EDWARD RIVER COUNCIL

DATA COLLECTION AND ANALYSIS OF THE NOVEMBER 2022 FLOOD EVENT DAVIDSON STREET AND NORTH DENILIQUIN

FINAL

SEPTEMBER 2024

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Project Data Collection and Analysis of the November 2022 Flood Event Davidson Street and North Deniliquin	**Project Number** **115027 05**
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2						

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EXECUTIVE SUMMARY

This Study acts as an extension to the Floodplain Risk Management Study and Plan completed in 2017 (Reference 4). A full assessment of the existing flood risk and that which was imposed on the study area during the November 2022 flood event has been conducted, including: review of existing studies, a summary of the 2022 event, the existing flood risk and behaviour, and the identification and multi-criteria assessment of potential flood mitigation options and their impact during design and historic events.

Background

The Edward River is located in the Riverina region in the south-west of New South Wales. The River is an anabranch of the Murray River, running parallel to it for approximately 380 km before re-joining it at Wakool Junction. This study concerns the section of the Edward River in the Deniliquin Study Area, and in particular, the North Deniliquin and Davidson Street regions. The majority of the Davidson Street area is classed as *Deferred Matter*, with large sections of *Public Recreation* and *General Residential* in North Deniliquin and surrounding the main business precinct on Davidson Street. The Davidson Street area lies in the middle of the floodplain, between the main Edward River channel and Brick Kiln Creek.

Existing Flood Environment

Deniliquin has significant flood affectation, with rare flood events completely inundating large sections of both the urban and rural area. Flooding in the area results from high rainfall over the Murray River catchment, which stretches into the Snowy Mountains in the Great Dividing Range. With respect to the Davidson Street area, the Davidson Street informal levee overtops just below the 5% AEP event, and events smaller than this are relatively benign in impact. Analysis of past flood events shows that the average rate of rise is approximately 0.3 m per day, the travel time between Lake Mulwala and Deniliquin during the 2022 event was found to be approximately 5-6 days.

Economic Impact of Flooding

A flood damages assessment was carried out for the inundation of residential and commercial properties in the area as part of the 2017 Floodplain Risk Management Study and Plan (Reference 4). The assessment was based on surveyed and estimated floor levels for all properties in the Study Area. The annual average damages for residential and commercial/industrial properties was found to be $3.04M (2017 dollars).

Flood Modification Risk Management Options

A number of options have been considered in this study, all of which are flood modification options. For each of these, they were tested in the 1%, 2%, and 5% AEP, and November 2022 events, and are outlined in Table 1. It was found through a multi-criteria assessment, that the highest-ranking options was that which raises a lowered section of levee along Jones Avenue. Another high-ranking option involves the lowering of a section of levee at the northern end of Morris Street and improves the ability for water to escape the Davidson Street area during rare flood events.

Table 1 Summary of Investigated Mitigation Options

Ref	Options
FM01	Filling gap in levee on Jones Ave - Tennis Court
FM02	Filling gap in levee on Jones Ave - Tennis Court. Lowering of southern section of Davidson Street Levee
FM03	Raising of Davidson Street by 500mm
FM04	Hole in north side of Davidson St Levee
FM05	Hole in north side of Davidson St Levee (Alternate)
FM06	Raising Davidson levee to the 1% AEP level

1. INTRODUCTION

Deniliquin has experienced severe flooding on several occasions since its settlement in the mid-19th century, with the largest flood on record occurring in 1870. This study, however, focusses on the notable flood event which occurred during November 2022. According to the Edward River at Deniliquin (409003) gauge, the Edward River peaked at 9.2 m (91.63 mAHD) on Tuesday 22nd November 2022, slightly below the 5% AEP design flood level, with initial warnings and predictions stating a potential peak of 9.6 m (92.03 mAHD), slightly below a 2% AEP event. Comparatively, the 2022 flood peaked 0.5 m above the October 2016 event, where the Edward River reached 8.62 m.

This study collates and analyses the available flood data from the November 2022 flood event and considers a range of mitigation options, with a focus on the Davidson Street area and improving road access during rare flooding events. There have been extensive previous studies relevant to the Davidson Street area, including the *Deniliquin Floodplain Risk Management Study and Plan* (Reference 4).

2. BACKGROUND

2.1. Study Area

The Edward River is located in the Riverina region in the south-west of New South Wales. The River is an anabranch of the Murray River, breaking off at Picnic Point and then running parallel to the Murray for approximately 380 km before re-joining at Wakool Junction. This study predominantly concerns the Davidson Street area (approximately 80 hectares), and potential impacts of mitigation options on surrounding regions within the floodplain.

Davidson Street is located within the general Edward River at Deniliquin floodplain, and is bounded by Brick Kiln Creek to the north and east, and Edward River itself to the south and west. The Davidson Street area is located north east of the National Bridge and contains around 100 residential and commercial properties. The majority of the Davidson Street area is zoned within the 2013 LEP (Reference 5) as *Deferred Matter*, with some areas of *Environmental Management, National Parks and Nature Reserves* and *Public Recreation* surrounding the business district of Davidson Street itself (Figure 2).

The Deniliquin Township is located on the south side of the river, while North Deniliquin is located to the north of Davidson Street, on the north side of Brick Kiln Creek. These surrounding localities are generally made of up of *General Residential* and *Local Centre* zoning.

The Davidson Street informal levee surrounds the area, affording protection up to approximately 91.7 mAHD.
Figure 1 shows the detail and notable characteristics of the study area. The North Deniliquin levee affords protection up to approximately 92.4mAHD, while the South Deniliquin levee provides protection to slightly above the 1% AEP event (92.8mAHD).

2.2. Previous Studies

A number of studies have investigated flooding in and around Deniliquin, including the Davidson Street area. These studies have included:

- Deniliquin Floodplain Management Study – Rankine and Hill, February 1984
  The study made a comprehensive assessment of flooding behaviour in the area which was used to determine the height of the levee system that was subsequently built and completed in April 2012. The study used a flood frequency analysis to determine design discharges, which were then used to estimated flood levels using a Standard Step Method of Backwater Analysis. The design flood levels were superseded by the recent flood study (Reference 3).

  The study recommended the existing levee system be upgraded to provide protection against the 1% AEP design event. This included extending the levees around North and South Deniliquin and raising the existing structure to a height of the 1% AEP flood level plus 1.0 m freeboard. The study included geotechnical investigations and found that some sections of the levee were poorly compacted and may fail during a flood.

It also found that a higher levee on Davidson Street would constrict flow and worsen flood affectation for North and South Deniliquin, and that the existing Davidson Street levee should be removed. The Davidson Street levee was found to be structurally inadequate for flood protection and there was risk of failure during an event.

- Deniliquin Flood Protection Levee Study – Sinclair Knight Merz, July 1997
  The study was undertaken subsequent to a levee upgrade being recommended and assessed the type and design of levee system necessary, including revising the estimate of the levee's freeboard. The study used the flood frequency analysis undertaken in the previous study (Reference 6) and the design levels determined by that study. The study recommended a freeboard of 0.5 m for South Deniliquin and 0.1 m for North Deniliquin. The freeboard in both locations was assessed in terms of its components (wave action, spillways, levee types etc.), its benefit from an economic viewpoint, and the community's needs. It concluded that the previously recommended 1 m freeboard was too high and should be lowered.

Other studies specifically relevant to the current investigation are summarised in the following sections.

2.2.1. Edward River at Deniliquin Flood Study, WMAwater, November 2014

A flood study was carried out for the Study Area within the former Deniliquin Council Local Government Area (LGA) in accordance with the NSW Government's Flood Prone Land Policy. The Flood Study aimed at determining design flood behaviour in the study area. Design flood behaviour was defined through the use of a flood frequency analysis and a 2D hydrodynamic model. Design flood levels were used to assess the flood behaviour around the town's levee system, as well as identify potential flooding issues.

Design flood behaviour was determined for events ranging from 20% to 0.5% Annual Exceedance Probability (AEP) as well as an extreme event. The analysis consisted of two parts: firstly, design discharges were derived from a flood frequency analysis, and secondly, a 2D hydraulic model based on the TUFLOW software was used to determine the flood levels and velocity corresponding to those discharges. The adopted design discharges determined by flood frequency analysis are given in Table 2. The extreme event was approximated by tripling the 'expected parameter' estimate of the 1% AEP flow. The hydraulic model was calibrated using three historical events (floods of 1956, 1975 and 1993). Design results produced by the calibrated model included peak flood depth and level, as well as hazard and hydraulic categories. A preliminary estimate of the 0.2% AEP event and the 1% AEP + 0.5 m extent was made for planning purposes as part of this study. The design flood behaviour produced by the study superseded the previous Study Area-wide assessment, completed in 1984 (Reference 6).

Table 2 Estimated Design Flows

`	Flow (m^3/s)	Flow (Ml/d)	*Gauge Level (mAHD)
10	998	86,200	**90.9**
5	1391	120,200	**91.6**
2	1861	160,800	**92.1**
1	2204	190,400	**92.3**
0.5	2425	209,500	**92.4**
0.2	2702	233,485	
PMF	6499	561,000	**93.2**

*Edward River @ Deniliquin (409003)

The current study uses the model established as part of the Flood Study.

2.2.2. Deniliquin Floodplain Risk Management Study and Plan, WMAwater, April 2017

The study followed on from the flood study completed in 2014, and includes a full assessment of the flood risk in the study area, known flooding hotspots, flood hazard categorisation, quantitative flood impacts and spatial categorisation of the flood risk. The study also analysed multiple mitigation measures and aimed to quantify their efficacy, and viability of implementation. Mitigation measures directly relevant to Davidson Street previously assessed and recommended are summarised in Table 3.

Table 3 2017 FRMS&P Recommended Options (Reference 4)

Ref	Option	Priority
FM01	Development and implementation of Vegetation Management Plan	**Low**
FM12	Davidson Street Flow Path Improvement	**High**
PM01	Revision of Flood Planning Level and Flood Planning Area	**High**
PM02	Update Planning Policies (DCP and LEP)	**Medium**
PM03	Amendments to s149 Certificates	**Medium**
PM04	Investigation of Voluntary Purchase	**Low**
RM01	Flood Emergency Management	**High**
RM02	Development of ‘Just in Time’ warning system	**Medium**
RM03	Evacuation Planning	**High**
RM04	Community Flood Awareness	**High**

Apart from these recommended options, other options were assessed but deemed unsuitable for further investigation. These included:

- Raising the Davidson Street levee to the 1% level;
- Raising the North, South and Davidson Street Levees to the 1% AEP level + 0.5 m freeboard;
- Drainage bypass channel through Davidson Street;
- Clearing and lowering of land on both sides of the National Bridge;
- Removal of Davidson Street levee;
- Clearing and lowering of Brick Kiln Creek;

- Reduce raised sections of the Davidson Street levee to make protection level consistent.

One of the most effective options investigated relevant to Davidson Street was FM12, which involved the removal of a 250 m section of the north side of the levee to improve water conveyance in the Davidson Street area. It was modelled to have the greatest impact in the 2% AEP event, with widespread reductions in peak flood levels along Davidson Street, and portions of North Deniliquin. Once overtopped, the current arrangement effectively "contains" the floodwater within the Davidson Street levee and does not allow water to escape the levee at the downstream (western) end.

3. FLOOD BEHAVIOUR

Deniliquin has significant flood affectation, with rare flood events completely inundating large sections of both the urban and rural area. Flooding in the area results from high rainfall over the Murray River catchment, which extends into the Snowy Mountains in the Great Dividing Range. Relatively frequent floods (less than 5% AEP) are, compared to larger events, quite benign, with most development located outside the 10% AEP flood extents. Flood events are also characterised by their long warning, with typically around one week's warning available. The following section summarises the historical flood events and design flood behaviour determined by the Flood Study (Reference 3).

More specifically, the Davidson Street area is currently afforded flood protection by the Davidson Street informal levee up to approximately 91.6mAHD, with the levee overtopping in the 5% AEP event. During a flood event, floodwater initially surrounds the area and is excluded by the informal levee. Floodwater approaches the Davidson Street area through the Riverside Caravan Park and water moving north from the river towards Davidson St at Herriot St. The current levee overtops at Jones Avenue (91.7 mAHD) where the levee has been lowered to make room for a tennis court. This corresponds to a height of approximately 9.19 m (approximately 91.62 mAHD) at the Edward River at Deniliquin gauge (409003). Once the levee has been overtopped, Davidson St acts as a levee, causing water to build up on the east of the road, inundating properties between Jones Ave and Morris St. Davidson Street itself is overtopped when the gauge reaches 9.62 m (92.05 mAHD), between Evans St and Hodgkins St, and flow inundates the downstream side of Davidson St. Once the water reaches this area, dwellings on the north side of Davidson Street become inundated, and the area becomes part of the broader floodplain, transmitting the flow of the river. The levee eventually breaches near the northern end of Morris Street. In the 1% AEP design event, there is approximately 12 – 18 hours between the levee overtopping, and Davidson Street becoming impassable at Jones Avenue. At the peak the entire Davidson Street area is inundated, with approximately 0.75 m of water over Davidson Street and between 0.5 – 1.5 m of water depth on properties either side of the road.

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The flood risk in the area relates to the area's use as a thoroughfare for the town, and to the inundation of residential and commercial properties. Davidson Street is the main route for traffic between North and South Deniliquin, as well as a portion of the highway traffic passing through Deniliquin. There is significant risk of a vehicle or pedestrian using the road once the road is overtopped and becoming swept away, possibly due to misjudging the hazard. The street is particularly important if North Deniliquin is ordered to be evacuated, in which case residents may attempt to use the road after it is safe to cross (which would be well after the evacuation order is given). Secondly, properties in the Davidson Street area are at risk of structural damage due to flooding, and of becoming uninhabitable for the weeks or months after a flood.

3.1. 2022 Event Summary

The 2022 event was relatively long compared to recent notable flooding events. Persistent, record rainfall in the Murray River catchment between August and November 2022 caused flood levels at the Edward River at Deniliquin gauge to remain above the moderate (7.2 m) threshold for nearly 6 weeks between late October and early December (Diagram 1). Albury Airport AWS, approximately 170 km south-east Deniliquin, recorded its wettest September, October and November on record in 2022 across 30 years of data. The peak flood level recorded during the event; 9.2 m (major threshold: 9.4 m), was reached on 22nd November, well below the predicted 9.6 m. Considering this peak level, the event was just below a 5% AEP (1 in 20 year) design event. A comparison of flood levels is shown in Table 4. Through modelling and recounts from locals and the NSW SES, the Davidson Street levee was not overtopped, and Davidson Street itself remained passable for the duration of the event. However, significant resources were allocated, both human and material, to sandbagging the lowered section on Jones Avenue (91.7 mAHD) which may have helped prevent water inundation at this location during the event. At the peak, it was reported that water was "lapping at the road" at the Herriott Road intersection.

A temporary levee was planned along the Davidson Street levee, but this was never constructed once the water level began to retreat. However, levee materials had already been transported to the upstream side of Davidson Street, causing confusion among some residents who expressed concerns that the levee might redirect flow paths and increase flood risk to their properties. Residents along Hodgkins Street and Morris Street employed sandbags to protect their properties. However, as the Davidson Street levee did not breach as predicted, these measures were not required.

Table 4 Comparison of November and Design Events (Edward River at Deniliquin (409003) gauge)

Flood Event	Flow (ML/day)	Peak Flood Depth at Gauge[1] (m)
Oct 1993	83,300	8.48
Oct 2016	84,000	8.48
Nov 1975	119,600	9.04
Jul 1956	154,100	9.37
Oct 1917	189,100	9.63
Sept 1955	110,900	8.95
Nov 1870	200,500	9.68
20% AEP	51,800	7.0
10% AEP	86,200	8.6
November 2022	**102,890**	**9.2**
5% AEP	120,200	9.4
2% AEP	160,800	9.9
1% AEP	190,400	10.1
0.5% AEP	209,500	10.2
PMF	561,500	11.0

[1]Peak flood depths are based on the rating curve produced in the Flood Study and are in reference to the new gauge location.

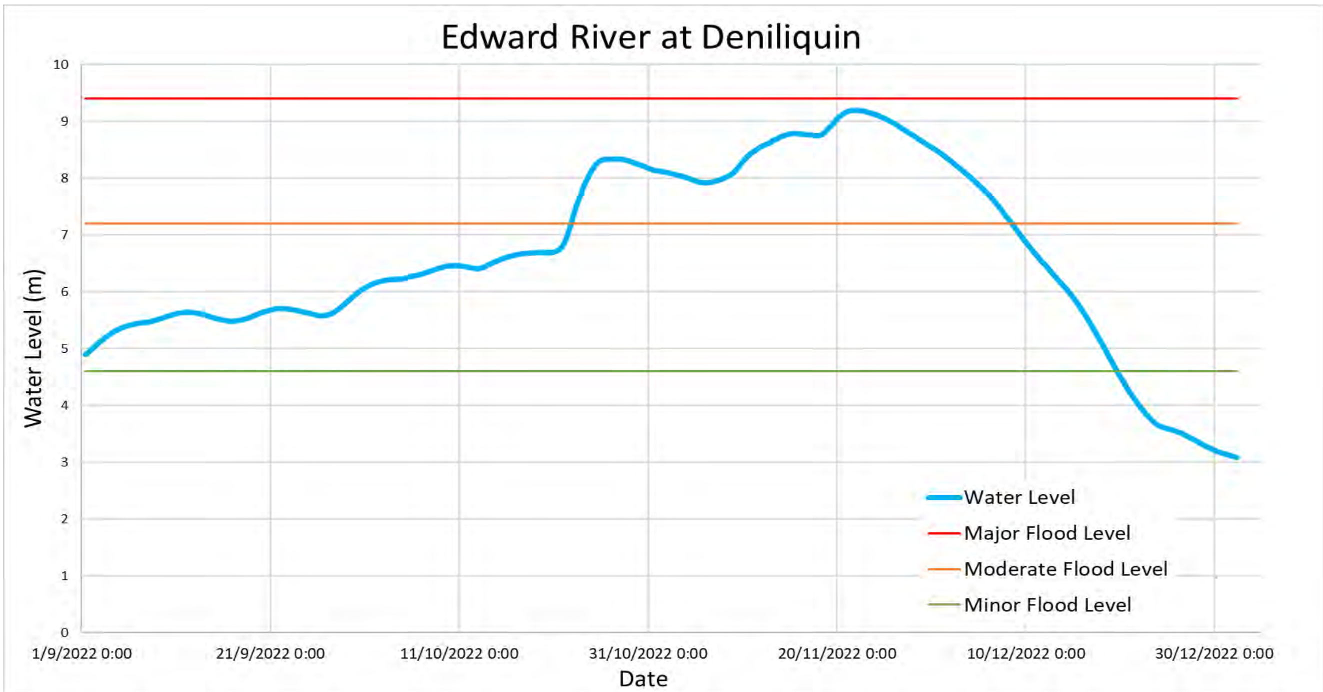

Diagram 1: Edward River @ Deniliquin Gauge (409003) - November 2022 Event

If a level of 9.4 m (major flood threshold) was reached, approximately 100 homes on the southern side of Davidson Street would likely be inundated. While creditable and sufficient “on the ground” recounts around the peak of the event were scarce, a situation report noted that a makeshift levee to protect Davidson Street to a level of approximately 9.5 m was planned to be built along the southern side of the street on the afternoon of 22nd November, before river levels peaked at 9.2 m and began falling. There were some unconfirmed accounts of people on Jones Avenue being impacted by floodwater being forced into their properties due to the fill that was placed along Davidson Street, in preparation for the construction of this makeshift levee.

3.1.1. Travel Time

According to the Local Flood Plan (Reference 17), there is one to two weeks’ time between a flood-producing flow leaving Hume Dam and the flood peak occurring at Deniliquin. The long warning time is a result of the large catchment area upstream of Deniliquin, and the well-developed system of gauges and flood forecasting systems in the Murray River catchment. However, the 2022 event was the result of months of persistent, record rainfall over the catchment thus travel times are difficult to determine here. On 16, 17 and 18 October, large releases of 107,000, 125,000 and 107,000 ML/day respectively were occurring at Lake Mulwala following heavy rainfall. It was not until 22 October that flow rates and water levels began to spike at the Edward River @ Deniliquin gauge. Thus, the travel time between Lake Mulwala and Deniliquin was approximately 5-6 days, as seen in Diagram 2.

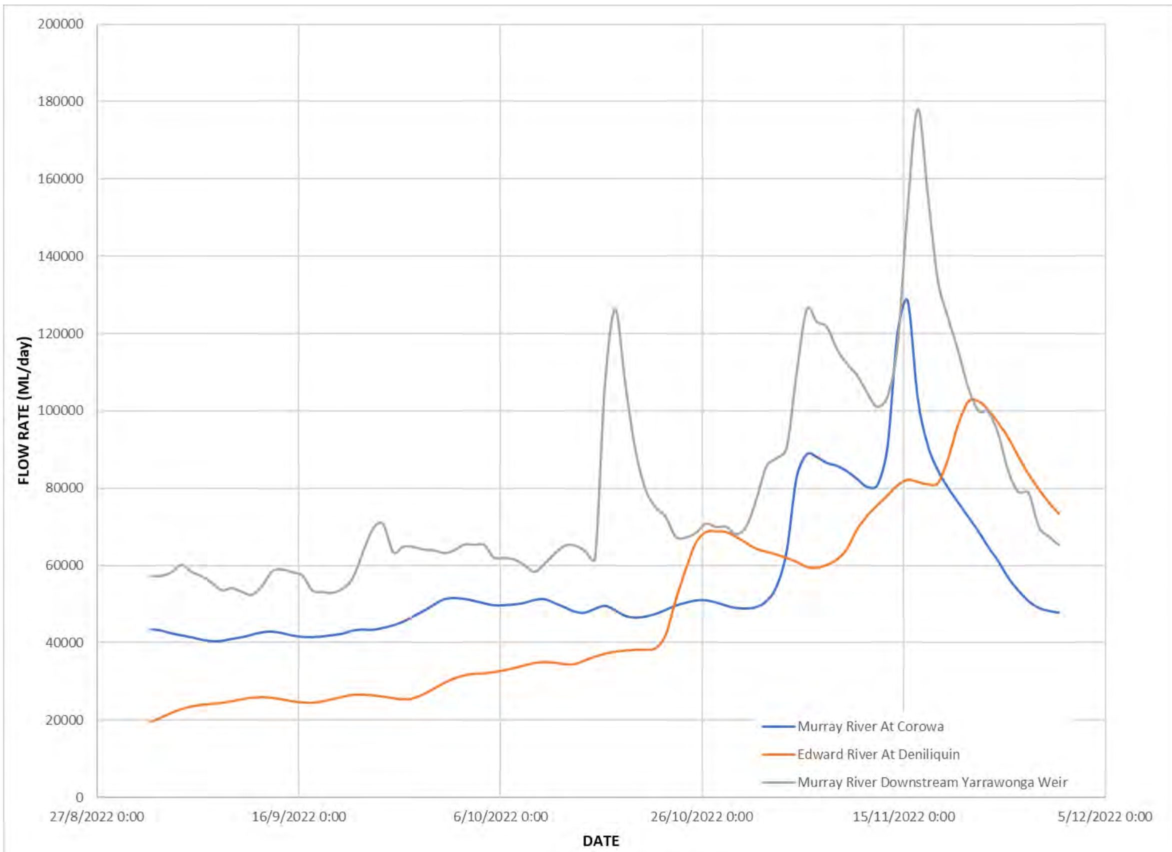

Diagram 2: 2022 Event Hydrograph

3.1.2. Rate of Rise

The rate of rise of floodwaters at Deniliquin is typically slow, with a gradual increase in river levels over the weeks preceding the flood peak. As with travel time, the slow rate of rise is a result of the very large catchment area upstream of Deniliquin. Analysis of flood events for which data is available shows that the average rate of rise in the two weeks preceding the flood peak is 0.3 m per day.

With respect to the November 2022 event, rates of rise were generally slow, gradually increasing from 6.1 m in late September to 9.2 m in late November (0.04 m per day on average) – the slowest rate of rise out of any recorded historic event. There was a small period of comparatively rapid rises between 20-24 October, where levels rose 1.2 m in 48 hours following heavy upstream rainfall between 10-14 October and large releases from Lake Mulwala.

Table 5: Average and Maximum Rates of Rise for Historical Events

Flood Event	Rate of rise (m/day) in lead up to flood peak	
	Average	Maximum
Sep 1889	0.3	0.9
Oct 1917	0.3	0.5
Jul 1931	0.1	0.3
Aug 1939	0.3	0.6
Sep 1955	0.3	0.6
Jul 1956	0.1	0.2
Nov 1975	0.3	0.6
Oct 1993	0.3	0.6
Oct 2016	0.3	0.6

Diagram 3 compares the rate of increase in flows over the duration of the 1993, 2016 and 2022 events. It is evident that the 2022 event produced a far slower rate of rise when comparing with other recent, major events. Both 1993 and 2016 show a small initial peak, before dropping slightly, then a rapid rise to the overall event peak flow. The 2022 event followed a similar pattern, however much less pronounced. This trend may be related to the successive flow out of Lake Mulwala.

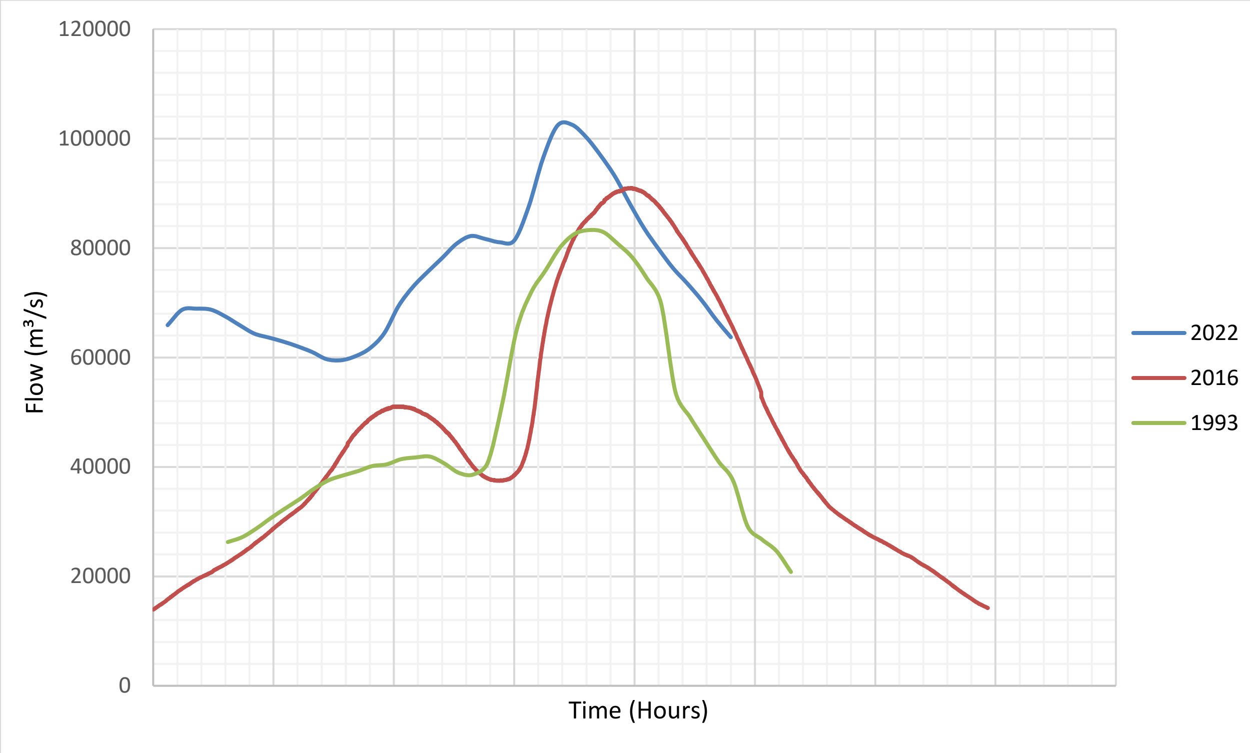

Diagram 3: Event Comparison

3.1.3. Warning Timeline

A warning timeline of the event, beginning in late September has been compiled to outline the warning lead times that were provided in the lead up, and during the peak of the event. As seen in Diagram 1, flood levels rose gradually during late September and early October, peaking at 8.32 m on 28 October. Levels then fell to 7.96 m in early November, before rising again and peaking at 9.2 m on 22 November. Initial warnings during November predicted the peak to be 9.6 m between 24 – 26 November. Table 6 outlines the approximate timeline as to when warnings were released, predicted flood levels, and approximate water level and upstream flows at the time of the warning.

Table 6: 2022 Event Warning Timeline

Time of Warning	Warning/description	Approx. water level at time of warning (m)	Approx. flow rate at Edward River @ Toonalook (ML/day)	Approx. flow rate at Murray River @ DS Yarrawonga Weir (ML/day)
9pm 29/09 2022	River may reach 6.5m by 6/10/2022	6.10	18,160	63,900
4pm 6/10/2022	River may reach 6.3m on 7/10/2022	6.25	20,020	61,870
3pm 7/10/2022	River may reach 6.5m by 14/10/2022	6.39	20,450	60,430
5pm 9/10/2022	River may reach 6.7m around 22/10/2022	6.44	20,840	59,930
3pm 12/10/2022	River may reach 6.5m around 12-13/10/2022	6.44	20,560	65,040
5pm 13/10/2022	River may reach 6.5m around 15-16/10/2022	6.49	21,060	64,530

5pm 15/10/2022	River may reach 6.7m around 22/10/2022	6.56	22,080	67,700
12pm 17/10/2022	River may reach 7.2m around "late October"	6.66	22,200	126,920
5pm 18/10/2022	River may reach 7.2m around "late October"	6.68	22,100	100,450
12pm 20/10/2022	River may reach 7.2m around 27-28/10/2022	6.69	22,070	77,330
4pm 24/10/2022	River may reach 8.5m around 26/10/2022	7.9	41,830	67,620
2pm 25/10/2022	River may reach 8.5m around 26/10/2022	8.2	43,720	69,630
12pm 28/10/2022	River peaked at 8.34m on 27/10/2022 and falling	8.32	44,870	69,900
2pm 1/11/2022	River currently falling. Renewed river rises possible from approx. 10/11/2022	8.12	41,900	86,100
5pm 4/11/2022	River currently falling. River to remain above 7.2m for next 7 days. Renewed river rises possible from approx. 10/11/2022	8.03	41,320	118,540
4pm 7/11/2022	River could reach 9m around 14-16/11/2022	7.96	39,460	118,340
4pm 8/11/2022	River could reach 9m around 14-16/11/2022	8.03	40,270	115,440
4pm 9/11/2022	Rises currently occurring. River could reach 9m around 14-16/11/2022	8.36	44,200	109,490
2pm 12/11/2022	River may reach 8.8m around 15/11/2022	8.58	47,110	98,260
6am 14/11/2022	River may reach 8.8m around 15/11/2022	8.75	48,880	109,080
1pm 16/11/2022	River may reach 8.8m around 17/11/2022	8.77	49,330	178,930
11am 17/11/2022	River may reach 9.4m around 24-26/11/2022	8.75	49,070	156,420
9am 18/11/2022	River may reach 9.4m around 24-26/11/2022. River may reach 9.5m around 25-27/11/2022. Further rises possible.	8.76	49,150	133,660
5pm 19/11/2022	River may reach 9.4m around 24-26/11/2022. River may reach 9.6m around 24-26/11/2022. Further rises possible.	8.92	50,970	122,980
1pm 20/11/2022	WATCH AND ACT West Deniliquin – prepare to isolate by 10.30am 23/11/2022. River may reach 9.6m on 23/11/2022.	9.09	52,870	114,800

1pm 20/11/2022	EMERGENCY WARNING Davidson Street Area – evacuate by 10am 23/11/2022.	9.09	52,870	114,800
2pm 22/11/2022	CLARIFICATION. Davidson Street evacuation still in place. Davidson Street remaining OPEN. River levels holding.	9.19	53,750	99,950
10am 23/11/2022	Evacuation Orders Cancelled. River peaked at 9.2m @ 1am 22/11/2022 and falling.	9.18	53,370	95,550

4. FLOOD MODEL CALIBRATION

4.1. Modelling Approach

The November 2022 flood has been modelled using the established flood model from the 2014 Edward River at Deniliquin Flood Study and revised as part of the 2017 Edward River at Deniliquin Floodplain Risk Management Study and Plan. Gauge height data from Gauge 409003 – Edward River at Deniliquin was used as the basis for the flow input into the TUFLOW model. The flood model had previously been calibrated to historical flood events, including those in 1956, 1975, 1993, and 2016. The November 2022 flood provides a valuable opportunity to further validate the model with a more recent event, enhancing flood intelligence and operational response.

