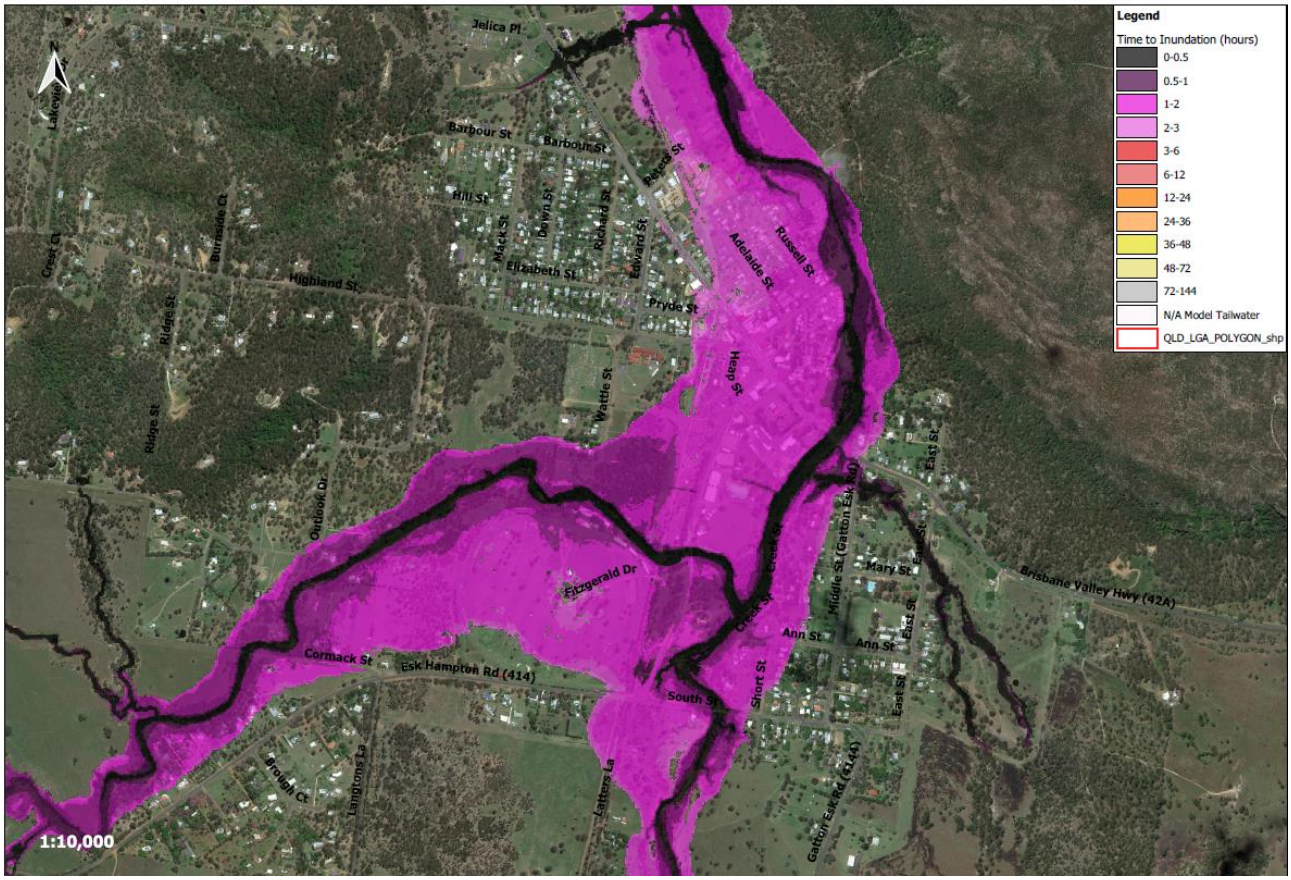

FIGURE 3-6 ESK TOWNSHIP CATCHMENT TIME TO INUNDATION (1 IN 2000 AEP)

Figure 3-5 and Figure 3-6 above in the Esk township show the change in TTI between the 1 in 100 and 1 in 2000 AEP. As it can be seen, all areas of the engaged floodplain, rapidly decrease in TTI in the 1 in 2000 AEP. This is an important concept to understand between low and high magnitude flooding as the TTI decreases, so does the overall flood risk, due to less time for residents and emergency services to respond. In addition, high magnitude floods also have higher hazard further increasing and compounding flood risk.

The data shown in the mapping will provide Council further guidance on TTI in these areas, for example where TTI is as short as 1 hour for the 1 in 2000 AEP event. A short TTI is associated with short response times to react to impending floodwaters, which may inhibit emergency response operations.

Across the Esk township, there are buildings and residents highly exposed to short flood response times, and short times of inundation above floor level. The raw GIS dataset provides TTI for all buildings and is a useful tool for Council to further investigate and understand these risks.

3.2.1 Time to Inundation Roads

The TTI to roads within the Esk township is shown in Figure 3-7. TTI is useful in determining which roads may flood first and is also useful in undertaking evacuation capability assessments. The emergency management chapter draws on this information to determine likelihood of evacuation capability, by comparing the TTI of the road and the time taken to evacuate.

This information and the process used to determine TTI would also be useful in future flood forecasting upgrades, to provide real time and far more accurate assessments of road closures, as opposed to pre-cooked “synthetic” flood events.

FIGURE 3-7 ROADS – TIME TO INUNDATION

As it can be seen from Figure 3-7, many of the roads in Esk are inundated very fast in a 1 in 2000 AEP event, with most flooded within 2 hours.

3.2.2 Time to Inundation Property

The TTI for buildings is mapped in Figure 3-8. TTI dataset is useful in determining which properties may flood first, distinguishing different types of awareness and education required (flash flooding verse riverine). The emergency management chapter uses this information with other aspects (hazard and vulnerability etc), to help determine the priority overall of the most at-risk residents.

This information and the process used to determine the TTI would also be useful in future flood forecasting upgrades, to provide real time and far more accurate assessments of road closures than pre-cooked "synthetic" flood events. The outputs produced whilst somewhat useful for background information, are static and do not align to real events. Combining this methodology with a forecast system would produce powerful intelligence that could help prioritise high risk properties during events.

FIGURE 3-8 BUILDINGS – TIME TO INUNDATION

Figure 3-8 shows a range of TTI values in the Esk township, of note is the very fast inundation times associated with flooding that breakouts in the entire area. This emphasises that there is very little time to respond to flooding in this catchment for residents.

3.3 Duration of Flooding Inundation Information

Duration of flood inundation (DFI) has been identified by calculating the length of time water exceeds a certain level. This has been calculated using the same events as the TTI methodology, i.e. 1 in 10 AEP, 1 in 100 AEP and 1 in 2000 AEP.

As identified in Figure 3-9 and Figure 3-10, the following is noted:

- During the 1 in 100 AEP, flooding in the Esk Township is of relatively short duration. In these sorts of events, as fast as houses are flooded, the floodwaters quickly recede; and
- During the higher magnitude floods (1 in 2000 AEP), flood duration increases and, in some cases, areas are flooded for up to 20 hours.

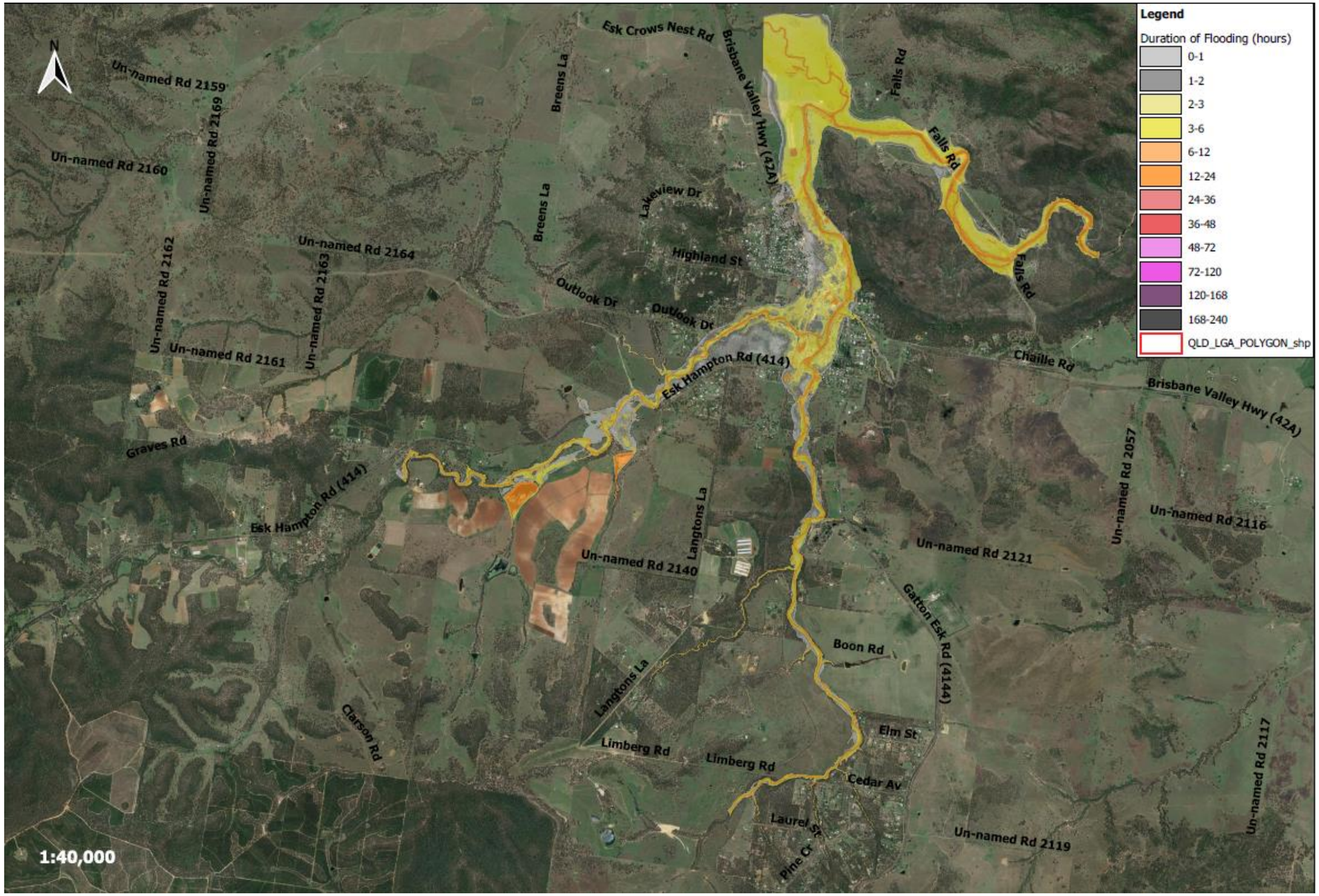

FIGURE 3-9 ESK DURATION OF INUNDATION 1 IN 2000 AEP

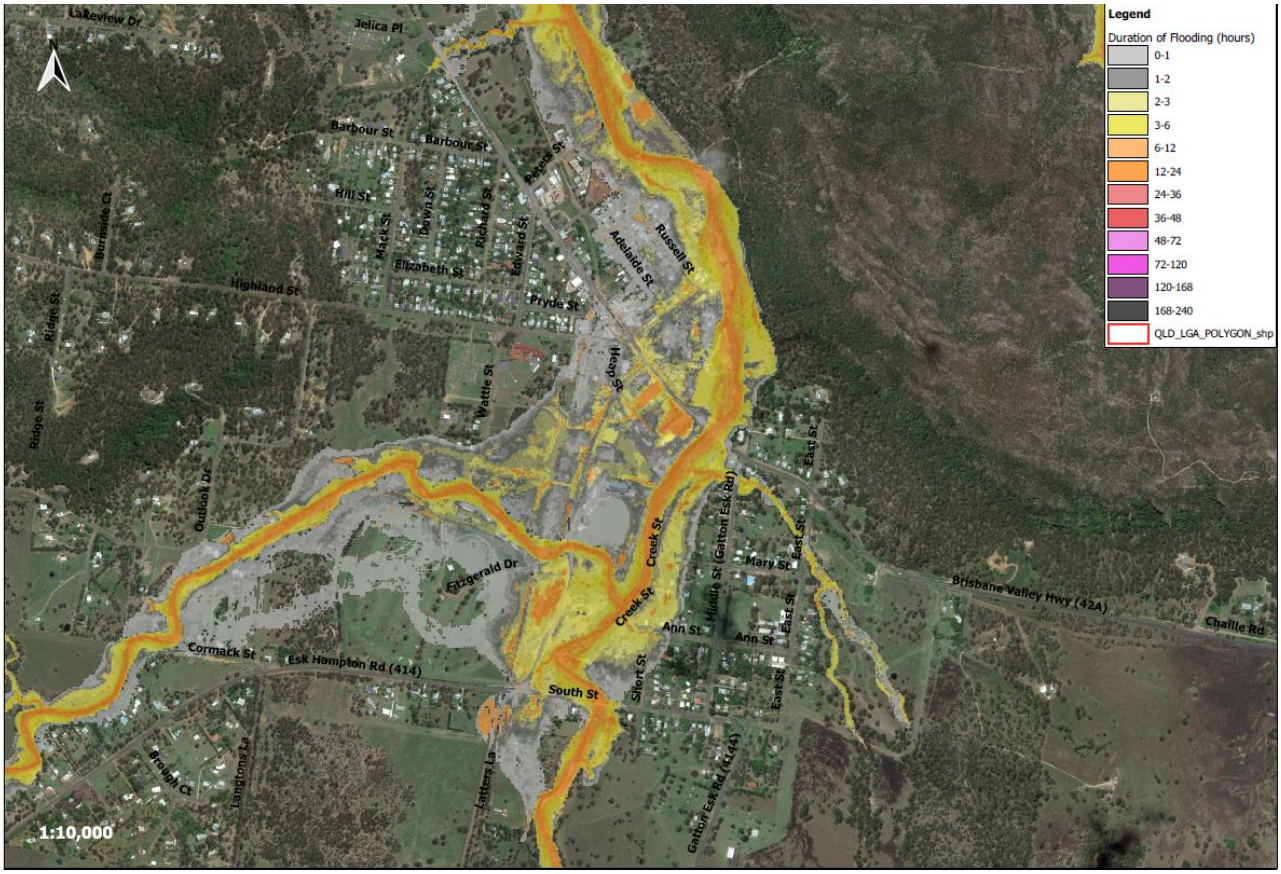

FIGURE 3-10 ESK TOWNSHIP DURATION OF INUNDATION 1 IN 100 AEP

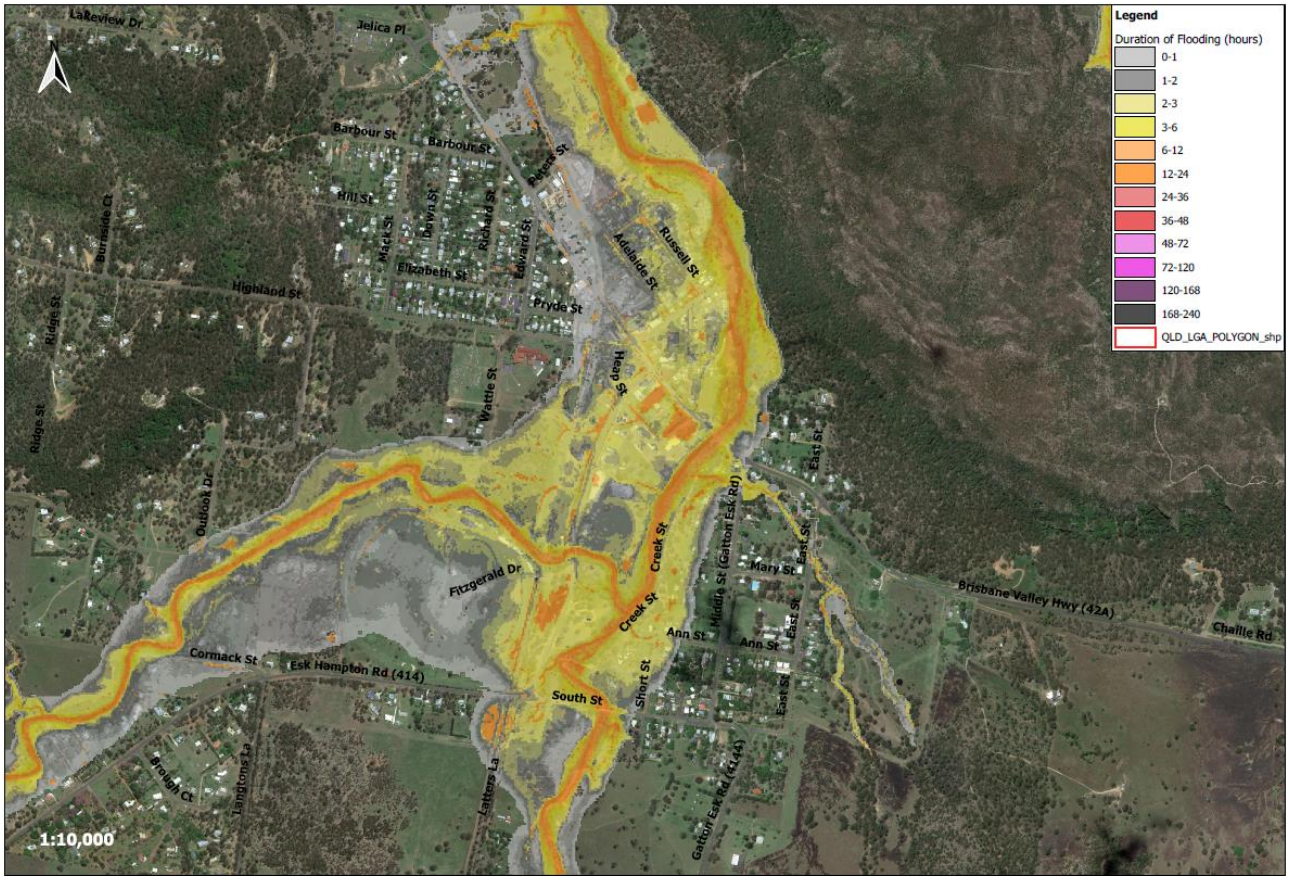

FIGURE 3-11 ESK TOWNSHIP DURATION OF INUNDATION 1 IN 2000 AEP

3.3.1 Duration of Inundation Roads

Detailed duration of flood mapping can be found in the electronic data pack. Examples of duration of flood inundation time frames to roads is shown in Figure 3-12.

This dataset is useful in determining which roads will flood the longest and could be considered for approximate information of road closure times and preparation for opening.

This information and the process used to determine the duration of inundation would also be useful in future flood forecasting upgrades, to provide real time and far more accurate assessments of road closures than pre-cooked “synthetic” flood events. The process would be useful in providing fairly accurate assessments within a forecast system of when roads are able to open again.

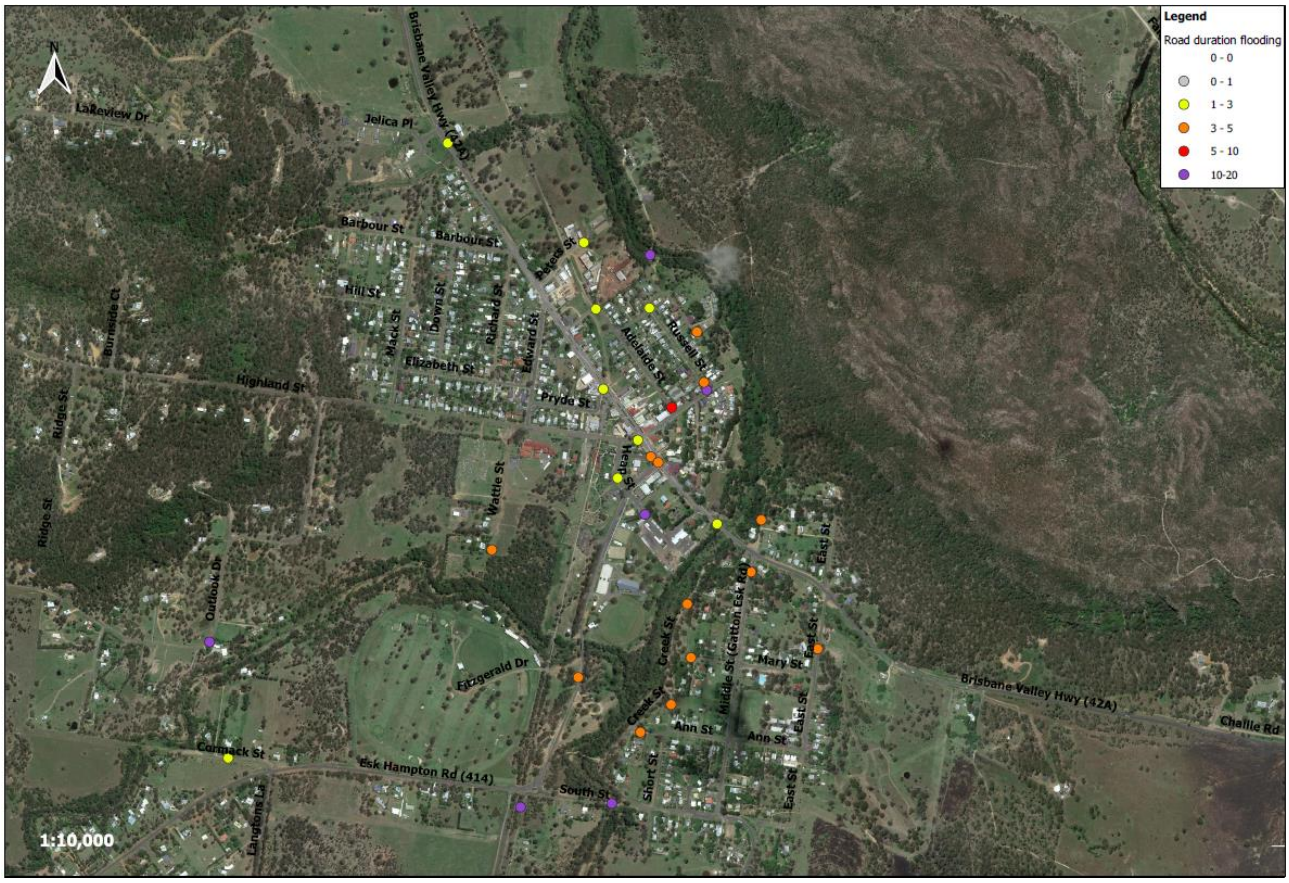

FIGURE 3-12 ROADS – DURATION OF INUNDATION ROADS

3.3.2 Duration of Inundation Property

Examples of duration of flooding to buildings is shown in Figure 3-13. The emergency management chapter uses this information with other aspects to help determine the residents that are exposed to long timeframes of flooding (beyond 12 hours). It is also used in combination with vulnerability to make further determination of the number of residents that may require assistance because of these constraints.

