Final Report

Flood Report for Kooyong Park Planning Proposal

EDM Group

June 2017

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30 June 2017

Peter O'Dwyer
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Dear Peter

Flood Report for Kooyong Park Planning Proposal

Water Technology is pleased to present the final flood report for your review prior to submission to Council as part of the planning proposal relating to the land known as Kooyong Park, located to the east of Moama and bounded by Moama Street, Holmes Street and Old Deniliquin Road.

If you have any queries regarding this report please contact me directly.

Yours sincerely

Ben Tate
Principal Engineer

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WATER TECHNOLOGY

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1 INTRODUCTION

This report documents a flood assessment of existing conditions flood behaviour for a 1% AEP flood event on the Murray River system at Kooyong Park, Moama, and the impacts of further developing the rural ring levees surrounding the property to an urban levee standard.

Two-dimensional hydraulic modelling was undertaken to assist with characterising the impact of flood behaviour across the Murray River Floodplain including the Kanyapella basin to approximately 7 km downstream of Echuca/Moama.

The flood modelling results were assessed against appropriate NSW planning policy and best practise floodplain management principles, providing information to support the application for the proposed development.

2 BACKGROUND

The proposed development site is located at Moama, east of the railway line and 500 m north of the Murray River, bounded by Holmes Street to the south, Moama Street to the west and Old Deniliquin Road to the east.

Flood hydrology was available through the 1997 Echuca Moama Flood Study[1], with the Moama Floodplain Management Study[2] completed in 2001, from which 1% AEP flows were adopted for this study. The previous studies estimated 1% AEP flows and levels for the Echuca wharf gauge site as well as flood contours extending across the floodplain. Flood level contours were available for the 10%, 5%, 2%, 1% and 0.5% AEP flood events. A one-dimensional hydraulic model was used to estimate flood levels. There is a Flood Planning Area over a large section of the land north of the NSW border. Additionally, there are Land Subject to Inundation Overlays (LSIO) and Floodway Overlays on the Victorian side of the border.

The catchment areas of the Murray River, Goulburn River and the Campaspe River upstream of Moama are approximately 40,000 km^2, 18,000 km^2 and 4,000 km^2 respectively. The catchments are predominantly agricultural with portions of forested land in the upper catchment.

A new two-dimensional hydraulic model was developed for this study to assist with characterising flood behaviour across the floodplain. Within the hydraulic model area there are two major forested areas, the Barmah National Park and the Kanyapella Game Reserve. The hydraulic model covers an area of 325 km^2 extending from the Kanyapella Basin to downstream of Echuca and Moama and is displayed in Figure 2-1. The model includes inflows from the Murray River, the Goulburn River and the Campaspe River.

The model includes details of the known levees in the area, including a ring levee that surrounds the subject site. The two-dimensional (2D) hydraulic model developed for this investigation is a major improvement on the old one dimensional (1D) model developed for the 1997 study. It allows the model to describe the detailed flow patterns across the floodplain, including the variable depth, velocity and flow directions along the Murray River and around physical features like bridges, culverts, roads, railway lines and levees. Figure 2-2 shows the site location and the existing levee locations and heights. The new two-dimensional hydraulic model was used primarily to categorise the flood hazard and flood function according to the NSW Floodplain Development Manual[3]. The flood contours developed in the Echuca Moama Flood Study, were used to assess the development against the flood level criteria, as required by the Murray Local Environmental Plan[4] and the Murray Development Control Plan[5].

[1] Sinclair Knight Merz (1997), *Echuca Moama Flood Study,* Shire of Campaspe, Shire of Murray
[2] Sinclair Knight Merz (2001), *Moama Floodplain Management Study, Shire of Murray*
[3] Department of Infrastructure, Planning and Natural Resources (2005), *Floodplain Development Manual: the management of flood liable land*
[4] Murray Shire Council (2011), *Murray Local Environmental Plan 2011, under the Environmental Planning and Assessment Act 1979*
[5] Murray Shire Council (2012), *Murray Development Control Plan 2012*