Given the prolonged nature of the November 2022 flood, during which the river remained above normal levels (~4 mAHD) for several months and affected a large catchment area, running the entire event through the model would have required an extensive simulation period. To manage this, only a portion of the hydrograph was used for the TUFLOW inflow, covering the month leading up to the flood peak and 10 days afterward. To account for the pre-peak river conditions without the need for extended simulations in each run, an initial water level (IWL) grid was employed. The long-duration hydrograph from the period when the river was above 4 m was modelled to simulate river activity before the peak. The IWL grid was then extracted at a point matching the initial discharge for the shortened event.

The levels of the November 2022 event IWL grid was 91.36 mAHD at the upstream boundary and 86.2 mAHD at the downstream boundary. The initial water level at the gauge was 89.37 mAHD. The model was run for a total of 40 days (960 hours) from 22nd October 2022 to 1st December 2022. The section of the gauge hydrograph used in the model stimulation, along with the IWL is shown in Diagram 4.

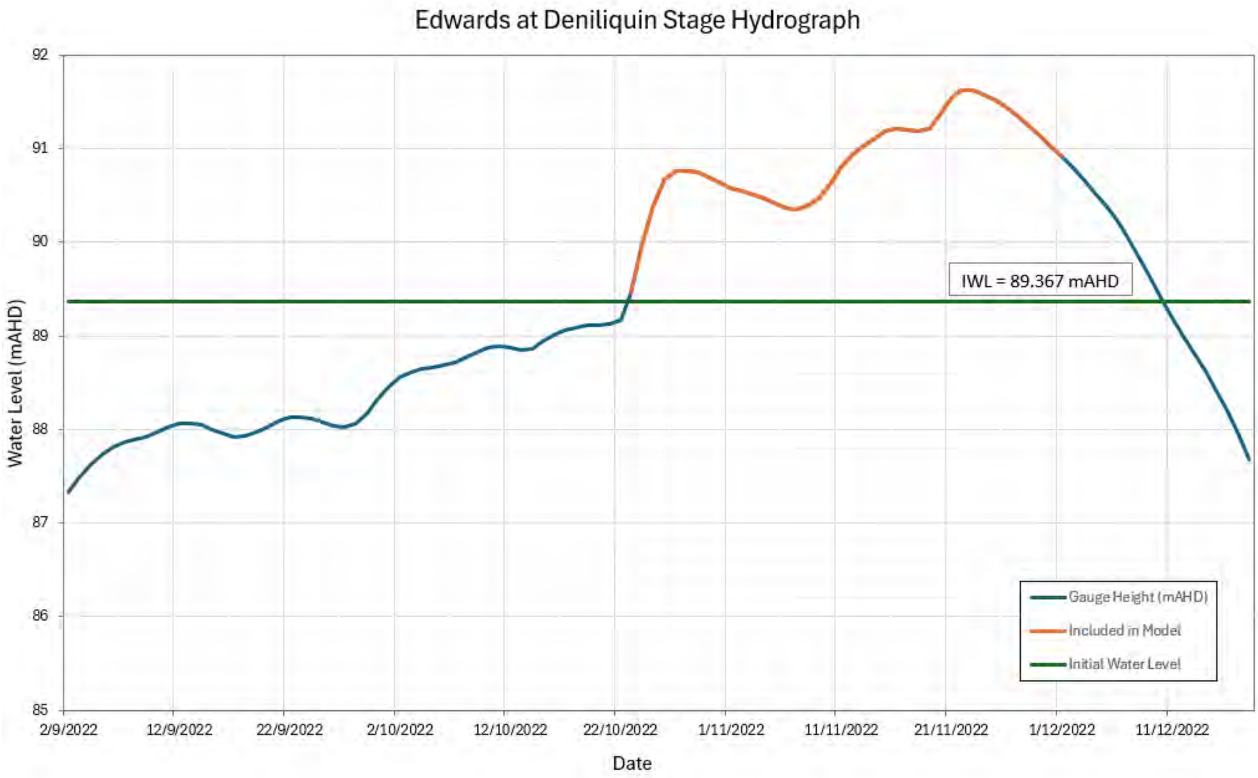

Diagram 4 Section of hydrograph used in Model

4.2. Calibration Data

Although the SES carried out surveys of the flood marks across the catchment following the November 2022 floods, this data was not made available to WMAwater at the time of this report. The modelled results could therefore only be calibrated against the water level recorded at the Edward River at Deniliquin (409003) gauge and available aerial photography.

4.3. Model Variations

No major changes to the model topography were made for this event since the model was run for the 2016 event. No modifications were made to account for the sandbagging which took place at the lowered section of the levee at Jones Avenue. However, comparison between the preliminary model results and the gauge data showed some discrepancies between the two hydrographs. The model was altered and iterated with several variation in an attempt to produce a more reasonable calibration. These steps are similar to what was carried out for calibration to the 2016 event as part of the Floodplain Risk Management Study and Plan. The test variables included:

1. Using the Flood Study rating curve instead of WaterNSW rating curve.
2. Changing the model tailwater.
   a. Taking an approximate average of the water levels at the Edward River at Deniliquin and Stevens Weir (409023) gauges during the flood event and overlaying the Stevens Weir profile at that average as a tailwater.
   b. Changing the model tailwater to be a weighted interpolation of the Edward River and Stevens Weir Gauges. This weighted interpolation was based on the distance of both gauges from the downstream model boundary and the shape of both hydrographs.

3. Scaling the inflow data.
4. Offsetting inflow to account for travel time between gauge and upstream boundary.

The following sections describe the applied approach.

4.3.1. Rating Curve Selection

WaterNSW operates Gauge No. 409003 ‘Edward River at Deniliquin’ which records stream water level (in metres gauge height). This stage data is converted into flow data based on a relationship of height to flow (rating curve). The rating curves produced by WaterNSW are typically built from a series of gaugings during flood events, and then extrapolated beyond the highest gauged event. The recorded gauge height and produced flow data (in ML/day) for the November 2022 event was obtained from WaterNSW in 15-minute time intervals.

In the 2014 Flood Study, the TUFLOW hydraulic model was calibrated to a range of historical events. This model produced a rating curve from a range of modelled flows which more accurately represented the out-of-bank flow behaviour compared with the WaterNSW rating curve extrapolation. As shown in Diagram 5, the WaterNSW and the Flood Study rating curve produce similar stage-flow relationship and are closely matched at high flows. However, between water heights of approximately 6 – 9 mAHD, the WaterNSW rating curve appears to underestimate flows when compared to the Flood Study rating curve. This can be seen in Diagram 5. A comparison of of the rating curves for the November event is shown in Diagram 6.

The TUFLOW-produced rating curve was selected to convert recorded gauge heights to flow for use in the model, similar to the 2016 event. The WaterNSW recorded gauge heights were converted to flows using interpolation of the TUFLOW rating curve, and this flow hydrograph was applied at the upstream inflow boundary of the model. All water levels during this event were within the Flood Study rating curve and so no extrapolation was necessary.

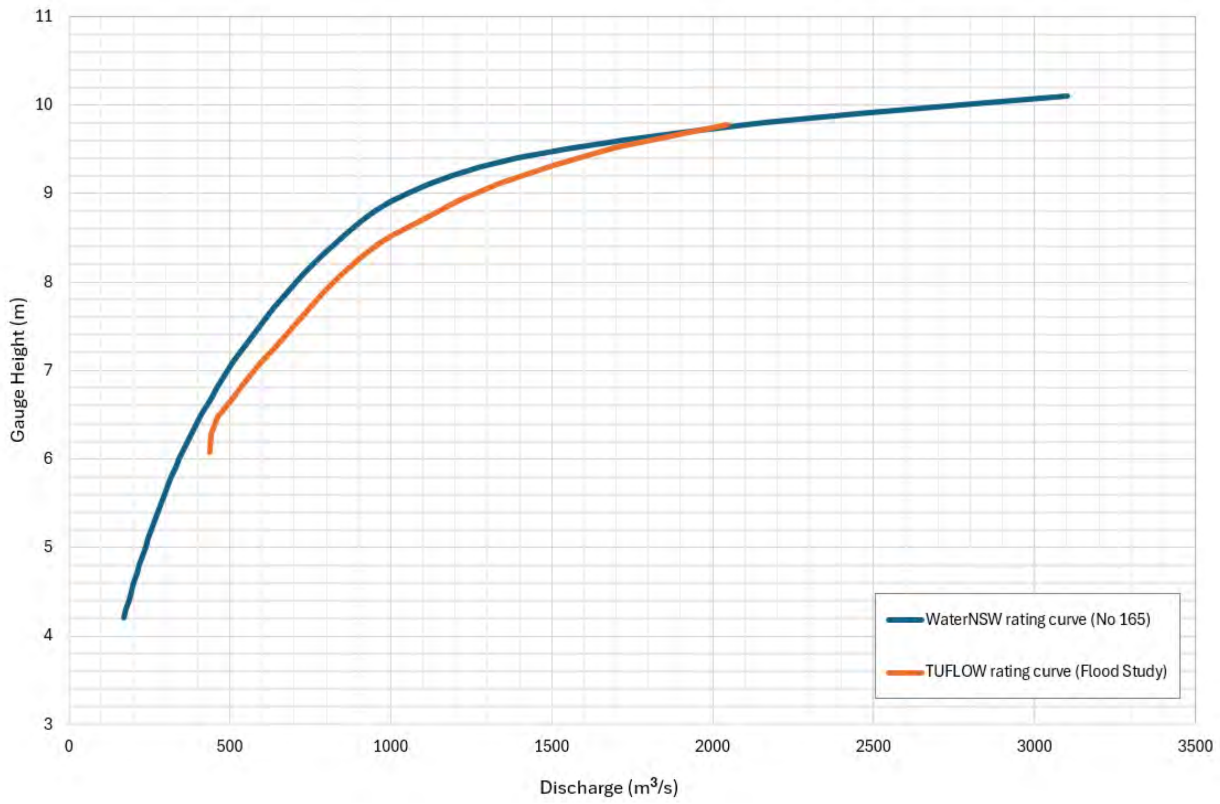

Diagram 5 Comparison of WaterNSW and Flood Study rating curves

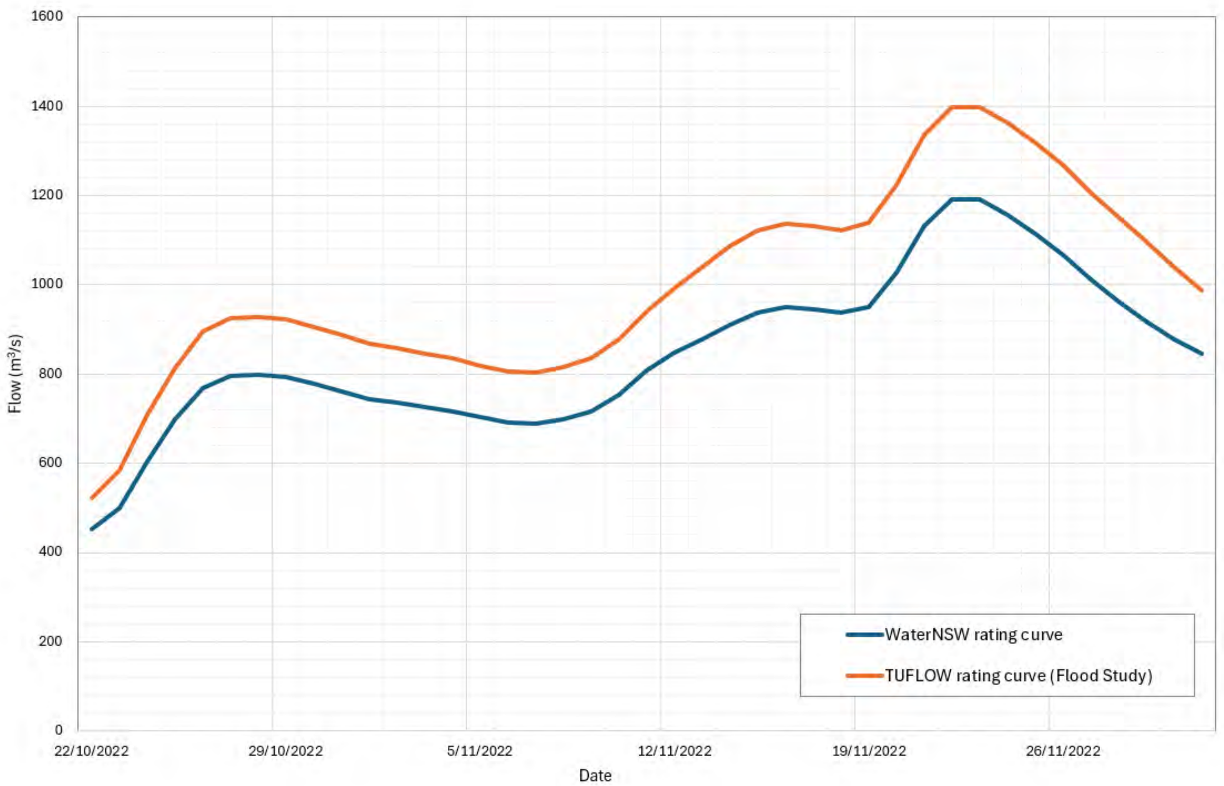

Diagram 6 Comparison of rating curves for November 2022 event

4.3.2. Model Tailwater

The height time-series of the downstream boundary was estimated by interpolating between the expected heights at Edward River at Deniliquin (409003) gauge and downstream of Stevens Weir gauge (409023). As with the calibration events, these are the locations of the two nearest gauges. The Stevens Weir (409023) gauge is located 20km downstream of the model boundary and 30km from the Edward River gauge. The interpolation was weighted based on distance from the downstream model boundary. The flatter hydrograph shape from the Stevens Weir gauge was used for the shape of the tailwater hydrograph.

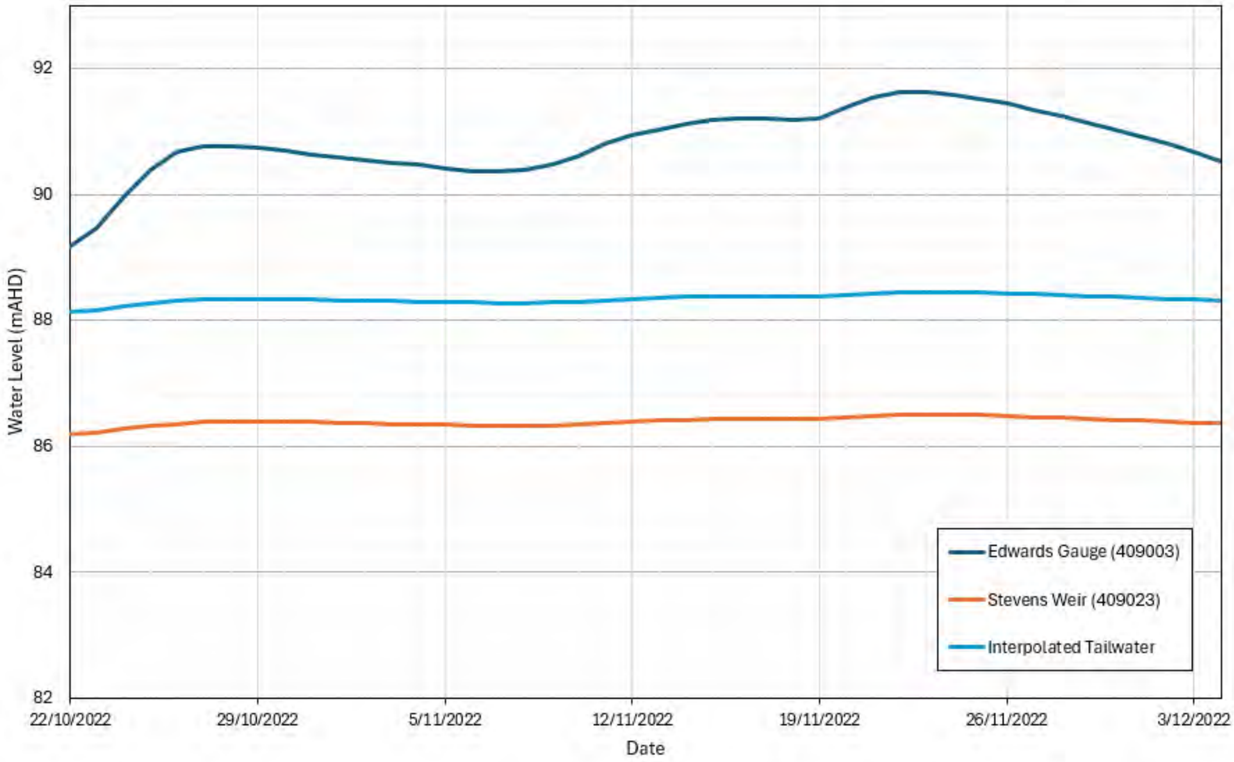

Diagram 7: Interpolated Tailwater

4.3.3. Revised Model Inflow

A comparison of the stage hydrographs for the modelled and recorded 2022 flood events found that the model initially overestimated peak flood behaviour at the gauge. To produce a more accurate flood level at the gauge, the model inflow was scaled to 90% of its initial value. The revised model achieved a closer match, particularly at the peak.

4.3.4. Offsetting Model Time

The initial model results showed a slight lag of approximately 2 hours compared to the recorded heights. This discrepancy is due to the Edward River at Deniliquin gauge being used as the inflow source, while the upstream model boundary, where this inflow is applied, is approximately 1.5 km upstream.

The travel time was calculated by determining the time difference between the peak flows at Stevens Weir and Edward River at Deniliquin gauge and dividing it by the distance between them, which is about 30 km. This calculation yielded an estimated travel speed of 0.1 km/hour. Based on this, the typical travel time from the upstream boundary to the gauge was approximately 1 hour 45 mins. Therefore, the model inflow was adjusted by 1.75 hours.

4.4. Comparison of November 2022 Model and Actual Event

A comparison of the stage hydrographs for the final modelled and recorded 2022 flood events is included in Diagram 8 below for the Edward River at Deniliquin Gauge location. It can be seen in the chart that the modelled event accurately replicates the recorded peak as well as the shape and timing of the event. The max difference is -0.15 m and the difference at peak was -0.02. This is considered an acceptable tolerance for calibration.

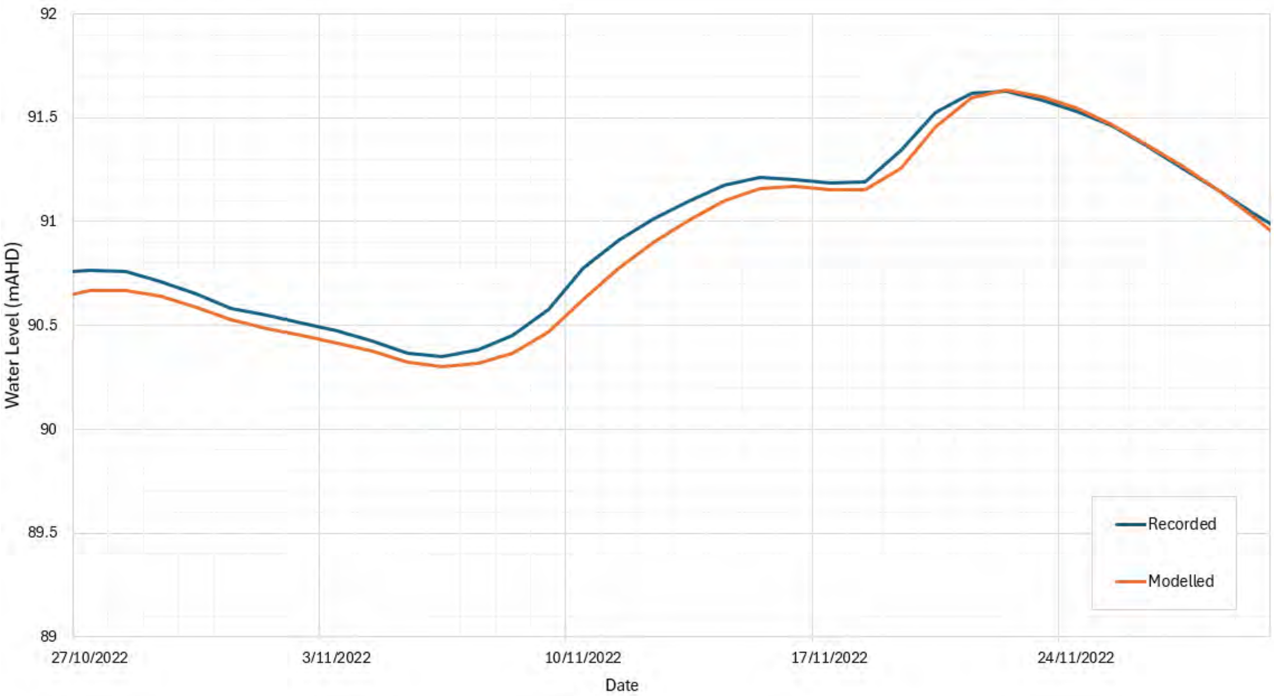

Diagram 8: Comparison of Recorded and Modelled Levels at Edward River at Deniliquin Gauge (409003)

Although flood marks from across the study area were not available, an aerial video by 7Six3 (https://www.youtube.com/watch?v=ImwyoYc2gG0) captured the extent of flooding across Deniliquin. Shots from this video have been compared with the model results to assess the accuracy of the model. This comparison is shown in Appendix B. It was assumed that the video was taken around the peak flood.

As shown Appendix B, the extent of flooding in the video generally matches the extent of the calibrated model shown in Figure 7. It shows how the area south of the Davidson Street area is completely inundated up to the levee. The Edward River Oval is completely inundated. The Edward River Hotel and the Deniliquin Riverside Caravan Park remain dry, along with the rest of the Davidson Street area as they are within the area protected by the levee. It is clear from the hydraulic model and the aerial photographs that the Davidson Street levee was not breached in the November 2022 event.

5. ASSESSMENT OF FLOOD RISK

5.1. Overview of Flood Risk – Davidson Street

Flooding in Deniliquin generally is characterised by long duration events that inundate large areas of riparian vegetation and spread across the higher, more urbanised areas in large flood events. In a 1% AEP flood event, the majority of flow is contained in the main channel of the Edward River, with velocities of 1.5 to 2 m/s and depths of 8 to 12 m (Figure 6). Outside of the main channel in the riparian zone, flow paths are less defined, and velocities are around 0.1 to 0.3 m/s, and depths are around 1 to 2 m deep in a large event.

In Davidson Street, the informal levee provides flood protection, preventing inundation of the area behind the levee until water levels reach approximately 91.7 mAHD (equivalent to 91.6 mAHD at the Edward River at Deniliquin gauge). Overtopping of this levee occurs just below the 5% AEP event. More frequent events have minimal impact and do not affect areas behind the levee. During the November 2022 event, the gauge peaked at 91.63 mAHD, which, according to the calibrated TUFLOW model, would have caused a small volume of water to enter the Davidson Street area (refer to Figure 7). However, community feedback indicates that the levee was not breached during this event, likely due to sandbagging at the low point on Jones Avenue, which was not included in the model. Therefore, it is probable that without the sandbagging, some properties on Jones Avenue would have experienced inundation during the November 2022 event.

In a large event, depths south of Davidson Street range between 1 m and 2.5 m; while north of the street depths range between approximately 0.5 m and 2.5 m. Similarly, to the rest of the floodplain, flow paths are poorly defined, and peak velocities are fairly low within the Davidson Street area, ranging between <0.1 and 0.3 m/s.

5.1.1. Davidson Street Informal Levee

Figure 1 shows the Davidson Street levee, which is an informal levee that is not maintained. The 1984 study (Reference 6) found that the levee was structurally inadequate and that there was risk of failure from slumping and/or piping under flood conditions. Without this occurring, the levee design height is approximately at 91.7mAHD, but the levee condition is assumed to be poor and inconsistent. Assuming the levee is not further modified during a flood event, and that there is no structural failure, it will inhibit flow during a 10% AEP event but will likely be overtopped in a 5% AEP event. The levee under current conditions overtops at a gauge height of approximately 9.3 m (approximately 91.7mAHD), with water first ingressing at a low point (crest at approximately 91.7mAHD) in the levee on Jones Avenue. Another low point is present at the northern section of the levee, near the northern end of Morris Street (91.8 mAHD).

5.2. Hydraulic Hazard

Hazard classification plays an important role in informing floodplain risk management in an area as it reflects the likely impact of flooding on development and people. The Australian Disaster Resilience Handbook 7 Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia (Reference 8), the NSW Flood Risk Management Manual, and Book 6, Chapter 7 of ARR 2019 (Reference 9) provide procedures for determining the hazard based on the flood velocity and depth. The Flood Risk Management guidelines and ARR (2019) provide revised hazard classifications that add clarity to the hazard categories and what they mean in practice. The classification is divided into six categories which indicate the restrictions on people, buildings and vehicles (Diagram 9):

- H1 – No constraints
- H2 – Unsafe for small vehicles
- H3 – Unsafe for all vehicles, children and the elderly
- H4 – Unsafe for all people and all vehicles
- H5 – Unsafe for all people and all vehicles. Buildings require special engineering design and construction; and
- H6 – Unsafe for people or vehicles. All building types considered vulnerable to failure.

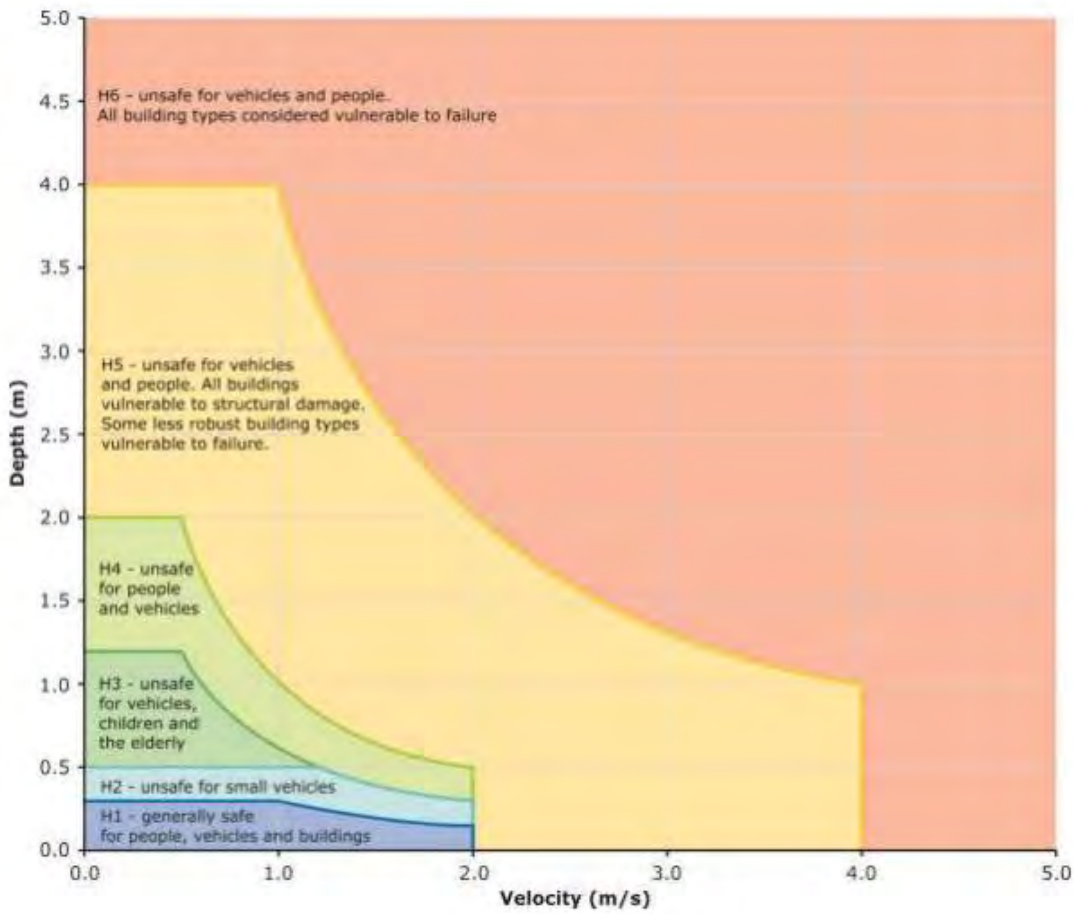

Diagram 9: Hazard Classification diagram (Source: AIDR, 2016)

Provisional hazard categories were produced for two design events (5% and 1% AEP) in the Flood Study (Reference 3). This report includes the hydraulic hazard classification for both these events as well as the November 2022 event and are shown on Figure 8 to Figure 10.

Once the levee is overtopped, and the Davidson Street area is inundated, much of the north of Davidson Street experiences H3 (unsafe vehicles, children and the elderly) in 5% AEP. Some part particularly around Davidson Street itself are classified H1 (Generally safe for people, vehicles and buildings) or H2 (generally safe for people and buildings but unsafe for vehicles). South of Davidson Street, experiences mainly H4 (unsafe for people and vehicles). There are isolated pockets of H5 (Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust building types vulnerable to failure) along the southern and eastern portions of the levee.

In the 1% AEP event, the Davidson Street Area experiences widespread H3-H5. Davidson Street itself and around the north section of the levee are H3 (Unsafe for vehicles, children and the elderly). The rest of the area is H4 and H5. In both considered events, the majority of the main channel itself is categorised as H6 (Unsafe for vehicles and people. All buildings types consider vulnerable to failure), and widespread H3-H5 in the general Edward River flow path extent. In the November 2022 event, the levee is not overtopped, thus no hazard impacts the Davidson Street area. Outside the levee, the Edward River channel is categorised as H6, Brick Kiln Creek is categorised as H5-H6, and the general flow path ranges between H1-H4.

5.3. Hydraulic Categories

Hydraulic categories describe the flood behaviour by categorising areas depending on their function during the flood event, specifically, whether they transmit large quantities of water (floodway), store a significant volume of water (flood storage) or do not play a significant role in either storing or conveying water (flood fringe). As with categories of hazard, hydraulic categories play an important role in informing floodplain risk management in an area. The hydraulic categories determined for the Study Area are shown in Figure 11 and Figure 12.

The percentage of flow conveyed by the designated floodway was measured at different sections of the floodplain. It was found that at the peak of the 1% AEP event, the area designated as floodway conveyed 97% of the flow at the National Bridge (with 3% of the flow passing outside the floodway, through North Deniliquin and to the north-east. Similarly, the floodway at Lawson Syphon conveyed 99% of the flow, and the floodway at Boggy Creek Road took 92%. Overall, the floodway conveyed more than 90% of the flow, and up to 99% at some locations. Once the Davidson Street levee is overtopped and floodwater impacts the area (in the 5% AEP event), the area behind the levee itself is categorised as floodway but does not convey a notable portion of the flow until the 1% AEP event.

The floodway's conveyance of the majority of the flow (in some sections, virtually the entire flow) is indicative of the topography of the floodplain around Deniliquin and the way in which it conveys floodwaters. The area between the established flood runners and the river (which is well approximated by the 5% AEP flood extent) conveys the majority of the flow, even in rare events. This is due to the remaining floodplain being extremely flat and having very few water courses. This conclusion is significant, as it means that any obstructors in this region i.e. levees, buildings etc. will have a notable impact on the flood behaviour and levels in the surrounding floodplain due to the redirection of flow.

6. STAKEHOLDER CONSULTATION

6.1. Community Consultation

The main objective of the community consultation process of this project was to gain feedback, gather information, and understand the behaviour of flooding during the November 2022 event. The consultation programme consisted of:

- 2 community meetings and distribution of a feedback form;
- Release of detailed online survey for further event and general flood impact feedback; and
- Collation and analysis of relevant feedback.

6.1.1. Community Feedback

In April 2023, a community consultation and feedback session was conducted, which allowed for an opportunity to provide an overview of Council's flood plans, current and future mitigation works, and collate useful event based information from impacted residents and business owners. The feedback form was distributed among attendees, with 14 responses returned in total to date. The locations of respondents are shown in Figure 3 (2 of 14 respondents did not state their address). Following this, an online feedback form was made available, however no responses were received.