In a similar fashion, this information could be used within a flood forecasting system to make fairly accurate assessments of residents that are exposed to long flooding duration above floor levels.

FIGURE 3-13 BUILDINGS – DURATION OF INUNDATION

Figure 3-13 above shows long times of inundation within the Esk Township. There are some properties that are exposed to inundation timeframes of up to 17 hours, which is worth noting with regards to the length of time residents may be exposed to dangerous flooding situations.

3.4 Flood Islands

Flood islands are a unique, complex, and relatively dangerous situation that can develop during flood events. Flood islands develop when servicing roads to areas are cut (often multiple) and the area is then isolated via no means of vehicle transportation, and likely pedestrian mobility. An analysis of flood islands has been undertaken in Esk township. Two types of flood islands can develop during flood events; low and high flood islands as shown in Figure 3-14 and Figure 3-15.

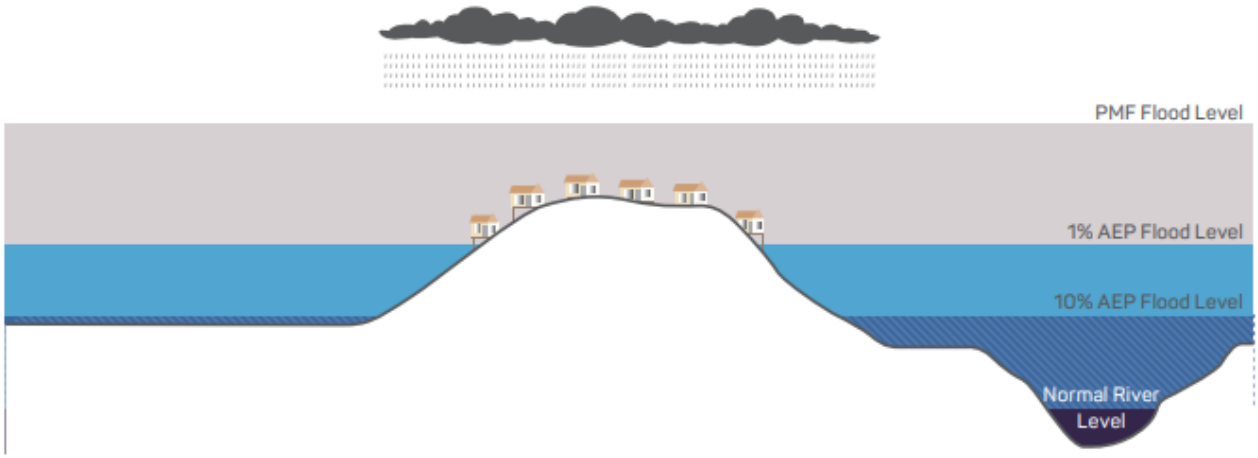

FIGURE 3-14 LOW FLOOD ISLAND (AIDR, 2017)

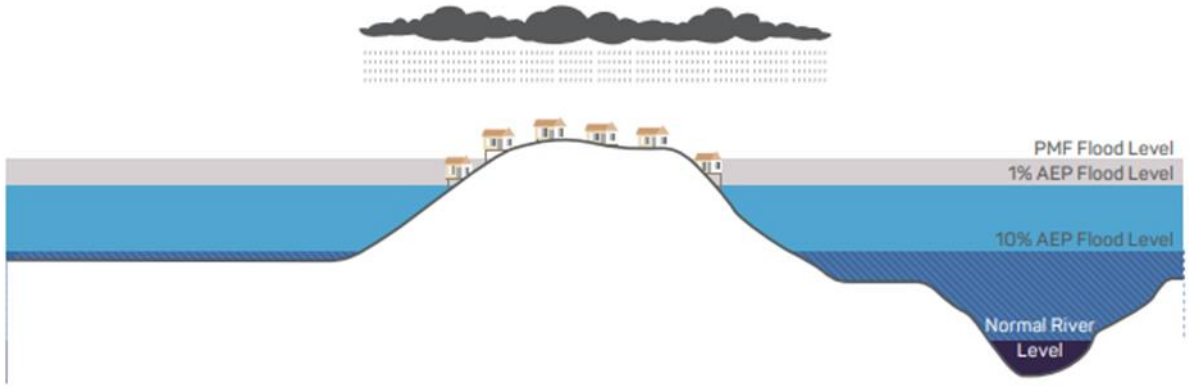

FIGURE 3-15 HIGH FLOOD ISLAND (AIDR, 2017)

3.4.1 Flood Island Distribution

Outputs of the flood island analysis areas are shown in Figure 3-16, the spatial data also contains further information on the respective AEP inundation events which can be useful in prioritising mitigation responses to flood islands, combined with other outputs such as time to inundation, vulnerability and hazard.

Within Esk there are 15 low flood islands and no high flood islands, five (5) of the low flood islands have buildings situated on them.

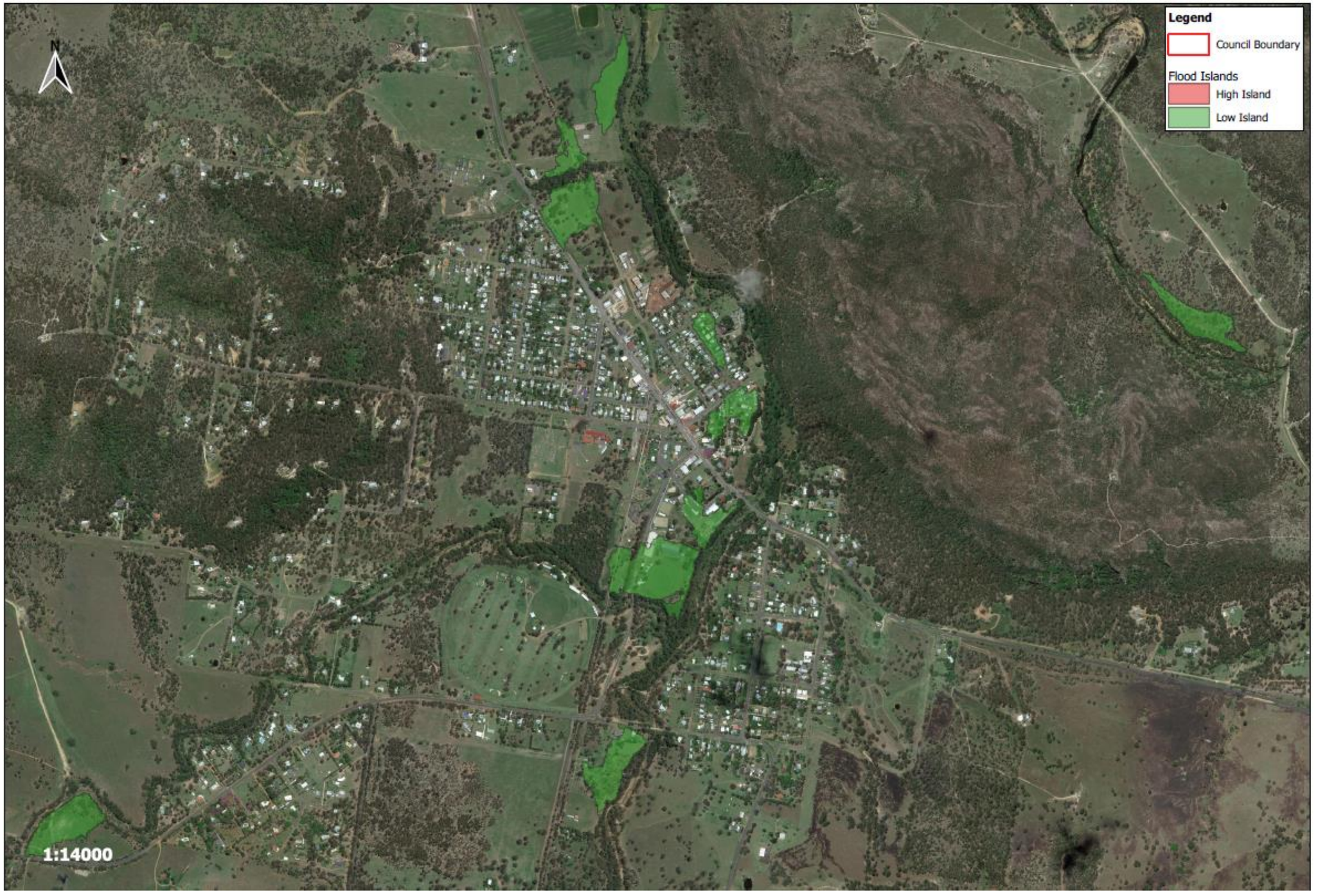

FIGURE 3-16 ESK FLOOD ISLANDS OVERVIEW

Figure 3-17 below shows an example low flood island at Russell Street, Esk. Table 3-1 provides and overall assessment of the flood islands within the Esk township.

The low island contains 10 residential buildings and is characterised by:

- Roads cut in the 1 in 50 AEP flood event. This occurs on Francis Terrace and Russell Street;
- The island fully submerges in the 1 in 100 AEP event; and
- In combination with other flood risk information such as hydraulic risk and TTI can then be used to determine overall flood risk on these flood islands.

FIGURE 3-17 EXAMPLE FLOOD ISLAND RUSSELL STREET

TABLE 3-1 ESK FLOOD ISLAND ASSESSMENT

Group	Address	No. of Habitable Buildings	Island Type	Road First Cut (AEP)	Submerged (AEP)
1	Russell Street Esk	10	Low	1 in 50	1 in 100
2	Hassell Street and Esk Caravan Park	27	Low	1 in 20	1 in 50
3	Somerset Street	1	Low	1 in 20	1 in 50
4	South Street	2	Low	1 in 100	1 in 2000

4 VULNERABILITY

An assessment of social vulnerability is traditionally beyond a conventional risk assessment; however, it is crucial for Councils to establish the characteristics of their population and their ability to respond to disaster such as a flood.

Factors such as awareness, physical vulnerability, socio-economic vulnerability, and mobility are social attributes that are mostly strongly related to vulnerability during floods. There are many aspects of social vulnerability to flooding, but these four vulnerability indices have been considered (SFMP) in detail. This suite of vulnerability indices recognises demographic characteristics, socio-economic status, health and access to information.

Figure 4-1 to Figure 4-5 shows the relative vulnerability for each indicator at a Statistical Area 1 (SA1) scale. As shown in Figure 4-5 the Esk township is considered in the upper 20% of vulnerability when considering the combined average of all vulnerability indicators.

4.1 Esk Vulnerability

The vulnerability analysis highlights areas in Esk that are highly vulnerable to flood events. This is an important concept to understand in a spatial context, as it affects the community's capacity to respond to flooding and reduces the overall resilience. A proportion of the vulnerability indices across the Esk township is shown in Table 4-1.

TABLE 4-1 PERCENTAGE OF ESK POPULATION THAT ARE VULNERABLE

Categories	Vulnerability Indices	% of Somerset LGA population	QLD Average
Physical Vulnerability	Under 5 years	5.1%	6.3%
	Over 65 years	29.7%	15.2%
	Lone person household	32.3%	23.5%
Social & Economic Vulnerability	Renting (house tenure)	24%	34.2%
	Household income (<$650)	33.4%	19.5%
	Unemployed (seeking work)	9.4%	7.6%
Mobility Vulnerability	Without vehicle access	4.0%	6.0%
	One parent families	5.1%	16.5%
	Group households	4.2%	4.7%
Awareness Vulnerability	Speaks Language Other Than English (LOTE) at home	3.8%	13.5%
	Without internet access	22.1%	13.6%

Vulnerability indices have been calculated for Esk. The relative values for each of the indices is mapped in Figure 4-1 to Figure 4-5.

As identified in Table 4-2, highly vulnerable persons that represent the upper 20% of the relative vulnerability ranking for each indicator are exposed to hydraulic hazard. Population has been calculated by multiplying the number of buildings by 2.2 for the average population per household in Esk. It is also assumed that all residents within each statistical area boundary (SA1) has the same degree of vulnerability.

The distribution of exposure of vulnerable persons show:

- Most people are located in lower hydraulic risk areas of HR4 and HR5 however there are high proportions in HR2 (b) and HR3 (b); and
- There are approximately 31 vulnerable people with high combined vulnerability within the highest frequency and highest hazard category of HR1(c).

TABLE 4-2 HYDRAULIC RISK VULNERABLE PERSONS

Vulnerability Index	HR1 (c)	HR1 (b)	HR2 (c)	HR2 (b)	HR2 (a)	HR3 (c)	HR3 (b)	HR3 (a)	HR4	HR5	Total
Physical	13	4	2	53	0	0	40	11	108	108	**339**
Social and economic	13	4	2	53	0	0	40	11	103	68	**295**
Mobility	0	0	2	13	0	0	11	0	40	145	**211**
Awareness	4	7	0	4	0	9	13	11	59	51	**158**
Combined	31	18	7	112	0	11	103	26	284	341	**933**

4.1.1 Physical Vulnerability

There are over 339 people within the upper 20% of the physical vulnerability index and are highly vulnerable and exposed to flooding. 72 people are within the potential hydraulic risk categories of HR1(c) to HR2a. Figure 4-1 shows the distribution of the most vulnerable people across the Esk area affected by physical factors such as age and disability.

4.1.2 Social and Economic Vulnerability

There are over 295 people that are classified as highly vulnerable, due to socio-economic factors that are exposed to flooding. There are 72 highly vulnerable people are in the top five hydraulic risk categories of HR1(c) to HR2(a). Figure 4-2 and Figure 4-3 show the distribution of the most vulnerable people across the Esk area affected by social and economic factors such as household income and unemployment.

4.1.3 Mobility Vulnerability

There are over 211 people that are classified as highly vulnerable due to mobility factors. Only 15 highly vulnerable people are located in the top five hydraulic risk categories of HR1(c) to HR2(a). Figure 4-4 shows the distribution of the most vulnerable people across the Esk, affected by mobility factors such as lack of vehicle access and group households with more than 5 residents.

4.1.4 Awareness Vulnerability

There are over 158 people within the upper 20% of the awareness vulnerability index that are considered to be highly vulnerable and exposed to flooding. Only 15 highly vulnerable people live in the top five hydraulic risk categories of HR1(c) to HR2(a). Figure 4-5 shows the distribution of the most vulnerable people across Esk, affected by awareness factors such as lack of access to the internet or language.

4.1.5 Combined Vulnerability

With regards to combined vulnerability there are approximately 933 people in the floodplain that are in the upper 20% of relative vulnerability of all indicators. 168 people are in the highest risk categories. Figure 4-5 shows the distribution of the most vulnerable people across Esk affected by a combination of vulnerability indicators.