Of those who responded, 3 (21%) reported to have been impacted by floodwater – 2 of them were outside the Davidson Street area, and the other was impacted by backwater from the gravity sewage system. There were 3 (21%) that reported to be required to sandbag, and 2 (14%) reported to evacuate. Of the 14 respondents, 8 (57%) reported to be happy with the emergency response, to varying extents. Of the remaining, it was commonly mentioned that there was a lack of communication, common misinformation, and frequent scare mongering. Less than half of the respondents considered the flood mapping to be accurate and true. Of those that deemed it inaccurate, it was mentioned that the mapping was hard to follow due to the impacts that the construction of the temporary levee along Davidson Street may have had on flood levels – if it was constructed as intended. Some general comments were also provided, with 4 (29%) of respondents opposing the decision to construct a temporary roadside levee along Davidson Street.

7. FLOOD DAMAGES SUMMARY

A flood damages assessment intends to estimate the monetary tangible costs to a community across a study area. An estimate of the average annual cost of flooding can also be made. This information can then be used to determine the benefits of proposed mitigation strategies, whereby the reduction in damage is considered the benefit of the mitigation option. When compared to the cost of implementing the measure, this results in the determination of a benefit cost ratio, with anything over one considered economically viable, or delivering value for money.

A summary of the flood damage assessment completed during the 2017 Floodplain Risk Management Study and Plan (Reference 4) has been included below. This includes a description of each of the damage categories, and a breakdown of the total estimated damages occurring for each event. NOTE: all dollar values are provided as of 2017.

Damages can be defined either as tangible or intangible. Tangible damages are those for which a monetary value can be easily assigned, while intangible damages are those to which a monetary value cannot be easily attributed. Tangible flood damages can be comprised of two categories: direct and indirect damages. Direct damages are caused by floodwaters wetting goods and possessions thereby damaging them and resulting in either costs to replace or repair or in a reduction to their value. Direct damages are further classified as either internal (damage to the contents of a building including carpets, furniture), structural (referring to the structural fabric of a building such as foundations, walls, floors, windows) or external (damage to all items outside the building such as cars, garages). Indirect damages are the additional financial losses caused by the flood, for example the cost of temporary accommodation, loss of wages by employees etc.

In order to quantify the damages caused by inundation for existing development a floor level database of 132 properties was compiled in September 2015. For remaining properties, estimates were made based on a combination of LiDAR data, visual inspection and comparison to nearby surveyed properties. For properties inside the south Deniliquin levee, a standard height above ground was assumed.

As North and South Deniliquin are protected by two formal levee systems, these need to be considered when calculating damages. In accordance with NSW Government Guidelines, a properly constructed and maintained levee is considered to only offer protection against floods up to the magnitude of the design flood. For events larger than the design flood, the levee may be deemed to have failed, and therefore inundation of the protected area should be assumed. It should be noted that if failure were not to occur, the economic cost of flooding is likely to be much lower, however the purpose of this approach is to provide a conservative estimation of possible damages.

The failure of the two levees was modelled by lowering 100 m segments at both the upstream and downstream ends of each of the North Levee and South Levee to a height halfway between the mean 1% AEP flood level and the existing natural surface behind the levee. Despite having been designed for a 1% AEP event, the insufficient freeboard and low spots mean the actual design level of the North Levee is below a 2% AEP event.

It has therefore been assumed to breach in the 2% AEP event. The South Levee was designed for a 1% AEP event, however the Flood Study (Reference 3) has shown the levee freeboard to be insufficient in some locations (< 0.5 m), and therefore has been assumed to be breached in the 1% AEP event. In smaller events both levees are assumed to be intact. Table 7 provides a summary of the combined tangible damages which were estimated using this methodology, including the expected average annual damages. It should be noted that this analysis was completed based on the study area outlined in the Floodplain Risk Management Study and Plan (Reference 4), and not the same as the study area used for the assessment in Section 8.3.

Table 7: Estimated Combined (Residential and Commercial/Industrial) Flood Damages for Deniliquin Study Area (Reference 4)

Event	No. Properties Affected[1]	No. Flooded Above Floor Level[2]	Total Damages for Event	% Contribution to AAD	Ave. Damage Per Flood Affected Property
20% AEP[3]	0	0	$ -	0	$ -
10% AEP	17	4	$ 694,000	1	$ 41,000
5% AEP	91	51	$ 4,372,000	4	$ 48,000
2% AEP	368	250	$ 23,517,000	14	$ 64,000
1% AEP	1993	1336	$ 100,958,000	20	$ 51,000
0.5% AEP	2505	1870	$ 138,172,000	20	$ 55,000
PMF	3739	3684	$ 359,597,000	41	$ 96,000
Average Annual Damages (AAD)			**$ 3,044,300**	**100**	**$ 810**

[1]'No. Properties Affected': there is flooding above ground level within the property boundary (i.e. the lot)
[2]'No. Flooded above floor level': there is flooding above the surveyed or estimated floor level of the house.
[3] There is inundation on the south part of a number of lots along the north bank of the Edward River, however the affectation is sufficiently far from the house or garages/sheds to warrant exclusion from the damages calculation.

The AAD estimate of $3.04 M is higher than expected for a large town situated on a major watercourse. This is due to the conservative approach to levee failure used to calculate damages. As described above, the NSW Government recommends modelling a levee-breach scenario in events greater than the levee's design capacity. Therefore, the number of properties affected is much greater than would be expected under a no-failure scenario. It is important to note that while the damages figure is highly conservative, it still shows the relative effects of different sized events and provides a basis for comparing proposed mitigation options and calculating B/C ratios.

Relevant to this study is the portion of damages which occur within the Davidson Street and North Deniliquin Study Area. Table 8 summarises the distribution of damages which occur across each defined region of the Deniliquin floodplain. It is evident that the Davidson Street area contributes a disproportionate amount to the total average annual damages, considering the population density of the area. Further, it can be concluded that Davidson Street is a high flood risk area, as 33 properties (32 of them are flooded to a depth >100 mm above floor level) are affected in the 5% AEP event, far higher than any other region of Deniliquin.

Table 8 Distribution of Damages (Combined Residential and Commercial/Industrial)

Location	% Contribution to AAD	Average Annual Damages (AAD)	No. Properties in 5% AEP	No. Properties in 1% AEP
South Deniliquin	54%	$ 1,652,824	0	968
North Deniliquin	13%	$ 394,667	0	155
Davidson Street	19%	$ 564,971	33	93
Other	14%	$ 429,701	7	149
Total	**100%**	**$ 3,042,162**	**40**	**1365**

An analysis of the intangible flood damages was also conducted in the FRMS&P (Reference 4). It considered the qualitative impact that had been identified in post flood surveys and concluded that the stress caused by flood events was due to occurrences such as the loss of personal items, financial strains and injury can lead to a severe negative impact on the quality of life of victims. There were several Response Modification (RM) measures considered which were directed at improving community awareness and reducing the stress caused by misunderstanding of the flood behaviour in Deniliquin (Reference 4).

8. MITIGATION OPTIONS

8.1. Background

Floodplain risk management measures are actions which can be undertaken in both the short and long term which assist in managing the risk of flooding. Measures range from flood modification measures, such as levees and retarding basins, to response measures, such as emergency response planning and property modification measures, such as house raising or development controls. The measures considered below were developed by collation of community feedback, experience in similar studies, and suggestions made by Council. For this study, a focus has been placed on flood modification measures, such as levee raising and modifications, and road raising within the Davidson Street area. The section following describes the management measures that have been assessed in detail for the Study Area and includes a damage assessment for each option. The damage assessment assumes a design life of 50 years with a 7% discount factor for all options.

8.2. Option Assessment

The following section describes each considered option, and its impact on the flood behaviour in the Davidson Street and North Deniliquin area.

8.2.1. FM01 – Raising of levee on Jones Avenue

Option Description

Option FM01 describes the raising of a section of levee along Jones Avenue, which has been removed due to the construction of a residential tennis court at 318 Jones Avenue. Current condition levee crests either side of this site are approximately 92.4mAHD, while the lowered section at the tennis court is approximately 91.7 mAHD. As part of this option, the removed part of the levee has been raised to remain consistent with the remaining levee at this section. As noted in the FRMS&P (Reference 4), the condition of the levee in general is expected to be poor. A study conducted in 1984 (Reference 6) assessed the effect of the levee on the area, and it was concluded that it would be beneficial to remove the levee altogether, in order to avoid blocking the main floodplain flowpath, and to reduce the exaggeration of sense of protection that the levee provides to the community. During the 2022 event, significant resources were allocated, both human and material, to sandbagging this lowered section. Currently, this lowered section of the levee along Jones Avenue is shown to be the first point of overtopping of the levee, overtopping some 12 hours prior to any other section in the 1% AEP event (assuming no sandbagging has been undertaken).

Modelled Impacts

Option FM01 only achieves minimal reductions on flood levels between 0.05 to 0.01m within the Davidson Street area in the 1% AEP event (Figure 14). However, in more frequent events such as the 5% AEP event (Figure 13), the levee is prevented from overtopping, and inundation prevented within the Davidson Street levee. The levee crest was not exceeded by the water level in the November 2022 event (Figure 15), thus the external impacts for an event of this severity are inconsequential. Outside of the Davidson area, there are no adverse impacts on flood levels for most events.

There is a small area in North Deniliquin where flood level increase by up to 0.05m in the 2% AEP event. No adverse impacts are observed in the 1% AEP event as the wider North Deniliquin floodplain is activated.

The increased levee crest level along Jones Avenue, results in a change in timeline as of when, and where the levee overtops. Current conditions (without sandbagging) cause the levee to first overtop along Jones Avenue. Modelled impacts of the raised crest level show the levee in the 1% and 2% AEP events now overtopping first at the Riverside Caravan Park at the western end of Davidson Street, followed by the section at the Davidson Street and Herriott Street intersection. Despite this, inundation behind the levee is still delayed by between 12-18 hours in the modelled design 1% AEP event (and similar for events smaller than this where the levee is overtopped), with Davidson Street becoming passable for a longer period of time.

Damages

This option has no impact on damages in events more frequent than the 5% AEP. In the 5% AEP, this option has significant benefits where it is expected that 40 properties are no longer flooded above floor level and 54 are no longer affected. This benefit is concentrated in the Davidson Street area, where all 33 flooded properties are no longer flooded in the 5% AEP. In larger events, there are minimal changes to the flooded properties. In the 1% AEP, predicted flood levels decreases by approximately 0.02m within the Davidson Street area but this has little impact on damages as the properties are still impacted. A summary of the combined damages are shown in Table 9 for FM01.

This option would result in a reduction in Annual Average Damages in the order of $120,000 for Deniliquin. The estimated cost of this options is $500,000. Therefore, this option has a B/C ratio of 3.52.

Table 9: Estimated Combined Damages (Residential and Commercial) for FM01 in the Deniliquin Study Area

Event	No. Properties Affected	No. Flooded Above Floor Level	Total Damages for Event	% Contribution to AAD	Ave. Damage Per Flood Affected Property
20% AEP	0	0	$ -	0	$ -
10% AEP	17	4	$ 693,000	1	$ 41,000
5% AEP	37	11	$ 1,627,000	2	$ 44,000
2% AEP	369	254	$ 23,467,000	13	$ 64,000
1% AEP	2013	1349	$ 101,396,000	21	$ 50,000
0.5% AEP	2518	1877	$ 138,615,000	21	$ 55,000
PMF	3734	3675	$ 354,255,000	42	$ 95,000
Average Annual Damages (AAD)			**$ 2,925,578**	**100**	**$ 2,300**

8.2.2. FM02 – Raising of levee on Jones Avenue and improved flow path.

Option Description

Option FM02 is a variation of FM01, which includes the raised section of levee along Jones Avenue. In addition to this, a section of the levee east of Jones Avenue has been lowered to allow ingress, and escape of water from a lower point within the levee.There is a significant lowering of the topography to the rear of properties on the southern side of Davidson Street, where depths reach over 1 m during rare events, first due to water encroaching from Jones Avenue via the existing lowered section of levee. Ground levels in this area range between 89.2 - 90.5mAHD, compared to surrounding levels of >91.5mAHD. The intent of this option is to allow this region to become inundated during rare events and improve the flow path of escaping floodwater, thus reducing impacts on property, primarily by reducing the duration of inundation.

Modelled Impacts

This option is shown to behave similarly to FM01, with only minimal reduction in flood levels in rare events. Flooding of the Davidson Street area behind the levee is also eliminated in the 5% AEP event (Figure 16), as with FM01. Analysis of modelled flood levels showed FM02 to be slightly less effective (<5 mm difference) when compared to FM01. In the 1% AEP event, flood levels are reduced in the southern part of the Davidson Street area, but this option has no impact in the northern section of the Davidson Street area. In rarer events, this FM01 delays inundation in rare events by up to 12 hours. The mapping for the 5% AEP, 1% AEP and November 2022 events are presented in Figure 16, Figure 17 and Figure 18 respectively.

Damages

The quantitative impact on properties is very similar to that in FM01, reducing the AAD by $123,000. This can be attributed to the reduction in flooded properties in the Davidson Street area in the 5% AEP event. A summary of the combined damages for FM02 is shown in Table 10.

The estimated cost of this option is $1,500,000, with a B/C ratio of 1.22.

Table 10: Summary of combined damages (Residential and Commercial) for FM02

Event	No. Properties Affected	No. Flooded Above Floor Level	Total Damages for Event	% Contribution to AAD	Ave. Damage Per Flood Affected Property
20% AEP	0	0	$ -	0	$ -
10% AEP	17	4	$ 693,000	1	$ 41,000
5% AEP	37	11	$ 1,627,000	2	$ 44,000
2% AEP	369	254	$ 23,467,000	13	$ 64,000
1% AEP	2004	1343	$ 101,039,000	21	$ 50,000
0.5% AEP	2507	1872	$ 138,287,000	20	$ 55,000
PMF	3734	3675	$ 354,228,000	42	$ 95,000
Average Annual Damages (AAD)			**$ 2,921,193**	**100**	**$ 2,300**

8.2.3. FM03 – Raising of Davidson Street by 500 mm.

Option Description

Option FM03 involves the raising of Davidson Street itself by 0.5 m along the length, between National Bridge and Brick Kiln Creek. As part of the scope of this project, the ability to keep Davidson Street open, or prolong the accessibility of Davidson Street during flood events has been a focus. Currently, the lowest point in the road is located near the intersection with Evans Street, where ground elevations are approximately 91.6 mAHD, and is inundated between a 10% and 5% AEP event.

Modelled Impacts

This option achieves a decrease to flood levels north of Davidson Street in events larger than the 5% AEP (the levee is not overtopped in events more frequent than the 5% AEP), with adverse impacts to flood levels upstream, and south of Davidson Street (as Davidson Street itself acts as a levee). In the 5% AEP event (Figure 19), the area upstream of Davidson Street is no longer flooded whereas significant increases in flooding between 0.1 – 0.2 m are experienced south of Davidson Street. The increases south of Davidson Street results in a high number of properties experiencing more severe flooding when the levee overtops; but it should be noted that a similar number of properties north of the street are benefited. Outside of the Davidson Street levee area, there are no adverse impacts from FM03 in the 5% AEP event.

In the 1% AEP event (Figure 20), reductions in levels north of the Davidson Street of 0.05 - 0.1 m are observed. South of the Davidson Street increases of 0.05 to 0.2m area observed. The impacts in the 1% AEP extends to the wider floodplain, increasing by 0.01 to 0.05 m south of the Davidson Street levee and in North Deniliquin. Minor decreases between 0.01 to 0.05 m north of the levee.

Damages

The number of properties affected in the 5% AEP event is reduced by 50 properties, while the number of properties flooded above floor level decreases by 36. However, in larger events such as the 1% and 0.5% AEP event there are overall increases in the number of properties affected. Overall, FM03 decreases the AAD by $49,950. The cost of this option is very high, estimated to be in the order of $7,500,000. A B/C ratio of 0.1 has been estimated for this option. A summary of the combined damages for this option are shown in Table 11.

Table 11: Summary of Combined Damages (Residential and Commercial) for FM03

Event	No. Properties Affected	No. Flooded Above Floor Level	Total Damages for Event	% Contribution to AAD	Ave. Damage Per Flood Affected Property
20% AEP	0	0	$ -	0	$ -
10% AEP	17	4	$ 693,000	1	$ 41,000
5% AEP	41	15	$ 2,127,000	2	$ 52,000
2% AEP	371	254	$ 23,522,000	13	$ 63,000
1% AEP	2062	1399	$ 105,163,000	21	$ 51,000
0.5% AEP	2558	1927	$ 142,318,000	21	$ 56,000
PMF	3733	3673	$ 354,777,000	41	$ 95,000
Average Annual Damages (AAD)			**$ 2,994,750**	**100**	**$ 2,300**

8.2.4. FM04 – Improved Davidson Street flow path

Option Description

This option consists of the removal of a 50 m section of the Davidson Street levee between Morris Street and Fitznead Street to allow water to escape the area during rare flood events. A study conducted in 1984 (Reference 6) deemed the levee to be in poor condition, inadequate for repairs and upgrades, which may result in unexpected catastrophic failure. However, this option investigates the removal of a northern section of the levee to improve the flow path in the Davidson Street area. In rare flood events, water will overtop the levee initially from the southern side, before being trapped from continuing northward along the natural flow path. The option would involve the removal of approximately 1500 m^3 of earth. The FRMS&P completed in 2017 (Reference 4), investigated a similar option, and stated that an option such as this would assist in reducing the false sense of security that the Davidson Street levee affords the residents of the area in addition to improving flood behaviour.

Modelled Impacts

This option reduces flood levels minimally in the Davidson Street area in events, at and greater than the 2% AEP event. In the 1% AEP (Figure 23) event, flood levels are reduced by 0.01 – 0.05 m, with no adverse impacts outside the levee. In the 2% AEP event, flood levels are reduced more consistently by around 0.03 m behind the levee, and by up to 0.05 m in North Deniliquin; with no adverse impacts outside the levee. Despite these reductions in levels for rare events, the region is impacted by flooding more frequently, and severely during more frequent events. In the 5% AEP (Figure 22) event, increases in levels of up to 0.5 m occur north of Davidson Street, while increases by up to 0.2 m occur south of the street. These impacts, in some cases, are relevant to properties in the area. If this option had been implemented prior to the November 2022 event (where the levee did not overtop) (Figure 24), modelling shows large areas of new inundation north of Davidson Street.

This new region of inundation would impact properties on the north side of Davidson Street – approximately 30 properties newly flooded in the 5% AEP and November 2022 events. More properties are more severely impacted in more frequent events, while approximately 100 properties are less severely impacted in the 2% AEP event. Therefore, in summary, FM04 has a minor benefit in reducing flood levels during rare events, but results in the study area experiencing flooding much more frequently, and more severely during frequent events. The location of proposed works are shown in the option figures.

Damages

This option results in an increase in AAD by approximately $141,400 compared with the existing case. This is mainly due to the increase in the number of properties flooding in the frequent events. In the 10% AEP event, 10 more properties are affected and an additional 7 are flooded above floor level compared with the existing case. In the 5% AEP event, 31 and 34 properties were newly affected and flooded above floor level respectively. A summary of the combined damages are shown in Table 12.

The cost of option is estimated to be around $1,100,000, which would result in a B/C ratio of -2.1. This is due to the increase in AAD.

Table 12: Summary of Combined Damages (Residential and Commercial) for FM04

Event	No. Properties Affected	No. Flooded Above Floor Level	Total Damages for Event	% Contribution to AAD	Ave. Damage Per Flood Affected Property
20% AEP	0	0	$ -	0	$ -
10% AEP	27	11	$ 1,186,000	2	$ 44,000
5% AEP	122	85	$ 7,491,000	7	$ 61,000
2% AEP	368	250	$ 23,248,000	14	$ 63,000
1% AEP	1992	1336	$ 100,861,000	19	$ 51,000
0.5% AEP	2504	1871	$ 138,104,000	19	$ 55,000
PMF	3734	3675	$ 354,221,000	39	$ 95,000
Average Annual Damages (AAD)			**$ 3,186,080**	**100**	**$ 2,400**

8.2.5. FM05 – Improved Davidson Street flow path (alternate)

Option Description

Similar to FM04, this option involves a lowering of a northern section of the levee to improve the flowpath in the area. A 120 m section of the levee was removed (approximately 4000 m³) at the northern end of Morris Street was modelled. Compared to FM04, the location of the works in FM05 are at a lower point in the natural topography, and theoretically a more suitable position for the works. During community feedback sessions and meetings with Council, it was noted that a lot of pressure was being placed on the northern section of the levee during flood events. Removal of this section of levee will improve the path of water to escape the area when the southern portion of the levee is overtopped, and also reduce the exaggerated sense of security which the levee affords the Davidson Street area. The FRMS&P completed in 2017 (Reference 4), investigated a similar option and it was deemed to be suitable for further assessment.

Modelled Impacts

Option FM05 is more effective in reducing flood levels in the Davidson Street area in rare events when compared to FM04. In the 1% AEP (Figure 26) event, flood levels are reduced by 0.02 – 0.05 m, with no adverse impacts outside the levee. In the 2% AEP event, flood levels are reduced more consistently by around 0.07 m behind the levee, and by up to 0.14 m in North Deniliquin; with no adverse impacts outside the levee. Due to this increased reduction in flood levels compared to FM04 in the 1% AEP event, 100 properties experience less severe flooding in the 1% AEP event, as opposed to none under FM04 conditions. Modelling of more frequent events (<5% AEP) however shows an increase in peak flood levels, impacted more frequently, and more severely. In the 5% AEP (Figure 25) event, increases in levels of up to 0.4 m occur north of Davidson Street, with no notable adverse impacts south of the street. In events such as that in November 2022 (slightly less than a 5% AEP event) where the levee does not overtop under current conditions (Figure 7), modelling shows widespread regions of new inundation north of Davidson Street (Figure 18) where water ingresses through the removed section of levee. It can be concluded that FM05 is more effective in reducing peak flood levels compared to FM04 during rare flooding events and has slightly less of an adverse impact on flood levels in the area during more frequent events.

Damages

The estimated AAD for FM05 is approximately $62,000 greater than the existing case. Similarly to FM04, this due to the increase in newly flooded properties in more frequent events in the Davidson Street area. Despite reducing the flood level through the Davidson Street area in the rarer events, the changes to the number of properties affected/flooded does not significantly change. A summary of the damages associated with FM05 are shown in Table 13.

The cost of this option is approximately $1,200,000 which would result in a B/C ratio of -0.76. This is due to the increase in AAD.

Table 13: Summary of Combined Damages (Residential and Commercial) for FM05

Event	No. Properties Affected	No. Flooded Above Floor Level	Total Damages for Event	% Contribution to AAD	Ave. Damage Per Flood Affected Property
20% AEP	0	0	$ -	0	$ -
10% AEP	25	9	$ 1,124,000	2	$ 45,000
5% AEP	108	70	$ 5,928,000	6	$ 55,000
2% AEP	366	249	$ 22,922,000	14	$ 63,000
1% AEP	1983	1331	$ 100,381,000	20	$ 51,000
0.5% AEP	2497	1867	$ 137,721,000	19	$ 55,000
PMF	3734	3674	$ 354,142,000	40	$ 95,000
Average Annual Damages (AAD)			**$ 3,106,678**	**100**	**$ 2,300**

8.2.6. FM06 – Raising of Davidson Street levee to 1% AEP level

Option Description

Option FM06 involves the raising of the Davidson Street levee to the 1% AEP level, for the entire length of the levee (approximately 93mAHD). Analysis of current base design flood events shows the Davidson Street area is inundated (levee is overtopped) in approximately the 5% AEP event. Previous studies such as that conducted in 1984 (Reference 6), concluded that the levee should be removed in order to improve the natural flowpath within the floodplain. However, updated modelling and increased community pressure has warranted the re-analysis of this option due to likely improved representation of the flow behaviour within the floodplain. This option was considered in the FRMS&P (Reference 4) and has been remodelled to determine its impacts during the November 2022 event.

Modelled Impacts

Option FM06 eliminates flooding of the area for all events up to and including the 1% AEP event (including eliminating flooding for up to 100 properties in the 1% and 2% AEP events), however modelling shows that it has significant impacts on flood levels upstream and in the area surrounding the levee itself – up to 220 properties experience increases in flooding by 0.02 m or more, while 23 properties are newly flooded in the 1% AEP event. Modelling of the November 2022 (Figure 30) and 5% AEP (Figure 28) event show no adverse impacts to flood levels outside the Davidson Street levee. Although, in rarer events such as the 2% events increases of 0.1 m upstream of the levee, and up to 0.2 m in North Deniliquin are observed.

Similarly in the 1% AEP event (Figure 29), increases of up to 0.05 m are observed upstream of the levee, and up to 0.1 m in North Deniliquin and effectively reduces the level of protection afforded by the North and South Deniliquin levees.

Damages

FM06 would result in a reduction in AAD in the order of $320,000 when compared with the existing case. There is a significant reduction in the number of properties affected / flooded in events below the 1%, primarily due to newly protected Davidson Street area. However, this measure increases the overall number of flooded properties in events greater than 1% AEP.

The estimated cost of this option is estimated to be $7,000,000, resulting in a B/C ratio of 0.68. Additional works would be required to offset the third party impacts which would further reduce the economic viability of the option.

Table 14: Summary of Combined Damages (Residential and Commercial) for FM06

Event	No. Properties Affected	No. Flooded Above Floor Level	Total Damages for Event	% Contribution to AAD	Ave. Damage Per Flood Affected Property
20% AEP	0	0	$ -	0	$ -
10% AEP	17	4	$ 693,000	1	$ 41,000
5% AEP	57	29	$ 3,219,000	4	$ 56,000
2% AEP	263	147	$ 12,043,000	8	$ 46,000
1% AEP	2053	1370	$ 98,720,000	20	$ 48,000
0.5% AEP	2548	1947	$ 139,017,000	22	$ 55,000
PMF	3631	3574	$ 345,826,000	45	$ 95,000
Average Annual Damages (AAD)			**$ 2,721,645**	**100**	**$ 2,100**

8.3. Quantitative Option Impact Summary

The following section summarises the impacts of the options in terms of number of properties affected by each option, for each modelled event. Figure 4 outlines the properties which were included as part of this option impact assessment. There were 700 properties within the Davidson Street and North Deniliquin subject area for this assessment, however, only 651 of these had been allocated a floor level as part of the FRMS&P. Those that did not have a floor level, were removed from the database for the purposes of this assessment.

8.3.1. Property Impact

Table 15 outlines the number of properties, which either benefit, or are adversely impacted as a result of each modelled option compared to the current study area conditions. All values are relative to above floor level flooding.

Table 15: Property Impact Summary

	Newly Flooded				No Longer Flooded				If flooded, increase of more than 0.02 m?				If flooded, decrease of more than 0.02?			
OPTION/EVENT	**1%**	**2%**	**5%**	**Nov2022**	**1%**	**2%**	**5%**	**Nov2022**	**1%**	**2%**	**5%**	**Nov2022**	**1%**	**2%**	**5%**	**Nov2022**
FM01	1	1	0	0	1	0	40	0	0	7	0	0	39	107	0	0
FM02	0	0	0	0	1	0	40	0	0	6	0	0	11	106	0	0
FM03	8	3	2	0	0	1	24	0	93	35	18	0	82	80	0	0
FM04	0	0	34	35	1	3	0	0	0	0	58	35	0	104	0	0
FM05	0	0	27	32	1	5	0	0	0	0	51	32	100	107	0	0
FM06	23	3	0	0	112	110	40	0	225	9	0	0	2	0	0	0

8.3.2. Discussion

Analysis of Table 15 shows that there are greatly varying impacts on property between options and events. For most options, it is evident that the greatest positive impact on flood levels is seen in events more frequent than the 2% AEP, as events greater than this activate the entire floodplain. Option FM01 and FM02 perform very well in the 5% AEP event, as the levee is no longer overtopped. 40 properties are no longer affected above floor level in the 5% AEP event, and more than 100 properties experience a reduction in flood level for both options. However, FM01 and FM02 are ineffective in larger events once the levee is broadly overtopped, although 39 properties and 11 properties experience a reduction in flood levels in the 1% AEP event under FM01 and FM02 option conditions, respectively. These options also have relatively minimal adverse impacts on flood levels upstream, and the number of properties that are more severely impacted.

Option FM03, which involves the raising of Davidson Street itself by 0.5 m, is effective in greatly reducing the impact on properties north of Davidson Street but causes notable increases to levels south of the street. In the 5% event, 24 properties are no longer flooded, and 18 properties experienced an increase in flood levels, predominantly on the southern side of Davidson Street. In rare events, while up to 80 properties experience a decrease in flooding severity, an almost equal number experience and increase in levels on the upstream side of Davidson Street.

FM04 and FM05 are both effective in rare events in reducing the time that properties are inundated and reducing the peak depth of flooding in the Davidson Street area. – between 80 and 100 properties in the 2% AEP event. Only FM05 is effective in reducing the peak flood depth experience by properties in the 1% AEP event – up to 100 positively impacted. During frequent events, both options caused adverse impacts, with properties impacted earlier, more severely, and more frequently. Both options were shown to result in up to 30 properties being newly flooded in the 5% AEP and November 2022 events, with more experiencing an increase in peak flood level for events of this severity.

Option FM06 causes the greatest impacts, both positive and negative to the Davidson Street and North Deniliquin area. In the 1% AEP event, 23 properties are newly flooded and 225 properties will experience an increase in flood levels (all in the North Deniliquin area). Minimal adverse impacts are caused in more frequent events. On the other hand, flooding is completely eliminated in all events in the Davidson Street area, with 112, 110 and 40 properties no longer flooded in the 1%, 2% and 5% AEP events respectively.

8.4. Multi-criteria Analysis

The Floodplain Development Manual (Reference 1) and the Flood Risk Management Manual (Reference 2) recommends the use of multi-criteria assessment matrices (MCMA) when assessing flood risk mitigation measures. A MCMA provides a method by which options can be assessed against a range of criteria and offers a greater breadth of assessment than is available by considering only the reduction in flood risk or economic damages. Such additional criteria may include social, political and environmental considerations and intangible flood impacts, that cannot be quantified or included in a cost-benefit analysis. It should be noted that the assessment of the suitability of floodplain mitigation options is a complex matter, and an MCMA will not give a definitive ‘right’ answer. Rather, it provides a tool to debate the relative merits of each option.

8.4.1. Scoring System

A scoring system has been devised to allow stakeholders to assess the various options across a consistent basis to allow for direct comparison. The scoring system is divided into four key criteria: Flood Behaviour, Economic, Social and Environmental. Scores for each criterion are to be assigned to each option then summed to determine the overall score. Options with higher scores indicate benefits across a range of criteria and should be prioritised over those with lower positive scores, which may be more neutral or have a combination of pros and cons. Conversely, options with the lowest negative scores indicate the option would cause adverse outcomes in several criteria, outweighing the positives and should not be considered further. The scoring system is provided in Table 16 and the outcomes of the assessment shown in Table 17.

There are various assumptions made in this assessment which affect the way the results could be interpreted.

- "Net" number of properties was selected as criteria due to the both adverse, and positive impact that each option has, due to the nature of the natural, and modified floodplain.

- "Community acceptance" result for each option is draft value based on community feedback and requests during the project inception community meeting and returned survey forms.

- Vehicle and road access criteria is based on both peak flood levels and duration of inundation of the road itself.

Discussion of the results is provided in 8.4.2.

8.4.2. Results

As shown in the matrix (see Table 17), each option has a range of positive and negative effects, making direct comparisons between options difficult. Notable points related to the interpretation of Table 17 are:

- Some options have a great positive impact in rare events, while having adverse impacts in frequent events (FM04 and FM05), which make conclusions regarding impact on flood behaviour difficult.
- Due to the nature of the floodplain, most options that have great positive impacts on the Davidson Street area for example, but result in adverse impact upstream and in North Deniliquin.
- All options have either neutral or adverse impacts on the environment, due to either newly flooded areas of great modifications to the natural floodplain and floodway.
- Most options have a positive impact on road and vehicular access (and in turn, positive impact on SES and risk to life) as Davidson Street is allowed to either stay open for longer periods, or open completely during events that would otherwise cut off the road.
- Generally, across all options, adverse political issues will arise as a result of the implementation of any of these options. In particular, options which involve work on the Davidson Street levee (FM01, FM02, FM04, FM05 and FM06) directly conflict with the Council current adopted status of the existing Davidson Street levee. If these options are to be taken forward, then Council would need to altered the status of the entire levee, and likely acquire easements over the footprint.
- FM03 and FM06 are extremely large and technically intricate projects to implement, thus financial and technical feasibility criteria score low.
- Community acceptance for considered options were generally low, as most options cause adverse impacts on flood levels elsewhere in the floodplain, particularly upstream.