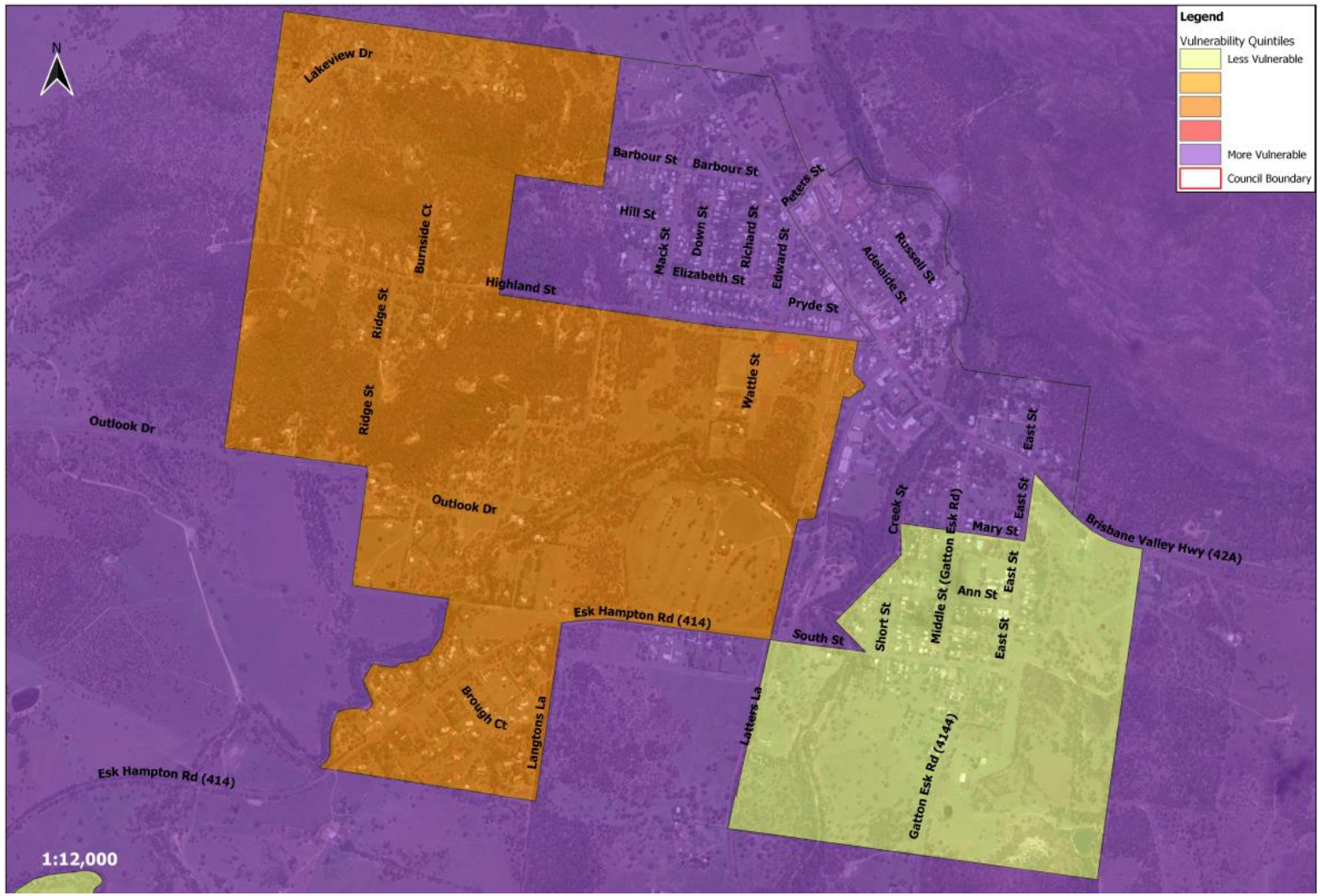

FIGURE 4-1 PHYSICAL VULNERABILITY DISTRIBUTION ESK TOWNSHIP

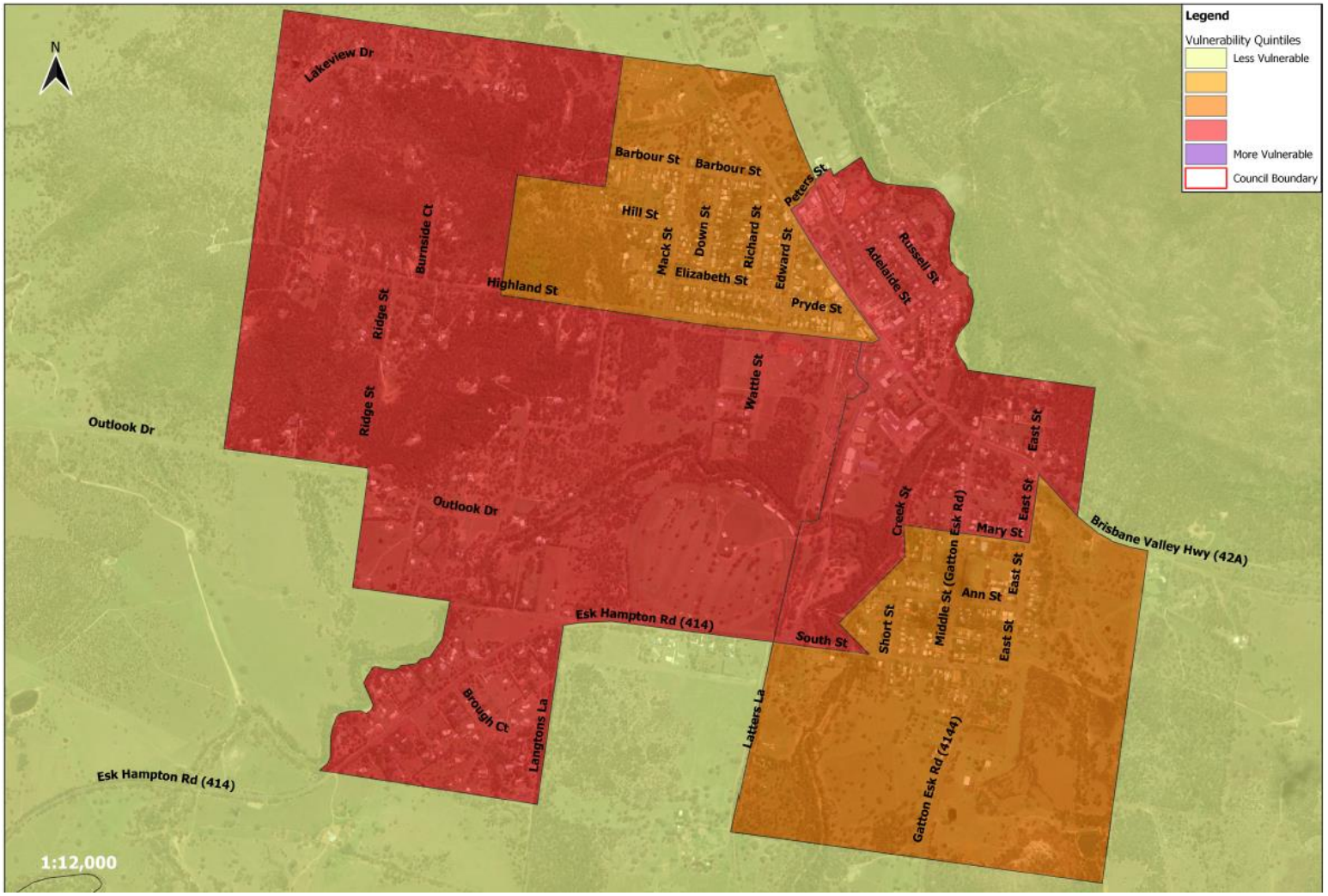

FIGURE 4-2 SOCIO-ECONOMIC VULNERABILITY DISTRIBUTION ESK TOWNSHIP

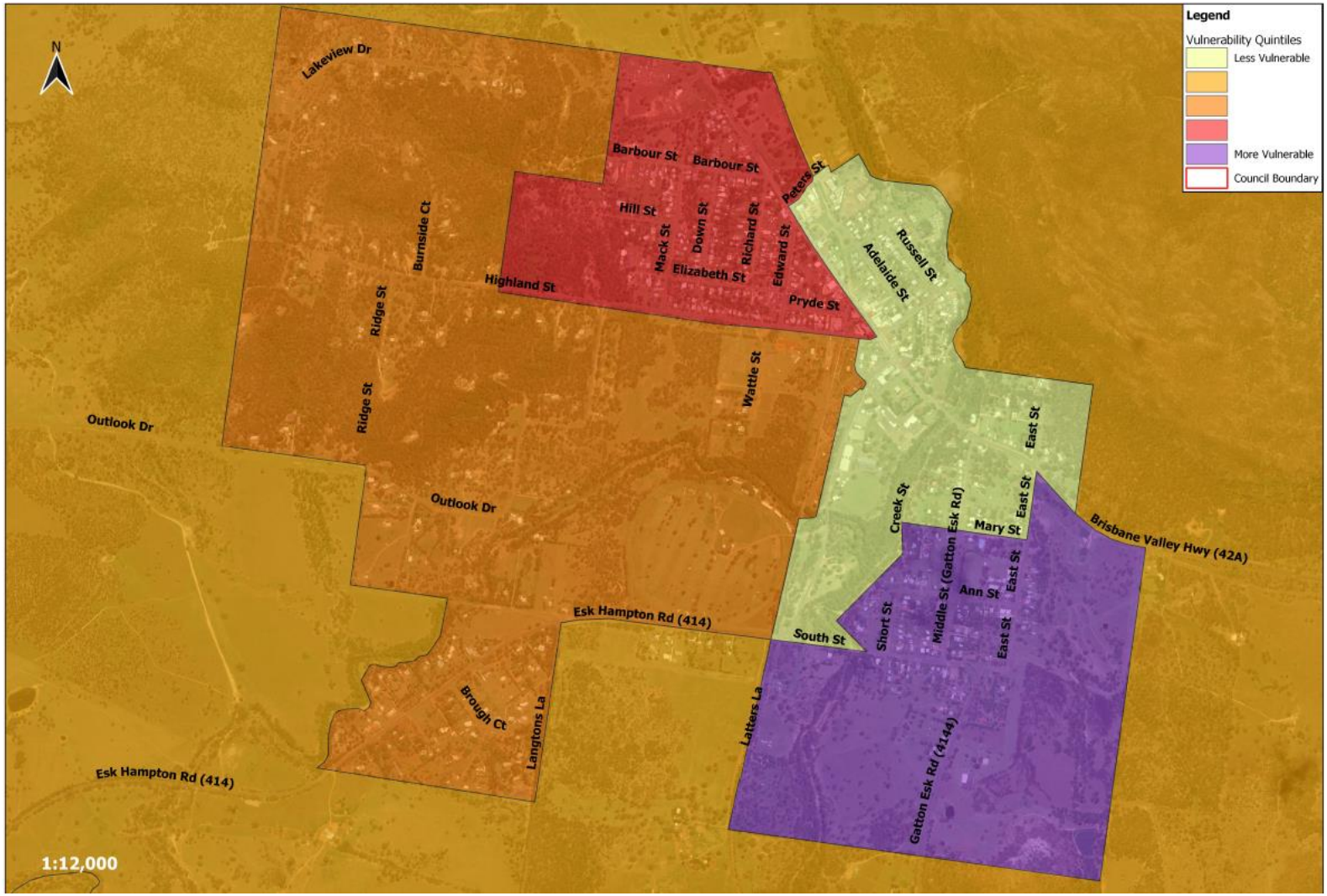

FIGURE 4-3 MOBILITY VULNERABILITY DISTRIBUTION ESK TOWNSHIP

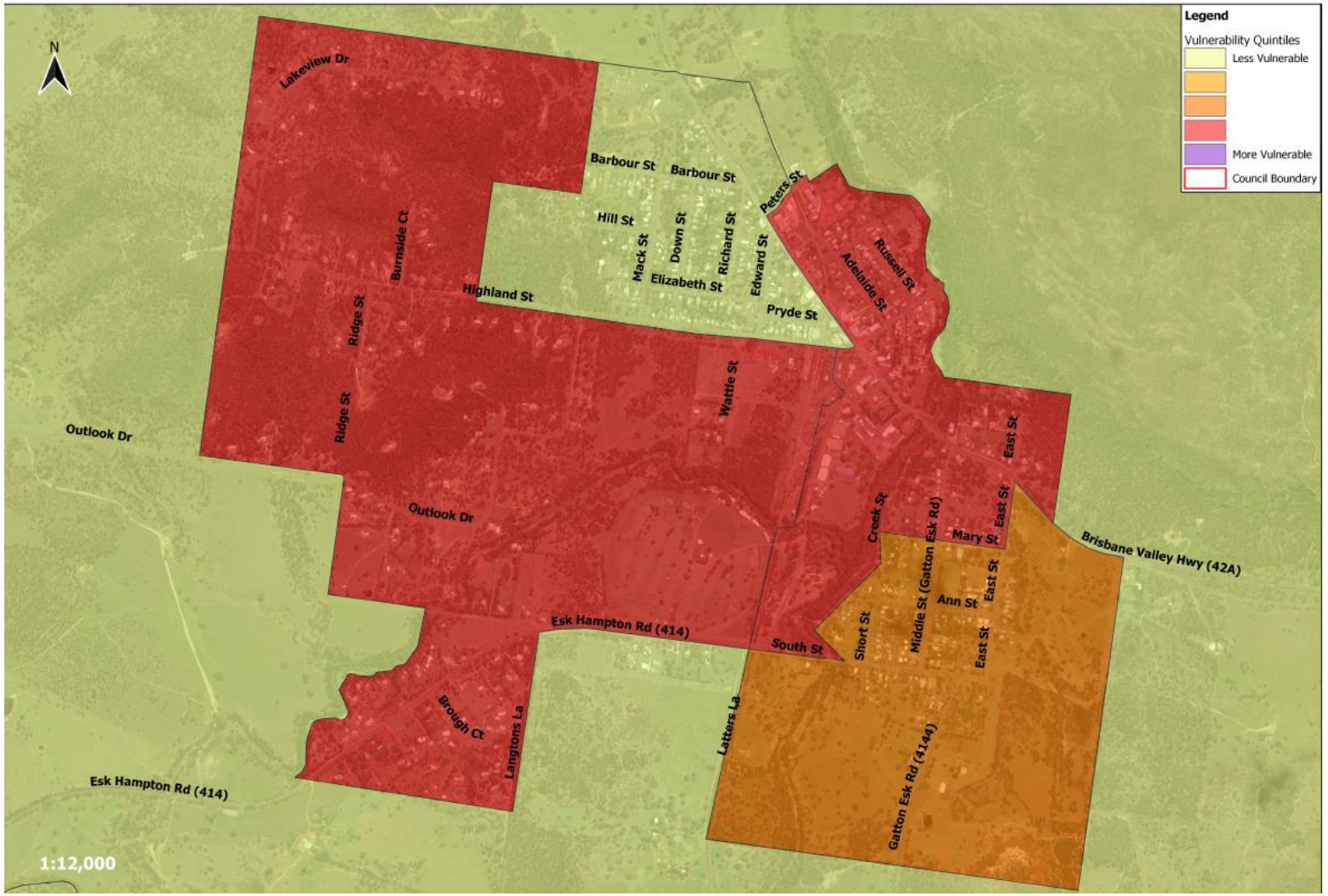

FIGURE 4-4 AWARENESS VULNERABILITY DISTRIBUTION ESK TOWNSHIP

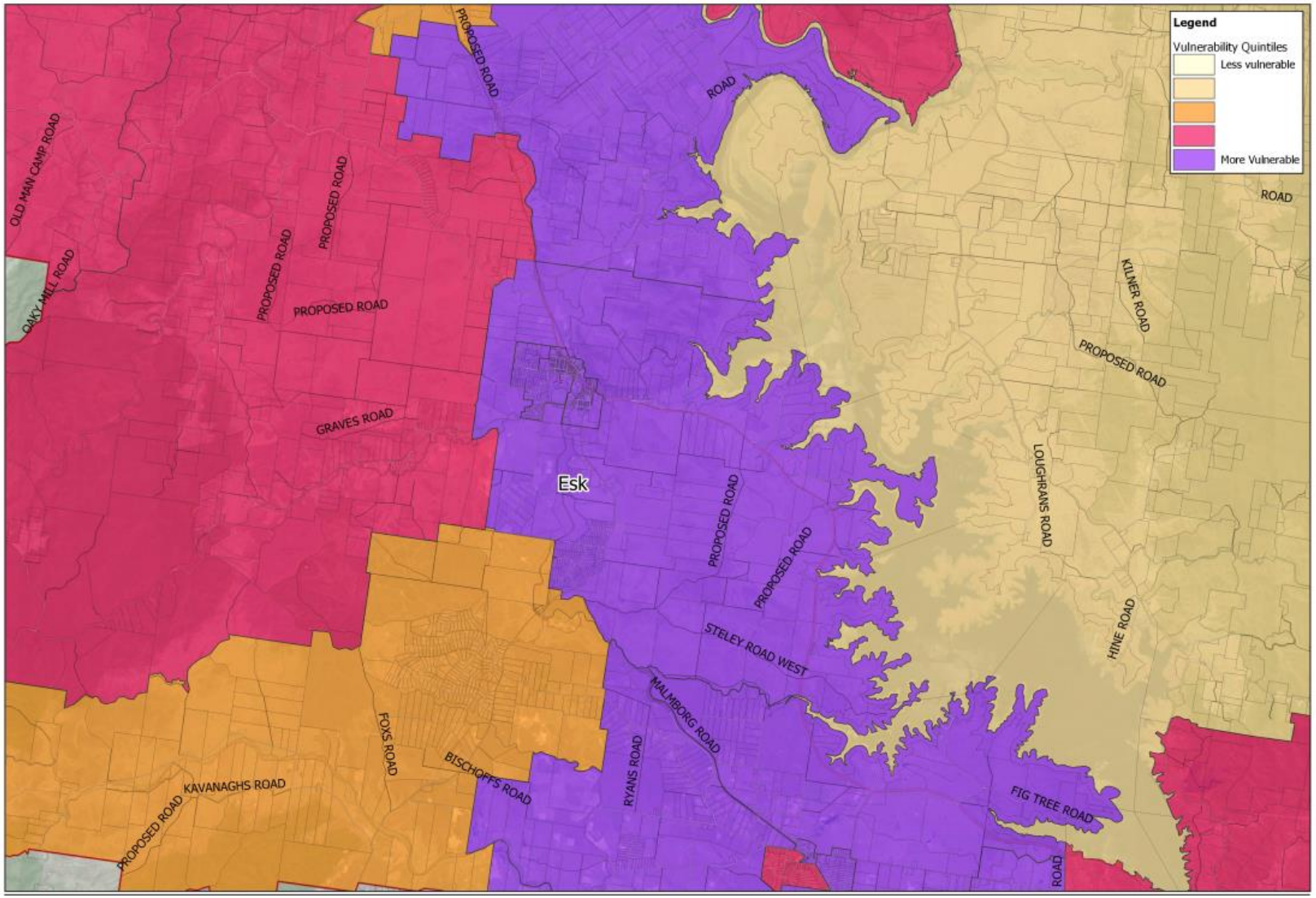

FIGURE 4-5 COMBINED VULNERABILITY DISTRIBUTION

5 FLOOD DAMAGES

The flood damage assessment methodology used, seeks to maintain regional consistency. The methodology used in the LFMP follows a similar process for categorising, analysing, and displaying flood damages for the Somerset catchments to the SFMP[4]. For more details about how this method applies to the Somerset LGA, please refer to the *Somerset Regional Local Floodplain Management Plan Technical Evidence Report.* A summary of the method used, and the unmitigated flood damages results tables are provided in this section.

5.1 Existing Damage Overview

The following section presents the results of the damage assessment using the adopted SFMP methodology outlined in the TER report. Ultimately, whilst total damages per magnitude of flood event is an important aspect to consider and understand, the Average Annual Damages (AAD) is the defining factor of how much flood damages are expected to cost the Esk community each year on average.

Reducing these average annual damages is an important aspect of floodplain management, to reduce the overall impact of flooding. This target is not an isolated goal but a part of a multi-pronged approach to flood management across all work packages. Damages are used in the flood mitigation works and property specific actions prioritisation processes (where reducing damages is a primary aspect of these structural and non-structural measures).

5.1.1 Residential Damages

The results of the total residential tangible damages and average annual damage calculations are shown below in Table 5-1 and Table 5-2. Of note in the residential damages is the following:

- There are no damages within the high frequency events (1 in 1 and 1 in 2 AEP). Damages are very small in the 1 in 5 AEP, however then increase significantly in the 1 in 10 AEP event;
- Damages increase approximately eight-fold (8x) from the 1 in 10 AEP to 1 in 20 AEP event and triple (3x) to the 1 in 50 AEP event. This is associated with the creek breaking out and inundating the floodplain with wider extents and more houses;
- There is a consistent rise in flood damages across events as the magnitude of flood event increases; and
- The AAD for direct and indirect damages for residential is $228,745.

Table 5-1 shows the expected direct actual damages (i.e. economic flood damages expected to occur) for residential buildings across each modelled flood event and the expected indirect damages, which primarily represent clean up and recovery costs.

Table 5-2 shows the expected annual average damages (AAD) for properties within each flood event. This is totalled for a combined AAD figure for the whole of Esk.

[4] For full refence to the research and application of the SFMP damages calculation method please refer to the *Brisbane River Strategic Floodplain Management Plan Technical Evidence Report*

TABLE 5-1 TOTAL RESIDENTIAL DAMAGES

AEP (1 in X)	Direct Actual	Indirect	Total
1	$0.00	$0.00	$0.00
2	$0.00	$0.00	$0.00
5	$9,551.00	$1,433.00	$10,983.00
10	$107,997.00	$16,200.00	$124,197.00
20	$860,470.00	$129,071.00	$989,541.00
50	$2,546,551.00	$381,983.00	$2,928,534.00
100	$4,353,661.00	$653,049.00	$5,006,710.00
200	$6,416,512.00	$962,477.00	$7,378,989.00
500	$9,482,44900	$1,422,367.00	$10,904,816.00
1000	$12,880,463.00	$1,932,070.00	$14,812,533.00
2000	$15,789,765.00	$2,368,465.00	$18,158,229.00
PMF	$35,874,488.00	$5,381,173.00	$41,255,661.00

TABLE 5-2 RESIDENTIAL AVERAGE ANNUAL DAMAGE

AEP (1 in X)"	Direct Actual	Indirect	Total
1	$0.00	$0.00	$0.00
2	$0.00	$0.00	$0.00
5	$1,433.00	$215.00	$1,648.00
10	$5,877.00	$882.00	$6,759.00
20	$24,212.00	$3,632.00	$27,843.00
50	$51,105.00	$7,666.00	$58,771.00
100	$34,501.00	$5,175.00	$39,676.00
200	$26,925.00	$4,039.00	$30,964.00
500	$23,848.00	$3,577.00	$27,426.00
1000	$11,181.00	$1,677.00	$12,859.00
2000	$7,168.00	$1,075.00	$8,243.00
PMF	$12,658.00	$1,899.00	$14,556.00
AAD	**$198,909.00**	**$29,836.00**	**$228,745.00**

5.1.2 Commercial and Industrial Damages

The results of the total commercial and industrial tangible damages and average annual damage calculations are shown below in Table 5-3.

Of note in this damage class is the following:

- There are no flood damages until the 1 in 20 AEP, indicating that most properties would be on the floodplain away from the creek running through Esk township;
- There is a very large increase between the 1 in 100 AEP and the 1 in 200 AEP events;
- If a 1 in 100 AEP event were to occur in Esk, it is estimated that there would be $75,231 of commercial and industrial damages; and,
- Overall, it could be considered that these types of damages are relatively low.

TABLE 5-3 TOTAL COMMERCIAL AND INDUSTRIAL DAMAGES

AEP (1 in X)"	Direct Actual	Indirect	Total
1	$0.00	$0.00	$0.00
2	$0.00	$0.00	$0.00
5	$0.00	$0.00	$0.00
10	$0.00	$0.00	$0.00
20	$0.00	$0.00	$0.00
50	$23,891.00	$13,140.00	$37,031.00
100	$48,536.00	$26,695.00	$75,231.00
200	$141,870.00	$78,028.00	$219,898.00
500	$372,521.00	$204,886.00	$577,407.00
1000	$681,742.00	$374,958.00	$1,056,701.00
2000	$1,029,790.00	$566,385.00	$1,596,175.00
PMF	$17,214,294.00	$9,467,862.00	$26,682,156.00

5.1.3 Other Building Damage

Other damages, which includes damages expected to occur on public utility buildings, were assessed in accordance with the adopted measures in the SFMP methods. Total tangible damages and average annual damage calculations are shown below in Table 5-4. There are similar trends to the commercial damages.

TABLE 5-4 OTHER BUILDING TOTAL DAMAGES

AEP (1 in X)"	Direct Actual	Indirect	Total
1	$0.00	$0.00	$0.00
2	$0.00	$0.00	$0.00
5	$0.00	$0.00	$0.00
10	$0.00	$0.00	$0.00
20	$106,282.00	$58,455.00	$164,738.00
50	$492,882.00	$271,085.00	$763,968.00
100	$1,151,390.00	$633,264.00	$1,784,654.00
200	$2,054,904.00	$1,130,197.00	$3,185,101.00
500	$3,057,126.00	$1,681,419.00	$4,738,545.00
1000	$4,814,871.00	$2,648,179.00	$7,463,050.00
2000	$7,488,228.00	$4,118,525.00	$11,606,753.00
PMF	$33,750,337.00	$18,562,685.00	$52,313,022.00

5.1.4 Road Infrastructure Damages

The results of the road infrastructure damages are shown below in Table 5-5.

Of note with the road damages includes:

- There are no classified major roads in the Esk area which will reduce road damages significantly. It should be noted that the Brisbane Valley Highway does not meet the damage trigger for major road;
- There are 68 kilometres of roads affected in total on the floodplain which in general is low amount. There are damages in high frequency events (1 in 1 and 1 in 2 AEP) indicating that some roads have very low flood immunity which is commonly associated with rural roads; and,
- There is a substantial increase in damages at the 1 in 20 and 1 in 50 AEP event for major roads. Reasons may include major roads having immunity requirements around the 1 in 100 or 1 in 50 AEP and once the road breaches at this immunity level, damages increase accordingly.

TABLE 5-5 ROAD DAMAGES

AEP (1 in X)	Length of Minor Road (kms)	Damages	AAD
2	1.07	$80,912.00	$39,066.00
5	1.26	$95,290.00	$26,430.00
10	1.77	$133,846.00	$11,457.00
20	3.70	$280,004.00	$10,346.00
50	5.46	$413,010.00	$10,395.00

AEP (1 in X)	Length of Minor Road (kms)	Damages	AAD
100	6.31	$476,775.00	$4,449.00
200	7.38	$557,412.00	$2,585.00
500	8.10	$611,946.00	$1,754.00
1000	8.60	$649,772.00	$631.00
2000	9.14	$691,169.00	$335.00
PMF	14.34	$1,084,182.00	$435.00
Total	**68.14**	**$5,074,318.00**	$107,884.00

5.1.5 Total Tangible Damages

Total Tangible damages have been calculated across the LFMP area and are shown below in Table 5-6 and Table 5-7.

Of note with tangible damages:

- A noticeable increase in flood exposure is exhibited in the 1 in 20, 1 in 50 and 1 in 100 AEP events. Between the 1 in 10 and 1 in 20 AEP damages increase approximately sevenfold (7x); and,
- Damages to residential and roads infrastructure represents a large portion of the overall damage figure. Residential damages are prominent in the lower magnitude events and transport damages become more prominent in the higher magnitude events (i.e. 1 in 50 AEP onwards).

TABLE 5-6 TOTAL TANGIBLE DAMAGES

AEP (1 in X)"	Residential	Commercial-Industrial	Other Buildings	Transport	Utilities	Clean up	Total
1	$0.00	$0.00	$0.00	$75,351.00	$0.00	$5,651.00	$81,003.00
2	$0.00	$0.00	$0.00	$80,912.00	$0.00	$6,068.00	$86,982.00
5	$10,983.00	$0.00	$0.00	$95,290.00	$824.00	$8,032.00	$115,134.00
10	$124,197.00	$0.00	$0.00	$133,846.00	$9,315.00	$20,052.00	$287,420.00
20	$989,541.00	$0.00	$164,738.00	$280,004.00	$74,216.00	$113,137.00	$1,621,656.00
50	$2,928,534.00	$37,031.00	$763,968.00	$413,010.00	$219,640.00	$327,164.00	$4,689,397.00
100	$5,006,710.00	$75,231.00	$1,784,654.00	$476,775.00	$375,503.00	$578,915.00	$8,297,888.00
200	$7,378,989.00	$219,898.00	$3,185,101.00	$557,412.00	$553,424.00	$892,112.00	$12,787,136.00
500	$10,904,816.00	$577,407.00	$4,738,545.00	$611,946.00	$817,861.00	$1,323,793.00	$18,974,869.00
1000	$14,812,533.00	$1,596,175.00	$7,463,050.00	$649,772.00	$1,110,940.00	$1,922,435.00	$27,555,905.00
2000	$18,158,229.00	$1,596,175.00	$11,606,753.00	$691,169.00	$1,361,867.00	$2,506,065.00	$35,922,259.00
PMF	$41,255,661.00	$26,682,156.00	$52,313,022.00	$1,084,182.00	$3,094,175.00	$9,332,190.00	$133,861,386.00
AAD	$228,745.00	$11,864.00	$81,631.00	$107,884.00	$17,156.00	$33,546.00	$480,858.00

TABLE 5-7 TANGIBLE AAD

AEP (1 in X)"	Residential	Commercial-Industrial	Other Buildings	Transport	Utilities	Clean up	Total	%AAD
2	$0.00	$0.00	$0.00	$39,0660.00	$0.00	$2,930.00	$41,996.00	8.73%
5	$1,648.00	$0.00	$0.00	$26,430.00	$1240.00	$2,115.00	$30,317.00	6.30%
10	$6,759.00	$0.00	$0.00	$11,457.00	$507.00	$1,404.00	$20,128.00	4.19%
20	$27,843.00	$0.00	$4,118.00	$10,346.00	$2,088.00	$3,330.00	$47,727.00	9.93%
50	$58,771.00	$555.00	$13,931.00	$10,395.00	$4,408.00	$6,605.00	$94,666.00	19.69%
100	$39,676.00	$561.00	$12,743.00	$4,449.00	$2,976.00	$4,530.00	$64,936.00	13.50%
200	$30,964.00	$738.00	$12,424.00	$2,585.00	$2,322.00	$3,678.00	$52,713.00	10.96%
500	$27,426.00	$1,196.00	$11,885.00	$1,754.00	$2,057.00	$3,324.00	$47,643.00	9.91%
1000	$12,859.00	$1,087.00	$6,101.00	$631.00	$964.00	$1,623.00	$23,265.00	4.84%
2000	$8,243.00	$798.00	$4,767.00	$335.00	$618.00	$1,107.00	$15,870.00	3.30%
PMF	$14,556.00	$6,928.00	$15,660.00	$435.00	$1,092.00	$2,900.00	$41,597.00	8.65%
AAD	**$228,745.00**	**$11,864.00**	**$81,631.00**	**$107,884.00**	**$17,156.00**	**$33,546.00**	**$480,858.00**	

5.1.6 Total Intangible Damages

The total intangible damages were calculated in accordance with the SFMP method and are shown below for residential intangible damages below in Table 5-8.