The assessment matrix is given in Table 16 with each of the assessed management options scored against the range of criteria. There are various assumptions made in this assessment which affect the way the results could be interpreted.

- “Net” number of properties was selected as criteria due to the both adverse, and positive impact that each option has, due to the nature of the natural, and modified floodplain.

- “Community acceptance” result for each option is draft value based on community feedback and requests during the project inception community meeting and returned survey forms.
- Vehicle and road access criteria is based on both peak flood levels and duration of inundation of the road itself.

Table 16: Multi-criteria Analysis Scoring Matrix

	Criteria	Metric	Score -3	-2	-1	0	1	2	3
Economic	Economic Merits	*Comparison of the economic benefits against the capital and ongoing costs*	BC < 0.1	BC: 0.1- 0.5	BC: 0.5-0.9	BC = 1 (Or NA)	BC: 1.0 - 1.4	BC: 1.4 - 1.7	BC >1.7
	Implementation Complexity	*Potential design, implementation and operational challenges and constraints. Risk can increase with implementation timeframe*	Major constraints and uncertainties which may render the option unfeasible	Constraints or uncertainties which may significantly increase costs or timeframes	Constraints or uncertainties which may increase costs or timeframes moderately	NA	Constraints that can be overcome with moderate investment of time and resources	Constraints that can be overcome easily	No constraints or uncertainties
	Staging of Works	*Ability to stage proposed works*			Works cannot be staged	NA	Some minor components of the works may be staged	Some major components of the works may be staged	
Social	Impact on Emergency Services	*Change in demand on emergency services (SES, Police, Ambulance, Fire, RFS etc).*	Major disbenefit	Moderate Disbenefit	Minor Disbenefit	Neutral	Minor Benefit	Moderate Benefit	Major Benefit
	Road Access	*Flood depths and duration changes for key transport routes*	Key access roads become flooded that were previously flood free	Significant increase in main road flooding (depth and/or duration)	Moderate increase in local or main road flooding (depth and/or duration)	No Change	Moderate decrease in local or main road flooding (depth and/or duration)	Significant decrease in main road flooding (depth and/or duration)	Local and main roads previously flooded now flood free
	Impact on critical and/or vulnerable facilities	*Disruption to critical facilities*	Inoperational for several days	Inoperational for one day	Inoperational for several hours	No Change	Period of inoperation reduced by 0-4 hours	Period of inoperation reduced by > 4 hours	Prevents disruption of critical facility altogether
	Impact on Properties	*No. of properties flooded over floor. Across all events*	>5 adversely affected	2-5 adversely affected	<2 adversely affected	None	<5 benefitted	5 to 10 benefitted	>10 benefitted
	Impact on flood hazard	*Change in hazard classification*	Significantly increased in highly populated area (Increasing to H5/H6)	Moderately increased in populated area (Increasing by 2 or more categories)	Slightly increased (Increase by 1 category)	No Change	Slightly reduced (Decrease by 1 category)	Moderately reduced in populated area (Decrease by 2 or more categories)	Significantly reduced in highly populated area (Decrease from H5/H6)
	Community Flood Awareness	*Change in community flood awareness, preparedness and response*	Significantly reduced	Moderately reduced	Slightly reduced	No Change	Slightly improved	Moderately improved	Significantly improved
	Social disruption	*Closure of or restricted access to community facilities (including recreation)*	Normal access significantly reduced or facilities disrupted for > 5 days	Normal access routes moderately reduced or facilities disrupted for 2-4 days	No Change to access but facilities disrupted for up to 12 hours	No Change	Reduces duration of access disruption or facility disruption by up to 12 hours	Reduces duration of access disruption or facility disruption by 2-4 days	Prevents disruption of access or facility altogether
	Community and stakeholder support	*Level of agreement (expressed via formal submissions and informal discussions)*	Strong opposition by numerous submissions	Moderate opposition in several submissions	Individual submissions with opposition	Neutral	Individual submissions with support	Moderate support in several submissions	Strong support by numerous submissions
Environmental	Impacts on Flora & Fauna (inc. street trees)	*Impacts or benefits to flora/fauna*	Likely broad-scale vegetation/habitat impacts	Likely isolated vegetation/habitat impacts	Removal of isolated trees, minor landscaping.	Neutral	Planting of isolated trees, minor landscaping.	Likely isolated vegetation/habitat benefits	Likely broad-scale vegetation/habitat benefits
	Heritage Conservation Areas and Heritage Items	*Impacts to heritage items*	Likely impact on State, National or Aboriginal Heritage Item	Likely impact on local heritage item	Likely impact on contributory item within a heritage conservation area	No impact	Reduced impact on contributory item within a heritage conservation area	Reduced impact on local heritage item	Reduced impact on State, National or Aboriginal Heritage item
Other Aspects	Financial Feasibility and Funding Availability	*Capital and ongoing costs and funding sources available*	Significant capital and ongoing costs, or no external funding or assistance available	Moderate capital and ongoing costs, no funding available	High capital and ongoing costs, partial funding available	NA	Moderate capital and ongoing costs, partial funding available; or low capital and ongoing costs, no funding available	Low to moderate capital and ongoing costs, partial funding available	Full external funding and management available
	Compatibility with existing Council plans, policies or projects	*Level of compatibility*	Conflicts directly with objectives of several plans, policies or projects	Conflicts with several objectives or direct conflict with one or few objectives	Minor conflicts with some objectives, with scope to overcome conflict	Not relevant	Minor support for one or few objectives	Some support for several objectives, or achieving one objective	Achieving objectives of several plans, policies or projects

[1]Critical facilities are those properties that, if flooded, would result in severe consequences to public health and safety. These may include fire, ambulance and police stations, hospitals, water and electricity supply, buses/train stations and chemical plants. Vulnerable facilities refer to those properties with vulnerable occupants, such as nursing homes or schools.

[2]Community and stakeholder support scores will be completed following Public Exhibition

Table 17: Multi-criteria Matrix Assessment Results

		Economic			Social								Environmental		Other Aspects			
ID	Option	Economic Merits	Implementation Complexity	Staging of Works	Impact on Emergency Services	Road Access	Impact on critical and/or vulnerable facilities[1]	Impact on Properties	Impact on flood hazard	Community Flood Awareness	Social disruption	Community and Stakeholder Support[2]	Impacts on Flora & Fauna (inc. street trees)	Heritage Conservation Areas and Heritage Items	Financial Feasibility and Funding Availability	Compatibility with existing Council plans, policies or projects	**Total Score**	**Overall Rank**
FM01	Raising of levee on Jones Avenue	3	2	0	2	2	0	3	1	-2	1	1	0	0	-2	-2	9	1
FM02	Raising of levee on Jones Avenue and improved flow path	2	2	0	1	1	0	3	1	1	0	-1	0	0	-2	-2	6	2
FM03	Raising of Davidson Street by 500 mm	-2	-2	-1	3	3	0	1	1	1	1	-3	0	0	-3	2	1	3
FM04	Improved Davidson Street flow path	-3	2	0	0	0	0	-3	-2	1	0	-2	0	0	2	1	-4	5
FM05	Improved Davidson Street flow path (alternate)	-3	1	1	0	0	0	-3	1	1	0	-2	0	0	1	1	-2	4
FM06	Raising of Davidson Street levee to 1% AEP level	-1	-3	-1	3	3	0	3	2	-3	2	-2	-2	0	-3	-2	-4	5

8.5. Option Summary

Table 18 Deniliquin Floodplain Risk Management Plan

Reference	Option	Description	Benefits	Concerns	Responsibility	Funding
FM01	Filling gap in levee on Jones Ave - Tennis Court	Existing conditions have a hole in levee where a residential tennis court has been built. The levee at this section has been raised to be consistent: ~ 92.4mAHD	Prevents flooding in the Davidson Street area up to and including the 5% AEP event. Levee overtopping is more predictable and consistent.	Unlikely acceptance from property owner where lowered section of levee is present.	Council responsible for works	NSW Government funding may be available for feasibility, detailed design, and construction
FM02	Filling gap in levee on Jones Ave - Tennis Court. Lowering of southern section of Davidson Street Levee	Existing conditions have a hole in levee where a residential tennis court has been built. The levee at this section has been raised to be consistent: ~ 92.4mAHD. Gradual lowering of levee between two points, 180m apart. Lowest point = 91.5mAHD	As FM01. Allows the lower and uninhabited area of land behind the southern properties along Davidson Street to be inundated first.	Unlikely acceptance from property owner where lowered section of levee is present. Other properties south of Davidson Street will be impacted more frequently.	Council responsible for works	NSW Government funding may be available for feasibility, detailed design, and construction
FM03	Raising of Davidson Street by 500mm	Raising Davidson Street by 0.5m between bridge at western and eastern end.	Davidson Street likely passable by vehicle up to and including the 2% AEP event. Reductions in depths north of Davidson Street by up to 0.2 m in rare events.	Significant cost and scale of project. Notable increases in flood levels south of Davidson Street (up to 0.2 m in the 1% AEP event).	Council and Transport for NSW	NSW Government funding may be available for feasibility, detailed design, and construction
FM04	Hole in north side of Davidson St Levee	Removal of ~ 50m section of levee between Morris Street and Fitznead Street	Improves the flowpath of water in the Davidson Street area and allows for water to escape at the downstream end of the levee, reducing peak flood levels in rare flooding events.	Properties, particularly north of Davidson Street, are much more severely impacted in smaller events, and impacted more frequently overall. Low community acceptance with impacted owners.	Council responsible for excavation	NSW Government funding may be available for feasibility, detailed design, and construction
FM05	Hole in north side of Davidson St Levee (Alternate)	Removal of ~ 120m section of levee near northern end of Morris Street	As FM04, but slightly superior in its benefits. Slightly lower peak flood levels.	As FM04.	Council responsible for excavation	NSW Government funding may be available for feasibility, detailed design, and construction
FM06	Raised levee to 1% level	Davidson Street levee raised to 1% AEP level	Flooding eliminated in the Davidson Street area for all events up to and including the 1% AEP event.	Over 200 properties experiencing an increase to flood levels, and 23 newly flooded in the 1% AEP event. Significant project cost and scale.	Council responsible for works	NSW Government funding may be available for feasibility, detailed design, and construction

9. REFERENCES

1 NSW Government
Floodplain Development Manual
2005

2. NSW Government
Flood Risk Management Manual: The management of flood liable land
2022

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Report No. DC 10096
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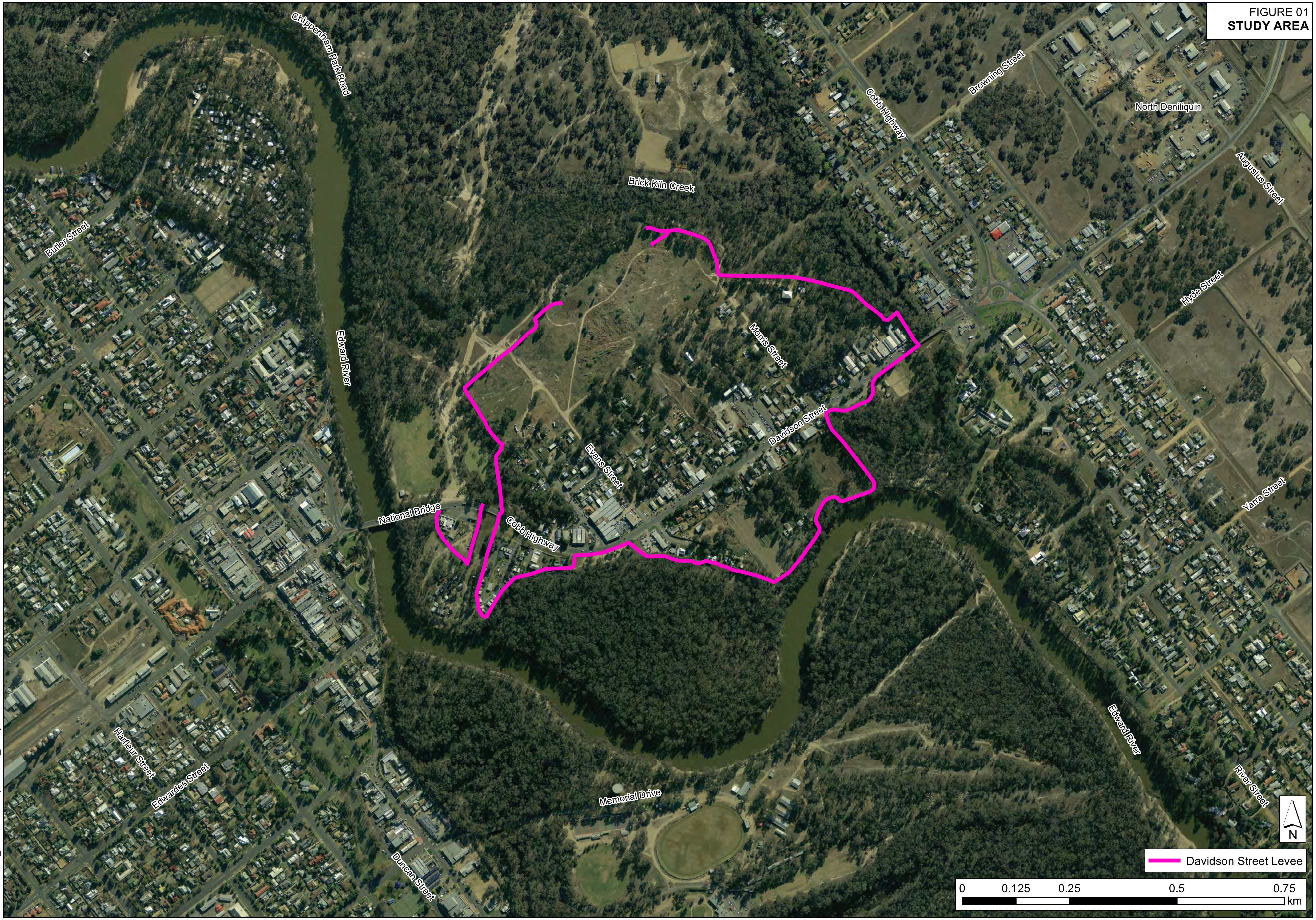
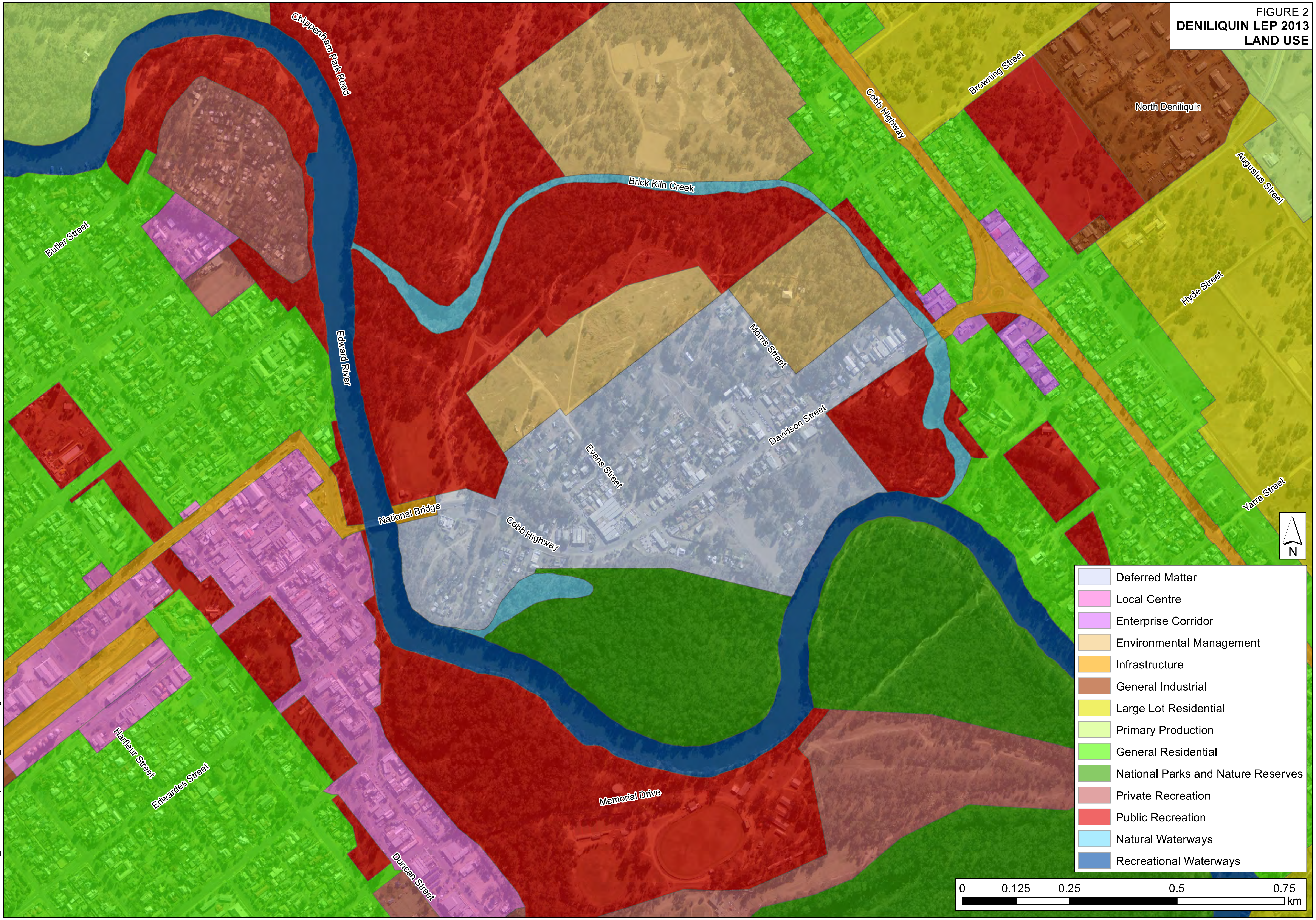
Figures

FIGURE 01
STUDY AREA



J:\Jobs\115027_05\GIS\Arcmaps\FIG01_Study Area.mxd

FIGURE 2
DENILIQUIN LEP 2013
LAND USE

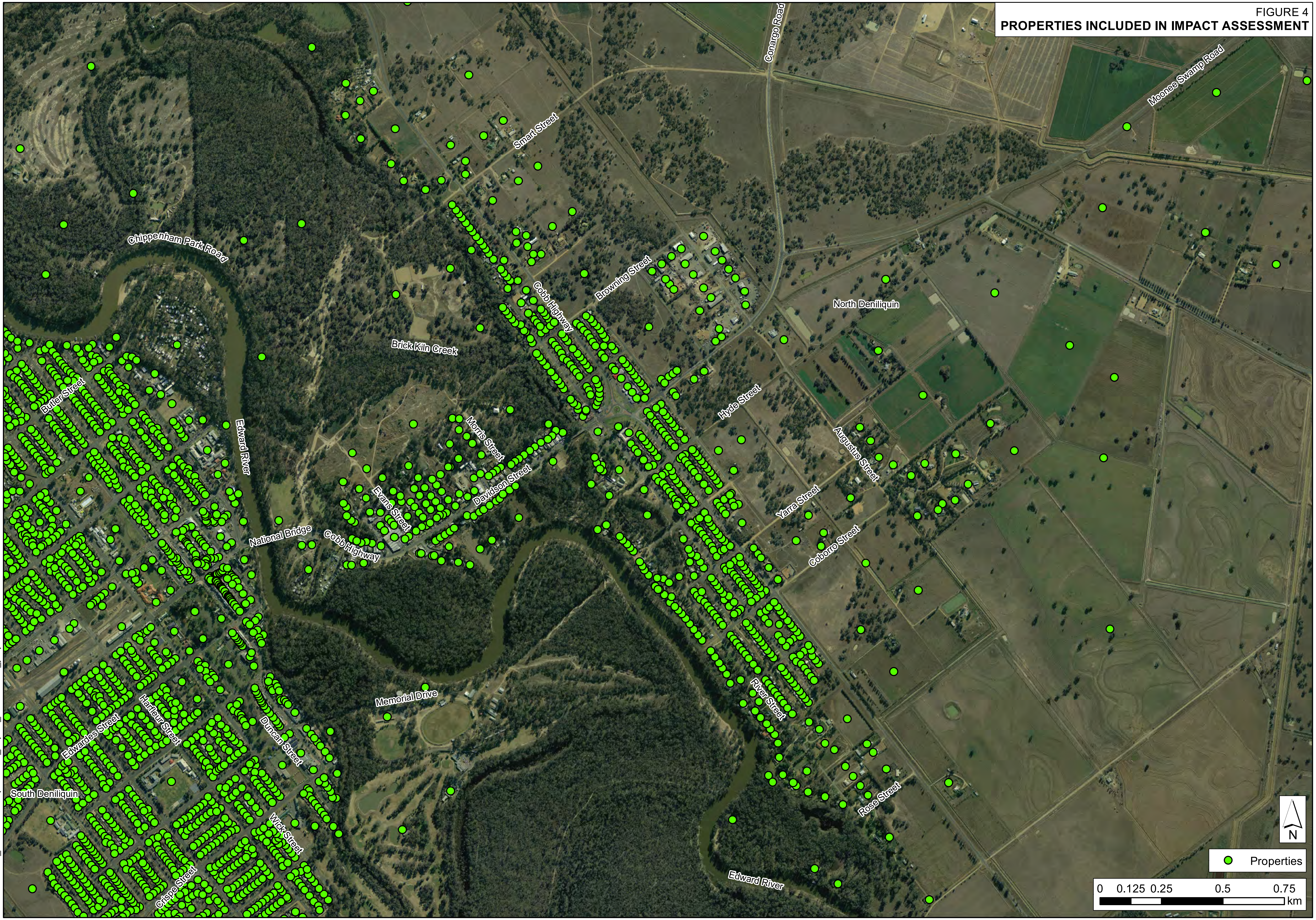


J:\Jobs\115027_05\GIS\Arcmaps\FIG02_LandZoning.mxd

FIGURE 3
LOCATION OF FEEDBACK RESPONDENTS

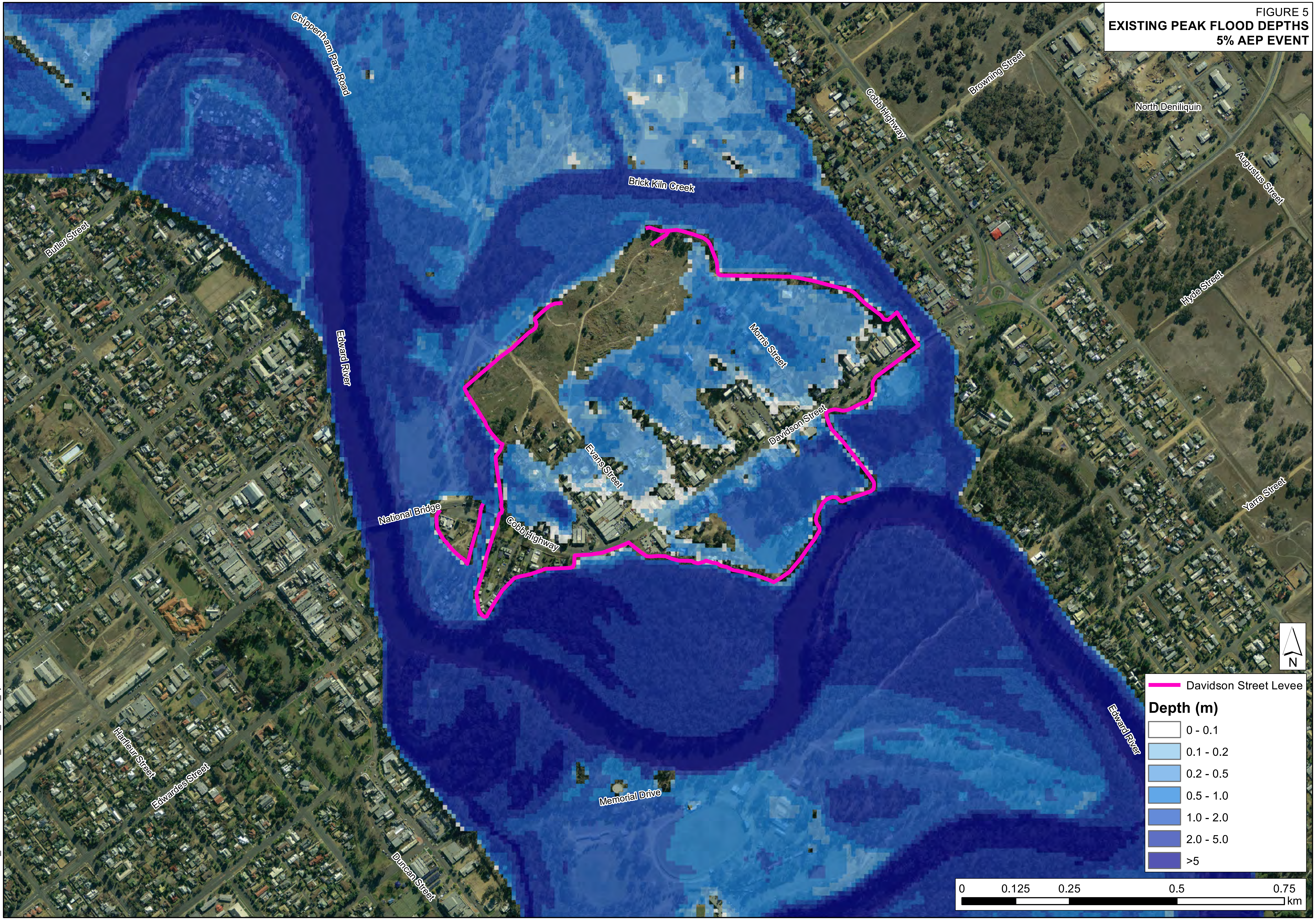
J:\Jobs\115027_05\GIS\Arcmaps\FIG03_Feedback_Respondents.mxd

FIGURE 4
PROPERTIES INCLUDED IN IMPACT ASSESSMENT



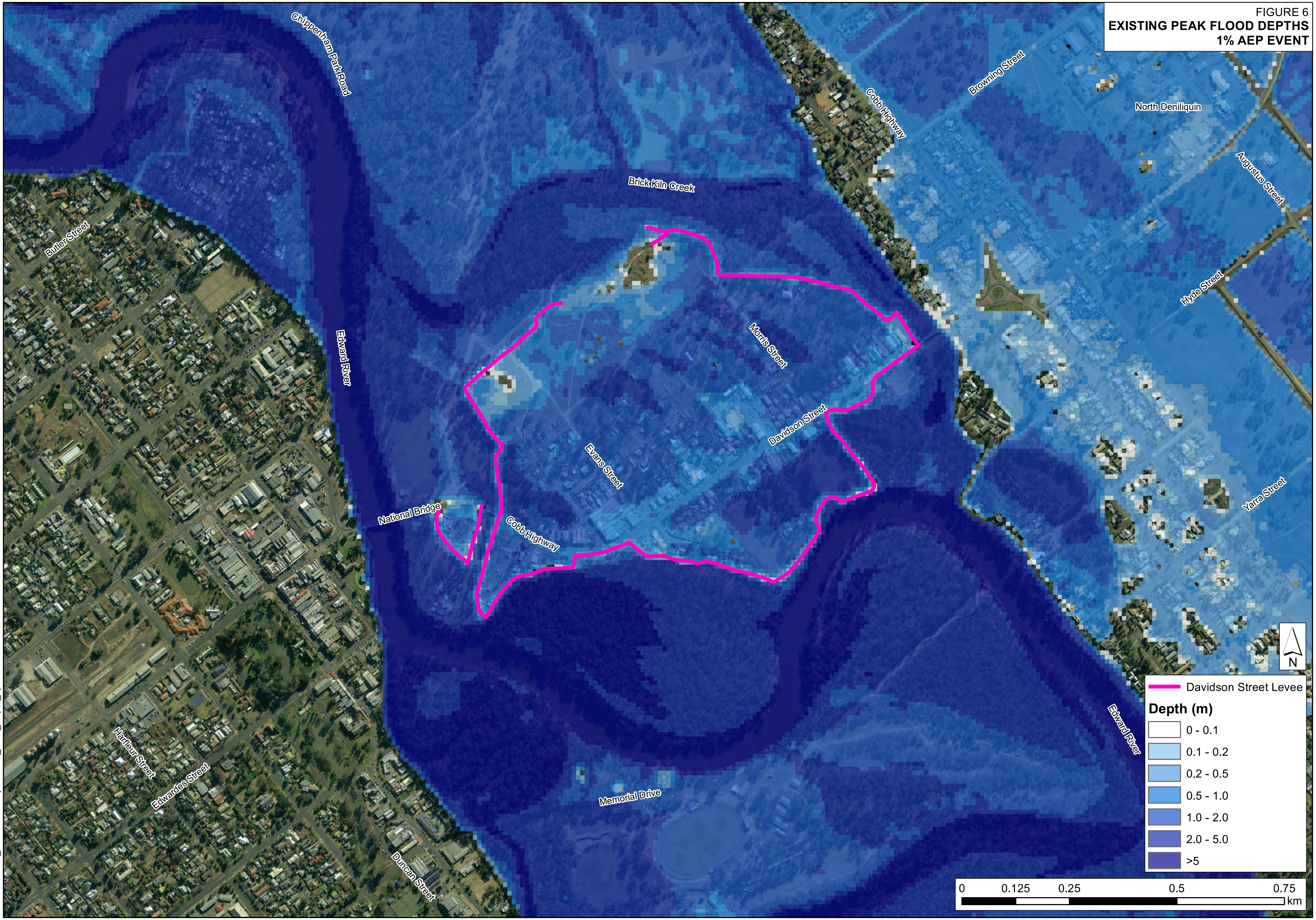
J:\Jobs\115027_05\GIS\Arcmaps\FIG04_Impact_assessment_properties.mxd

FIGURE 5
EXISTING PEAK FLOOD DEPTHS
5% AEP EVENT



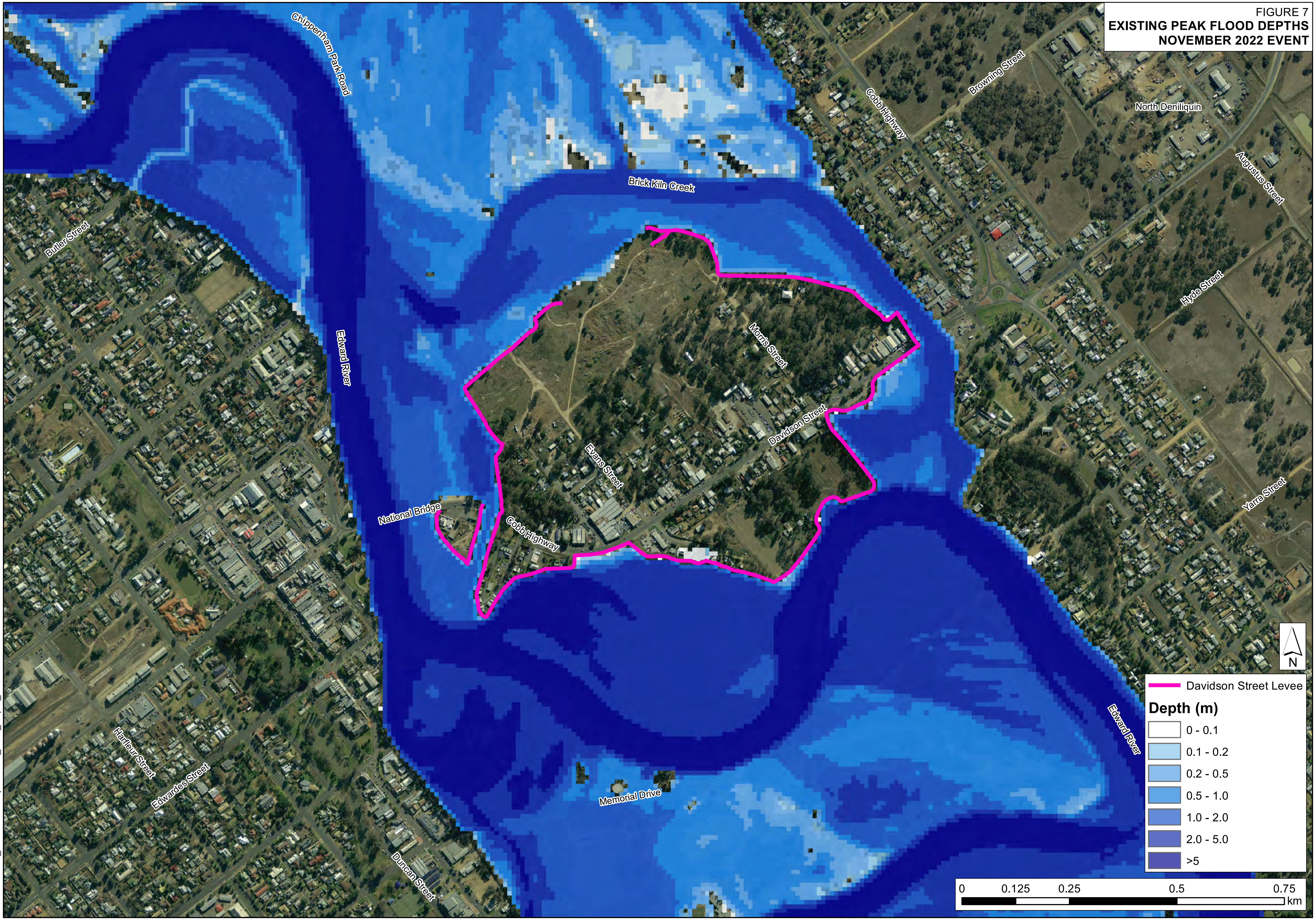
J:\Jobs\115027_05\GIS\Arcmaps\FIG05_EXG_Depth_5pAEP.mxd

FIGURE 6
EXISTING PEAK FLOOD DEPTHS
1% AEP EVENT

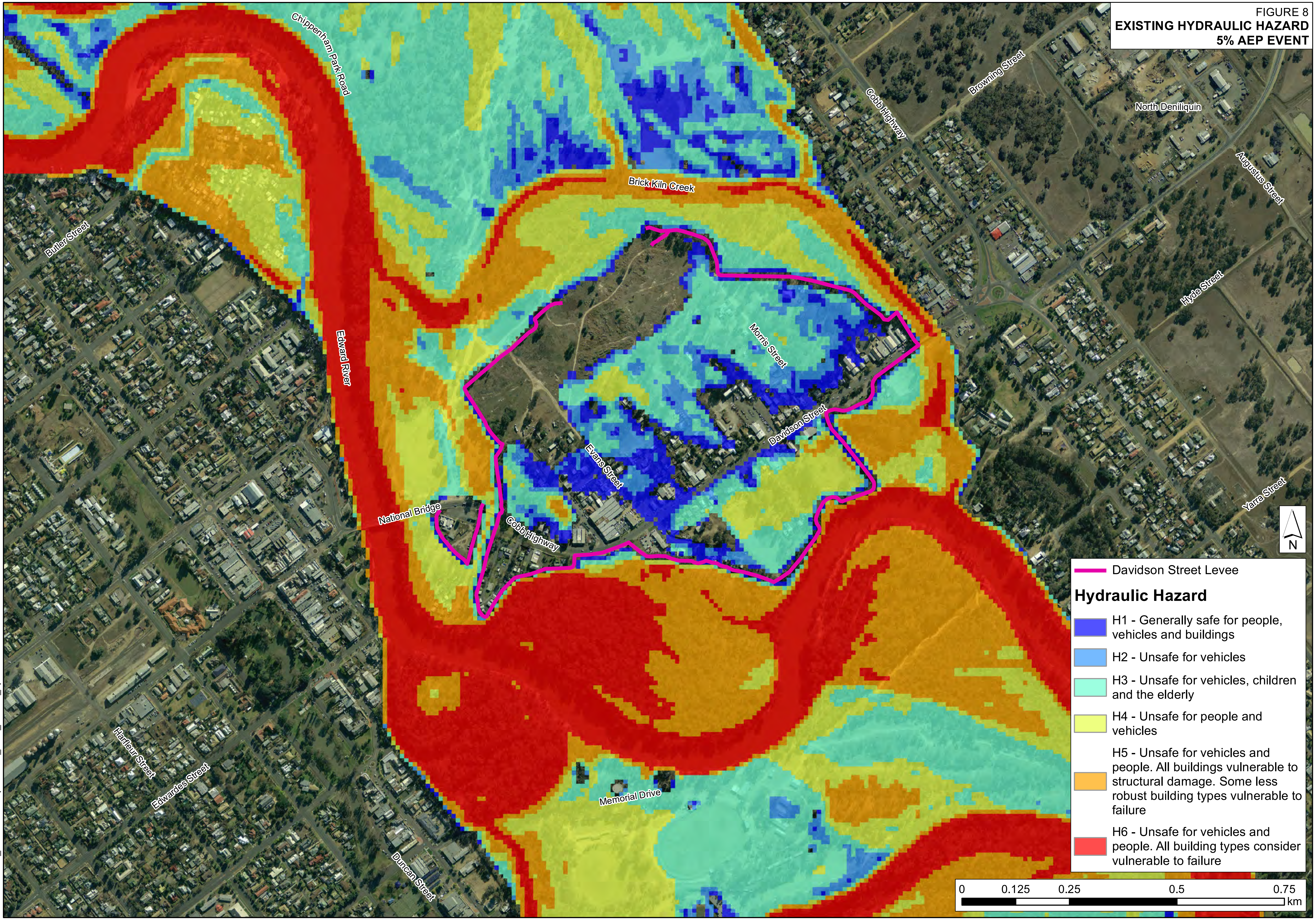


J:\Jobs\115027_05\GIS\Arcmaps\FIG06_EXG_Depth_1pAEP.mxd

FIGURE 7
EXISTING PEAK FLOOD DEPTHS
NOVEMBER 2022 EVENT



J:\Jobs\115027_05\GIS\Arcmaps\FIG07_EXG_Depth_Nov2022.mxd



J:\Jobs\115027_05\GIS\Arcmaps\FIG08_EXG_Hazard_5pAEP.mxd

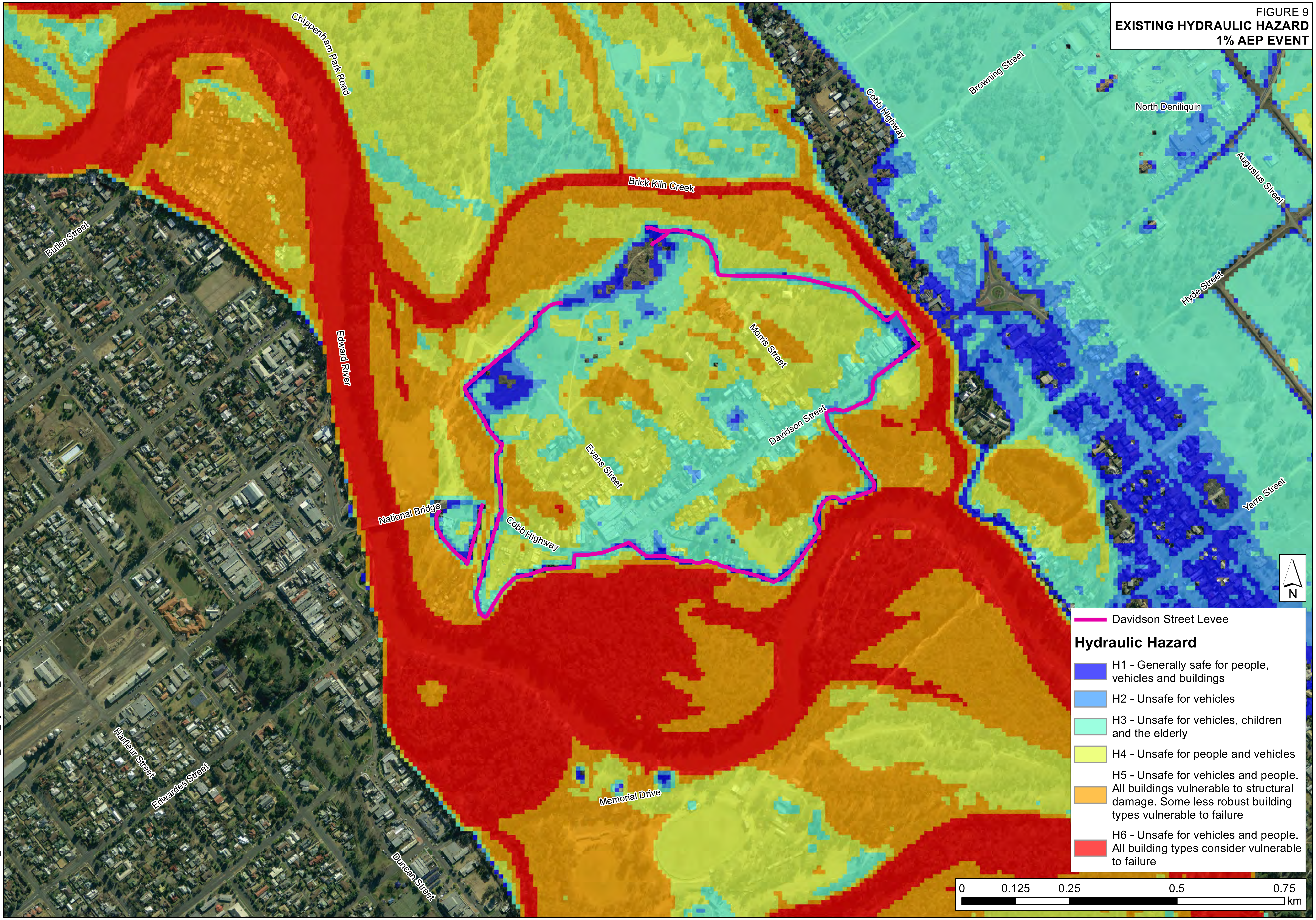
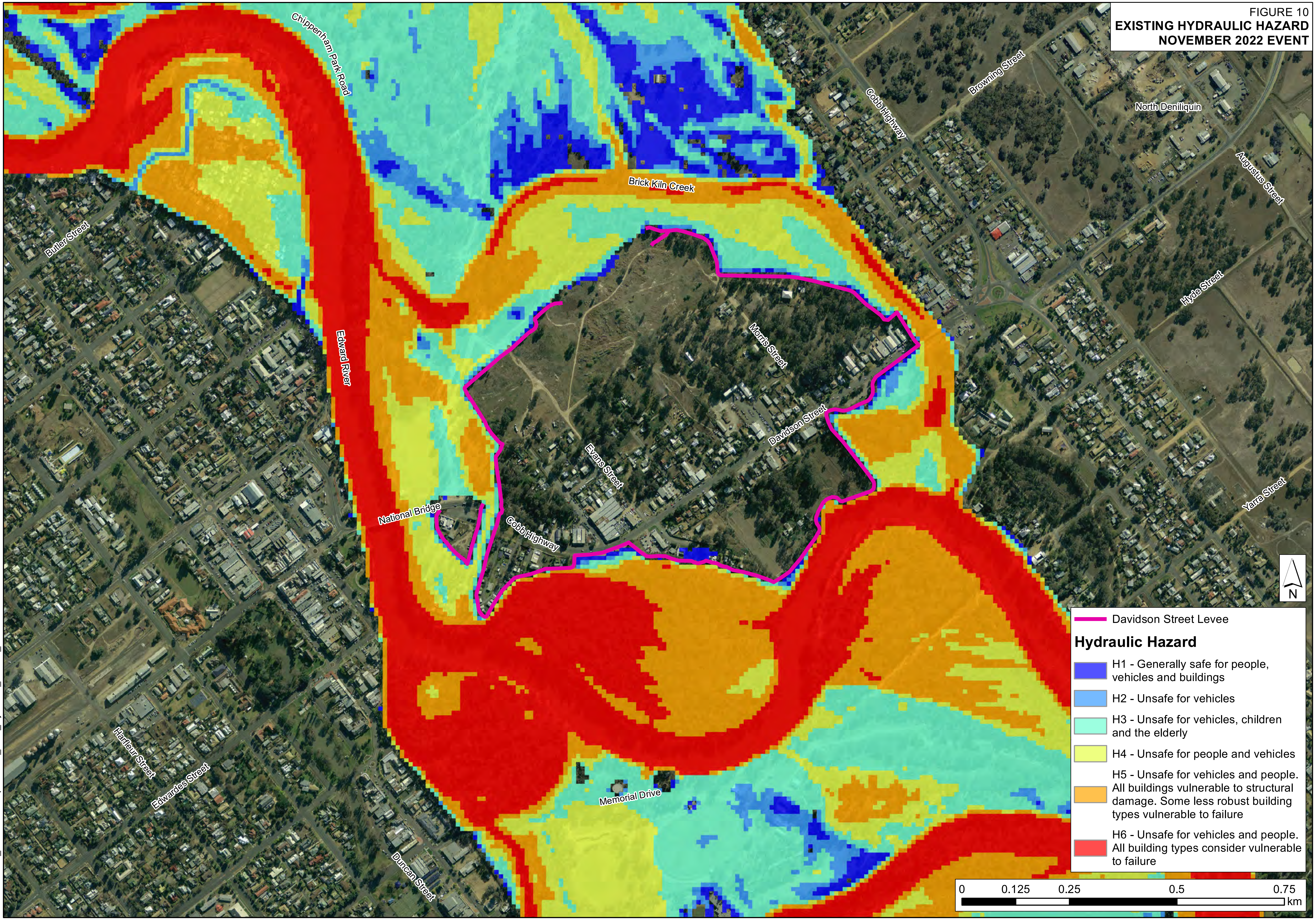
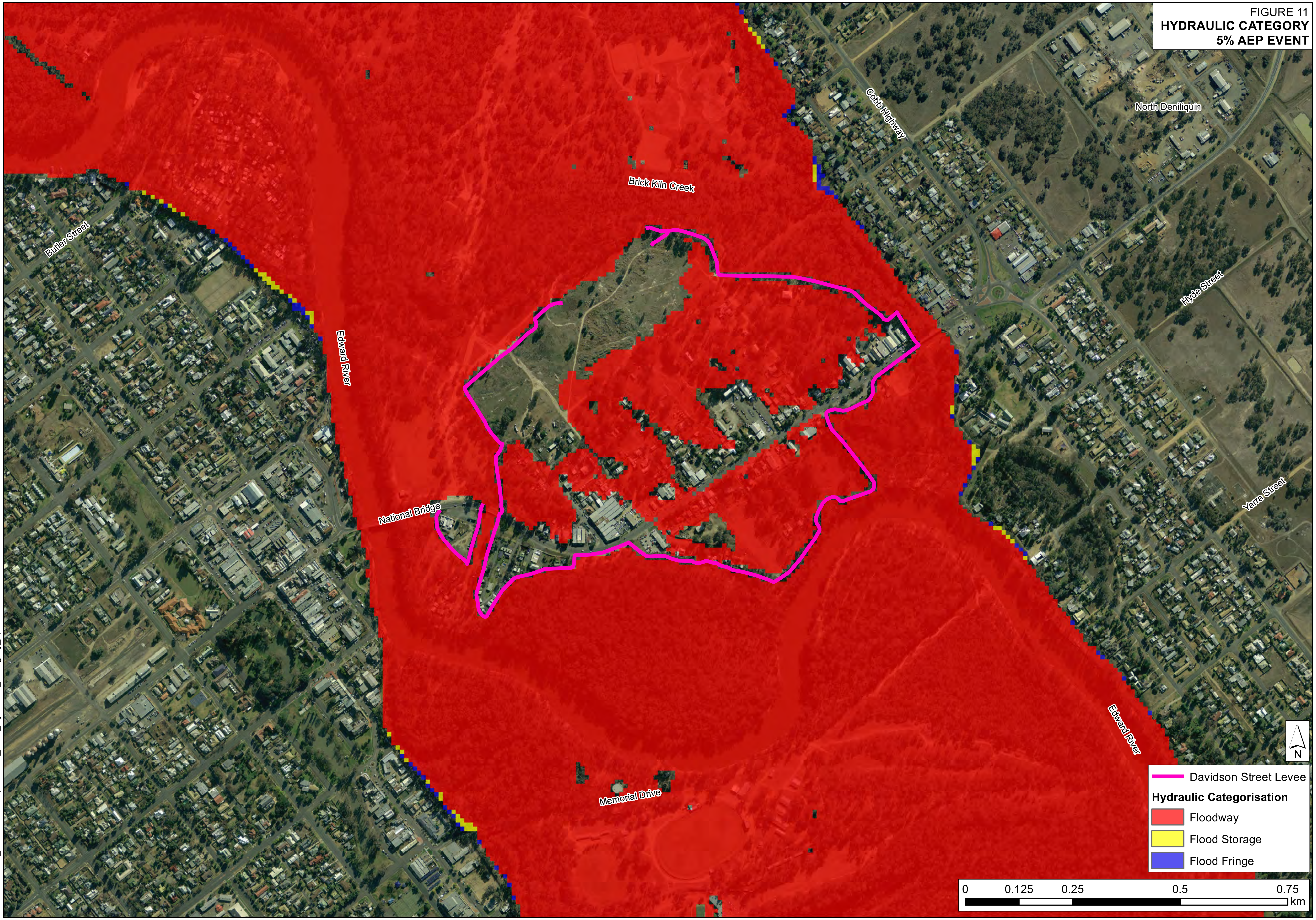


FIGURE 9
EXISTING HYDRAULIC HAZARD
1% AEP EVENT

J:\Jobs\115027_05\GIS\Arcmaps\FIG09_EXG_Hydraulic_Hazard_1pAEP.mxd



J:\Jobs\115027_05\GIS\Arcmaps\FIG10_EXG_Hydraulic_Hazard_Nov2022.mxd



J:\Jobs\115027_05\GIS\Arcmaps\FIG11_EXG_Hydraulic_Category_5pAEP.mxd

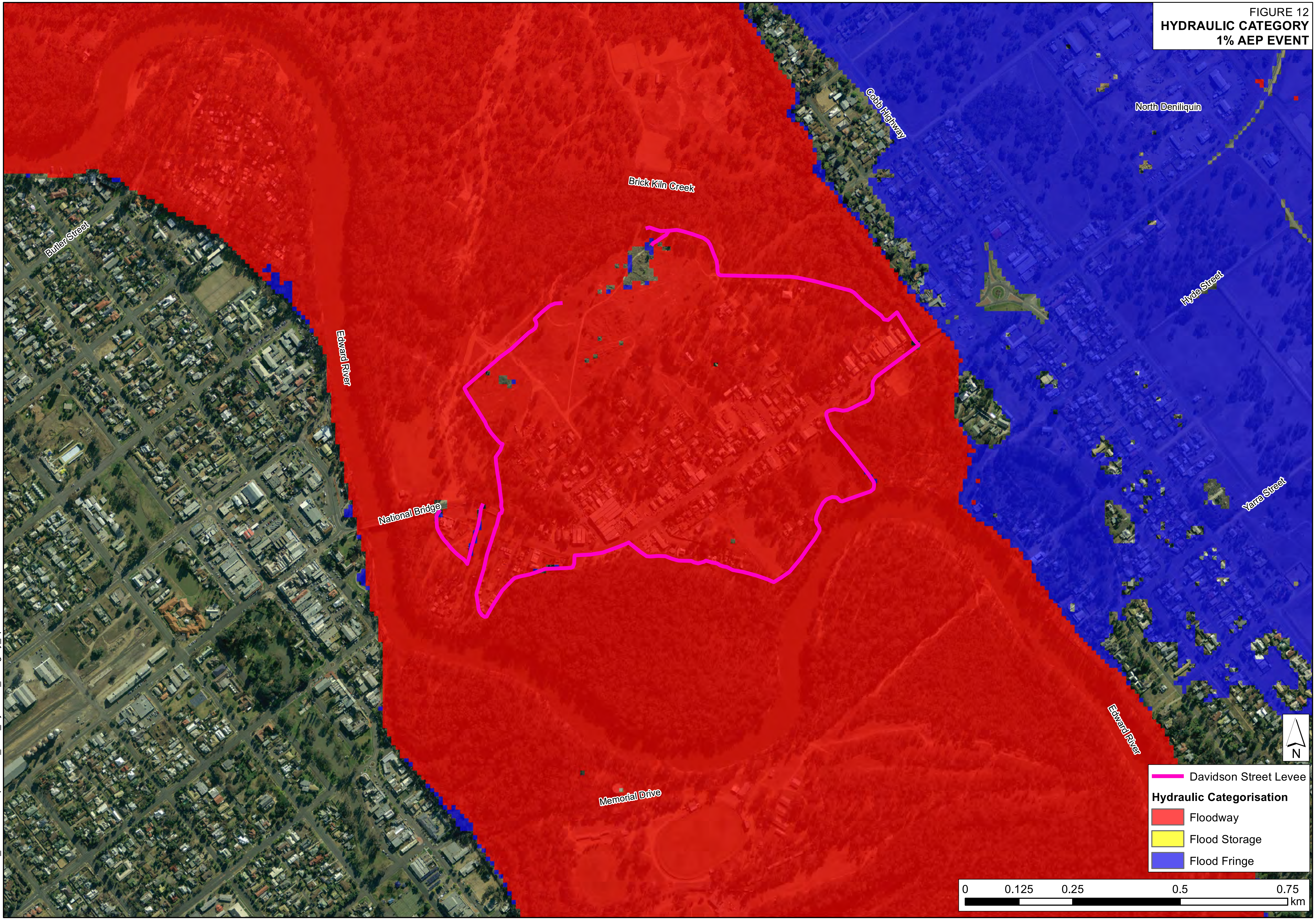
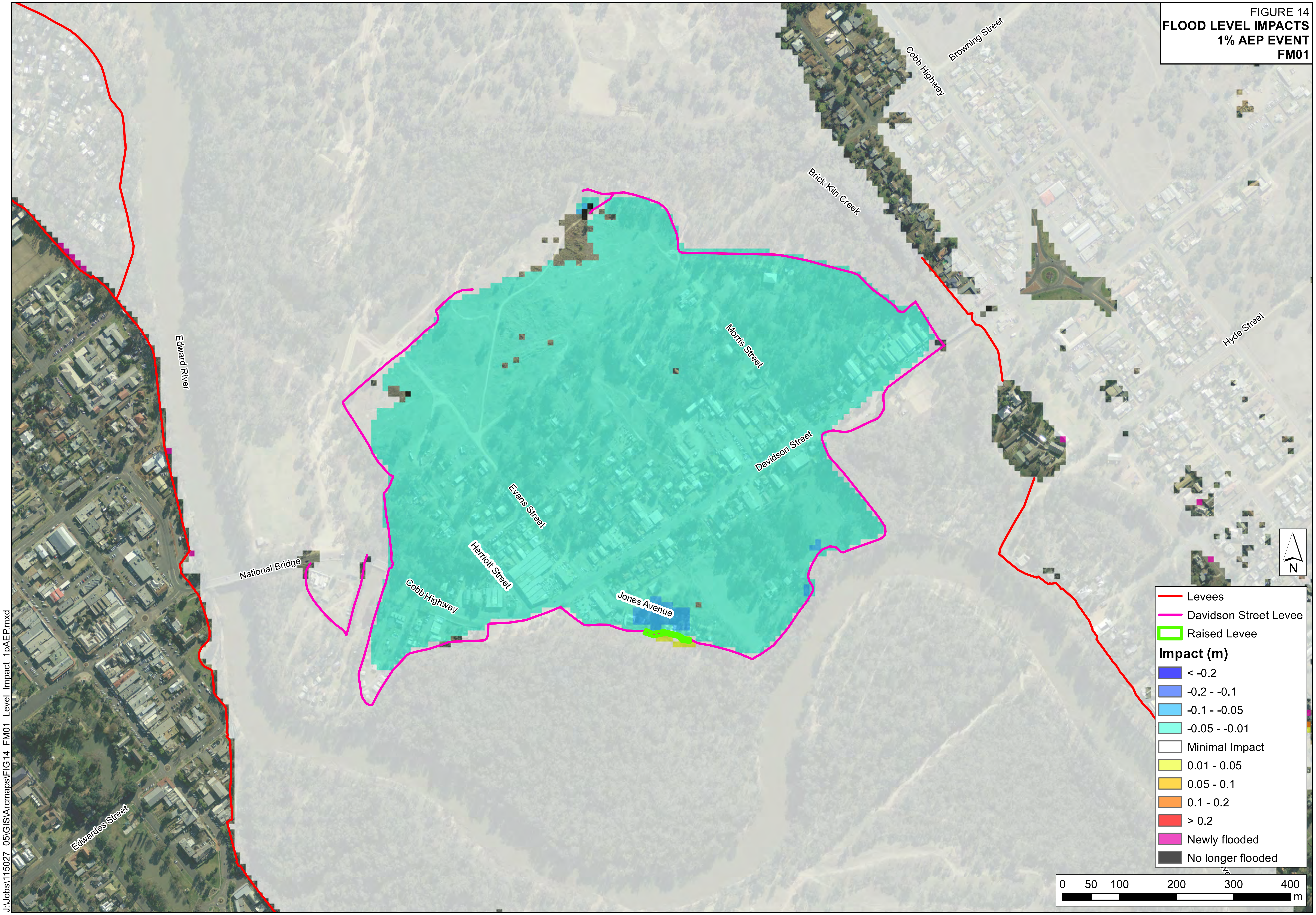


FIGURE 12
HYDRAULIC CATEGORY
1% AEP EVENT
North Deniliquin
Cobb Highway
Brick Kiln Creek
Butler Street
Edward River
Hyde Street
National Bridge
Yarra Street
Edward River
Memorial Drive
N
Davidson Street Levee
Hydraulic Categorisation
Floodway
Flood Storage
Flood Fringe
0
0.125
0.25
0.5
0.75
km
J:\Jobs\115027_05\GIS\Arcmaps\FIG12_EXG_Hydraulic_Category_1pAEP.mxd

FIGURE 13
FLOOD LEVEL IMPACTS
5% AEP EVENT
FM01
Browning Street
Cobb Highway
Brick Kiln Creek
Edward River
Morris Street
Davidson Street
Evans Street
Herriott Street
National Bridge
Cobb Highway
Jones Avenue
Hyde Street
Edwardes Street
N
Levees
Davidson Street Levee
Raised Levee
Impact (m)
< -0.2
-0.2 - -0.1
-0.1 - -0.05
-0.05 - -0.01
Minimal Impact
0.01 - 0.05
0.05 - 0.1
0.1 - 0.2
> 0.2
Newly flooded
No longer flooded
0 50 100 200 300 400
m
J:\Jobs\115027_05\GIS\Arcmaps\FIG13_FM01_Level_Impact_5pAEP.mxd

FIGURE 14
FLOOD LEVEL IMPACTS
1% AEP EVENT
FM01

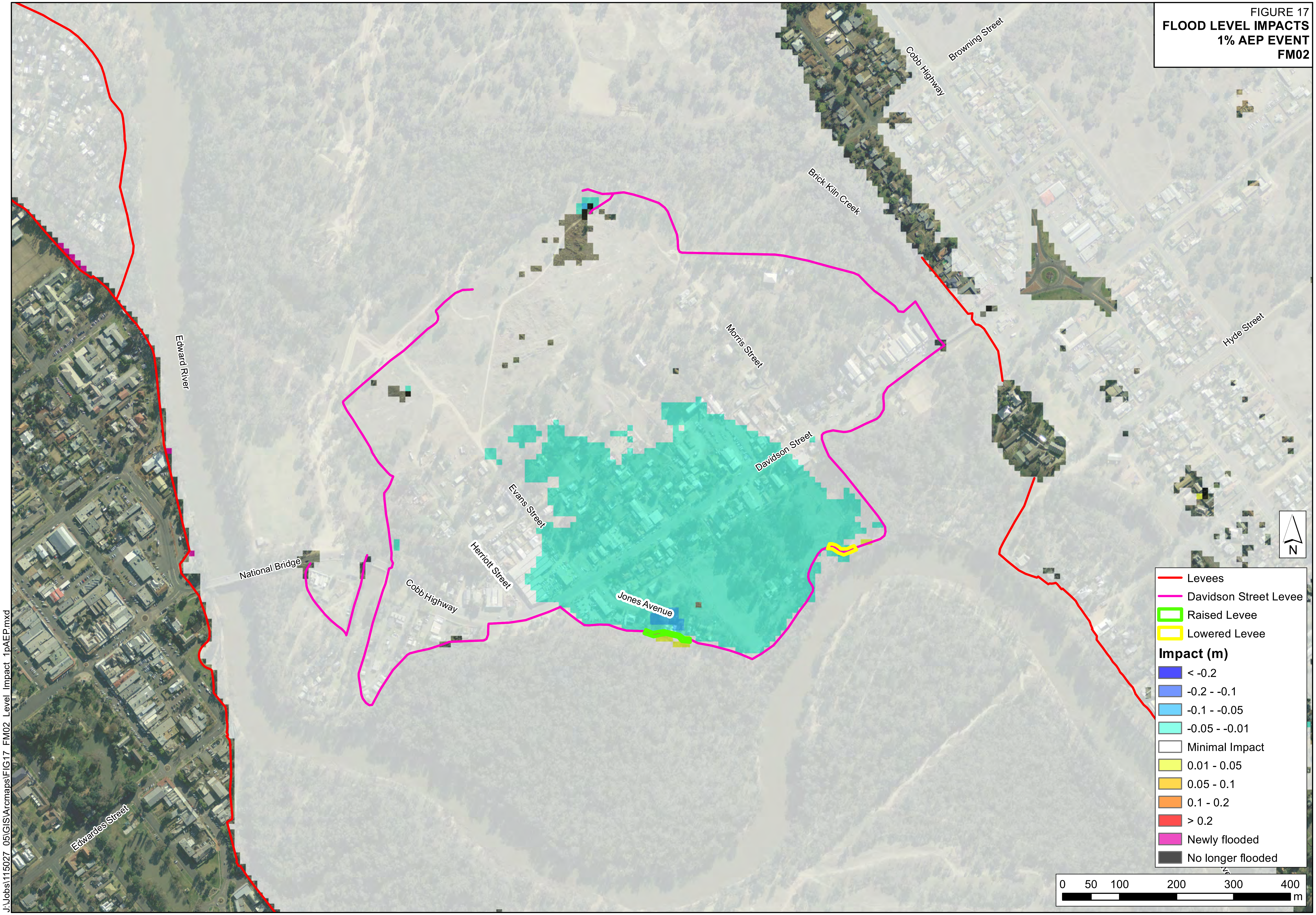


J:Jobs\115027_05\GIS\Arcmaps\FIG14_FM01_Level_Impact_1pAEP.mxd


FIGURE 15
FLOOD LEVEL IMPACTS
NOVEMBER 2022 EVENT
FM01
Browning Street
Cobb Highway
Brick Kiln Creek
Edward River
Morris Street
Hyde Street
Davidson Street
Evans Street
Herriott Street
National Bridge
Cobb Highway
Jones Avenue
Edwardes Street
N
Levees
Davidson Street Levee
Raised Levee
Impact (m)
< -0.2
-0.2 - -0.1
-0.1 - -0.05
-0.05 - -0.01
Minimal Impact
0.01 - 0.05
0.05 - 0.1
0.1 - 0.2
> 0.2
Newly flooded
No longer flooded
0 50 100 200 300 400
m
J:Jobs\115027_05\GIS\Arcmaps\FIG15_FM01_Level_Impact_Nov2022.mxd