TABLE 5-8 INTANGIBLE AAD

AEP (1 in X)"	Residential
1	$0.00
2	$0.00
5	$0.00
10	$0.00
20	$0.00
50	$2,049,974.00
100	$6,008,052.00
200	$12,544,281.00
500	$25,081,078.00
1000	$39,993,839.00
2000	$56,290,511.00
PMF	$189,776,039.00
AAD	$290,753.00

5.1.7 Average Annual Damages

The final average annual damages have been calculated for the LFMP and are shown below in Table 5-9 and Table 5-10. Similar to past comments the following is noted:

- There are some damages in the very high frequency events primarily associated with infrastructure damage. This information should be cross checked with the road immunity maps to pinpoint roads that do not have sufficient flood immunity to reduce flood damages;
- The 1 in 50 event has the highest AAD. This is associated with the floodplain engaging. In addition, the 1 in 500 also has a high AAD indicating severe damage for a less frequency event and would be a notable event to plan for considering its likelihood and impact; and,
- Overall, the LFMP has shown a very high AAD of $771,612. This could be considered a relatively low AAD in comparison to other areas investigated but there are also lower property numbers and only one flood source (i.e. not associated with the Brisbane River). With this regard, the AAD could be considered high.

TABLE 5-9 TOTAL DAMAGES

AEP (1 in X)"	Tangible	Intangible	Total
1	$81,003.00	$0.00	$81,003.00
2	$86,982.00	$0.00	$86,982.00
5	$115,134.00	$0.00	$115,134.00
10	$287,420.00	$0.00	$287,420.00
20	$1,621,656.00	$0.00	$1,621,656.00
50	$4,689,397.00	$2,049,974.00	$6,739,370.00
100	$8,297,888.00	$6,008,052.00	$14,305,940.00
200	$12,787,136.00	$12,544,281.00	$25,331,418.00
500	$18,974,869.00	$25,081,078.00	$44,055,947.00
1000	$27,555,905.00	$39,993,839.00	$67,549,744.00
2000	$35,922,259.00	$56,290,511.00	$92,212,770.00
PMF	$133,861,386.00	$189,776,039.00	$323,637,425.00

TABLE 5-10 AVERAGE ANNUAL DAMAGES

AEP (1 in X)"	Tangible	Intangible	AAD Total
2	$41,996.00	$0.00	$41,9960.00
5	$30,317.00	$0.00	$30,317.00
10	$20,128.00	$0.00	$20,128.00
20	$47,727.00	$0.00	$47,727.00
50	$94,666.00	$30,750.00	$125,415.00
100	$64,936.00	$40,290.00	$105,227.00
200	$52,713.00	$46,381.00	$99,093.00
500	$47,643.00	$56,438.00	$104,081.00
1000	$23,265.00	$32,537.00	$55,803.00
2000	$15,870.00	$24,071.00	$39,941.00
PMF	$41,597.00	$60,286.00	$101,883.00
AAD	**$480,858.00**	**$290,753.00**	**$771,612.00**

5.1.8 Individual Property Damages

Another powerful way to understand and leverage on the use of damages is to utilise the information available in the master database. This database has assigned AAD to each property and this can be used in a variety of ways to visually understand damage hotspots as shown below in Figure 5-1. This information is also being used in the property specific actions chapter to assist the prioritisation of a program of flood resilient materials programs (as damage is the primary mechanism being targeted for mitigation). As it can be seen in Figure 5-1, the primary damages are within the Esk township, but there are also properties with high flood damages to the north of the township.

FIGURE 5-1 INDIVIDUAL RESIDENTIAL PROPERTY AVERAGE ANNUAL DAMAGE – EXISTING FLOOD CONDITIONS

AAD for the township of Esk is shown in Figure 5-2. Flood mitigation options have been targeted to reduce flooding in high damage areas of the township and the property specific actions chapter uses the AAD information to prioritise a program of potential voluntary purchase or implementing flood resilient building materials.

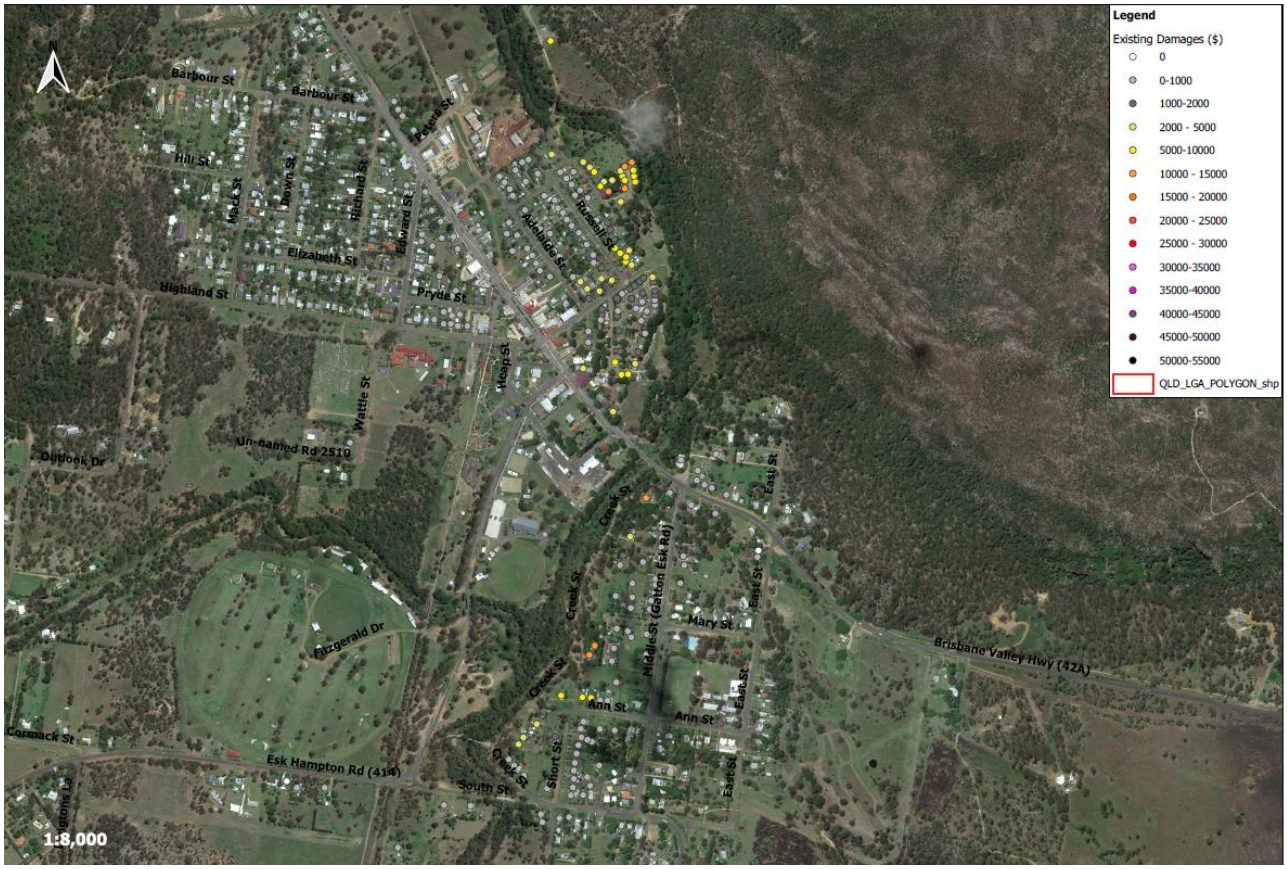

FIGURE 5-2 ESK TOWNSHIP AVERAGE ANNUAL DAMAGES

6 ESK – OVERALL FLOOD RISK

Traditionally, flood risk has been defined by simplistic assessment based around frequency of flooding (level of immunity). Over time, flood risk assessments look at the consequence of these flood events such as an understanding of hazard across the floodplain.

Outputs of this project seek to extend the understanding and detail of flood risk factors which will further influence the responses to flood risk exposure of built assets and residents and ultimately inform a more refined and detailed understanding of overall flood risk.

By examining layers of flood risk information, appropriate mitigation response for any built asset or community can be identified. The master database built for the LFMP contains all the flood risk factors critical for this analysis.

This section provides a summary of the overall current flood risk by examining particular examples around the Esk. These examples consider critical infrastructure, sensitive institutions and residential flood risks. The examples in this section show a combination of the following factors:

- Hydraulic Risk (combination of flood frequency and hazard);
- Vulnerability (special circumstances that introduce further risk through social and economic functions);
- Time to inundation (an understanding of how long it takes for an area, asset or residence to inundate);
- Duration of flooding (an understanding of how long an area, asset or residence may be flooded for); and
- Isolation (and understanding of whether residents are isolated on low or high flood islands).

This section also provides several limitations for due consideration when using the data presented in this report.

6.1 Esk Caravan Park

An example of a sensitive use is shown in Figure 6-1 and Figure 6-2. This shows the flood exposure of the Esk Caravan Park. The area is exposed to hydraulic risk from the HR4 and HR3 (a) categories. Of more concern are the areas exposed to HR3 (b) and one building with HR2 (b). It should be noted that during the 1 in 2000 AEP there are flood depths of 1.5 metres.

Caravan parks often have permanent residents who are elderly or vulnerable, and tourists who are not aware of the flood risks in the area or the method to respond to flooding. This vulnerability combined with the hydraulic risk significantly elevates the overall flood risk.

In addition, the following is noted about the park:

- The site is located on a low flood island that is isolated in a relatively small flood event (1 in 20 AEP) and then is full submerged in a 1 in 50 AEP;
- The area is rapidly inundated during major events (5 hours in a 1 in 100 AEP and 2 hours in a 1 in 2000 AEP event). This provides little warning or for emergency services to respond; and,
- With regards to vulnerability as mentioned previously, Caravan and Tourist parks are considered some of the most vulnerable uses particularly in combination with presence of elderly residents. This is reflected in the vulnerability mapping with high levels through most of the indicators.

Considering the relatively low flood immunity, being isolated with higher hazards, a fast time to inundation, large flood depths and vulnerable residents, this location and current use overall has a very high combined flood risk.

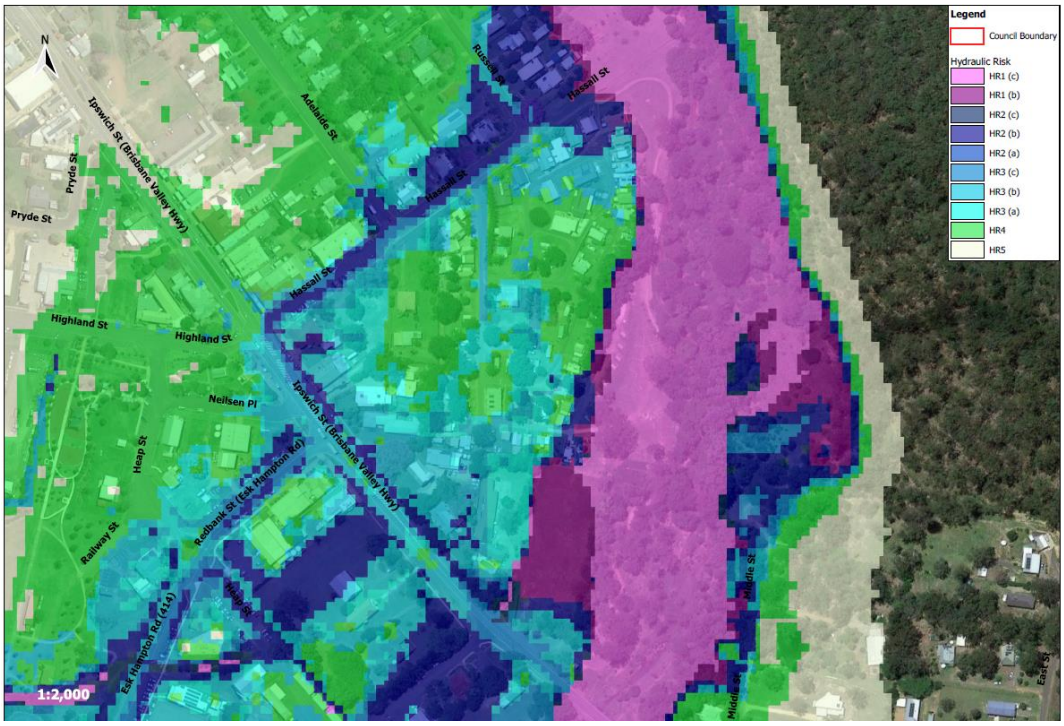

FIGURE 6-1 ESK CARAVAN PARK HYDRAULIC RISK

FIGURE 6-2 ESK CARAVAN PARK

6.2 Francis Terrace Residential Area

An example of a sensitive use is shown in Figure 6-3 and Figure 6-4. This shows the flood exposure of the Francis Terrace residential area. The area is exposed to very high flood risks overall and in particular the houses closest to the creek have the highest flood risk (HR1c). It should be noted that during the 1 in 2000

AEP event, there are houses which have over 3 metres of flood water in inundation which is combined with high velocities (2.2 m/s). In addition, the following is noted about the area

- The site is located on a low flood island that is isolated in a moderate flood event (1 in 50 AEP) and then is full submerged in a 1 in 100 AEP;
- The area is rapidly inundated during major events (3 hours in a 1 in 100 AEP and as short as 2 hours in a 1 in 2000 AEP event). This provides little warning or for emergency services to respond;
- The area has high levels of vulnerability in the socio economic, physical and awareness categories; and
- The area has relatively high flood damages in comparison to the rest of the Esk area.

Considering the relatively low flood immunity, being isolated with higher hazards, a fast time to inundation, large flood depths, velocities and vulnerable residents, this location and existing land use overall has a very high combined flood risk. It should be noted that this area has targeted property specific actions with two houses listed for acquisition, please refer to chapter 8.

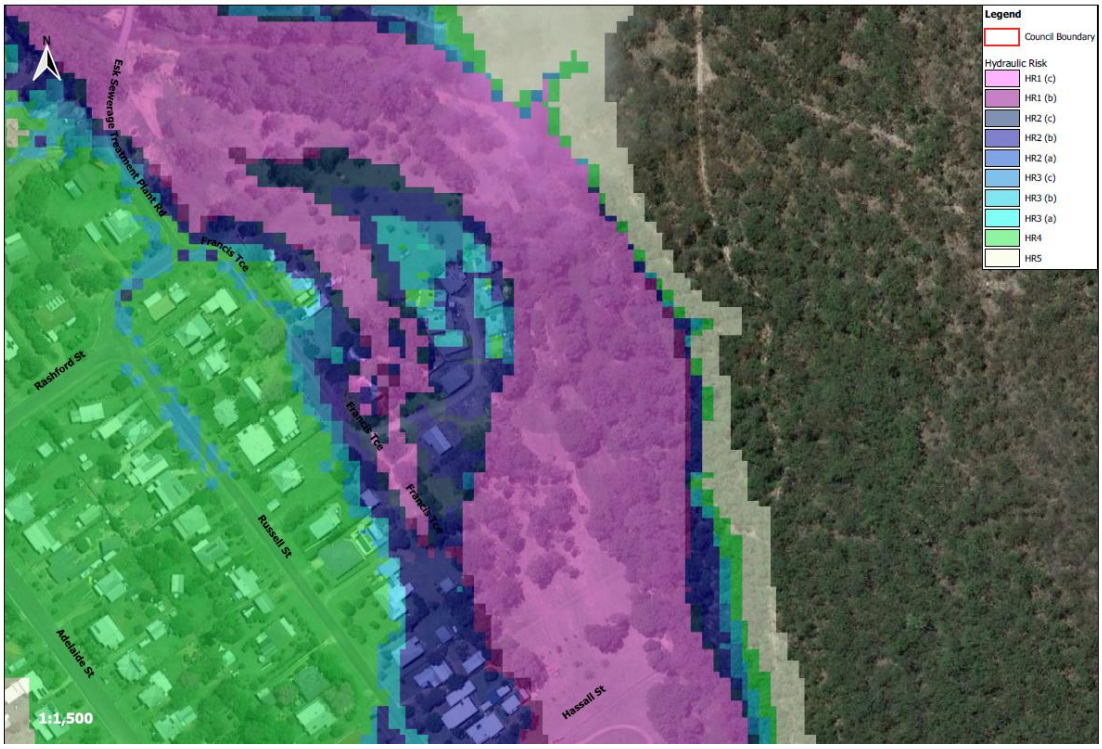

FIGURE 6-3 FRANCIS TERRACE AREA HYDRAULIC RISK

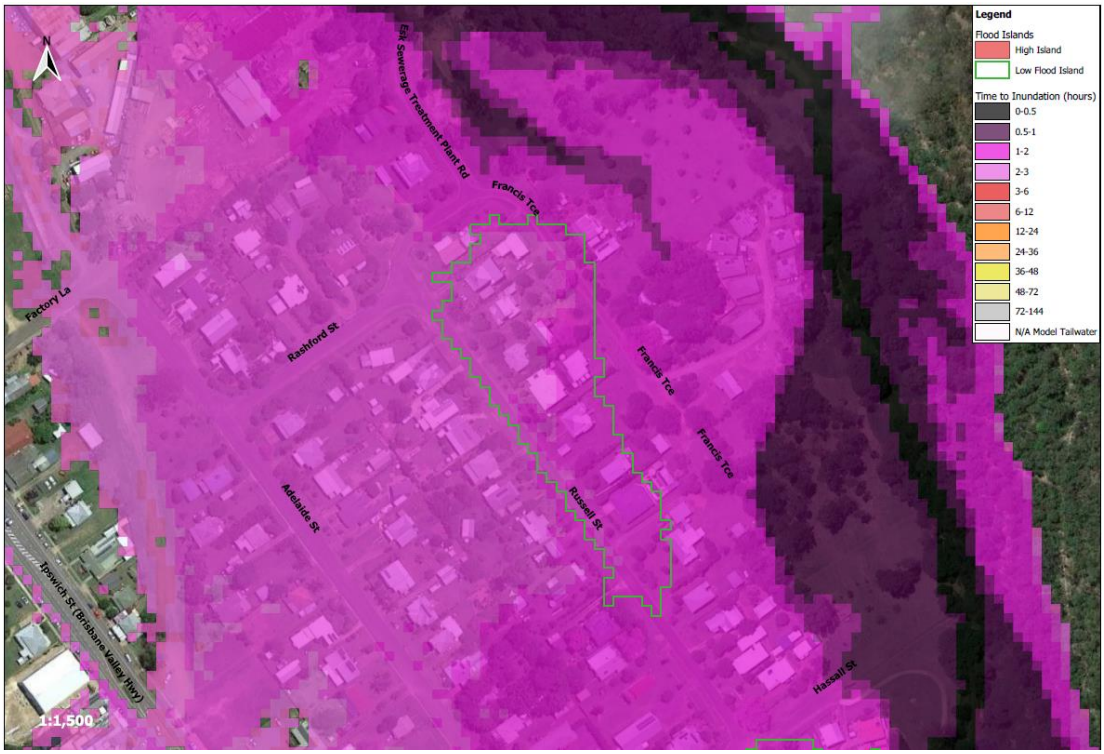

FIGURE 6-4 FRANCIS TERRACE AREA FLOOD RISK

7 FLOOD MITIGATION MEASURES

This section presents the structural flood mitigation measures that were assessed through detailed flood modelling, damage assessment, costings, cost benefit assessment and a multi criteria analysis. It should be noted that non-structural mitigation options are also presented in the property specific actions chapter and can be readily compared with the structural options.

7.1 Options Identified

The list of flood mitigation options identified for Esk are shown in Table 7-1. A description is also provided with a recommendation of whether further detailed assessment by Council should be undertaken. The mitigation options considered:

- Whether the option would be cost effective, i.e. the potential cost verse likely damages reduced. Large costs and small damage reduction would render the option not cost beneficial;
- The ability to significantly reduce flooding as these options are targeted for major regional flood events;
- Practicalities of design, its construction and consideration of the likely impact to private property; and
- The residual risk from these potential assets and asset management burden to Council.

TABLE 7-1 OPTION ASSESSMENT

Option	Description	Comments	Further Detailed Assessment?
Wattle Street Bypass Channel	A bend in Redbank Creek upstream of Wattle Street may cause breakout of floodwaters at this location. A channel was proposed to limit the amount of breakout flooding.	It is likely that a channel would not be able to be practically constructed and/or would need to be of significant size to contain flood waters. It has been determined that this option will not be effective.	No
Esk Levee Option 1	The main township levee Option 1 involved a levee from Redbank Creek (past Wattle Street) to the RJ Rashford Recreation Ground	This levee option is likely to provide significant benefit to the residential and commercial areas of the main township. It is expected however that impacts will occur to properties to the south of the levee. This option is shortlisted for further detailed assessment.	Yes
Esk Levee Option 2	The main township levee Option 2 extends beyond the RJ Rashford recreation ground to the Brisbane Valley Highway	Similar to Option 1, Option 2 will have significant benefit and is expected to have increased benefit overall. This option is shortlisted for further detailed assessment.	Yes

Option	Description	Comments	Further Detailed Assessment?
Upstream Basin	A large basin proposed in the upstream catchment of Redbank Creek to lower discharges downstream and reduce flooding.	Initial estimates of basin size indicate a very large basin would be required to reduce flow significantly enough to reduce flooding. In addition, extensive property acquisition would be required, and the basin would likely become a 'referable dam' under the dam safety regulations as part of the Water Supply (Safety and Reliability) Act 2008. Overall, this basin would not be cost effective and has not been shortlisted for further detailed assessment.	No
Property Specific Actions	A program of works to be developed based on flood characteristic criteria and prioritising programs for flood resilient building materials and potential voluntary house purchase.	Further detail is provided in the Property Specific Actions chapter.	Yes

7.2 Options Analysis and Costings

A description and assessment of each of the Esk Structural Flood Mitigation Options is shown below. For a full description of the process undertaken for this component please refer to the *Somerset Regional Local Floodplain Management Plan Technical Evidence Report*. Two options were assessed for the Esk township levee, with only one option proceeding forward to cost benefit assessment.

7.2.1 Esk Township Levee Option 1

An overview of the Esk Township Levee Option 1 is provided below.

7.2.1.1 Description

This levee option is primarily aimed at restricting or removing the Redbank Creek breakout which floods the main Esk township. The components of mitigation option include:

1. An earthen levee with approximately 1000 metres in length extending from past Wattle Street to the RJ Rashford Recreation Ground;
2. 1 in 4 batters with a 1 metre wide top platform; and

3. Significantly reducing flooding on residential and commercial properties in the main Esk Township as well as reductions on further residential properties on the fringe of the township. It is not expected to reduce flooding altogether in the 1 in 100 AEP event.

It is expected that there will be negative impacts to properties surrounding the levee due to the large floodplain that has been displaced and the change in flood characteristics.

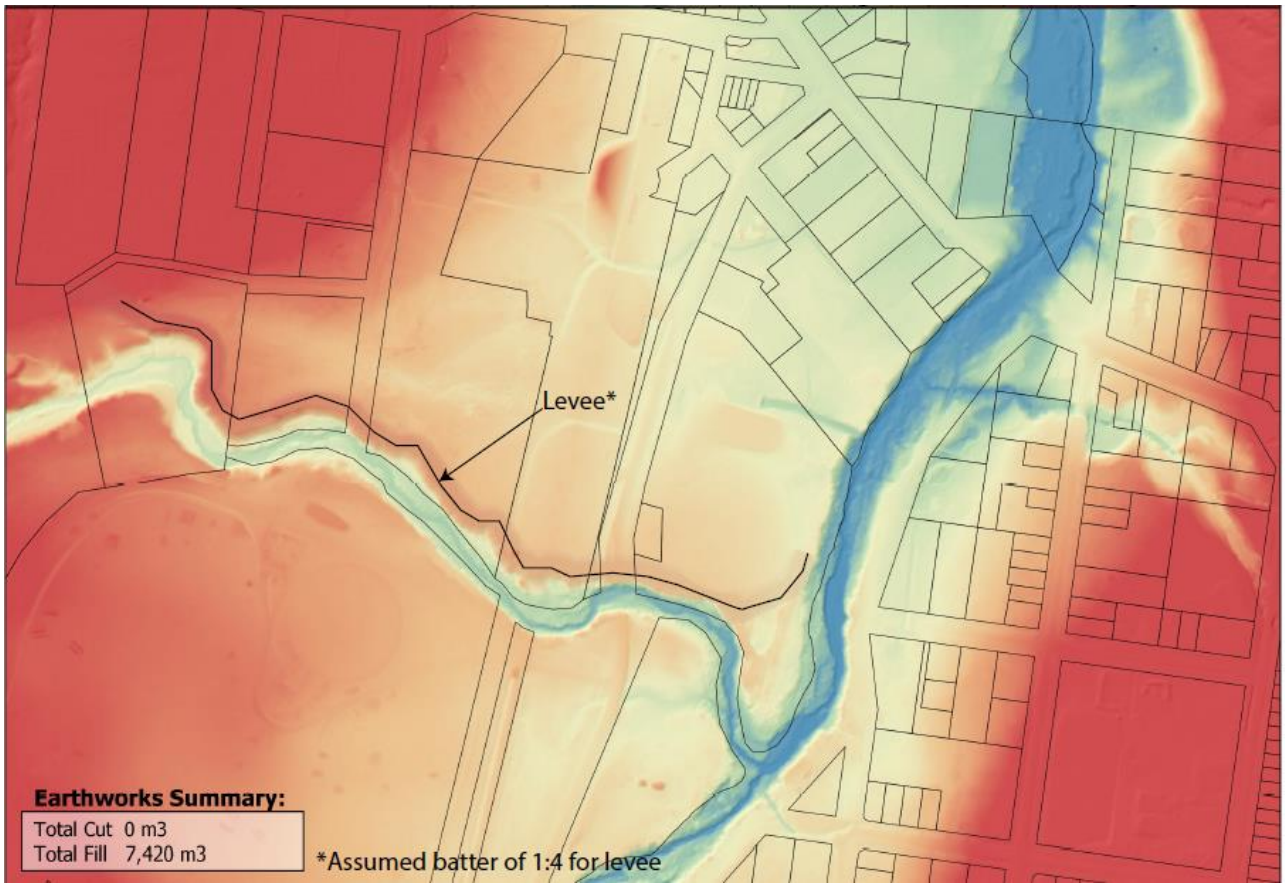

FIGURE 7-1 ESK LEVEE OPTION 1 ARRANGEMENT

7.2.1.2 Flood Modelling Results

As shown in Figure 7-2 there is a large change to water levels and flood characteristics across the area and these include:

- Significant positive afflux (worsening) in the areas south of Redbank Creek. Residential properties may be affected by increased floodwaters of over 250mm in a 1 in 100 AEP. This is a significant afflux and would require extensive consultation, possible property acquisition and/or adjustment to properties to implement this measure.
- To the north of the levee, there are some recreational, commercial and residential properties that are shown to become 'dry' in a 1 in 100 AEP event. With floodwaters at this magnitude, removed altogether.
- Further downstream, there are significant reductions of water level during the 1 in 100 AEP (greater than 250mm) to many residential properties along Russell Street, Francis Terrace and Hassall Street.
- There is also significant reduction to the Esk Caravan Park along Sandy Creek. This is particularly important as this is considered a highly vulnerable use with potentially vulnerable occupants.

Overall, whilst the benefits are significant and should be considered further in detail, there is also extensive impact to the residents south of Redbank Creek.

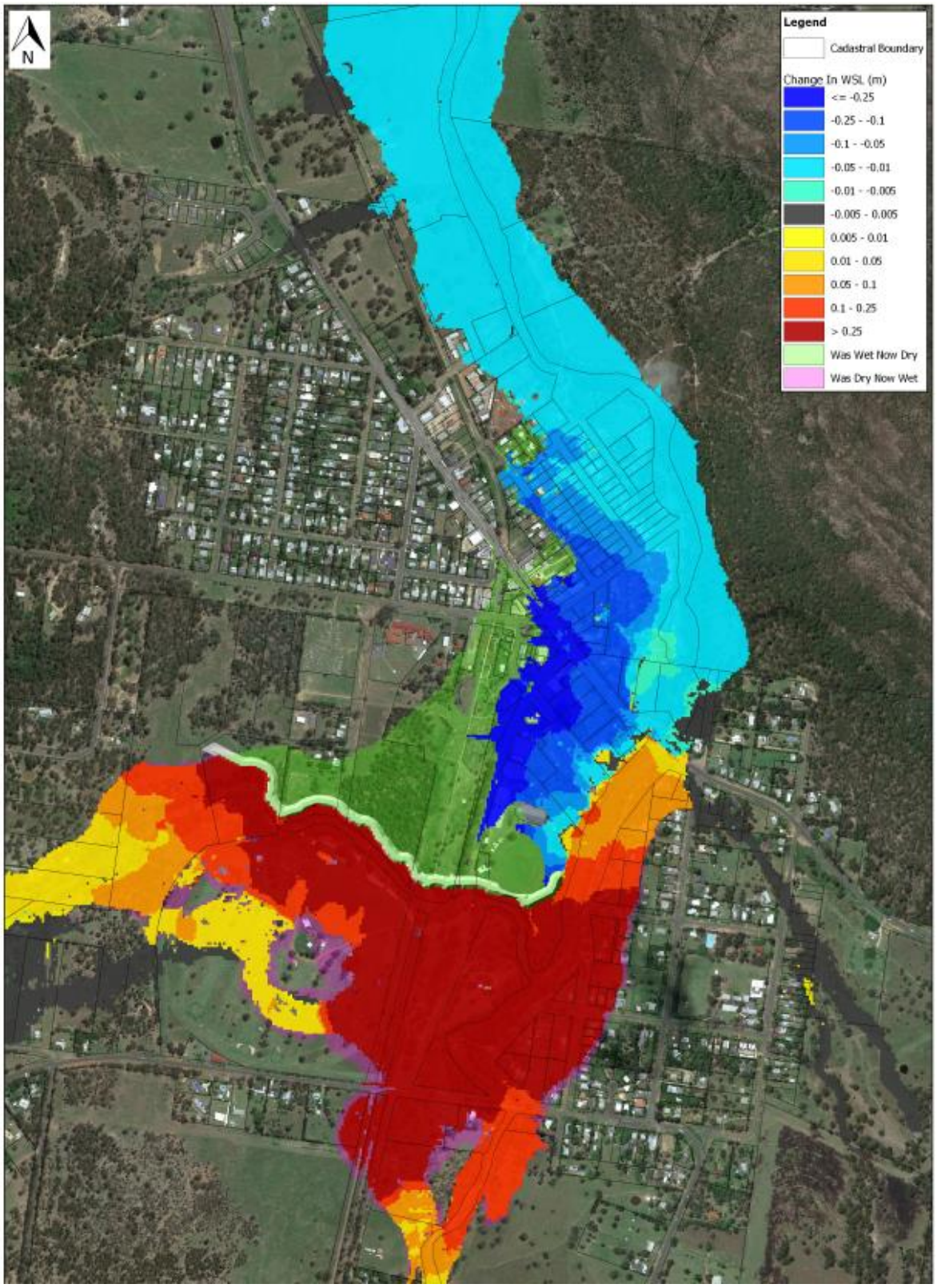

FIGURE 7-2 ESK TOWNSHIP LEVEE OPTION 1 - 1 IN 100 AEP AFFLUX

7.2.1.3 Costings

The costs associated with the Esk Township Levee Option 1 is shown in Table 7-2. The total cost for this project is estimated at $1.2 million.

TABLE 7-2 OPTION COSTINGS

Items	Unit	Quantity	Unit Rate	Amount
Clearing and Preparation	M^2	8,000	$8.00	$64,000.00.00
Imported Basin Core	M^3	15,600	$35.00	$259,665.00
Excavate and Replace Foundation	M^3	1,500	$60.00	$90,000.00
Final Profiling	M^2	10,000	$5.00	$50,000.00
Spillway Rock	M^3	300	$120.00	$36,000.00
Spillway Concrete	M^3	75	$200.00	$15,000.00
Seeding and Turf	M^2	10,000	$5.00	$50,000.00
Spillway Downstream Channels	M^2	1000	$80.00	$80,000.00
Retrofitting Parks and Property	item	1	$100,000.00	$100,000.00
Total Construction Cost				**$744,665.00**
Pre-Construction Items				
Mobilisation, Traffic Control, Erosion and Sediment Control, Environmental Plans and Setup	%	7		$52,126.00
Design, Survey and Modelling	%	14		$104,253.00
Project Management, Applications and other costs	%	7		$52,126.00
Sub Total				**$208,506.00**
Total				**$953,171.00**
Contingency	%	30		$285,951.00
Grand Total				**$1,239,122.00**

7.2.1.4 Benefit Cost Assessment

The damages associated with a variety of flood events with the proposed mitigation in place has been simulated and the resultant reduction in AAD is shown in Table 7-3.

TABLE 7-3 OPTION BENEFIT RELATIVE TO CURRENT FLOOD CONDITIONS

Option	Total AAD without option in place[5]	Total AAD with option in place	Reduction in AAD	Option Benefit over 100-year lifespan (NPV)
Esk Township Levee Option 1	$480,858	$477,799	$3,059	43,669

When assessing the financial cost and benefit of the Esk Levee Option 1, the benefit to cost ratio was found to be **0.03**. As a result, the option does not return a benefit at all from a flooding and economics point of view.

TABLE 7-4 BCR CALCULATION

Option Benefit Over 100-year Lifespan (NPV)	Total Capital Cost	Benefit / Cost Ratio (BCR)
43,669	$1,239,123	**0.03**

Sensitivity of the parameters for this option included:

- The maintenance cost was reduced by half and this still returned a low BCA value below 0.5; and,
- Adjusting the discount rate still returned a low BCA below 0.5.

A benefit cost assessment that show a BCR value of below 0.5 are not recommended to proceed as little economic benefit is provided. Based on the sensitivity testing also returning a value of below 0.5, the option is recommended not to proceed forward for further detailed assessment.

7.2.1.5 Multi Criteria Assessment

Generally, for flood mitigation options only costs and benefits are utilised to make determination of the overall scoring of mitigation options. The LFMP has followed the SFMP process to provide additional consideration of a wide range of tangible and intangible benefits and costs. The MCA is used to further assess and score the options to provide a further prioritised list for Council to consider.

TABLE 7-5 MCA ASSESSMENT

Criteria Category	Criteria Detail	Overall Weighting	Esk Levee Option 1
Safety of people	Reduce hydraulic risk rating (now and future)	18.8%	3.0
	Improve time for evacuation (now and future)	6.3%	2.5
Social	Targets vulnerable community members or areas	2.5%	4
	Social health benefits	1.5%	3
	Improves community flood resilience (now and future)	3.0%	3
	Recreation and amenity	1.5%	2

[5] Total tangible damages, please refer section 5.1.5 for further details.

Criteria Category	Criteria Detail	Overall Weighting	Esk Levee Option 1
	Connection and collaboration	1.5%	2
	Community Attitude	2.0%	1.5
Economic	Reduce damages and costs to residential property (now and future)	9.0%	2.5
	Reduce damages and costs to business and industry (now and future)	5.0%	2.5
	Option likely to be cost beneficial (now and future)	6.0%	1
Feasibility	Physical / technical (now and future)	9.0%	1.5
	Legal / approval risk	5.0%	1.5
	Residual Risk/Asset Management	9.0%	2
Key infrastructure and transport	Improve availability and function (now and future)	5.0%	2.5
	Protection of regional water supply quality and security - catchment protection (quality and yield)	5.0%	2.5
Environment and natural resource management	Species impacts	2.0%	2.5
	Vegetation and habitat impacts	2.0%	2
	Ecosystem health and connectivity (fish passage/fauna movement)	2.0%	1.5
	Reduction in landscape salinity / improved moisture retention and groundwater recharge	2.0%	2.5
	Reduction in erosive capacity / soil movement - channel stability / geomorphology	2.0%	2

Overall, the Esk levee township option 1 has benefit in certain areas due to the decrease in depth, but this was also balanced with the negative impact to some properties. The option scored higher in some social categories such as targeting vulnerable uses and resilience due to the benefits afforded to the vulnerable use (caravan park).

The option scores lower in technical and legal aspects because of the difficulty in implementation, mainly due to impact to and potential construction on private properties. There are also some negative environmental aspects associated with the option and residual risk associated with the events above the 1 in 100 AEP not being mitigated.

TABLE 7-6 MCA RESULT

Criteria Category	No Change Value	Esk Levee Option 1
Safety of people	0.63	0.72

Criteria Category	No Change Value	Esk Levee Option 1
Social	0.29	0.31
Economic	0.50	0.41
Feasibility	0.58	0.48
Key infrastructure	0.25	0.25
Environment & NRM	0.25	0.21
Total	2.49	2.37
Result		-0.13

As it can be seen from MCA results, the option generally only has a marginally positive MCA score and would not be recommended for further detailed investigation.

7.2.2 Esk Township Levee Option 2

An overview of the Esk Township Levee Option 2 is provided below. Two options were investigated at Esk with levees due to the effectiveness shown with modelling.

7.2.2.1 Description

This levee option is primarily aimed at restricting or removing the Redbank Creek breakout which floods the main Esk township. This levee extends the length of Levee Option 1. The components of mitigation option include:

1. An earthen levee with approximately 1400 metres in length extending from past Wattle Street to the Brisbane Valley Highway;
2. Approximately 1 in 4 batters with a 1 metre wide top platform; and,
3. Significantly reducing flooding on residential and commercial properties in the main Esk Township as well as reductions on further residential properties on the fringe of the township. It is not expected to eliminate flood impacts altogether in the 1 in 100 AEP event.

It is expected that there will be negative impacts to properties surrounding the levee due to the large floodplain that has been displaced and the change in flood characteristics.

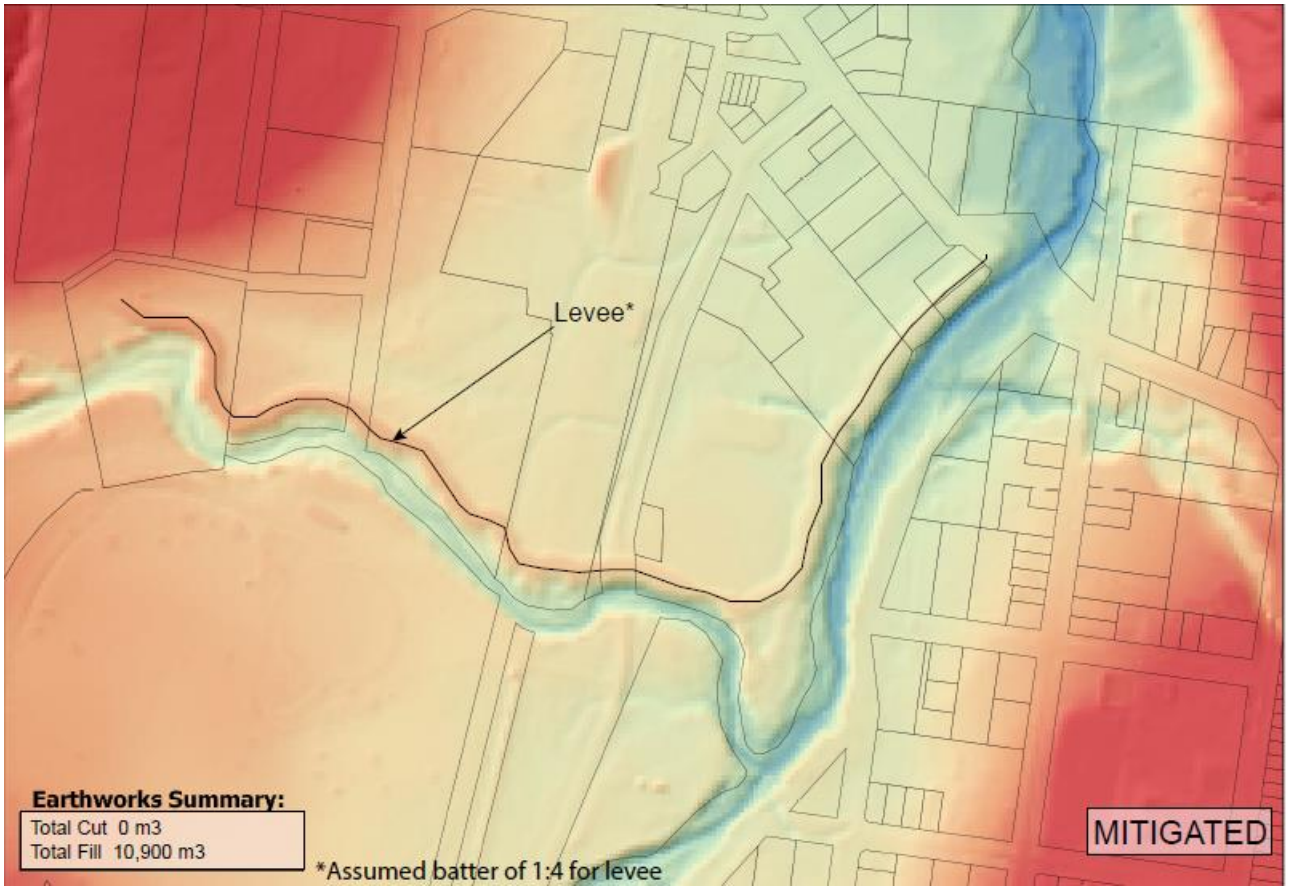

FIGURE 7-3 LEVEE OPTION 2 ARRANGEMENT

7.2.2.2 Flood Modelling Results

As it can be seen from Figure 7-4, there is a large change to water levels and flood characteristics across the area and these include:

- Significant positive afflux (worsening) in the areas south of Redbank Creek. Residential properties may be affected by increased floodwaters of over 250mm in a 1 in 100 AEP. This is a significant afflux and would require extensive consultation, possible property acquisition and/or adjustment to properties to implement this measure.
- To the north of the levee, there are some recreational, commercial and residential properties that are shown to become 'dry' in a 1 in 100 AEP event. With floodwaters at this magnitude, removed altogether.
- Further downstream, there are significant reductions of water level during the 1 in 100 AEP (greater than 250mm) to many residential properties along Russell Street, Francis Terrace and Hassall Street; and,
- There is also significant reduction to the Esk Caravan Park along Sandy Creek. This is particularly important as this is considered a highly vulnerable use with potentially vulnerable occupants.

Levee Option 2 has considerably more benefit than Option 1, as more properties experience mitigation from a 1 in 100 AEP. Overall, whilst the benefits are significant and should be considered further in detail, there is also extensive impact to the residents south of Redbank Creek.