FIGURE 16
FLOOD LEVEL IMPACTS
5% AEP EVENT
FM02

FIGURE 17
FLOOD LEVEL IMPACTS
1% AEP EVENT
FM02



J:\Jobs\115027_05\GIS\Arcmaps\FIG17_FM02_Level_Impact_1pAEP.mxd

FIGURE 18
FLOOD LEVEL IMPACTS
NOVEMBER 2022 EVENT
FM02

J:Jobs\115027_05\GIS\Arcmaps\FIG18_FM02_Level_Impact_Nov2022.mxd

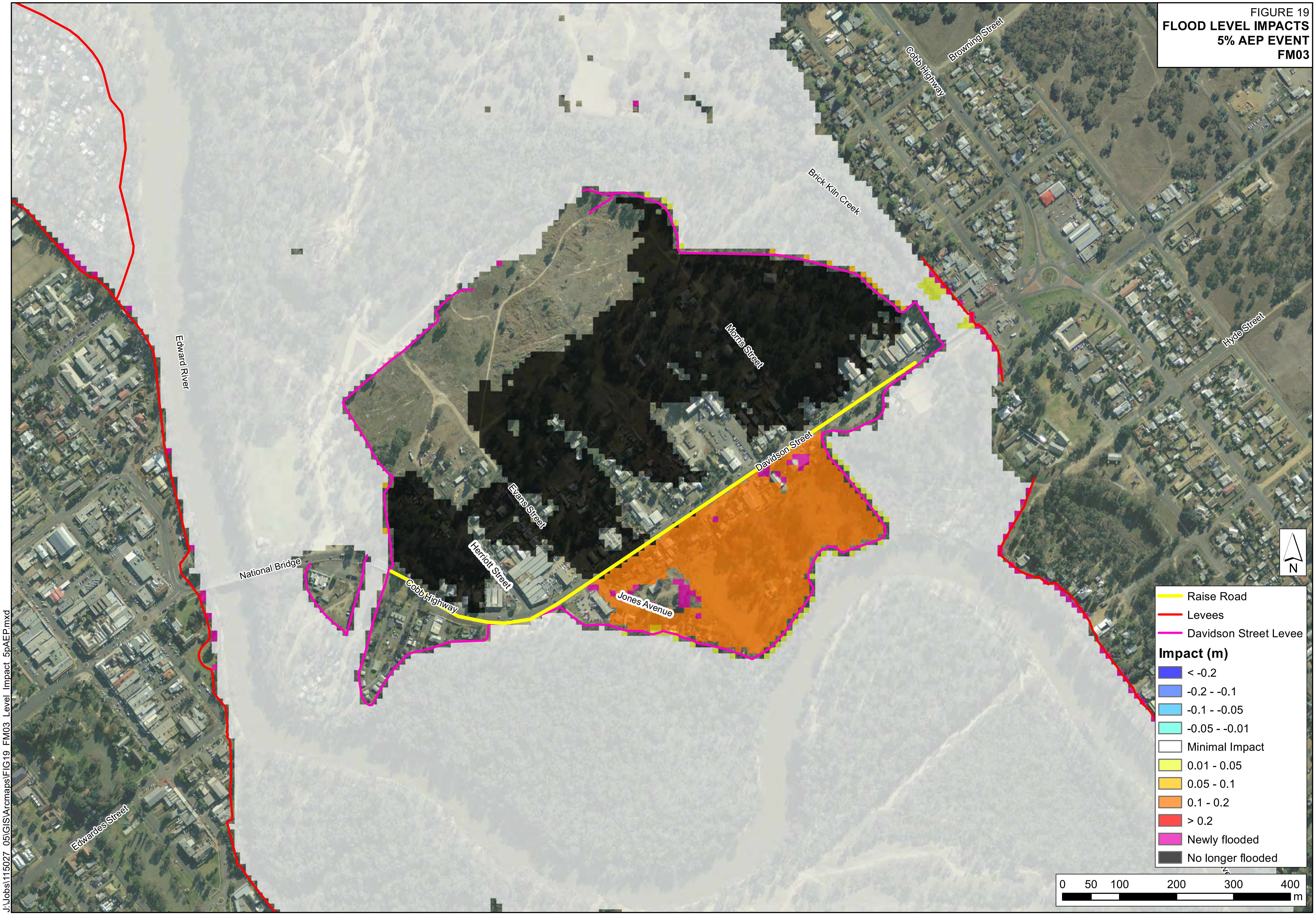
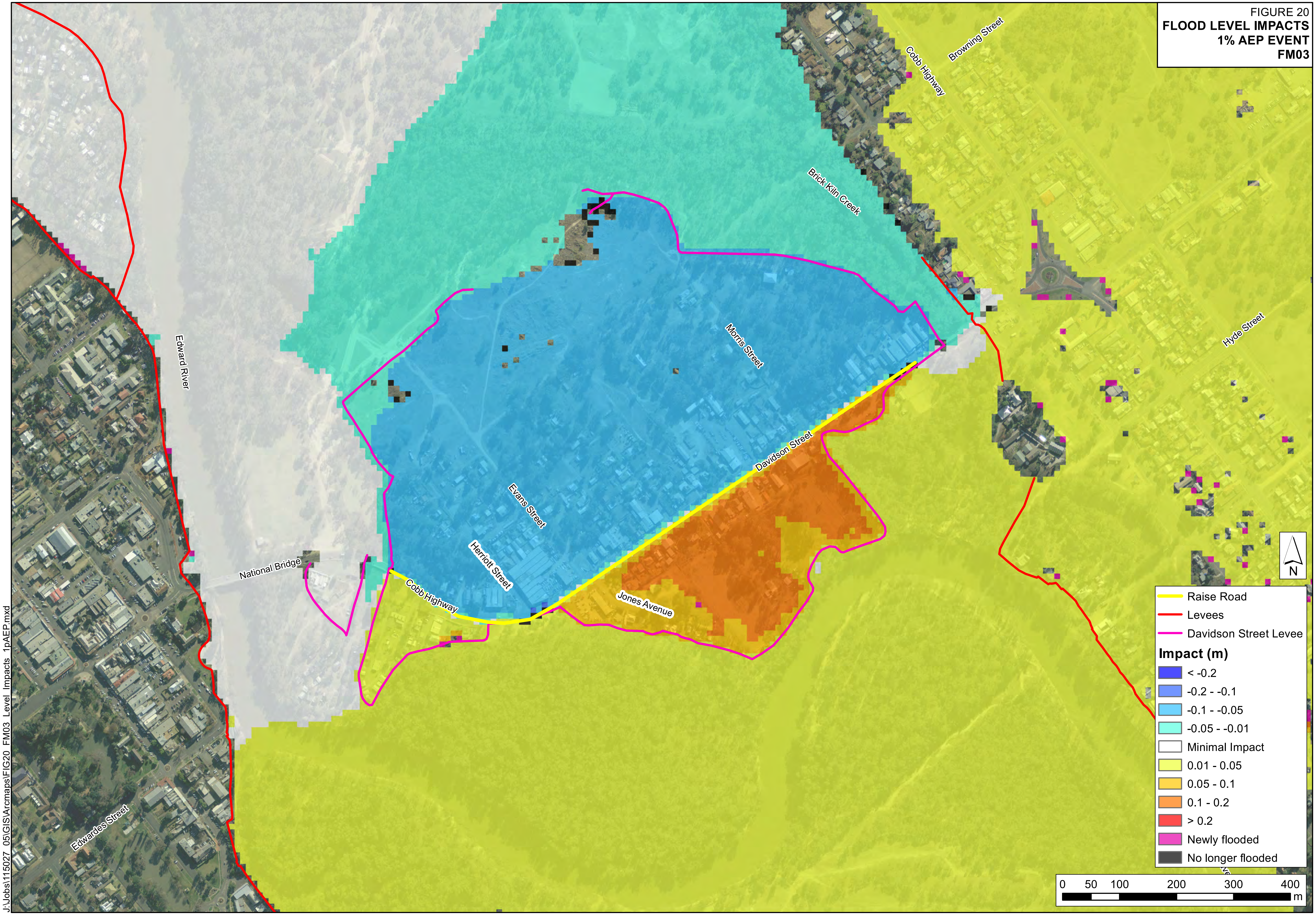


FIGURE 19
FLOOD LEVEL IMPACTS
5% AEP EVENT
FM03
Browning Street
Cobb Highway
Brick Kiln Creek
Hyde Street
Edward River
Morris Street
Davidson Street
Evans Street
Herriott Street
National Bridge
Cobb Highway
Jones Avenue
Edwardes Street
Raise Road
Levees
Davidson Street Levee
Impact (m)
< -0.2
-0.2 - -0.1
-0.1 - -0.05
-0.05 - -0.01
Minimal Impact
0.01 - 0.05
0.05 - 0.1
0.1 - 0.2
> 0.2
Newly flooded
No longer flooded
N
0 50 100 200 300 400
m
J:Jobs\115027_05\GIS\Arcmaps\FIG19_FM03_Level_Impact_5pAEP.mxd

FIGURE 20
FLOOD LEVEL IMPACTS
1% AEP EVENT
FM03

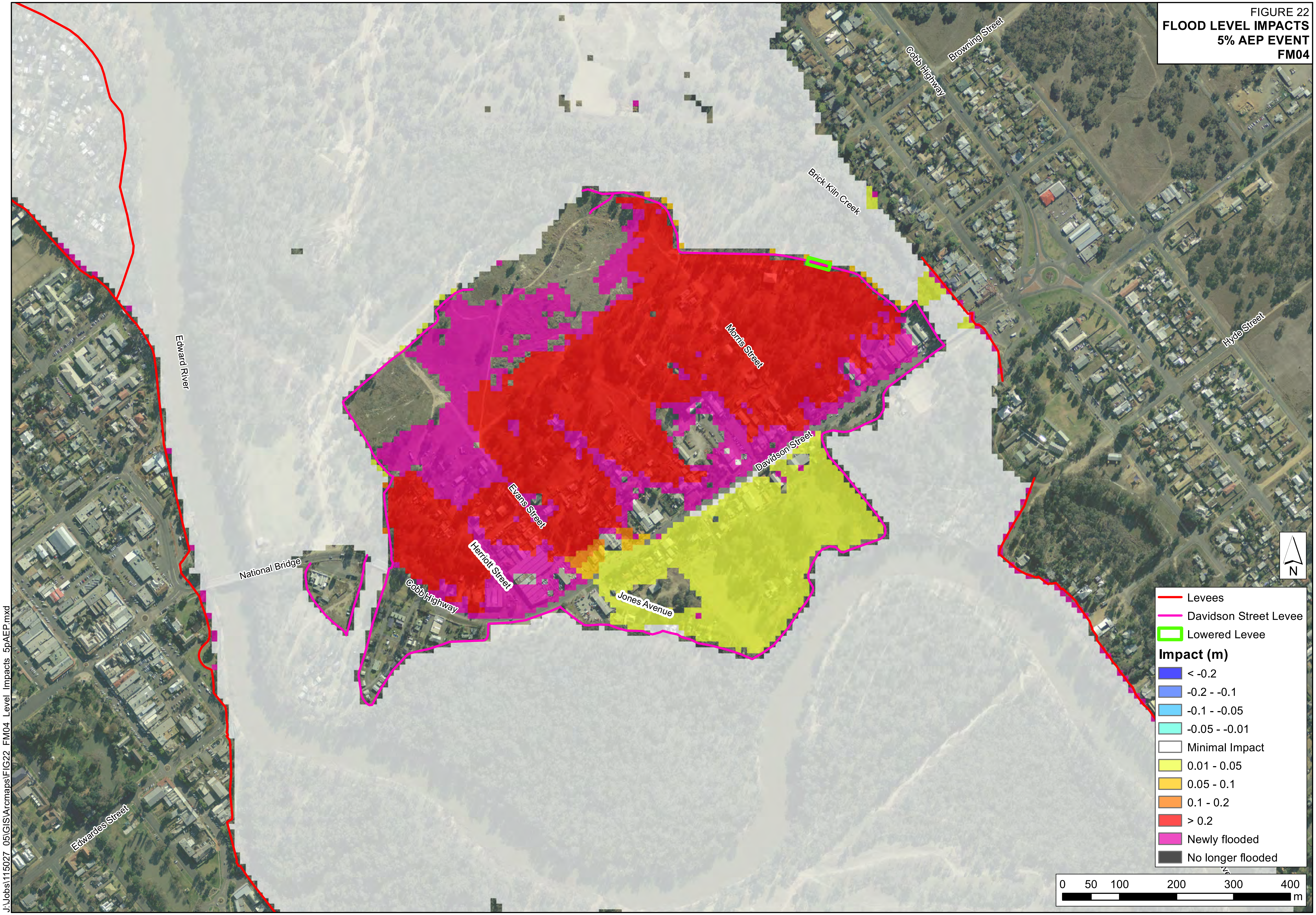


J:\Jobs\115027_05\GIS\Arcmaps\FIG20_FM03_Level_Impacts_1pAEP.mxd

FIGURE 21
FLOOD LEVEL IMPACTS
NOVEMBER 2022 EVENT
FM03

J:\Jobs\115027_05\GIS\Arcmaps\FIG21_FM03_Level_Impacts_Nov2022.mxd

FIGURE 22
FLOOD LEVEL IMPACTS
5% AEP EVENT
FM04



J:\Jobs\115027_05\GIS\Arcmaps\FIG22_FM04_Level_Impacts_5pAEP.mxd

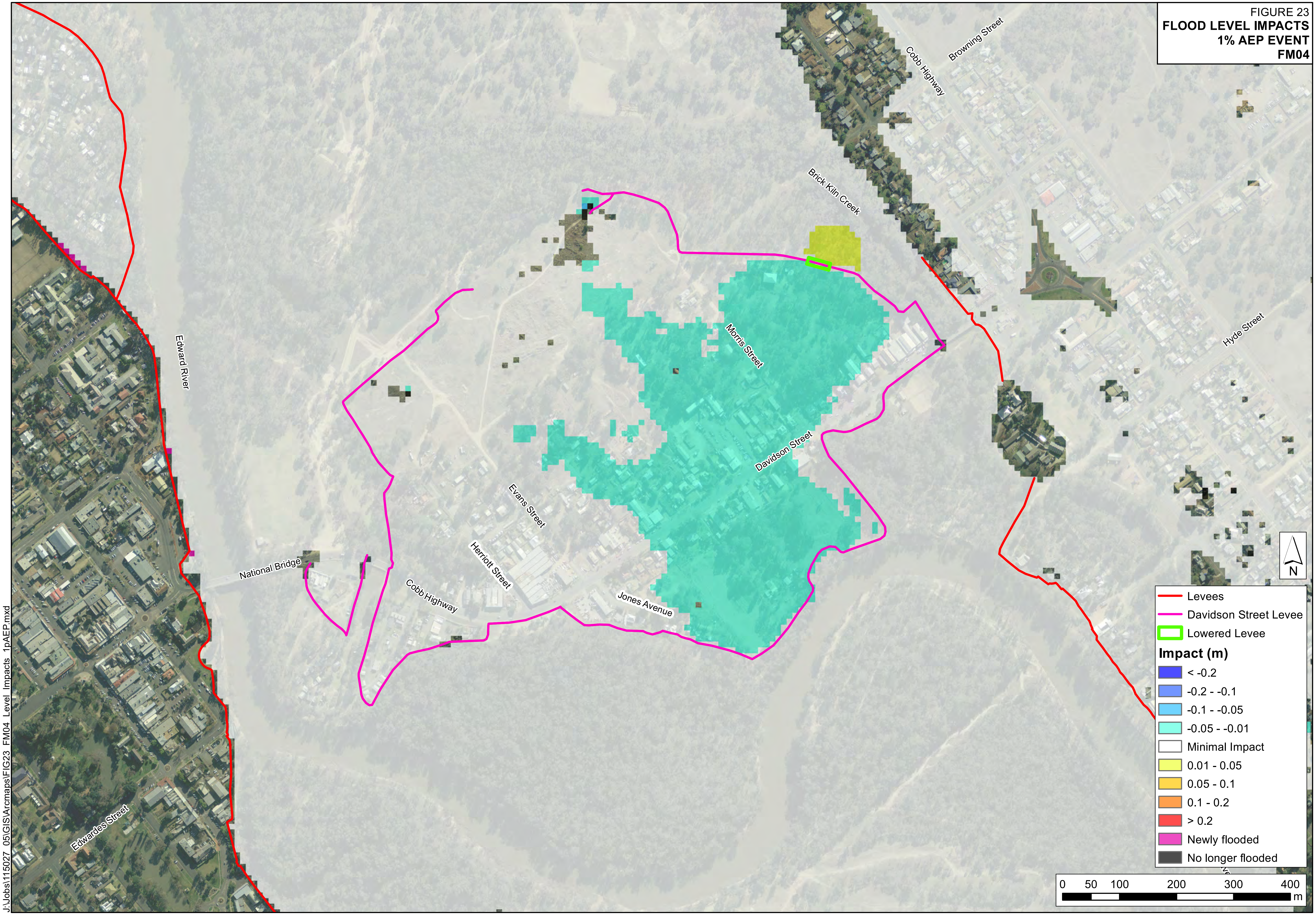


FIGURE 23
FLOOD LEVEL IMPACTS
1% AEP EVENT
FM04
Browning Street
Cobb Highway
Brick Kiln Creek
Hyde Street
Edward River
Morris Street
Davidson Street
Evans Street
Herriott Street
National Bridge
Cobb Highway
Jones Avenue
Edwardes Street
Levees
Davidson Street Levee
Lowered Levee
Impact (m)
< -0.2
-0.2 - -0.1
-0.1 - -0.05
-0.05 - -0.01
Minimal Impact
0.01 - 0.05
0.05 - 0.1
0.1 - 0.2
> 0.2
Newly flooded
No longer flooded
0 50 100 200 300 400
m
N
J:\Jobs\115027_05\GIS\Arcmaps\FIG23_FM04_Level_Impacts_1pAEP.mxd

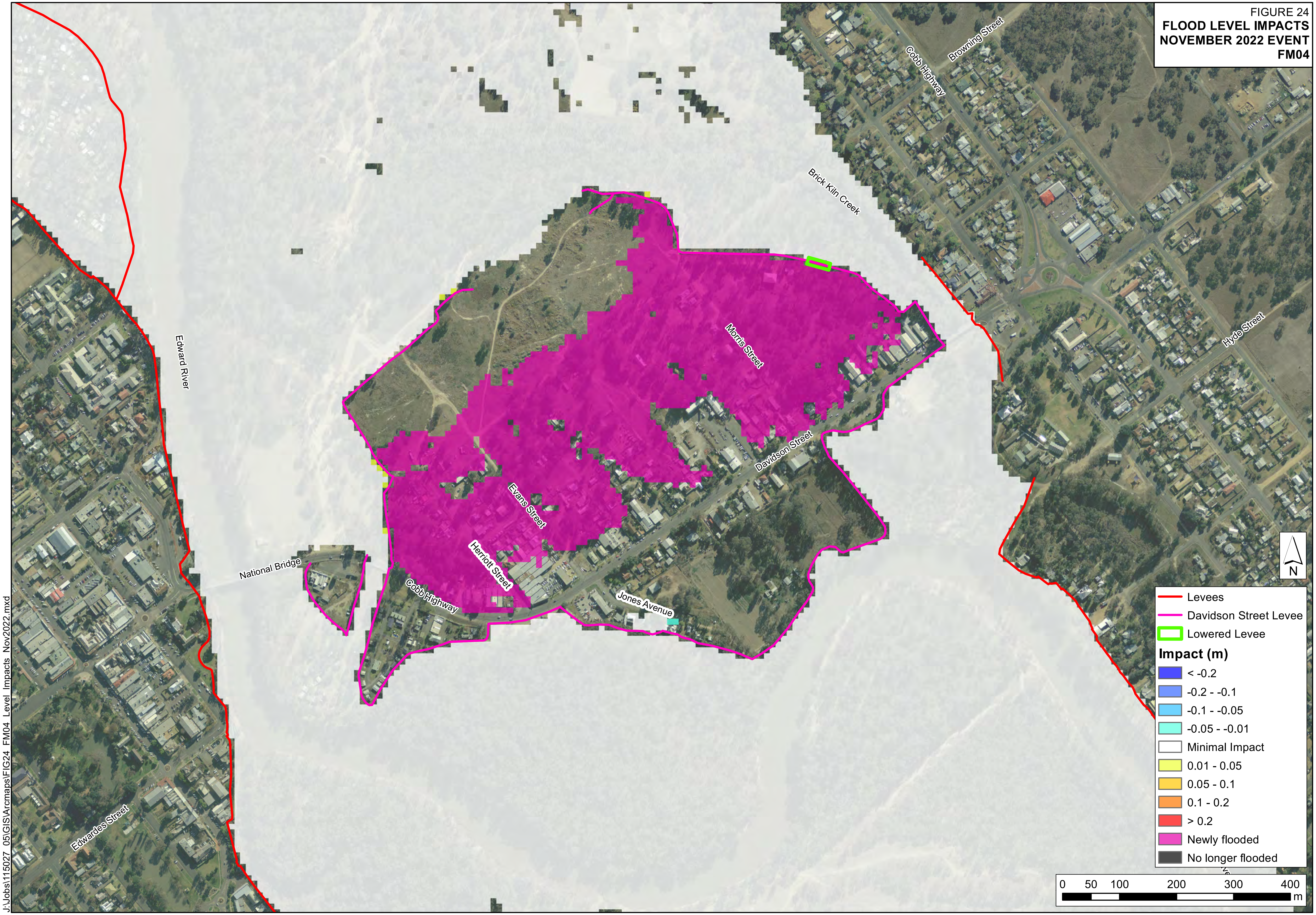


FIGURE 24
FLOOD LEVEL IMPACTS NOVEMBER 2022 EVENT FM04

J:\Jobs\115027_05\GIS\Arcmaps\FIG24_FM04_Level_Impacts_Nov2022.mxd

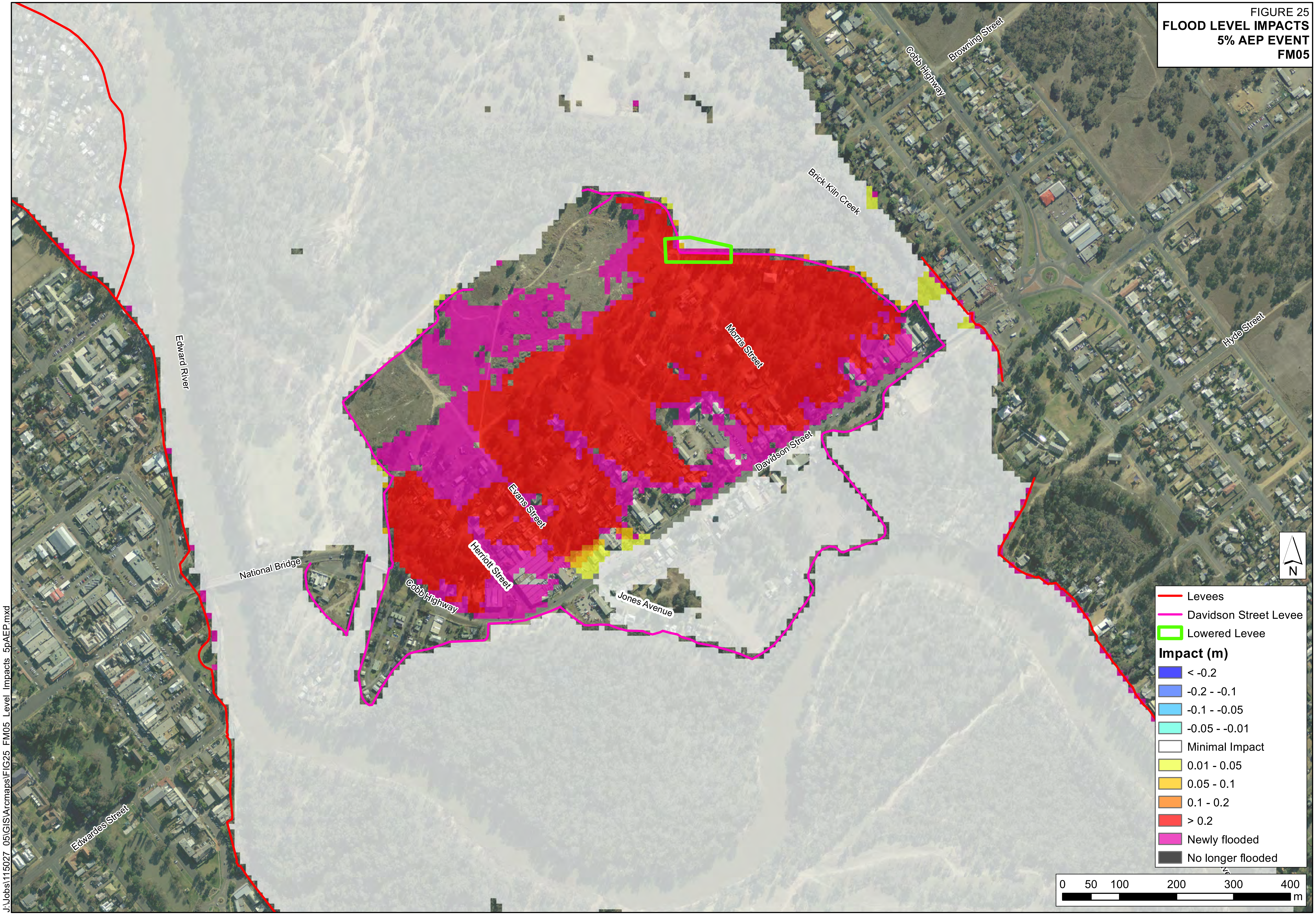


FIGURE 25
FLOOD LEVEL IMPACTS
5% AEP EVENT
FM05
Browning Street
Cobb Highway
Brick Kiln Creek
Edward River
Morris Street
Hyde Street
Davidson Street
Evans Street
National Bridge
Herriott Street
Cobb Highway
Jones Avenue
Edwardes Street
Levees
Davidson Street Levee
Lowered Levee
Impact (m)
< -0.2
-0.2 - -0.1
-0.1 - -0.05
-0.05 - -0.01
Minimal Impact
0.01 - 0.05
0.05 - 0.1
0.1 - 0.2
> 0.2
Newly flooded
No longer flooded
N
0 50 100 200 300 400
m
J:\Jobs\115027_05\GIS\Arcmaps\FIG25_FM05_Level_Impacts_5pAEP.mxd

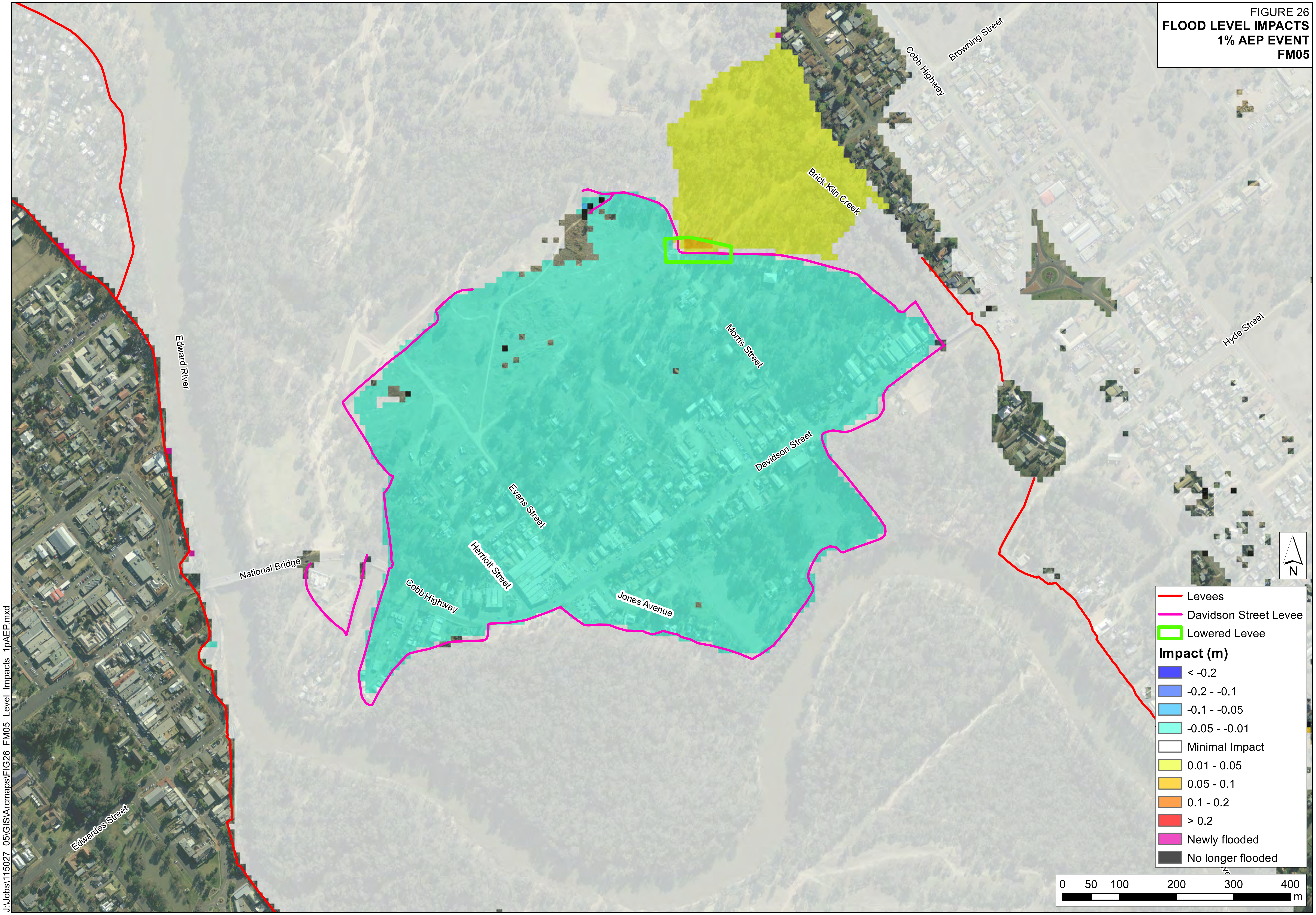
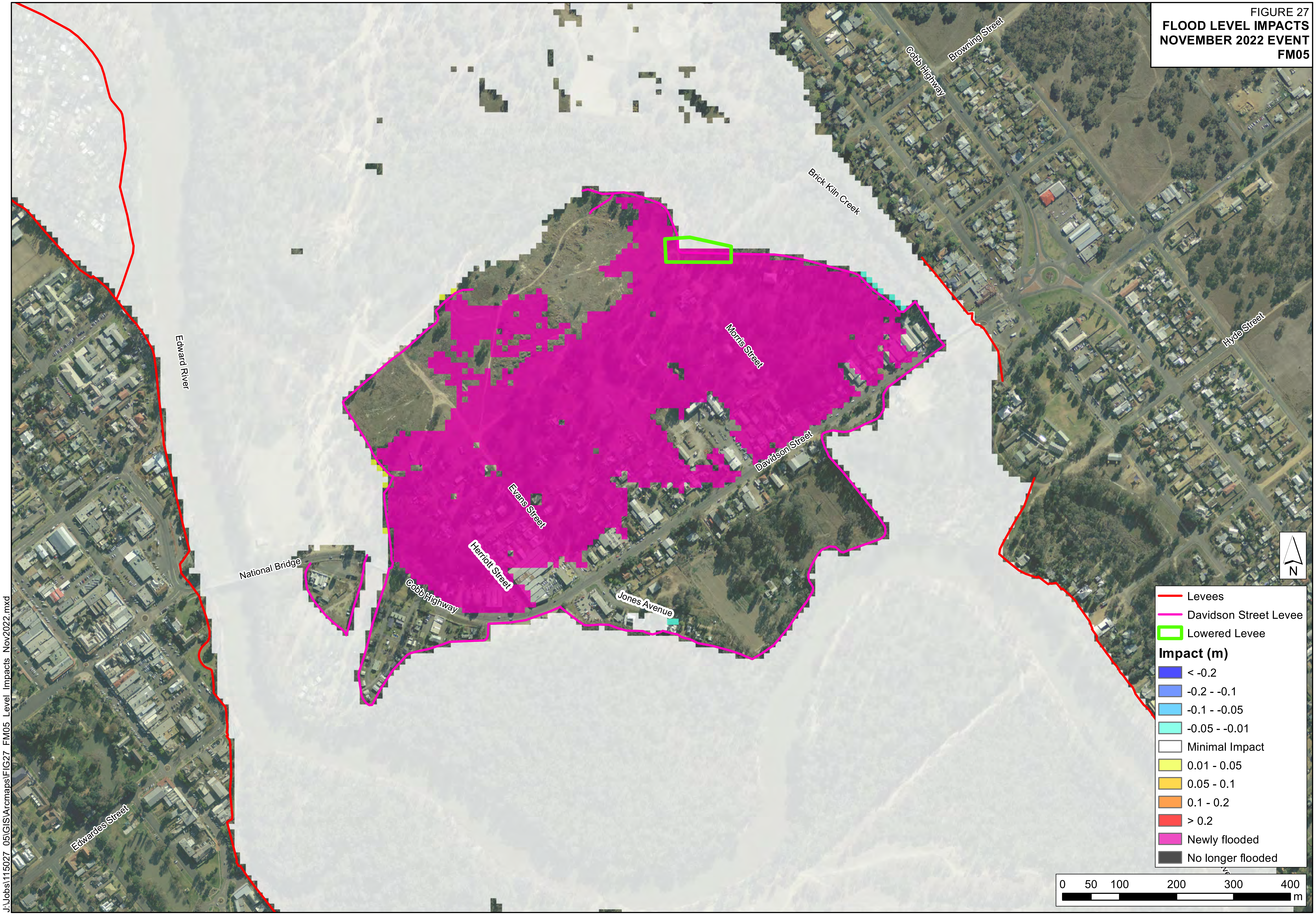