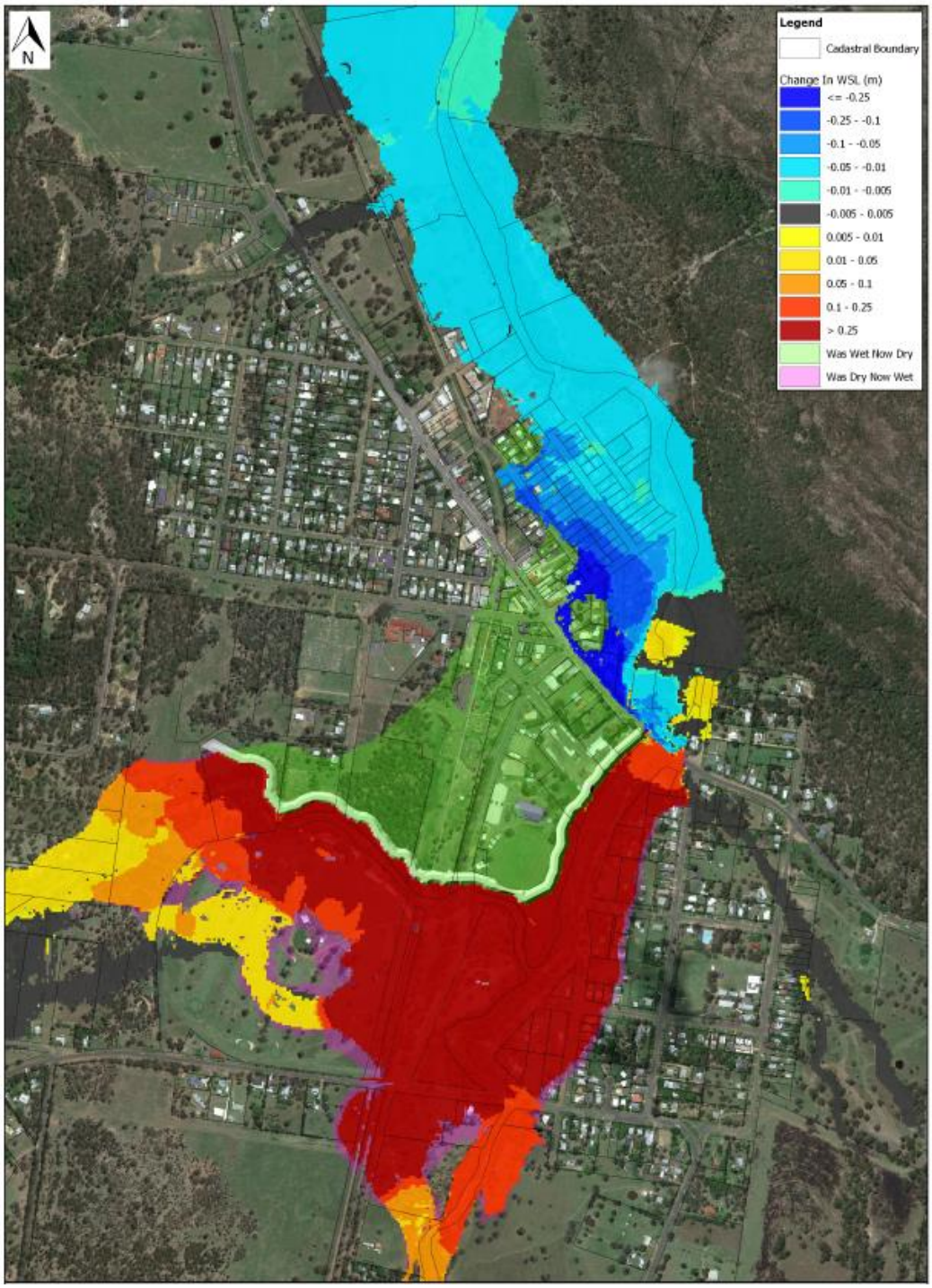

FIGURE 7-4 LEVEE OPTION 1 - 1 IN 100 AEP AFFLUX

7.2.2.3 Costings

The costs associated with the Esk Township Levee Option 2 are shown in Table 7-7. The total cost for this project is estimated at $1.79million.

TABLE 7-7 OPTION COSTINGS

Items	Unit	Quantity	Unit Rate	Amount
Clearing and Preparation	M^2	11,200	$8.00	$89,600.00
Imported Basin Core	M^3	15,600	$35.00	$546,000.00
Excavate and Replace Foundation	M^3	2,100	$60.00	$126,000.00
Final Profiling	M^2	14,000	$5.00	$70,000.00
Spillway Rock	M^3	300	$120.00	$36,000.00
Spillway Concrete	M^3	75	$200.00	$15,000.00
Seeding and Turf	M^2	14,000	$5.00	$70,000.00
Spillway Downstream Channels	M^2	1000	$80.00	$80,000.00
Retrofitting Parks and Property	item	1	$100,000.00	$100,000.00
Total Construction Cost				**$1,112,600.00**
Pre-Construction Items				
Mobilisation, Traffic Control, Erosion and Sediment Control, Environmental Plans and Setup	%	6		$66,756.00
Design, Survey and Modelling	%	12		$133,512.00
Project Management, Applications and other costs	%	6		$66,756.00
Sub Total				**$267,024.00**
Total				**$1,379,624.00**
Contingency	%	30		$413,887.00
Grand Total				**$1,793,511.00**

7.2.2.4 Benefit Cost Assessment

The damages associated with a variety of flood events with the proposed mitigation in place has been simulated and the resultant reduction in AAD is shown in Table 7-8.

TABLE 7-8 OPTION BENEFIT RELATIVE TO CURRENT CONDITION

Option	Total AAD without option in place	Total AAD with option in place	Reduction in AAD	Option Benefit over 100-year lifespan (NPV)
Esk Township Levee Option 2	$480,858	$450,733	$30,125	$430,054

When assessing the financial cost and benefit of the Esk Levee Option 2, the benefit to cost ratio was found to be 0.24. As a result, the option does not return a benefit from a flooding and economics point of view.

TABLE 7-9 BCR CALCULATION

Option Benefit over 100-year lifespan (NPV)	Total Capital Cost	Benefit / Cost Ratio (BCR)
$430,054	$1,793,511	**0.24**

Sensitivity of the parameters for this option included:

- The maintenance cost was reduced by half and this provided a positive cost benefit of 0.21. Although this is still significantly below the desirable value of 0.5 to allow further consideration; and,
- Adjusting the discount rate to 4% still returned a BCA of 0.32 below the 0.5 threshold.

Based on the sensitivity also returning a value of below 0.5, the option is recommended not to proceed forward for further detailed assessment.

7.2.2.5 Multi Criteria Assessment

Generally, for flood mitigation options only costs and benefits are utilised to make determination of the overall scoring of mitigation options. The LFMP has followed the SFMP process to provide additional consideration of a wide range of tangible and intangible benefits and costs. The MCA is used to further assess and score the options to provide a further prioritised list for Council to consider.

TABLE 7-10 MCA ASSESSMENT

Criteria Category	Criteria Detail	Overall Weighting	Option 2
Safety of people	Reduce hydraulic risk rating (now and future)	18.8%	3.0
	Improve time for evacuation (now and future)	6.3%	2.5
Social	Targets vulnerable community members or areas	2.5%	4
	Social health benefits	1.5%	3
	Improves community flood resilience (now and future)	3.0%	3
	Recreation and amenity	1.5%	2
	Connection and collaboration	1.5%	2
	Community Attitude	2.0%	1.5
Economic	Reduce damages and costs to residential property (now and future)	9.0%	2.5
	Reduce damages and costs to business and industry (now and future)	5.0%	2.5
	Option likely to be cost beneficial (now and future)	6.0%	1
Feasibility	Physical / technical (now and future)	9.0%	1.5

Criteria Category	Criteria Detail	Overall Weighting	Option 2
	Legal / approval risk	5.0%	1.5
	Residual Risk/Asset Management	9.0%	2
Key infrastructure and transport	Improve availability and function (now and future)	5.0%	2.5
	Protection of regional water supply quality and security - catchment protection (quality and yield)	5.0%	2.5
Environment and natural resource management	Species impacts	2.0%	2.5
	Vegetation and habitat impacts	2.0%	2
	Ecosystem health and connectivity (fish passage/fauna movement)	2.0%	1.5
	Reduction in landscape salinity / improved moisture retention and groundwater recharge	2.0%	2.5
	Reduction in erosive capacity / soil movement - channel stability / geomorphology	2.0%	2

Overall, the Esk levee township option 2 has benefit in certain areas due to the decrease in depth, but this was also balanced with the negative impact to some properties. The option scored higher in some social categories such as targeting vulnerable uses and resilience due to the benefits afforded to the vulnerable use (caravan park).

The option scores lower in technical and legal aspects because of the difficulty in implementation, mainly due to impact to and potential construction on private properties. There are also some negative environmental aspects associated with the option and residual risk associated with the events above the 1 in 100 AEP not being mitigated.

TABLE 7-11 COMBINED MCA RESULT – COMPARISON OF OPTION 1 AND OPTION 2

Criteria Category	No Change Value	Esk Levee Option 1	Esk Levee Option 2
Safety of people	0.63	0.72	0.72
Social	0.29	0.31	0.32
Economic	0.50	0.41	0.41
Feasibility	0.58	0.48	0.48
Key Infrastructure	0.25	0.25	0.25
Environment & NRM	0.25	0.21	0.21
Total	2.50	2.37	2.39

Criteria Category	No Change Value	Esk Levee Option 1	Esk Levee Option 2
Result		-0.13	-0.08
Rank		2	1

In addition to the overall scoring, Council would also be burden with a 'referable dam', ongoing maintenance costs and residual risks associated with events above the 1 in 100 AEP and the impact of potential structural failure. As shown in Table 7-11, both options have a negative MCA score and are not be recommended for further detailed assessment.

8 PROPERTY SPECIFIC ACTIONS

8.1 Introduction

While the onus to enact these measures will predominately reside with home owners within the region, Council can facilitate this process by considering the recommendations made at the end of this chapter; and will be effective when implementation is coordinated between the suite of flood mitigation options presented as a part of the floodplain management plan.

There are several actions house owners can take to increase flood resilience, including: residential property buy-back and voluntary purchase, house raising and flood-proofing (via retrofitting flood resilient building materials).

8.1.1 House Purchase

House purchase programs are costly to implement, and while applied to local government areas, reply on state and federal funding. These programs are used in areas that are susceptible to frequent and severe flooding, to mitigate the risk posed to life and property, referred to as property buy-back schemes, voluntary house purchase, or compulsory resumption programs.

8.1.2 Retrofitting Flood Resilient Materials

There are a range of building techniques and materials that can be retrofitted to homes in flood risk areas aimed at improving the resilience of buildings and their contents. Materials that are resistant to inundation damage such as double-brick, brick veneer, tiling or water-proof flooring and lining, water-resistant timber framing, closed-cell insulation, and eliminating cavities behind stairs and wall spaces. Also included is the movement of internal services such as electricity power points, air conditioning units and/or hot-water units above a certain flood level.

8.2 Methodology

Properties will be screened for their exposure to hazard, i.e. those properties that are subject to a higher hazard H5 and H6 in a 1 in 100 AEP event are exposed to potential structural failure and therefore will be put forward as suitable for voluntary house purchase.

The next group of properties which are exposed to habitable floor flooding in a 1 in 20 AEP will be screened for hazard. Those exposed to H1 to H4 hazard category in a 1 in 100 AEP will be suitable for potential retrofitting of resilient building materials.

The properties listed as suitable for either potential voluntary house purchase or retrofitting building materials will undergo a damages assessment to compare expected reductions in damages resulting from flooding after property specific actions have been implemented. The cost-benefit analysis uses flood damage assessment to determine the economic viability of an option.

8.2.1 Cost Benefit Ratio

Cost assumption

The following median house prices will be used to price a potential voluntary house purchase program and used to assess the cost benefit to Council.

TABLE 8-1 MEDIAN HOUSE PRICE BY SUBURB IN SOMERSET LGA

Locality	Median House Price[6]
Esk	$322,500

The expected cost of retrofitting materials to create resilient buildings has been established by NCEconomics as part of the Brisbane River SFMP program. The following table shows the average cost per m2 to establish a resilient building. The cost of 'like for like' rebuilding and incremental cost of resilient build from the study by NCEconomics is shown below:

TABLE 8-2 THE COST OF LIKE FOR LIKE REBUILDING AND THE INCREMENTAL COST OF RESILIENT BUILD

Building Type	Average Cost[7] per m2
Fully detached single story on stumps (FDSS – stumps)	$239
FDSS – stumps (raise)	$401
Fully detached single story – slab on ground (FDSS – SOG),	$171
Fully detached double story – slab on ground for the bottom floor only (FDDS – SOG)	$171

These costs will be used to assess whether retrofitting building materials is an economically viable option for Council.

Benefits

An estimate of the reduction in average annual damage (AAD) will be calculated for the whole catchment over the lifetime of a property. The assumptions for AAD reduction are based upon the NCEconomics study as part of the Brisbane River SFMP program. 70% reduction of internal damages will be applied to each residential building and aggregated across the study area.

TABLE 8-3 CLASSIFICATIONS OF FLOOD DAMAGE REDUCED BY RETROFITTING BUILDING MATERIALS

Building Type	Internal[8]	External	Structural	Indirect	Intangible
FDSS – Stumps	70%	No	No	Partial	Partial
FDSS - SOG	70%	No	No	Partial	Partial

8.3 Results

A cost benefit analysis of each property specific action type is presented in this section. Each potential program is summarised to give an overview of property numbers, hazard exposure, costing, and further analysis of suitability of the options available to Council. For example, a combination of priority properties and the full list of suitable properties placed through the cost benefit analysis to provide an overall picture of the economically viability.

[6] Source: Realestate.com.au date: 25th June 2020
[7] Cost per m2 assumption from NCEconomics study for the Brisbane River SFMP (2016)
[8] Reduction to AAD assumption from NCEconomics study for the Brisbane River SFMP (2016)

8.3.1 Voluntary House Purchase (VHP)

Potential voluntary house purchase (VHP) of residential buildings has been considered across the Esk township. The implementation of a VHP program should be considered across the Somerset LGA as a whole, the methods and results presented in this report are for consideration only.

In the Esk township there are 3 residential buildings that are exposed to both frequent flooding (i.e. 1 in 10 AEP) and high hazard categories in a 1 in 100 AEP (H5 or H6).

Distribution of properties that may be eligible for a voluntary house purchase program is presented in Table 8-4. A summary of the property attributes is shown in Table 8-5.

TABLE 8-4 DISTRIBUTION OF PROPERTIES ELIGIBLE FOR HOUSE PURCHASE

Priority Group	AEP	Hazard Category	Number of Properties
1	1 in 10 AEP	H6	0
2	1 in 10 AEP	H5	3

TABLE 8-5 SUMMARY OF PROPERTIES ELIGIBLE FOR HOUSE PURCHASE

Priority Group	Type		FL	AAD	Median House Price
1	No suitable properties				
2	MUDS	H5	107.76	$11,154	$322,500
	FDSS-Stumps	H5	112.38	$10,966	$322,500
	FDSS-SOG	H5	107.76	$10,047	$322,500
Total				$32,167	$967,500

VHP would be a fully effective measure of removing people and property from the risks of flooding including reduction in damages including partial and intangible damages. The lots have the potential to be turned into open space and an enjoyable recreational area for residents. The social impact of removing homes from the community are not insignificant on an individual scale and these impacts are to be considered by Council on a case by case basis.

Given the low number of properties exposed to the criteria in Esk, a benefit cost ration (BCR) has been applied to all properties suitable for VHP.

8.3.2 BCR for VHP all Properties

In summary this option would:

- Remove all suitable properties from the risks associated from exposure frequent nuisance flooding associated within the 1 in 10 AEP events;
- Prevent a total $20,330 in AAD across the Esk township;
- Properties potentially eligible are shown in Figure 8-1.

TABLE 8-6 OPTION BENEFIT RELATIVE TO CURRENT CONDITION

Property Specific Action	Total AAD without option in place	Total AAD with option in place	Reduction in AAD	Option Benefit over 50-year lifespan (NPV)
VHP All Properties	$228,745	$208,415	$20,330	$282,723

When assessing the financial cost and benefit of a buying back properties across Esk, the benefit to cost ratio was found to be 0.3. That is the costs of buying the property in current market conditions, are approximately 3 times more than the benefits that could be achieved over a 50-year lifespan.

TABLE 8-7 BCR CALCULATION

Option Benefit over 50-year lifespan (NPV)	Total Cost (Based on median house price)	Benefit / Cost Ratio (BCR)
$282,723	$967,500	0.3

8.3.3 Voluntary House Purchase – Summary and Recommendation

It is recommended that Council consider implementation of a VHP program in Esk. Despite the BCR, there are other benefits that can be realised, such as removing the risk to life completely. The damages reduction is costed over a 50-year lifespan of the property, however, if the lot is converted and contributes to open space, the risk is removed in perpetuity.

An analysis of the all the potentially eligible properties has a BCR of 0.3. The cost of this option for properties is approximately $967,500 and the estimated benefits accumulated over a 50-year lifespan is $282,700.

The timing of flood hazard impacts means that planning for a range of options needs to commence immediately, focusing on VHP and retrofitting building materials. The way in which these options are implemented, either individually or as a combined package of solutions, requires further investigation during the planning stage with input from the local community.

FIGURE 8-1 PROPERTIES POTENTIALLY ELIGIBLE FOR PROPERTY SPECIFIC ACTION IN ESK

8.3.4 Retrofitting Building Materials

Retrofitting building materials to residential buildings exposed to flooding risks has been considered in Esk. The implementation of a Resilient Building Materials program could be considered across the Somerset LGA as a whole. The methods and results presented in this report are for consideration only. In the township of Esk there are 7 residential buildings that are exposed to both frequent flooding (i.e. 1 in 20 AEP) and lower hazard categories in a 1 in 100 AEP (i.e. H1 to H4).

Distribution of properties that may be eligible for retrofitting of building materials is presented in Table 8-8. A summary of the property attributes is shown in Table 8-9.

TABLE 8-8 DISTRIBUTION OF PROPERTIES ELIGIBLE FOR RETROFITTING BUILDING MATERIALS

Priority Group	Damages (AAD)	Number of Properties
1	Above $10,000	3
2	$5,000 to $10,000	4
3	<$5,000	0

TABLE 8-9 SUMMARY OF PROPERTIES POTENTIALLY ELIGIBLE FOR RETROFITTING BUILDING MATERIALS

Priority Group	Type	Building Area M2	FL (mAHD)	AAD	Hazard In 1 In 100 AEP
1	FDSS-SOG	176.7	112.38	$10,857.00	H3
	FDSS-SOG	146.3	107.76	$10,665.00	H4
	FDSS-SOG	148.3	107.76	$10,233.00	H4
2	FDSS-Stumps	140.7	108.85	$9,683.00	H3
	FDSS-SOG	240.2	110.42	$6,488.00	H3
	FDSS-Stumps	111.0	110.42	$6,268.00	H3
	FDSS-SOG	110.2	112.71	$5,950.000	H3
3	No suitable properties				

A program to retrofit building materials would be an effective mitigation measure to reduce flood damages including partial and intangible damages.

A BCR is applied to the following scenarios:

1. All properties suitable for retrofitting building materials;
2. Priority Group 1 Only (greater than $10,000 AAD); and
3. Priority Group 2 Only (between $5,000 and $10,000 AAD).

8.3.5 BCR for Retrofitting Building Materials Applied to all Properties

In summary this scenario would:

- Create 7 flood resilient properties that are exposed to frequent flooding and H1 to H4 hazard in a 1 in 100 AEP; and,
- Prevent approximately $7,000 in AAD across Esk.

TABLE 8-10 OPTION BENEFIT RELATIVE TO CURRENT CONDITION

Property Specific Action	Total AAD without option in place	Total AAD with option in place	Reduction in AAD	Option Benefit over 50-year lifespan (NPV)
Resilient Building Materials to all properties	$228,745	$221,589	$7,156	$99,507

When assessing the financial cost and benefit of retrofitting building materials to all potentially eligible properties, the benefit to cost ratio was found to be 0.5. That is the benefits of retrofitting building materials is 50% of the cost over a 50yr lifespan.

TABLE 8-11 BCR CALCULATION

Option Benefit over 50-year lifespan (NPV)	Total Capital Cost of all properties	Benefit / Cost Ratio (BCR)
$99,507	$205,644	0.5

8.3.6 BCR Applied to Priority Group 1 Only

In summary this scenario would:

- Create four resilient properties exposed to frequent flooding and H1 to H4 hazard in a 1 in 100 AEP event; and,
- Prevent a total $4,234 in AAD across Esk.

TABLE 8-12 OPTION BENEFIT RELATIVE TO CURRENT CONDITION

Property Specific Action	Total AAD without option in place	Total AAD with option in place	Reduction in AAD	Option Benefit over 50-year lifespan (NPV)
Resilient Building Materials to Priority Group 1	$228,745	$224,511	$4,234	$58,875

When assessing the financial cost and benefit of retrofitting building materials to the Priority Group 1 (i.e. properties with AAD greater than $10,000) the benefit to cost ratio was found to be 0.7. That is the benefits of retrofitting building materials over a 50-year lifespan are 70% of the cost.

TABLE 8-13 BCR CALCULATION

Option Benefit over 50-year lifespan (NPV)	Total Capital Cost	Benefit / Cost Ratio (BCR)
$58,875	$80,586	0.7

8.3.7 BCR Applied to Priority Group 2 Only

In summary this scenario would:

- Create three resilient properties exposed to frequent flooding and H1 to H4 hazard in a 1 in 100 AEP event; and,
- Prevent a total $2,922 in AAD across Esk.

TABLE 8-14 OPTION BENEFIT RELATIVE TO CURRENT CONDITION

Property Specific Action	Total AAD without option in place	Total AAD with option in place	Reduction in AAD	Option Benefit over 50-year lifespan (NPV)
Resilient Building Materials to Priority Group 1	$228,745	$225, 511	$2,922	$40,633

When assessing the financial cost and benefit of retrofitting building materials to the Priority Group 2 (i.e. properties with AAD between $5,000 and $10,000) the benefit to cost ratio was found to be 0.4. That is the benefits of retrofitting building materials over a 50-year lifespan are 40% of the cost.

TABLE 8-15 BCR CALCULATION

Option Benefit over 50-year lifespan (NPV)	Total Capital Cost	Benefit / Cost Ratio (BCR)
$40,633	$102,958	0.4

8.3.8 Retrofitting Building Materials – Summary and Recommendation

It is recommended that Council consider implementation of retrofitting building materials to properties identified in Priority Group 1 (properties with AAD greater than $10,000) only. **This option has a benefit cost ratio of 0.7.** The cost of this option for all three eligible properties is approximately $80,000 and the estimated benefits accumulated over a 50-year lifespan is $58,000.

8.4 Summary of Property Specific Actions in Esk

A detailed economic assessment of property specific actions has been undertaken, considering the reduction annual average damages (AAD) across the groups of potentially eligible properties. The findings seem to align with commentary in this field that suggests implementing property specific actions is generally a viable option for reducing the impacts of flood events up to 1% AEP.

VHP presents a challenge as it is reasonable to assume that property owners may expect a pre-hazard market value for a property. Pre-hazard values have been used in this economic appraisal, however over time and continued to exposure to flooding risks this market value is likely to be adversely impacted as a result of the identified flood hazards.