FIGURE 26
FLOOD LEVEL IMPACTS
1% AEP EVENT
FM05
Browning Street
Cobb Highway
Brick Kiln Creek
Morris Street
Hyde Street
Edward River
Davidson Street
Evans Street
National Bridge
Herriott Street
Cobb Highway
Jones Avenue
Edwardes Street
Levees
Davidson Street Levee
Lowered Levee
Impact (m)
< -0.2
-0.2 - -0.1
-0.1 - -0.05
-0.05 - -0.01
Minimal Impact
0.01 - 0.05
0.05 - 0.1
0.1 - 0.2
> 0.2
Newly flooded
No longer flooded
N
0 50 100 200 300 400
m
J:\Jobs\115027_05\GIS\Arcmaps\FIG26_FM05_Level_Impacts_1pAEP.mxd

FIGURE 27
FLOOD LEVEL IMPACTS
NOVEMBER 2022 EVENT
FM05



J:\Jobs\115027_05\GIS\Arcmaps\FIG27_FM05_Level_Impacts_Nov2022.mxd

FIGURE 28
FLOOD LEVEL IMPACTS
5% AEP EVENT
FM06

J:\Jobs\115027_05\GIS\Arcmaps\FIG28_FM06_Level_Impacts_5pAEP.mxd

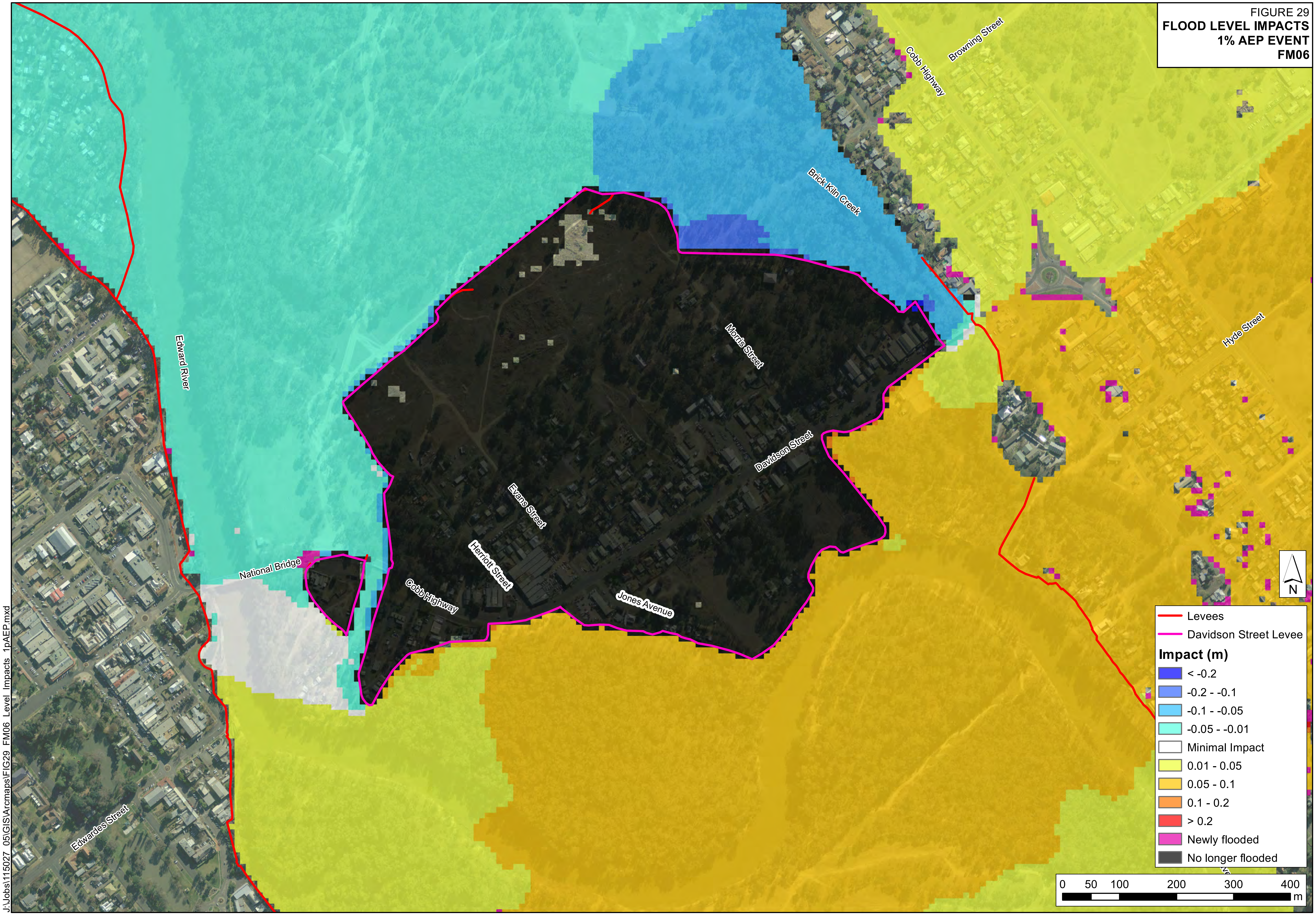
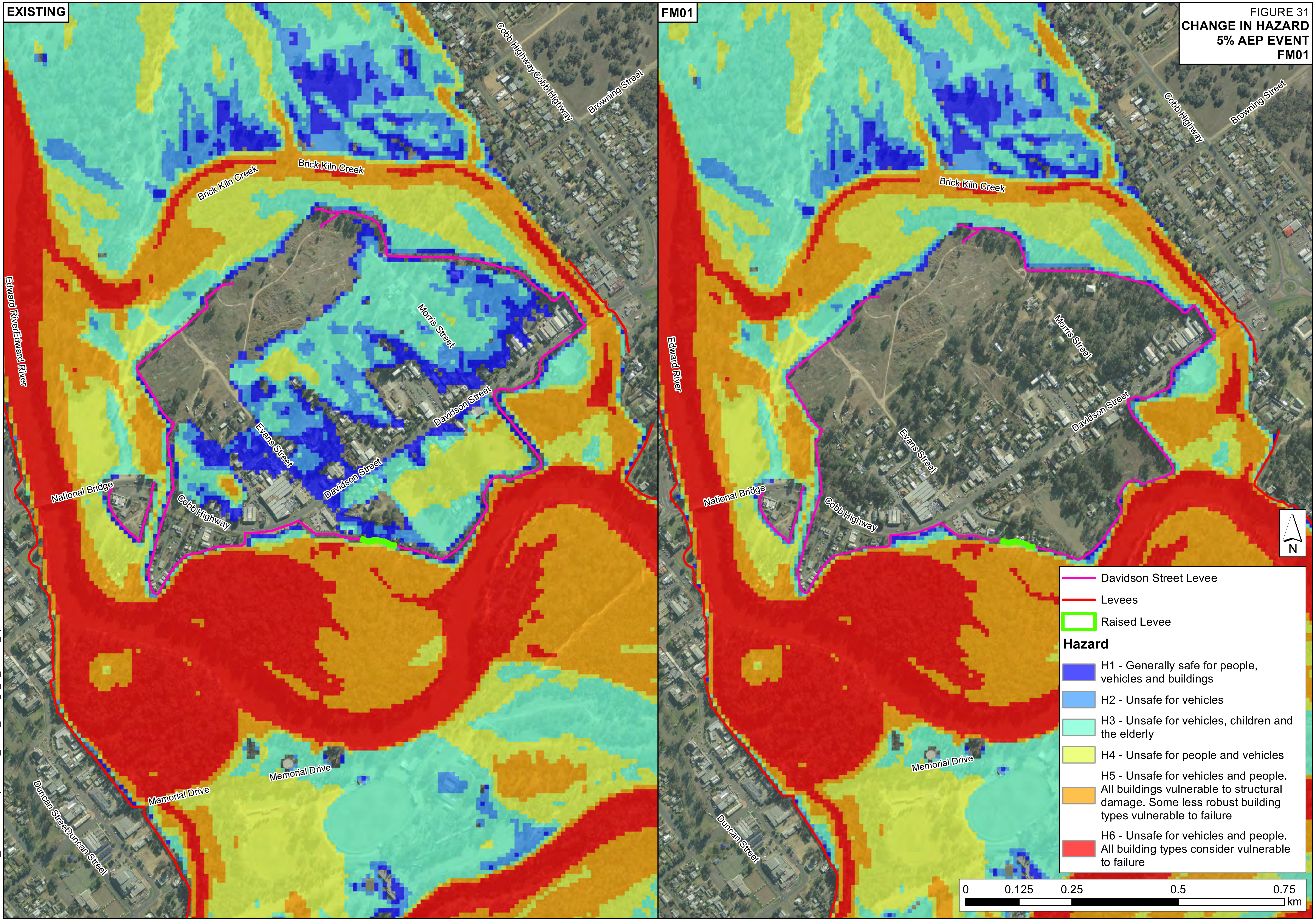


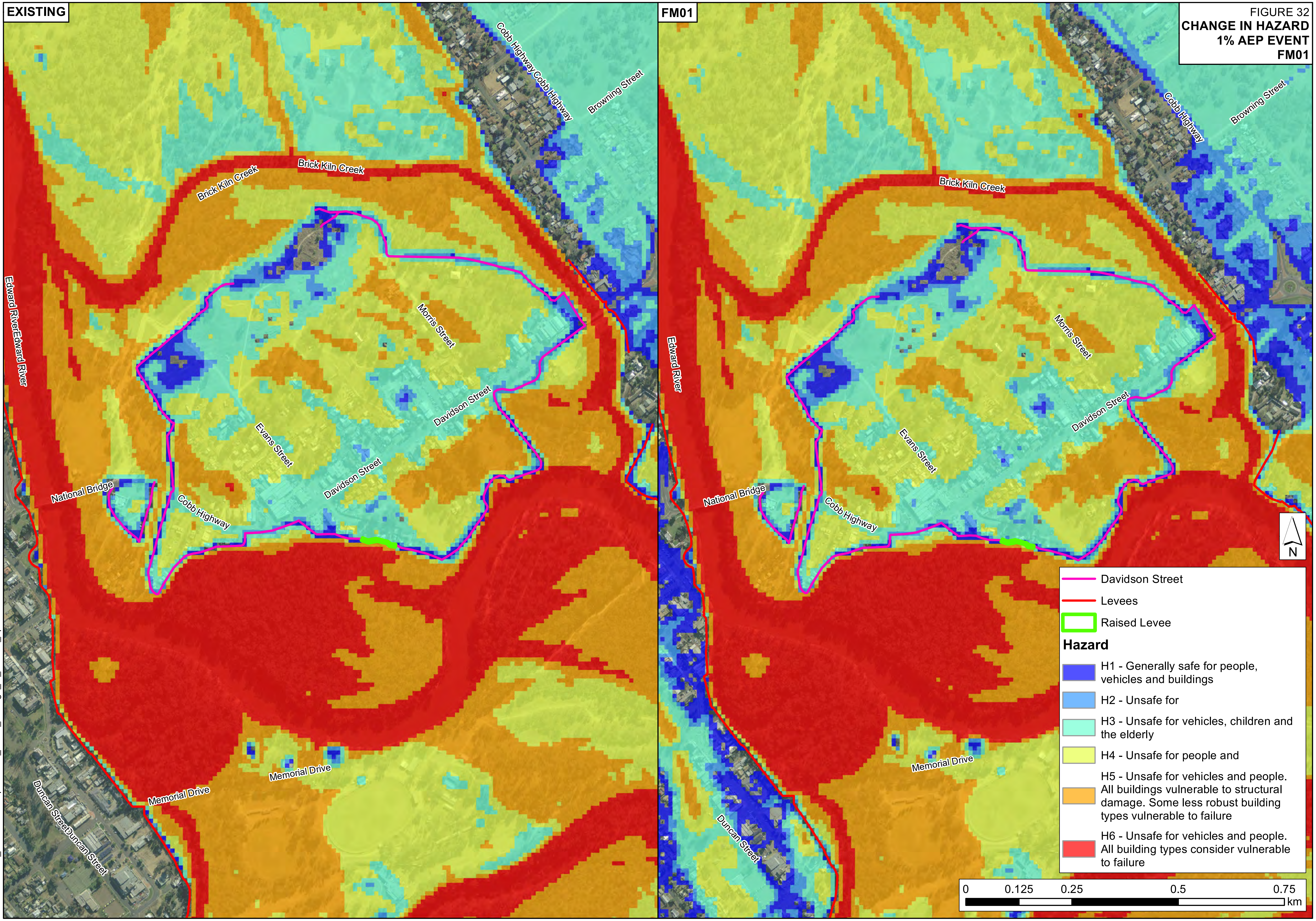
FIGURE 29
FLOOD LEVEL IMPACTS
1% AEP EVENT
FM06
Browning Street
Cobb Highway
Brick Kiln Creek
Edward River
Morris Street
Hyde Street
Davidson Street
Evans Street
Herriott Street
National Bridge
Cobb Highway
Jones Avenue
Edwardes Street
N
Levees
Davidson Street Levee
Impact (m)
< -0.2
-0.2 - -0.1
-0.1 - -0.05
-0.05 - -0.01
Minimal Impact
0.01 - 0.05
0.05 - 0.1
0.1 - 0.2
> 0.2
Newly flooded
No longer flooded
0 50 100 200 300 400
m
J:\Jobs\115027_05\GIS\Arcmaps\FIG29_FM06_Level_Impacts_1pAEP.mxd

FIGURE 30
FLOOD LEVEL IMPACTS
NOVEMBER 2022 EVENT
FM06

J:\Jobs\115027_05\GIS\Arcmaps\FIG30_FM06_Level_Impacts_Nov2022.mxd



J:\Jobs\115027_05\GIS\Arcmaps\FIG31_FM01_Change_in_Hazard_5pAEP.mxd



J:\Jobs\115027_05\GIS\Arcmaps\FIG32_FM01_Change_in_Hazard_1pAEP.mxd

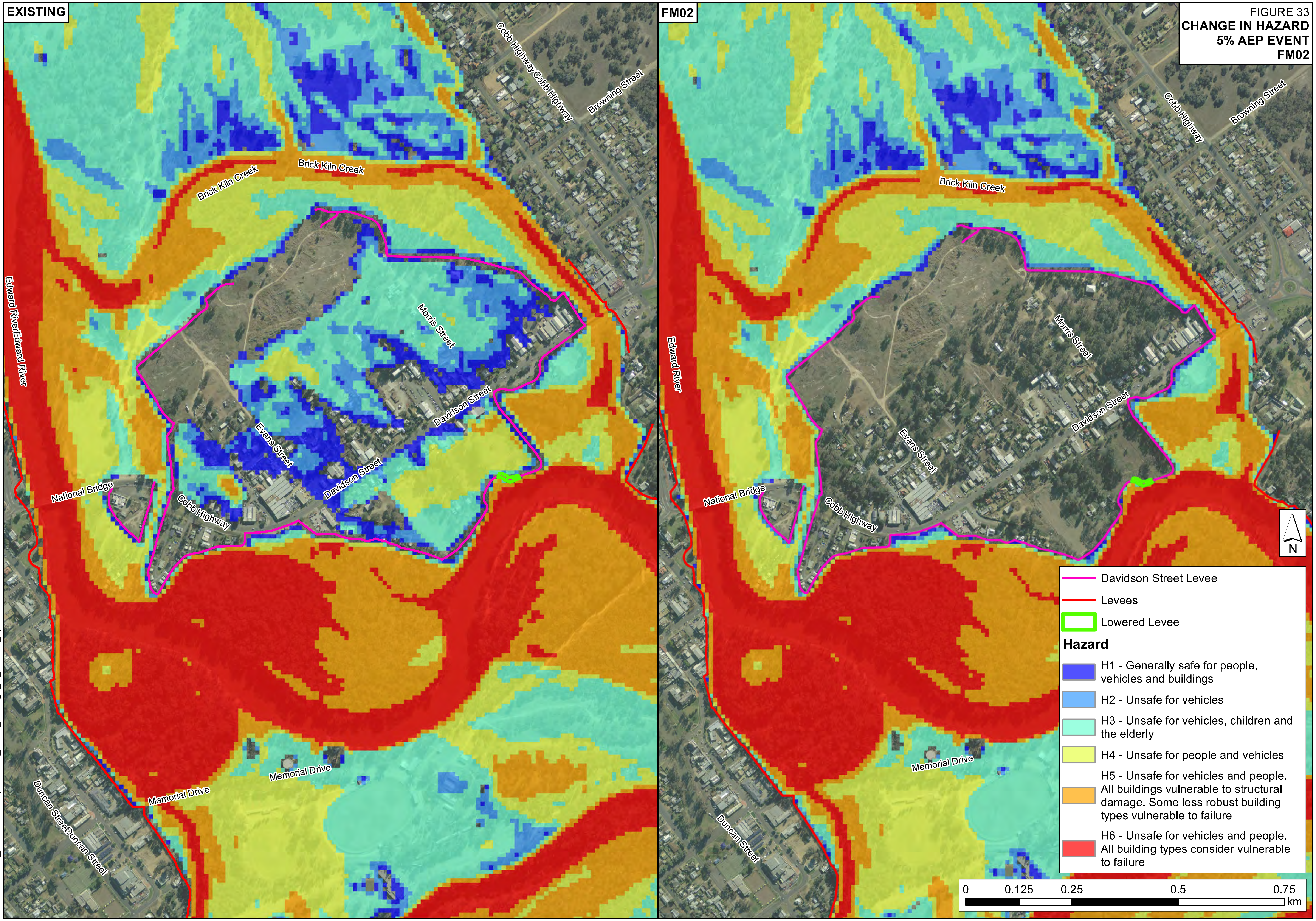
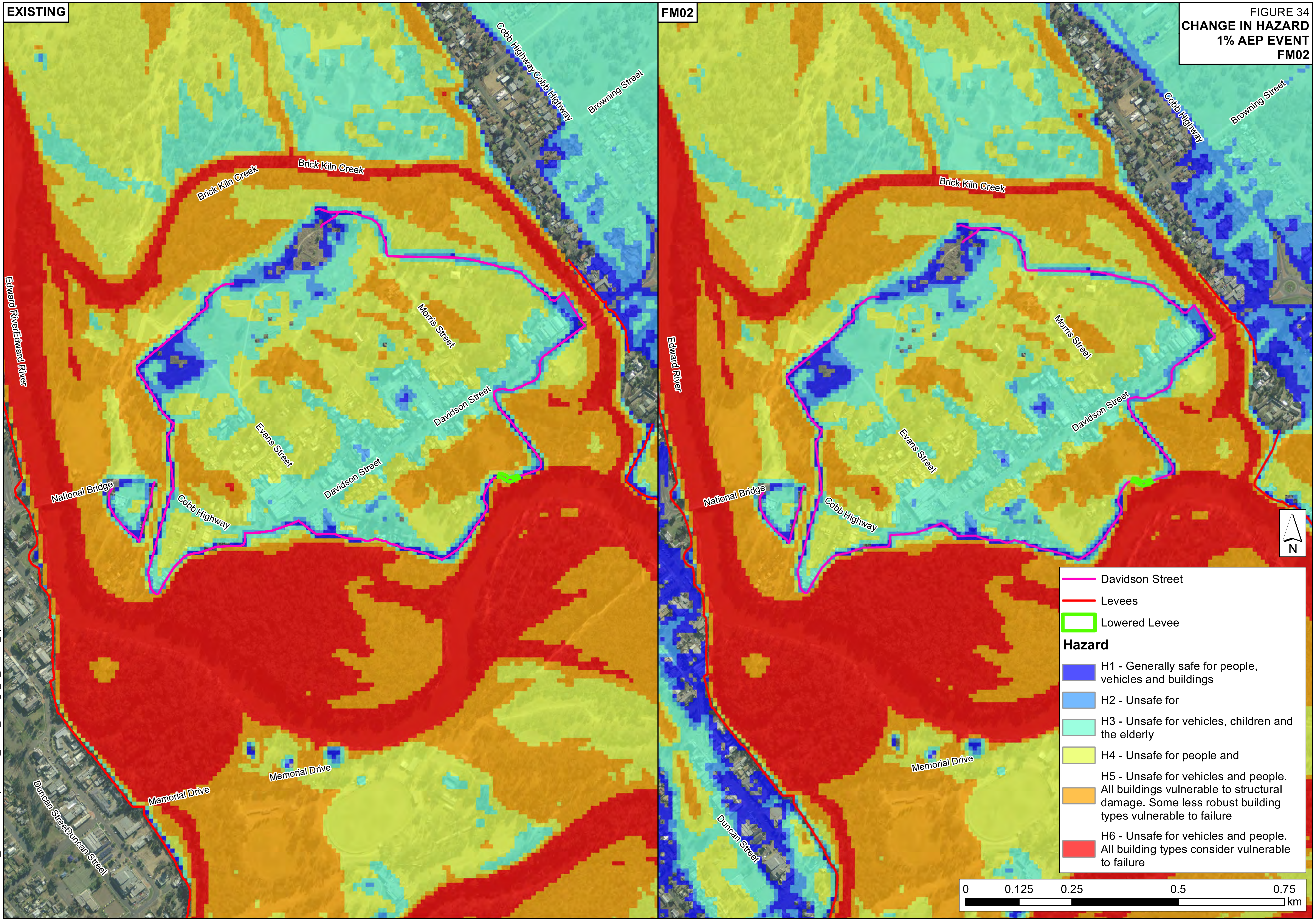


FIGURE 33
CHANGE IN HAZARD
5% AEP EVENT
FM02

J:\Jobs\115027_05\GIS\Arcmaps\FIG33_FM02_Change_in_Hazard_5pAEP.mxd



J:\Jobs\115027_05\GIS\Arcmaps\FIG34_FM02_Change_in_Hazard_1pAEP.mxd

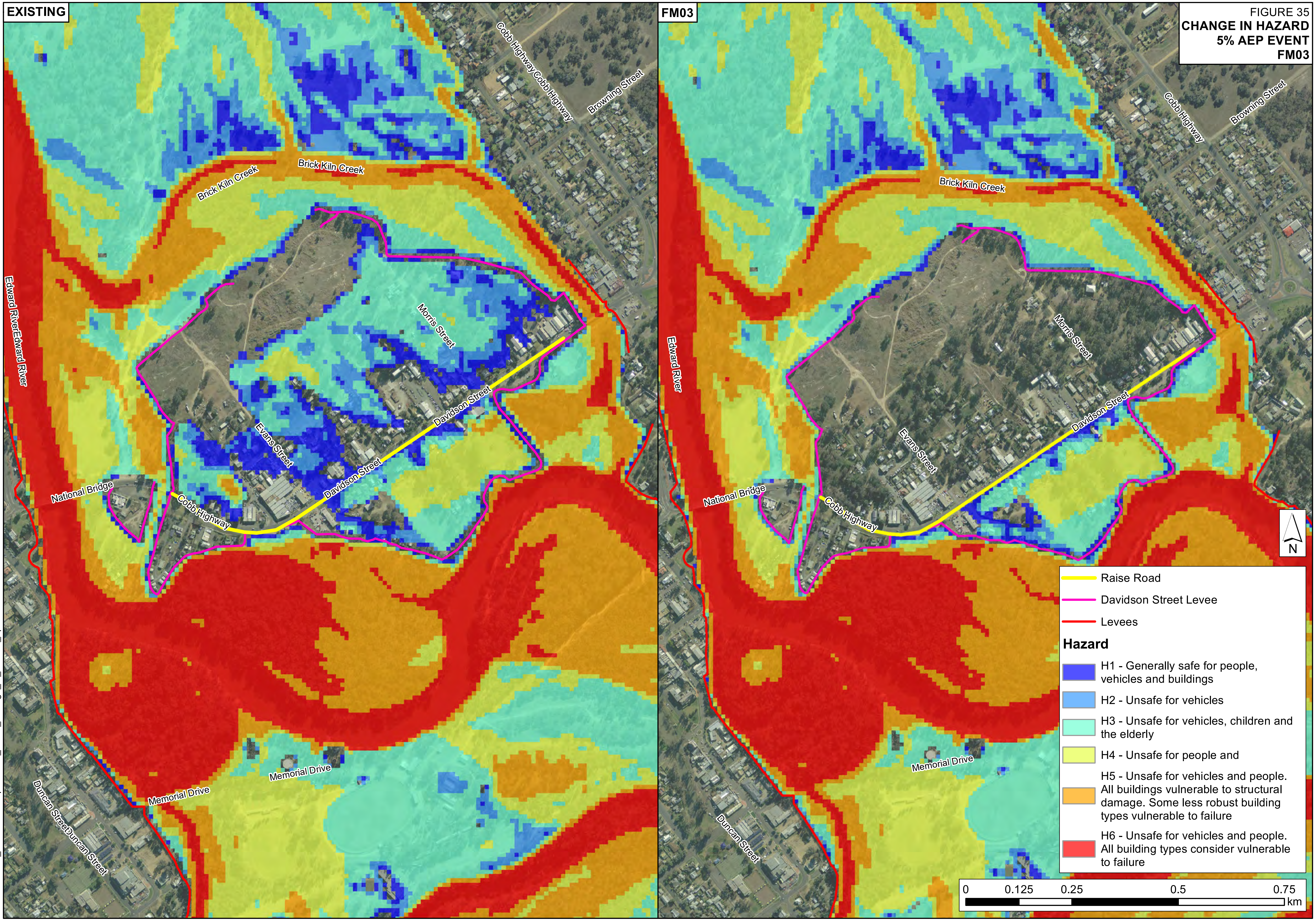


FIGURE 35
CHANGE IN HAZARD
5% AEP EVENT
FM03

J:\Jobs\115027_05\GIS\Arcmaps\FIG35_FM03_Change_in_Hazard_5pAEP.mxd

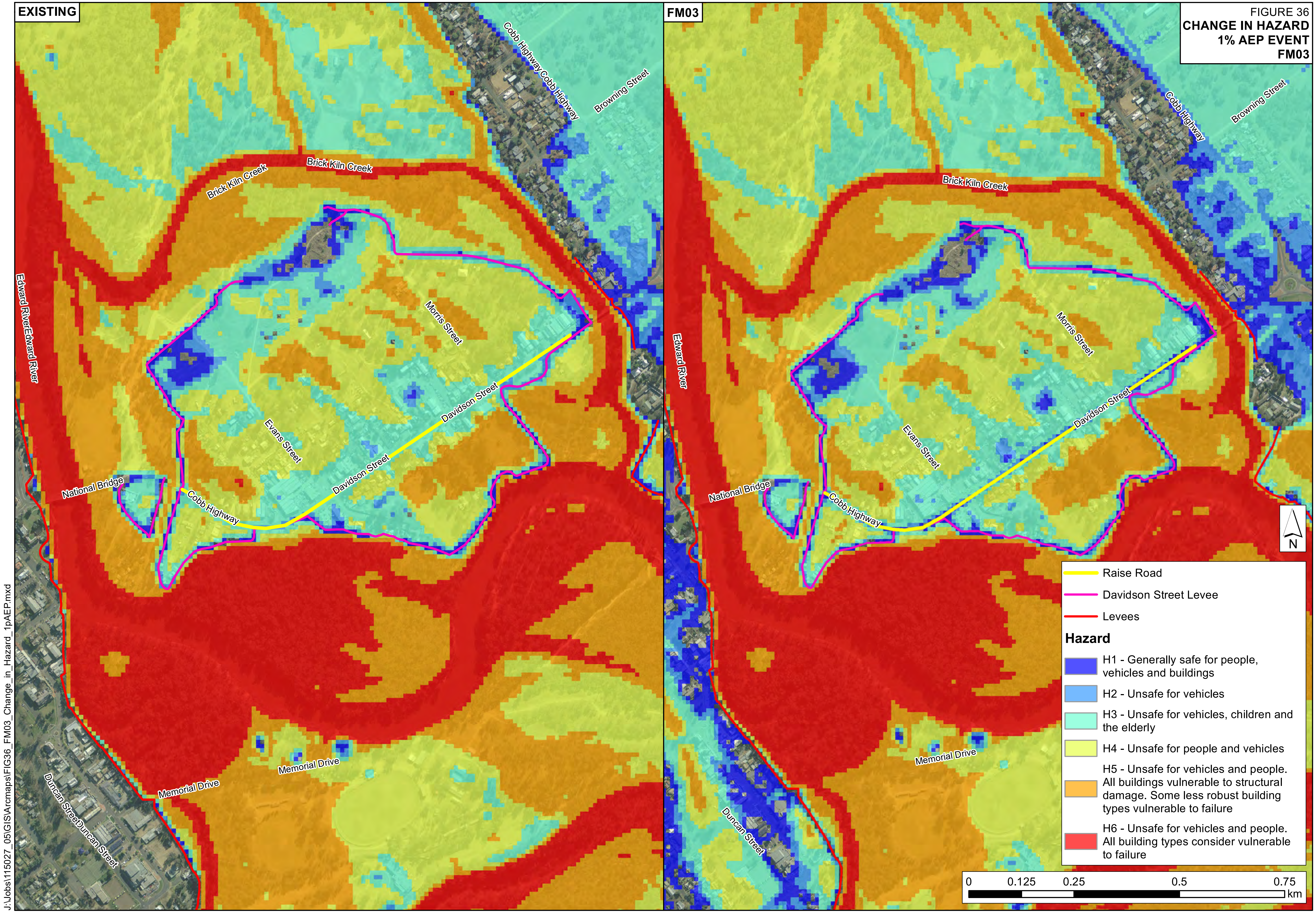
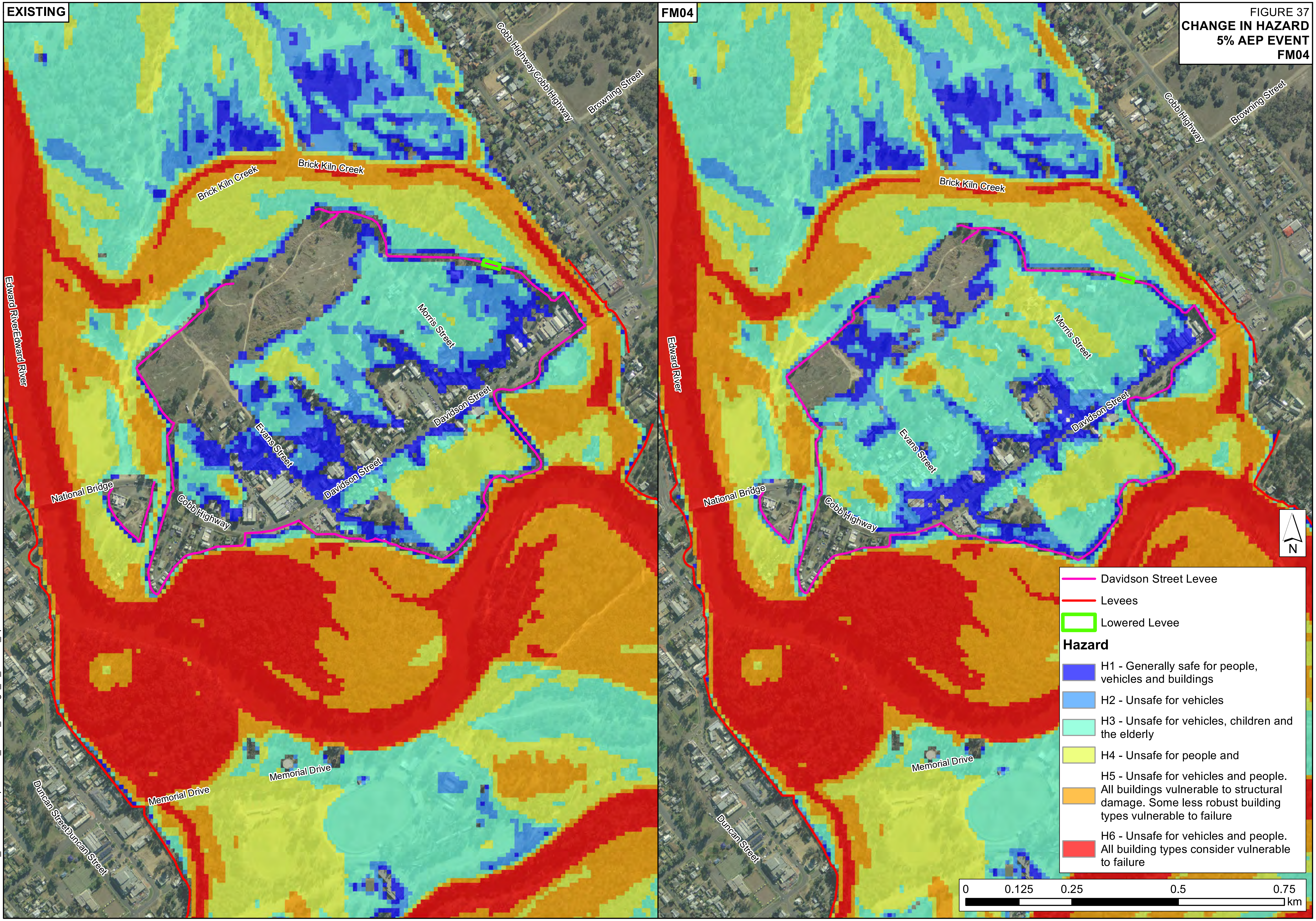