Given the potential intolerable risks associated with a flood hazards, there is a clear priority to plan for a range of options focusing on flood mitigation, property specific actions and emergency management. The way in which these options are implemented, either individually or as a combined package of solutions, requires further investigation during the planning stage with input from the local community.

The following recommendations are put to Council for consideration as part of a wider floodplain management strategy for Esk and the Somerset LGA:

- It is recommended that Council consider implementation of a Voluntary House Purchase program to all properties potentially eligible has a benefit cost ratio of 0.3;
- It is recommended that Council consider implementation of a program of retrofitting building materials to properties identified in Priority Groups 1 which has a benefit cost ratio of 0.7.

Implementation of two possible programs based on the hazard and damages-based prioritisation highlighted in this report may not be economically viable, however there are a number of further considerations:

- Council should follow up each property to understand the true flood risk to the property, i.e. is there a laundry or storage area that is flooded not habitable floor;
- Council should seek to ensure that residents most affected by flooding hazards are given the first opportunity to take part in a program;
- The order of priority should be regularly reassessed, based on updated information, to ensure that it is as accurate as possible;
- Each financial year, for as long as the program(s) continue, Council should allocate funding for offers to the highest priority eligible properties. These are properties that meet all eligibility criteria. It should be communicated that there is no forced resumption of properties under the Voluntary Home Purchase Program. It must be the choice of the property owner whether to sell to Council if an offer is made;
- Each financial year, for as long as the program(s) continue, all properties that meet the criteria for purchase, whether identified by Council or offered by the owner, should be prioritised for purchase based on the seriousness of anticipated flooding. This priority may change through the financial year depending on the number of Council offers accepted or declined;
- Advice on the programs should be linked to an existing flood awareness, education, and communications program as part of Get Ready Queensland or getting ready for summer campaigns;
- Implementation of the two possible programs needs to take account the financial cost and position of government funding that is available. At the time of writing, there is currently no available funding in Queensland that would be available to fully fund a house-purchase scheme or buy-back program. There are however some funding options available in limited form, such as the Local Government Grants and Subsidies Program (LGGSP), and the Queensland Disaster Resilience Funding. More discussion on funding can be found in the TER;
- Offers to buy property or installation resilient materials should be judged on a case by case basis – the programs should be voluntary, but how and when a site-specific measure is implemented depends on the length of the waiting list, whether the property owner approached Council or vice versa. For example, after making an offer to purchase property, Council may wait four weeks for a response before advising in writing that '*as the owner haven't accepted an offer to purchase that it was being withdrawn and with no guarantee that they would be approached again.'* Longer than three months can require a new property valuation; and
- Initial communication to homeowner to buy property should be include a caveat explaining that property **may** be eligible for consideration under this scheme. Some may be eligible under the criteria explained in this report and considered but ultimately not purchased or offered resilient building materials (e.g. due to budget or unable to agree reasonable works, etc).

9 EMERGENCY MANAGEMENT

Effective floodplain management planning requires a vast array of consideration and implementation of different techniques and tools to reduce flood risk to a tolerable or acceptable level. Measures such as flood mitigation aim to remove the risk altogether whereas emergency management measures are aimed at providing management techniques to better prepare and respond to flooding.

Emergency management overall is a complex arrangement through local government, state and federal government and is centred around PPRR: prevention, preparedness, response and recovery. Whilst the scope of this project is limited, the datasets used in the LFMP may help increase the preparedness, planning and response to flood events.

9.1 Introduction

The scope of the LFMP has been limited in the emergency management and community awareness components. Further detailed investigation would be required to provide useful outputs in the flood forecasting and intelligence space, evacuation planning and in particularly the community awareness component.

It is recommended that Council use the outputs of this project to further inform scope in these areas particularly in specific high flood risk areas to target.

9.2 Flood Forecasting and Intelligence

The process to determine a suitable flood forecasting and intelligence system is based on the level of risk in each township. Ultimately, a flood forecasting system in each LFMP area would be ideal, and this should be the end goal for Council where resources and funding become available. Further information is available in the *Somerset Regional Local Floodplain Management Plan Technical Evidence Report.*

9.2.1 Flood Forecast System Assessment

The township of Esk has the following characteristics when assessing suitability towards the required flash flooding system:

- The Esk township is generally not inundated to a major degree below the 1 in 20 AEP which reduces the risk with the frequency of flooding;
- Above the 1 in 20 AEP event and this level of frequency reduces the overall risk somewhat;
- During the major events however, inundation becomes widespread and there are properties exposed to very high hazards; and,
- There is a very rapid time to inundation for all properties in the floodplain making warning and evacuation difficult.

Because of the level of hazard and number of properties and in particular the sharp time to inundation, advanced warning is generally required on areas like this to respond to flash flooding. Advanced warning generally requires more advanced systems.

The Esk LFMP area could generally be classified as high risk and require the recommendations of BoM with regards to the implementation of an advanced flood forecasting system.

9.2.1.1 High Risk Flash Flood Warning System

As described above the characteristics and risk of the Esk township generally require the implementation of an advanced flash flood forecasting system. This system would encompass the following:

- Utilising BoM meteorological products such as Australian Digital Forecast Database (ADFD), Quantitative Precipitation Forecast (QPF) and rain fields products to provide lead times for the Esk community;
- Utilising the flood model constructed for this project to develop either a live hydrological or live hydraulic system to utilise the available products above; and
- Using future flood gauges in the area recommended below to supplement the system and provide potentially higher levels of accuracy with real time rainfall.

9.2.1.2 Interim Medium Risk Flash Flood Warning System

As the advanced flood warning systems are complex, require substantial funding and allocated resources to operate during flood events, an interim system is recommended to be employed as follows:

- Construction of a rain and river gauge on Redbank Creek at the Brisbane Valley Highway. This gauge will then be able to reference the rainfall intensity and predicted flood levels for each type of event. Alternatively, another rain gauge could also be provided higher in the catchment to determine spatial variation of rainfall;
- Utilising the rainfall and water level trigger maps shown in Figure 9-1 and linking these to the gauge data in the future. In the interim, the maps have been developed to use the bridge deck as a reference; and
- Using the flood intelligence developed as part of the LFMP to indicate high risk properties and associate these with the rainfall and water level trigger maps.

Whilst the interim system is not ideal as it does not provide accurate forecasts as rainfall is variable in temporal or spatial application and does not reflect synthetic design events, it would provide alignment for the BoM recommendations of a medium risk flash flooding system (with the installation of the gauge).

A full suite of rainfall and water level trigger maps for the Esk bridge have been to Council as part of the LFMP, for immediate use during flood events.

9.2.2 Flood Intelligence

Flood forecasting systems can be well supplemented with the flood intelligence developed as part of the LFMP. If an advanced system is implemented at any stage, the following process may be considered:

- The information developed in this LFMP can be utilised to improve flood intelligence in a flood forecasting system;
- Real time intelligence can be output for evacuation prioritisation by undertaking the same screening process to identify areas not considered safe to shelter in place;
- These outputs can then be linked to live evacuation routes considering road low point data, amount of water rover these road points and then subsequent safe passage paths;
- Other outputs can also be used in flood forecasting system such as the live identification of flood islands; and
- These outputs could also then be linked to Council disaster dashboards or specifically developed flood intelligence portals. All of this information could largely be automated as well.

Without the advanced system, the interim system can also take advantage of the precooked information developed as part of this project.

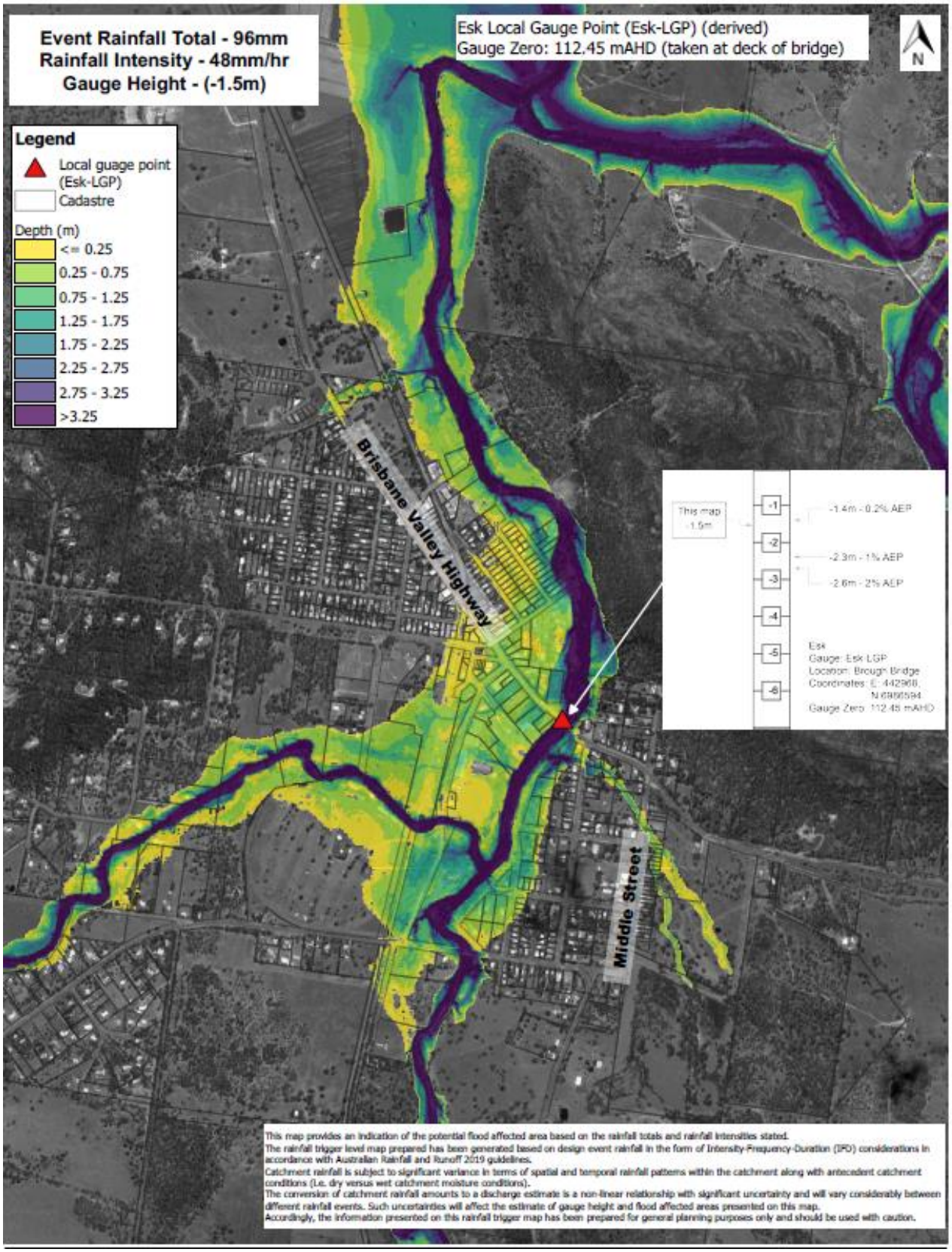

FIGURE 9-1 RAINFALL AND WATER LEVEL TRIGGER MAP ESK TOWNSHIP

9.3 Evacuation Prioritisation

The major component of scope for emergency management was the identification and development of an evacuation screening and prioritisation approach. It is important to understand the limitations and risks during evacuation and consider:

- Evacuation is limited by resources and needs to be targeted to the highest risk properties and prioritised;
- Flood events are response based due to the complexities of events and how they pan out during the event;
- Evacuation is often far more dangerous than sheltering in place due to being swept away in floodwaters etc and the hazards and complexity associated with human behaviour during events; and,
- Sheltering in place (if safe to do so) is often the recommended measure during flood events because of the complexities and risks associated with evacuation. It is also preferable for many reasons that people stay at home, with friends and not in formal evacuation centres.

In the first instance effective flood warning and intelligence can be provided to the community to enable members to voluntarily evacuate. It is always preferable that residents stay with family and friends outside of flood areas well before flood events happen. This requires effective warning, forecasting and flood intelligence measures as well as community awareness and education programs which is outside of the scope of this project.

The complexities of evacuating entire suburbs are made clear by the sheer numbers and resources required. Whilst this is the overall preference where significant risk is involved, this section of the LFMP documents a prioritisation method to attempt to locate properties at greater flood risk due to a number of factors (flood hazard, vulnerability and warning time).

9.3.1 Evacuation Screening Process

A screening process has been developed for use in the LFMP, for further information please refer to the Somerset Regional Local Floodplain Management Plan Technical Evidence Report.

9.3.2 Evacuation Screening Results

When processing the results, it was noted that all properties in each category have a time to inundation of less than 6 hours and all properties are highly vulnerable. The distribution of properties is shown below in Figure 9-2

TABLE 9-1 PRIORITISATION RESULTS

Screen	Detail (Flood Extent and Hazard)	Number of Properties	Priority
1	1 in 2000 AEP H5|H6	54	Highest
2	1 in 2000 AEP H3|H4	78	High
3	1 in 2000 AEP H1|H2	2	Lower

FIGURE 9-2 PROPERTIES CONSIDERED HIGHER PRIORITY FOR EVACUATION – ESK TOWNSHIP

9.4 Evacuation Centre Assessment

Evacuation centres are a critical element of preparing, responding and recovery from flood events. Whilst it is generally preferential for residents to take up shelter with family and friends, this is not always possible and high flood risks in areas may also generally prevent residents from navigating to relatives' homes. Thus, establishment of secure and safe evacuation centres becomes critical as a last resort to protect and houses residents during floods.

9.4.1 Evacuation Centres in Esk

Council have established three evacuation centres in the Esk township at the following locations:

- Somerset Civic Centre 35 Esk Hampton Road Esk;
- Esk Showground 72 Esk Hampton Road Esk; and,
- Esk State School 47 Ann Street Esk.

These evacuation centres are shown below in Figure 9-3. The centres are congregated on the southern side of Redbank Creek.

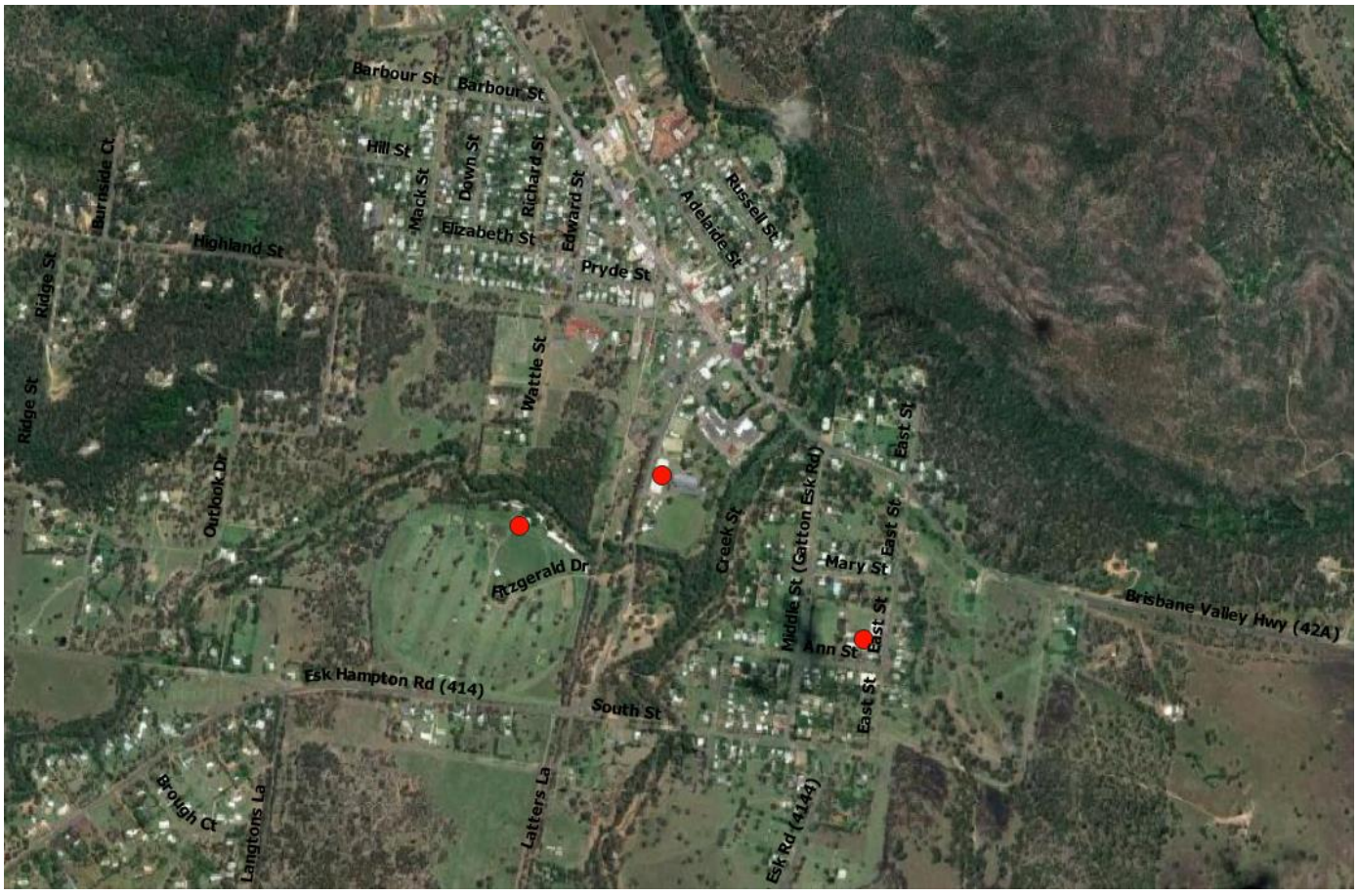

FIGURE 9-3 EVACUATION CENTRE LOCATIONS

9.4.2 Flood Risk Assessment

The location of evacuation centres is often selected with only minimal, historical flooding or no consideration for flood risk. The LFMP now presents a wealth of information that locates high risk residents requiring priority evacuation and the flood risks associated with particularly parcels of land and indeed established centres.

The following provides an assessment of each of the centre locations, considering flood risk, locations of high risk residents requiring priority evacuation and the suitability of site selection to service these residents.

9.4.2.1 Somerset Civic Centre

This evacuation centre location appears to have been placed to service the main Esk township north of the Redbank Creek bridge. The current location in general is heavily affected by flooding and has the following characteristics:

- The centre has approximately a 1 in 20 AEP flood immunity at ground level and the property and building surrounds begin flooding the 1 in 50 AEP event;
- In the 1 in 100 AEP flood event, the entire property submerges up to 0.8m, with the exception of one building in the central portion of the site. This building is fully inundated in the 1 in 2000 event;
- Hazards during the 1 in 100 AEP event are up to H3/4 and also areas of H5 indicating hazards surrounding the buildings that can risk life. During the 1 in 2000 AEP event there is significant hazard with many buildings impact by H5 hazard (risk to building damage);
- The area is affected by rapid inundation of floodwaters as fast as 2.5 hours in a 1 in 100 AEP event. In higher magnitude events this can be as quick as 1 hour;
- The centre is located on the main portion of the Redbank Creek floodplain when it breaches. The centre is afforded flood immunity to a certain point and then becomes a significant flood risk beyond this; and,
- The centre is located on a low flood island and it is likely the Esk Hampton Road will become flooded in a 1 in 20 AEP event preventing access and egress.

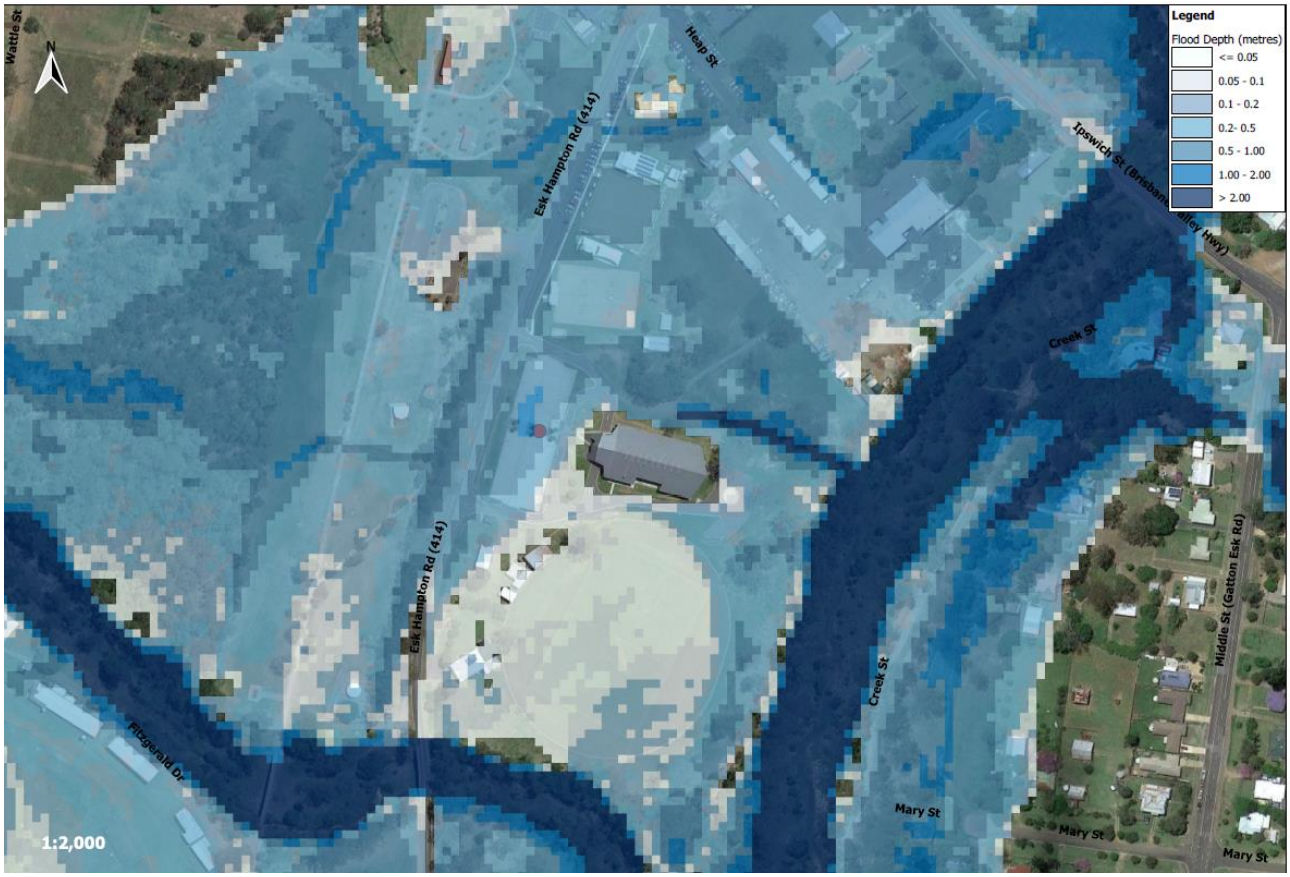

FIGURE 9-4 SOMERSET CIVIC CENTRE, ESK - 1 IN 100 AEP FLOOD DEPTH

As shown in Figure 9-4, the Somerset Civic Centre has a very high flood risk and may not be suitable as an evacuation centre for flooding purposes for the following reasons:

- The centre has low flood immunity, if people are evacuated to this centre, they will be exposed to very high hazards during high magnitude flood events (beyond the 1 in 100 AEP event); and,
- The centre cannot be easily accessed and is on a low flood island. Thus, residents from the north will not be able to access the centre and residents who are taking refuge will not be able to leave as flooding increases.