FIGURE 36
CHANGE IN HAZARD
1% AEP EVENT
FM03
EXISTING
FM03
Cobb Highway
Browning Street
Brick Kiln Creek
Edward River
Morris Street
Davidson Street
Evans Street
National Bridge
Memorial Drive
Duncan Street
Raise Road
Davidson Street Levee
Levees
Hazard
H1 - Generally safe for people, vehicles and buildings
H2 - Unsafe for vehicles
H3 - Unsafe for vehicles, children and the elderly
H4 - Unsafe for people and vehicles
H5 - Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust building types vulnerable to failure
H6 - Unsafe for vehicles and people. All building types consider vulnerable to failure
0
0.125
0.25
0.5
0.75
km
N
J:\Jobs\115027_05\GIS\Arcmaps\FIG36_FM03_Change_in_Hazard_1pAEP.mxd



J:\Jobs\115027_05\GIS\Arcmaps\FIG37_FM04_Change_in_Hazard_5pAEP.mxd

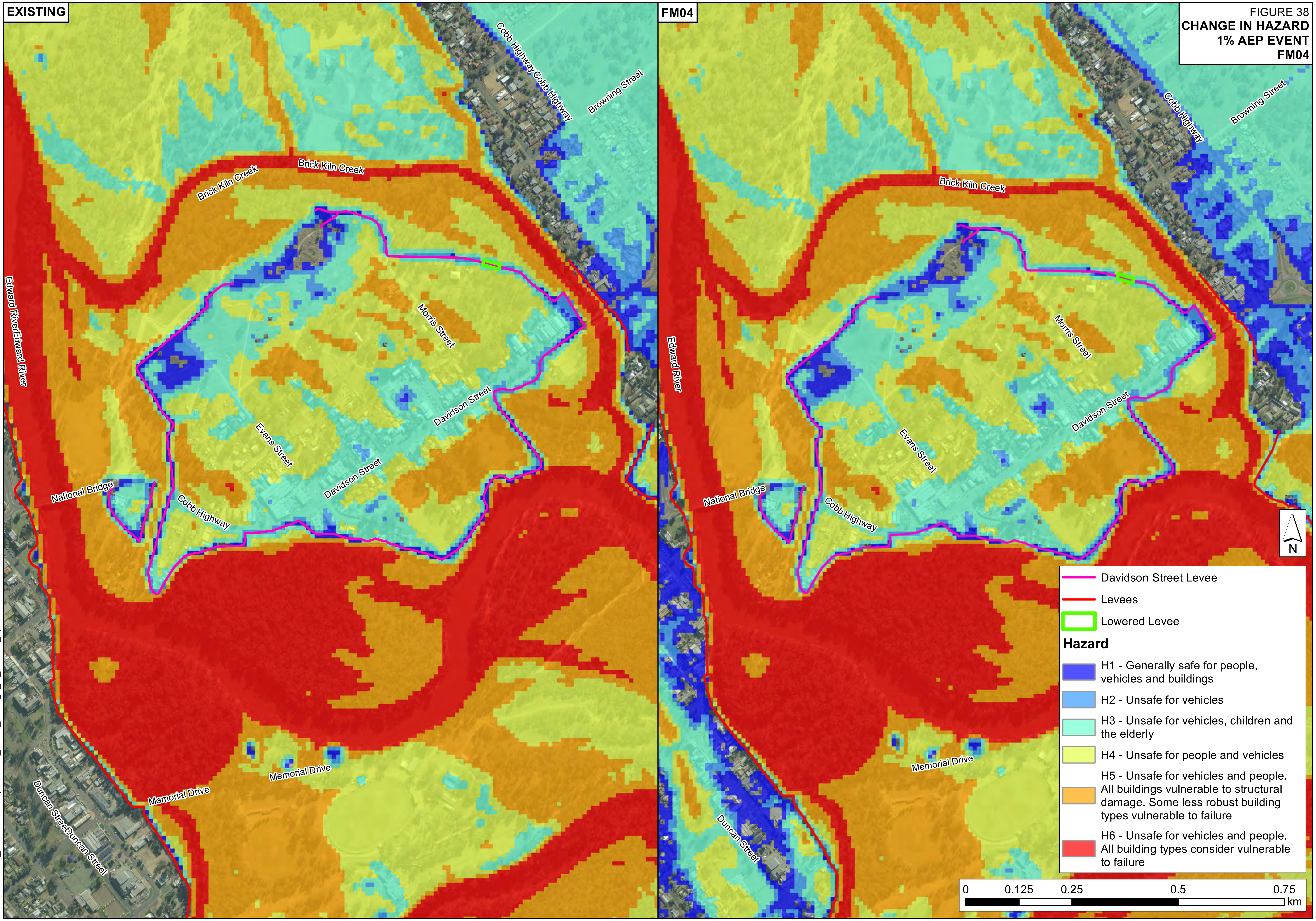
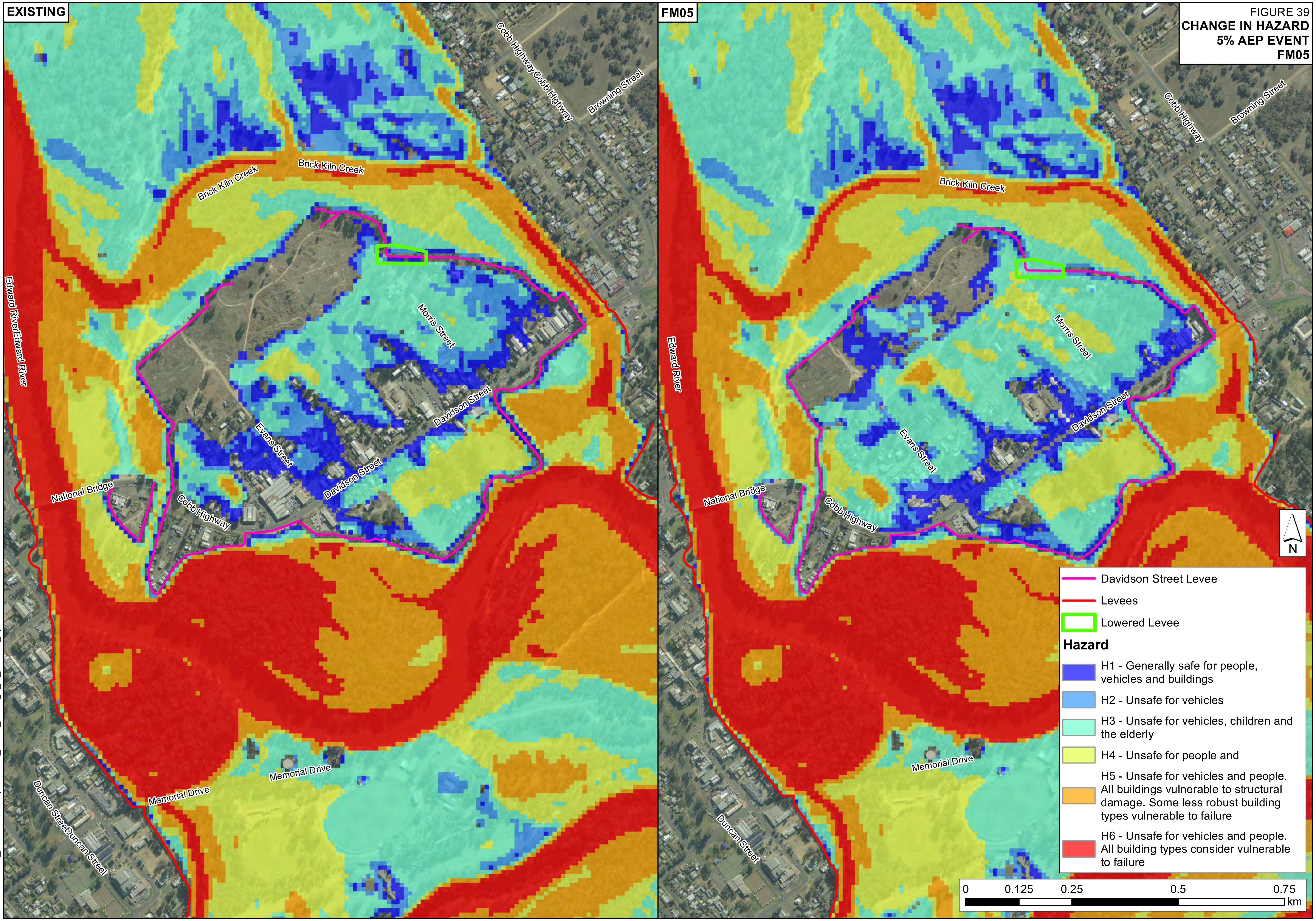
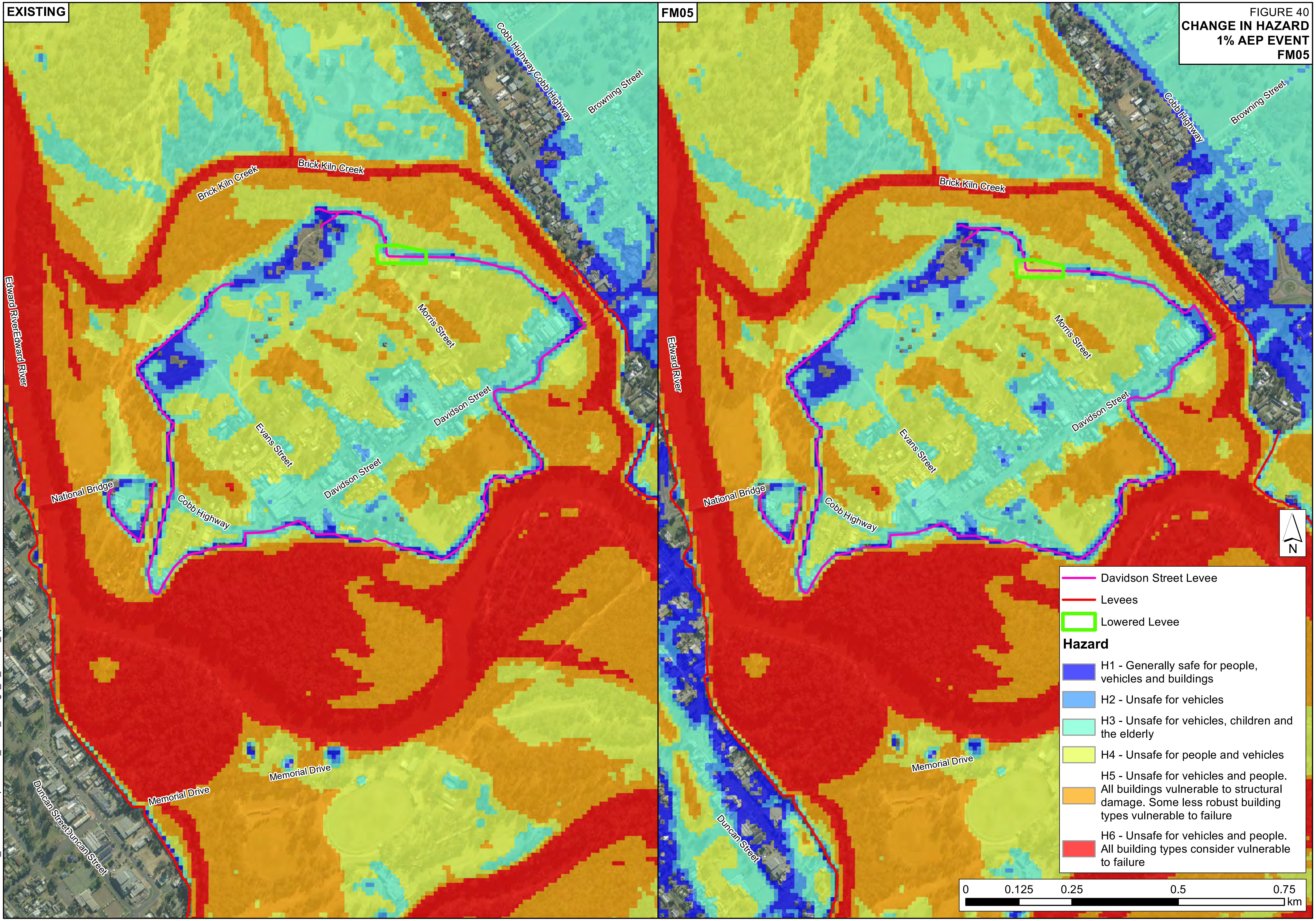


FIGURE 38
CHANGE IN HAZARD
1% AEP EVENT
FM04

J:\Jobs\115027_05\GIS\Arcmaps\FIG38_FM04_Change_in_Hazard_1pAEP.mxd

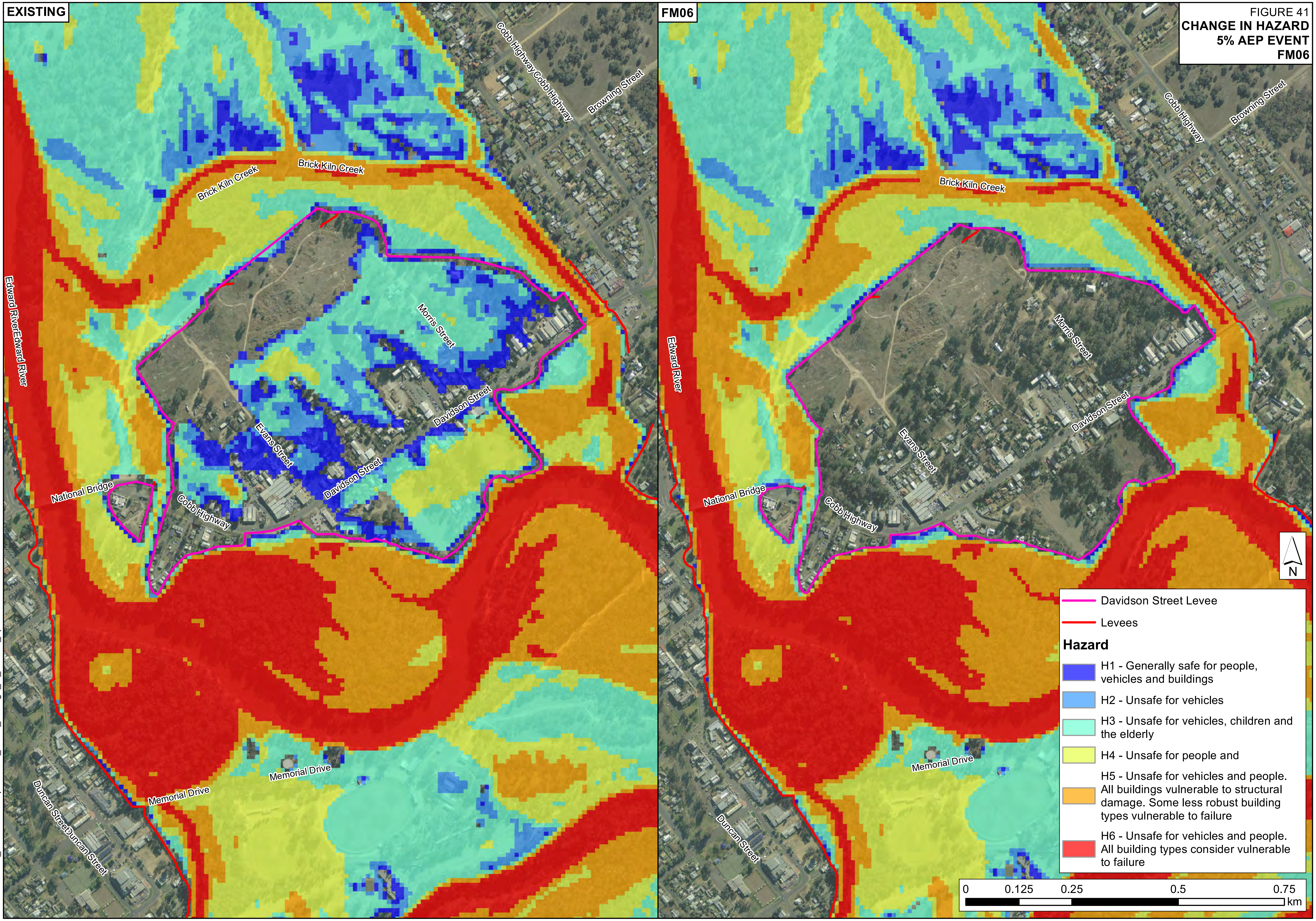


J:\Jobs\115027_05\GIS\Arcmaps\FIG39_FM05_Change_in_Hazard_5pAEP.mxd



J:\Jobs\115027_05\GIS\Arcmaps\FIG40_FM05_Change_in_Hazard_1pAEP.mxd

FIGURE 41
CHANGE IN HAZARD
5% AEP EVENT
FM06

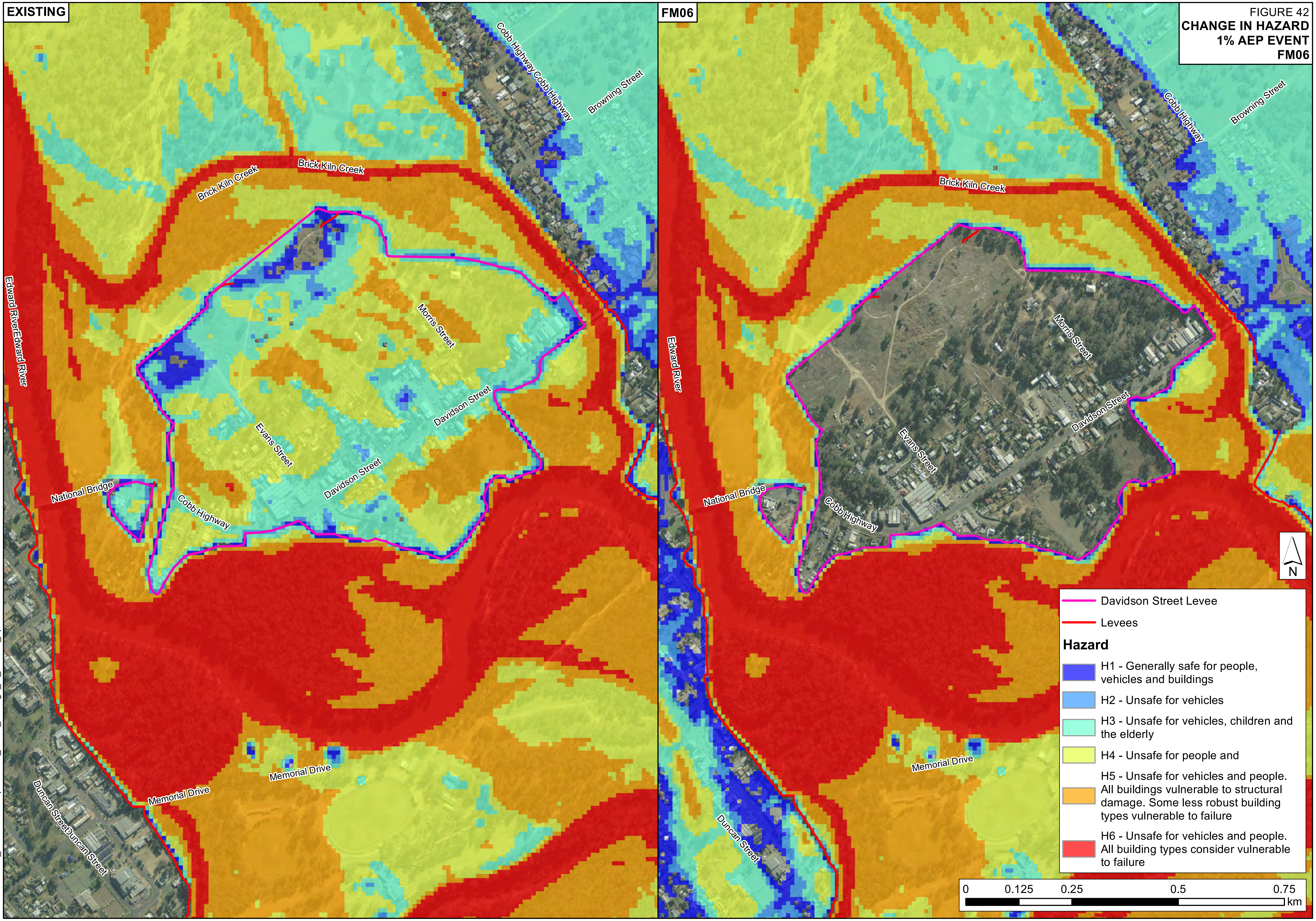


Davidson Street Levee

Levees

Hazard

- H1 - Generally safe for people, vehicles and buildings
- H2 - Unsafe for vehicles
- H3 - Unsafe for vehicles, children and the elderly
- H4 - Unsafe for people and
- H5 - Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust building types vulnerable to failure
- H6 - Unsafe for vehicles and people. All building types consider vulnerable to failure



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Appendix A

APPENDIX A. GLOSSARY

Taken from the Floodplain Development Manual (April 2005 edition)

acid sulfate soils	Are sediments which contain sulfidic mineral pyrite which may become extremely acid following disturbance or drainage as sulfur compounds react when exposed to oxygen to form sulfuric acid. More detailed explanation and definition can be found in the NSW Government Acid Sulfate Soil Manual published by Acid Sulfate Soil Management Advisory Committee.
Annual Exceedance Probability (AEP)	The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 m^3/s has an AEP of 5%, it means that there is a 5% chance (that is one-in-20 chance) of a 500 m^3/s or larger event occurring in any one year (see ARI).
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Average Annual Damage (AAD)	Depending on its size (or severity), each flood will cause a different amount of flood damage to a flood prone area. AAD is the average damage per year that would occur in a nominated development situation from flooding over a very long period of time.
Average Recurrence Interval (ARI)	The long term average number of years between the occurrence of a flood as big as, or larger than, the selected event. For example, floods with a discharge as great as, or greater than, the 20 year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event.
caravan and moveable home parks	Caravans and moveable dwellings are being increasingly used for long-term and permanent accommodation purposes. Standards relating to their siting, design, construction and management can be found in the Regulations under the LG Act.
catchment	The land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.
consent authority	The Council, government agency or person having the function to determine a development application for land use under the EP&A Act. The consent authority is most often the Council, however legislation or an EPI may specify a Minister or public authority (other than a Council), or the Director General of DIPNR, as having the function to determine an application.
development	Is defined in Part 4 of the Environmental Planning and Assessment Act (EP&A Act). **infill development:** refers to the development of vacant blocks of land that are generally surrounded by developed properties and is permissible under the current zoning of the land. Conditions such as minimum floor levels may be imposed on infill development. **new development:** refers to development of a completely different nature to that associated with the former land use. For example, the urban subdivision of an area previously used for rural purposes. New developments involve rezoning and typically require major extensions of existing urban services, such as roads, water supply, sewerage and electric power.

redevelopment: refers to rebuilding in an area. For example, as urban areas age, it may become necessary to demolish and reconstruct buildings on a relatively large scale. Redevelopment generally does not require either rezoning or major extensions to urban services.

disaster plan (DISPLAN) A step by step sequence of previously agreed roles, responsibilities, functions, actions and management arrangements for the conduct of a single or series of connected emergency operations, with the object of ensuring the coordinated response by all agencies having responsibilities and functions in emergencies.

discharge The rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (m^3/s). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving for example, metres per second (m/s).

ecologically sustainable development (ESD) Using, conserving and enhancing natural resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be maintained or increased. A more detailed definition is included in the Local Government Act 1993. The use of sustainability and sustainable in this manual relate to ESD.

effective warning time The time available after receiving advice of an impending flood and before the floodwaters prevent appropriate flood response actions being undertaken. The effective warning time is typically used to move farm equipment, move stock, raise furniture, evacuate people and transport their possessions.

emergency management A range of measures to manage risks to communities and the environment. In the flood context it may include measures to prevent, prepare for, respond to and recover from flooding.

flash flooding Flooding which is sudden and unexpected. It is often caused by sudden local or nearby heavy rainfall. Often defined as flooding which peaks within six hours of the causative rain.

flood Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.

flood awareness Flood awareness is an appreciation of the likely effects of flooding and a knowledge of the relevant flood warning, response and evacuation procedures.

flood education Flood education seeks to provide information to raise awareness of the flood problem so as to enable individuals to understand how to manage themselves an their property in response to flood warnings and in a flood event. It invokes a state of flood readiness.

flood fringe areas The remaining area of flood prone land after floodway and flood storage areas have been defined.

flood liable land Is synonymous with flood prone land (i.e. land susceptible to flooding by the probable maximum flood (PMF) event). Note that the term flood liable land covers the whole of the floodplain, not just that part below the flood planning level (see flood planning area).

flood mitigation standard The average recurrence interval of the flood, selected as part of the floodplain risk

	management process that forms the basis for physical works to modify the impacts of flooding.
floodplain	Area of land which is subject to inundation by floods up to and including the probable maximum flood event, that is, flood prone land.
floodplain risk management options	The measures that might be feasible for the management of a particular area of the floodplain. Preparation of a floodplain risk management plan requires a detailed evaluation of floodplain risk management options.
floodplain risk management plan	A management plan developed in accordance with the principles and guidelines in this manual. Usually includes both written and diagrammetic information describing how particular areas of flood prone land are to be used and managed to achieve defined objectives.
flood plan (local)	A sub-plan of a disaster plan that deals specifically with flooding. They can exist at State, Division and local levels. Local flood plans are prepared under the leadership of the State Emergency Service.
flood planning area	The area of land below the flood planning level and thus subject to flood related development controls. The concept of flood planning area generally supersedes the Aflood liable land@ concept in the 1986 Manual.
Flood Planning Levels (FPLs)	FPL=s are the combinations of flood levels (derived from significant historical flood events or floods of specific AEPs) and freeboards selected for floodplain risk management purposes, as determined in management studies and incorporated in management plans. FPLs supersede the Astandard flood event@ in the 1986 manual.
flood proofing	A combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding, to reduce or eliminate flood damages.
flood prone land	Is land susceptible to flooding by the Probable Maximum Flood (PMF) event. Flood prone land is synonymous with flood liable land.
flood readiness	Flood readiness is an ability to react within the effective warning time.
flood risk	Potential danger to personal safety and potential damage to property resulting from flooding. The degree of risk varies with circumstances across the full range of floods. Flood risk in this manual is divided into 3 types, existing, future and continuing risks. They are described below. **existing flood risk:** the risk a community is exposed to as a result of its location on the floodplain. **future flood risk:** the risk a community may be exposed to as a result of new development on the floodplain. **continuing flood risk:** the risk a community is exposed to after floodplain risk management measures have been implemented. For a town protected by levees, the continuing flood risk is the consequences of the levees being overtopped. For an area without any floodplain risk management measures, the continuing flood risk is simply the existence of its flood exposure.
flood storage areas	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can

increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas.

floodway areas Those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flows, or a significant increase in flood levels.

freeboard Freeboard provides reasonable certainty that the risk exposure selected in deciding on a particular flood chosen as the basis for the FPL is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. Freeboard is included in the flood planning level.

habitable room **in a residential situation:** a living or working area, such as a lounge room, dining room, rumpus room, kitchen, bedroom or workroom.

in an industrial or commercial situation: an area used for offices or to store valuable possessions susceptible to flood damage in the event of a flood.

hazard A source of potential harm or a situation with a potential to cause loss. In relation to this manual the hazard is flooding which has the potential to cause damage to the community. Definitions of high and low hazard categories are provided in the Manual.

hydraulics Term given to the study of water flow in waterways; in particular, the evaluation of flow parameters such as water level and velocity.

hydrograph A graph which shows how the discharge or stage/flood level at any particular location varies with time during a flood.

hydrology Term given to the study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.

local overland flooding Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.

local drainage Are smaller scale problems in urban areas. They are outside the definition of major drainage in this glossary.

mainstream flooding Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.

major drainage Councils have discretion in determining whether urban drainage problems are associated with major or local drainage. For the purpose of this manual major drainage involves:

- the floodplains of original watercourses (which may now be piped, channelised or diverted), or sloping areas where overland flows develop along alternative paths once system capacity is exceeded; and/or

- water depths generally in excess of 0.3 m (in the major system design storm as defined in the current version of Australian Rainfall and Runoff). These conditions may result in danger to personal safety and property damage to both premises and vehicles; and/or

- major overland flow paths through developed areas outside of defined drainage reserves; and/or
- the potential to affect a number of buildings along the major flow path.

mathematical/computer models The mathematical representation of the physical processes involved in runoff generation and stream flow. These models are often run on computers due to the complexity of the mathematical relationships between runoff, stream flow and the distribution of flows across the floodplain.

merit approach The merit approach weighs social, economic, ecological and cultural impacts of land use options for different flood prone areas together with flood damage, hazard and behaviour implications, and environmental protection and well being of the State=s rivers and floodplains.

The merit approach operates at two levels. At the strategic level it allows for the consideration of social, economic, ecological, cultural and flooding issues to determine strategies for the management of future flood risk which are formulated into Council plans, policy and EPIs. At a site specific level, it involves consideration of the best way of conditioning development allowable under the floodplain risk management plan, local floodplain risk management policy and EPIs.

minor, moderate and major flooding Both the State Emergency Service and the Bureau of Meteorology use the following definitions in flood warnings to give a general indication of the types of problems expected with a flood:

minor flooding: causes inconvenience such as closing of minor roads and the submergence of low level bridges. The lower limit of this class of flooding on the reference gauge is the initial flood level at which landholders and townspeople begin to be flooded.

moderate flooding: low-lying areas are inundated requiring removal of stock and/or evacuation of some houses. Main traffic routes may be covered.

major flooding: appreciable urban areas are flooded and/or extensive rural areas are flooded. Properties, villages and towns can be isolated.

modification measures Measures that modify either the flood, the property or the response to flooding. Examples are indicated in Table 2.1 with further discussion in the Manual.

peak discharge The maximum discharge occurring during a flood event.

Probable Maximum Flood (PMF) The PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain. The extent, nature and potential consequences of flooding associated with a range of events rarer than the flood used for designing mitigation works and controlling development, up to and including the PMF event should be addressed in a floodplain risk management study.

Probable Maximum Precipitation (PMP) The PMP is the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation, 1986). It is the primary input to PMF

	estimation.
probability	A statistical measure of the expected chance of flooding (see AEP).
risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the manual it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
runoff	The amount of rainfall which actually ends up as streamflow, also known as rainfall excess.
stage	Equivalent to Awater level@. Both are measured with reference to a specified datum.
stage hydrograph	A graph that shows how the water level at a particular location changes with time during a flood. It must be referenced to a particular datum.
survey plan	A plan prepared by a registered surveyor.
water surface profile	A graph showing the flood stage at any given location along a watercourse at a particular time.
wind fetch	The horizontal distance in the direction of wind over which wind waves are generated.

Appendix B

Memorial Drive Oval

Davidson Street Bridge

Edwards River Oval