It could be considered that this centre should only be used in low magnitude events. If people are evacuated to this centre and the flood magnitude increases, these people will be exposed to very high flood risk. In addition to this, the rapid time of inundation will make decision making very difficult and too short to relocate people to other locations. Overall, the evacuation centre location should be reconsidered to an area that is free from these types of flood risk.

9.4.2.2 Esk Showground

This evacuation centre location appears to have been placed to service the rural properties south of Redbank Creek. The current location in general is affected by flooding and has the following characteristics:

- The centre has approximately a 1 in 20 AEP flood immunity at ground level and the property and building surrounds begin flooding the 1 in 50 AEP event;
- In the 1 in 100 AEP Flood event, the entire property submerges up to 0.5m in places. In the 1 in 2000 AEP event there is up to one metre in depth on some buildings;
- Hazards during the 1 in 100 AEP event are up to H3/4 with risk to life. During the 1 in 2000 AEP event there are some areas affected by H5 hazard increasing the risk of structural failure of buildings;
- The area is affected by rapid inundation of floodwaters as fast as 2.5 hours in a 1 in 100 AEP event. In higher magnitude events this can be as quick as 1 hour;
- The centre is located on Redbank Creek floodplain when it breaches 1km upstream; and,
- The centre would be difficult to access during flood events for people to the south of Redbank Creek and likely impossible for residents to the north. Relocating people from this centre would be possible to Esk Hampton Road which is on high ground.

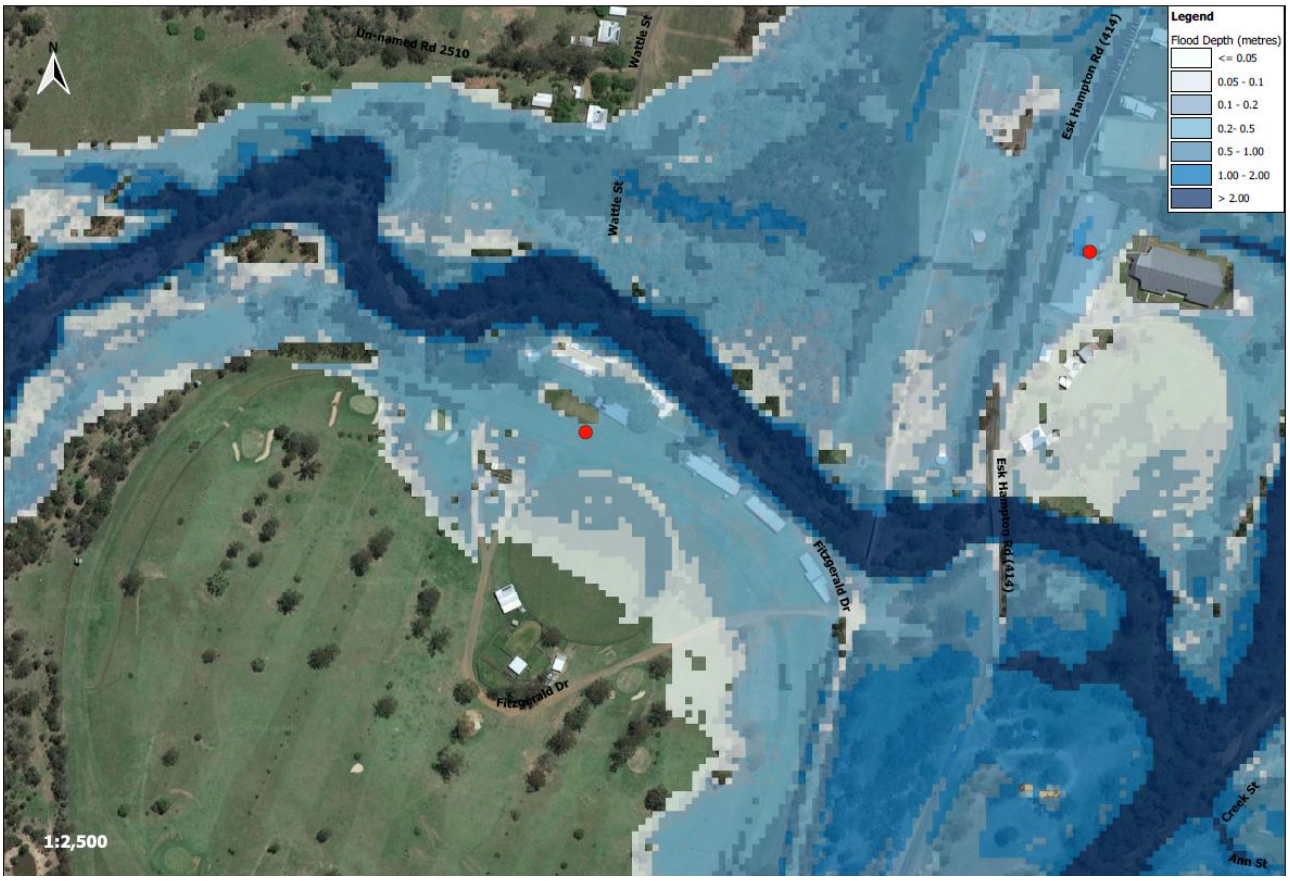

FIGURE 9-5 ESK SHOWGROUND 1 IN 100 AEP FLOOD DEPTH

Overall, the Esk Showground has very high flood risk and is likely not suitable as an evacuation centre for the following reasons:

- The centre has low flood immunity. If people are evacuated to this centre, they will be exposed to high hazards during high magnitude flood events (beyond the 1 in 100 AEP event); and,
- The centre cannot be easily accessed as it begins to flood. Relocation of people may be possible as flood magnitude increases.

It could be considered that this centre should only be used in low magnitude events. If people are evacuated to this centre and the flood magnitude increases, these people will be exposed to very high flood risk. In addition to this, the rapid time of inundation will make decision making very difficult and too short to relocate people to other locations. Overall, the evacuation centre location should be reconsidered to an area that is free from these types of flood risk.

9.4.2.3 Esk State School

This evacuation centre location appears to have been placed to service the rural properties south of Redbank Creek and the location is very suitable as there is no apparent flood risk at this site. Gaining access to this evacuation centre from north of Redbank Creek (and Esk township) and from the west of Sandy Creek would generally be high risk and should not be encouraged.

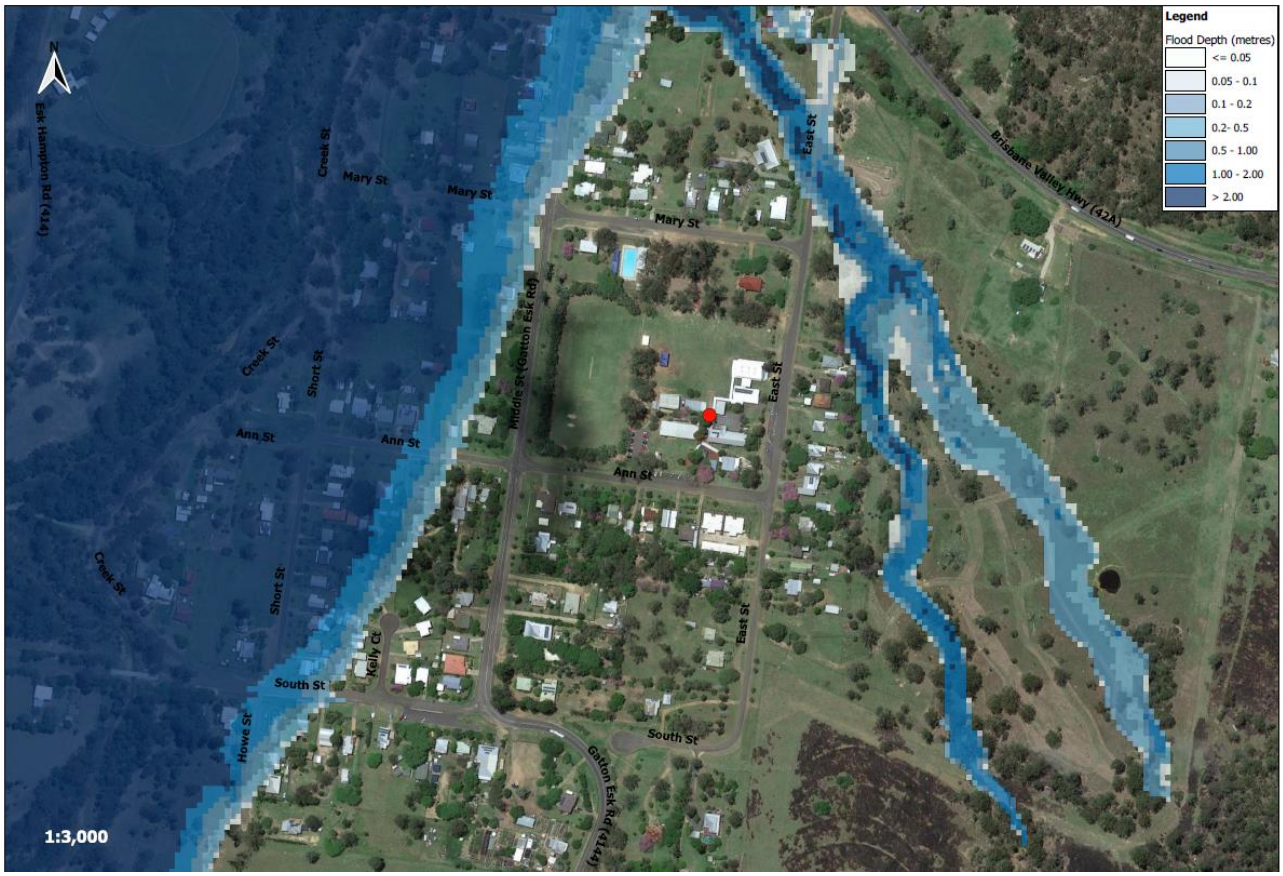

Figure 9-6 ESK STATE SCHOOL - PMF FLOOD DEPTH

Overall, the Esk State School remains a good location for areas to the south of the Esk Township and should be maintained due to being immune to flooding from Redbank and Sandy Creek.

9.4.3 Evacuation Centre Recommendations

Based on the flood risk assessment of evacuation centres in the Esk area, the following is recommended:

1. The Esk State School evacuation centre is a good location, free from flooding in the PMF and should be maintained to service the Esk community during flooding.

2. The Esk Showground in general is not a suitable location for an evacuation Centre. An alternative site is recommended further south (potentially around the Esk Country Golf Club). The centre could be used in minor floods, however the increased flood risk and time to respond to relocation should be noted.

3. The Somerset Civic Centre in general is not a suitable location for an evacuation Centre. An alternative site is recommended to service the main Esk township that is located outside of the floodplain. Towards the Esk Hospital along Highland Street would be a more appropriate location or anywhere west of the township.

9.5 Evacuation Route Planning

With the prioritised results shown in section 9.3, these areas were grouped into clusters and evacuation paths mapped out for each of the clusters as shown in Figure 9-7. It should be noted that assessment of the evacuation centres has shown that two centres were generally not appropriately located for high magnitude flooding and thus evacuation planning has not directed residents to these centres.

It should also be noted that there are other high risk properties not accounted for in the evacuation planning below and all flood risk factors should be understood to provide more awareness of all properties (outside of the main Esk township). A description of each of these routes is described in this section.

9.5.1 Cluster 1 | Russell and Adelaide Street Area

This area has significant numbers of high priority residents potentially requiring evacuation. As the Somerset Civic Centre is likely not safe for evacuation during high magnitude events, residents are recommended to head west towards the Esk Hospital. Areas past the hospital are outside of the floodplain.

As areas become inundated very quickly and properties along Francis Terrace and Russell Street in particular have high hazards associated with floods, it is critical to respond and act early to remove residents from this significant flood risk as it is likely that residents could perish in these types of conditions. Several of the roads are restricted with lower flood immunities and these are indicated by restricted evacuation routes.

Furthermore, early action will be required as roads between the hospital area and this cluster will submerge, become impassable and elevate dangers of evacuation. Alternatives to the hospital would be to traverse north west along the Brisbane Valley Highway and along Edward Street to get to the hospital area.

9.5.2 Cluster 2 | Mary and Ann Street Area

This area has some numbers of high priority residents potentially requiring evacuation. Fortunately, the Esk State School is ideally located and flood free and is a good safe position to evacuate to.

As areas become inundated very quickly and properties along Creek Street in particular have high hazards associated with floods, it is critical to respond and act early to remove residents from this significant flood risk as it is likely that residents could perish in these types of conditions.

Roads towards the Esk State School are generally rising roads out of floodwaters and thus do not generally introduce additional hazards when evacuating (if undertaken with sufficient warning). The exception to this is the single property along South Street that should traverse Sandy Creek and the properties north of the Brisbane Valley highway. These sections of road have lower flood immunities.

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Figure 9-7 Evacuation Routes Esk Township

10 SUMMARY AND RECOMMENDATIONS

10.1 Flood Risk Overview

The LFMP for Esk has been used to understand the extent and scale of flooding and to set policies for managing risks associated with flooding within the catchment. The plan can be used to guide capital investment, land use planning activities, disaster management planning and raise community awareness and understanding of flood risk and how it will be managed. The LFMP used the outputs from the Brisbane River Flood Studies, SFMP and Somerset Flood Studies which provides the data to help understand the flood behaviour of the catchments, to assess and characterise the nature of flood risk across the floodplain and how to best manage the risk.

The current flood risk assessment in Esk shows that flooding during the 1 in 100 AEP event generally affects residential dwellings on Russell St, Adelaide St, Creek St, Ann St and properties on the Brisbane Valley Highway near Sandy Creek and the SRC Offices. During the 1 in 2000 AEP event, the consequences of flooding increases dramatically with the entire township exposed to H3 and H4 flooding. There are also several houses exposed to the potential structural damage encountering H5 hazards.

Key statistics from the Esk LFMP findings show that under the 1 in 100 AEP, there are 212 residential properties that are at risk, whilst under the 1 in 2000 AEP event there are 324 residential properties at risk from flooding. Up to and including the 1 in 10 AEP there are 25 residential properties at risk, and 112 properties under the 1 in 20 AEP. In Esk, there are some properties that are exposed to inundation timeframes of up to 17 hours which means there are areas where residents may be exposed to dangerous flooding situations. Within Esk there are 15 low flood islands and no high flood islands, however only 5 of these low flood islands have buildings situated on them.

Various levels of vulnerability are faced by the township of Esk, with a total of 933 people being at risk from one or more of the four types of vulnerability: physical, social and economic, mobility and awareness. These vulnerabilities arise over all HR categories, with the highest number of people at risk under the HR2(b) and HR3(a) categories. Analysing this in the connect of evaluating flood damages; a total of $228,745 average annual damage can be associated with direct and indirect residential damage, a total of $107,884 for road infrastructure.

10.2 Flood Mitigation Responses

To address the flood risk faced by Esk and the community, several mitigation options have been explored. Detailed assessments of options considered practical, including cost benefit analysis and multicriteria assessment have been undertaken for Council's consideration.

In Esk, the following options were assessed in detail:

- Esk township Levee Option 1
  - Located from Redbank Creek (past Wattle Street) to the RJ Rashford Recreation Ground; and
  - Cost benefit ratio of 0.03.
- Esk township Levee Option 2
  - Similar locality to Option 1, extending past the RJ Rashford recreation ground to the Brisbane Valley Highway; and
  - Cost benefit ratio of 0.24.
- Property specific actions were considered which including:
  - Residential properties eligible for a potential Voluntary House Purchase Scheme.

- Cost benefit ratio of 0.3; and
- Residential properties eligible for Retrofitting Building Materials to create flood resilient properties;
  - Cost benefit ratio of 0.7.

The results of the assessment suggest the Esk township levee options would not be cost effective, however Council may consider the implementation of a Voluntary House Purchase program to all properties potentially eligible as there is a benefit cost ratio of 0.3; and all those properties identified in Priority Groups 1 for a program of Retrofitting Building Materials, as the cost benefit ratio is 0.7.

10.3 Emergency Management Responses

Effective floodplain management planning requires a vast array of consideration and implementation of different techniques and tools to reduce flood risk to a tolerable or acceptable level. Analysis of emergency management in Esk, has shown that the area can be classified as high risk and requires the recommendations of BoM with regards to implementation of an advanced flood forecasting system, which could encompass several methods. Assessment of the flood risk at the evacuation assessments was also undertaken, of which there are three in the township (Somerset Civic Centre, Esk Showground and Esk State School).

The results showed that the Esk Showground and Somerset Civic Centre are not suitable locations and an alternative has been proposed.

10.4 Recommendations

A summary of the wider recommendations for the township of Esk include and are detailed in Table 10-1. In summary, Council may consider:

- Updating Flood Levels using more accurate methods such as survey;
- Providing values classes for commercial damages;
- Implementing emergency management responses and property specific actions as no structural flood mitigation options have been found to be cost beneficial;
- Utilise the flood intelligence used in the LFMP to update land use planning outcomes in Esk;
- Utilise the details from the flood mitigation options to inform any zoning changes with No Feasible Alternatives Assessment Reports (FAAR);
- Installation of a rainfall and river gauge on Redbank Creek, utilise the rainfall and water level trigger maps in the short term and the implementation of an advanced flash flood forecast system in the long-term;
- Review of the evacuation prioritisation lists to provide a better understanding of high-risk residents; and,
- Review the use of evacuation centres at Esk Showgrounds and the Somerset Civic Centre due to their flood risk.

Recommendations are collated and listed below in Table 10-1 for consideration by Council. As the LFMP has been conducted with data in a point in time, continual monitoring and review is required.

TABLE 10-1 SUMMARY OF LFMP RECOMMENDATIONS – ESK TOWNSHIP

Category	Recommendation	Description
Monitoring and Review	LFMP updates	As flood information is updated over time, the LFMP should be reviewed in the context of the current understanding of flood risk. Council may consider, due to the scale of the project, updating the LFMP on a 5 to 10-year timeline.
Existing Risk	Review and implement Brisbane River SFMP Recommendations	Recommendations in the Current Flood Risk chapter of the SFMP are still relevant and should be pursued by the industry. These include more accurate property information, refined datasets and more research into areas such as flood damages etc.
Existing Risk	Review the use of updated commercial building damages from the Brisbane River SFMP Recommendations	The SFMP uses value classes to define different commercial damages based on how valuable the building contents may be. Unfortunately, this information was not made available and an average value class was used. Council may consider updating the commercial value damages after the LFMP is complete.
Existing Risk	Updating Flood Levels with more accurate methods such as survey	Floor levels have a substantial impact on overall flood damages and can skew results significantly. As the LFMP relies on estimated floor levels and overall damages are very high in the ICP overall, it is recommended that high risk areas are investigated in more detail. This should also extend to where detailed implementation of mitigation options is being undertaken to ensure accurate cost benefit assessments are realised.
Existing Risk	Providing values classes for commercial damages	The SFMP uses value classes to define different commercial damages based on how valuable the building contents may be. Unfortunately, this information was not made available and an average value class was used. Council may consider updating the commercial value damages after the ICP is complete.
Flood Mitigation	No structural flood mitigation options have been recommended for further detailed assessment in Esk and thus other management measures are critical to reduce flood risk in the area	All of the investigated structural flood mitigation measures are not cost beneficial for Esk. As high residual risk of flooding generally remains, it is recommended that emergency management recommendations are implemented and in particular a community education and awareness program is developed and undertaken for Esk

Category	Recommendation	Description
Land Use Planning	Utilise the risk-based flood intelligence in the Somerset LFMP TER to update land use planning outcomes in Esk	The SPP requires all Councils to update planning schemes and transition to a risk-based approach to flooding. This project has provided example approaches to risk based planning and also other outputs such as flood islands, vulnerability assessment, time to and duration of flooding and emergency management aspects that will be useful to transition to a full risk based approach to flooding
Land Use Planning	Utilise the details from the flood mitigation options to inform any zoning changes with No Feasible Alternatives Assessment Reports (FAAR)	When any zoning changes are considered to land, a No FAAR report should be undertaken to assess all of the alternatives to these zoning changes. A key component of this is investigating structural flood mitigation options which has been undertaken in this project. As there are generally no feasible alternatives, this will assist in the development of No FAAR reports.
Emergency Management	The recommendations within the flood forecasting section of the report including interim and ultimate options should be adopted.	The trigger-based maps provided with this project should be utilised as an interim measure to manage the relatively high flood risk in Esk. A combined water level and rainfall gauge is also recommended to be installed on Redbank Creek at the Brisbane Valley Highway to provide links to the interim and ultimate flood forecasting system. An additional rain gauge could also be installed within the catchment (further upstream) to provide spatial variation of rainfall patterns. Ultimately, Council should aim to implement an advanced forecasting system if resources permit for the Esk township.
Emergency Management	The developed evacuation prioritisation lists should be reviewed and utilised to provide a better understanding of high-risk residents.	The developed prioritisation lists provide a “triage” style of priority evacuations where sheltering in place is not safe to do so. In addition, the process developed could also be replicated to be utilised in flood forecasting systems to provide real time information and flood intelligence
Emergency Management	The evacuation centres at Esk Showgrounds and the Somerset Civic Centre should be reconsidered due to their flood risk (or at least noted).	The flood risk assessment of both centres revealed a high level of flood risk that would prevent residents accessing these centres and also potentially trap residents at these locations with higher flood risk. It is recommended that the use of these centres be reconsidered from a flooding perspective, and the project provides a wealth of information to choose more suitable sites. At minimum, these centres should only be considered as interim staging centres in high magnitude flood events or only for the use in minor flood events.

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