FIGURE 2-1 STUDY AREA

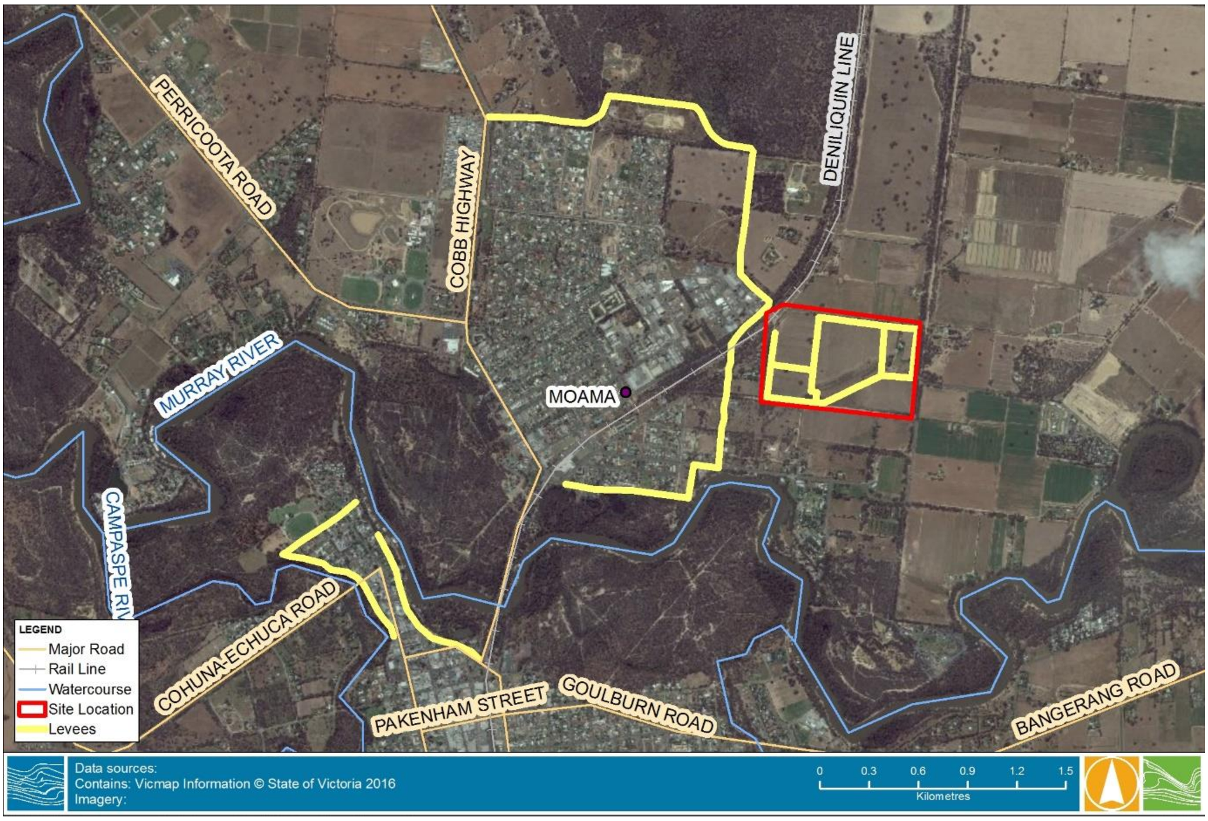


FIGURE 2-2 PROPOSED DEVELOPMENT SITE

3 HYDROLOGY AND HYDRAULIC MODELLING

The Murray River at Echuca and Moama has been the subject of several past flood investigations. The most relevant investigation in recent times was Echuca Moama Flood Study. The Flood Study details hydrological and hydraulic modelling of the Murray River, Goulburn River and Campaspe River upstream of Echuca and Moama. It is noted that more recent investigations for the Echuca-Moama bridge used the past hydrology from the Echuca Moama Flood Study also.

The Echuca Moama Flood Study developed a one-dimensional hydraulic model of the Murray, Goulburn and Campaspe Rivers, and used a combination of previous hydrology for the Murray and the Goulburn Rivers and new hydrology on the Campaspe River as inflow boundaries to the hydraulic model. The study undertook a detailed investigation into the likely concurrence of flows from the three rivers and the impact on flood levels at Echuca and Moama. The design hydrographs for the Murray River at Lower Moira, the Goulburn River at Yambuna and the Campaspe River at Echuca are shown in Figure 3-2, Figure 3-3 and Figure 3-4 respectively.

Whilst the one-dimensional hydraulic modelling approach from early studies has provided accurate information with regards to design flood levels, newer two-dimensional hydraulic modelling techniques provide more accurate information with regards to defining flood hazard and flood function. The previous design flow estimates on all three rivers remains the most detailed investigation completed into design hydrology at Echuca and Moama. As discussed above, these previous hydrology estimates were also adopted for recent investigations into the Echuca to Moama bridge crossing. The 1% AEP design flows extracted from the Echuca Moama Flood Study at each of the upstream locations used within this investigation are shown in Figure 3-1. As suggested in the Echuca Moama Flood Study, a lag of 20 hours was applied to the Campaspe River at Rochester to represent the design hydrograph at Echuca.

This investigation adopted the design hydrology from the Echuca Moama Flood Study as inflow boundaries into a new two-dimensional hydraulic model developed specifically for this investigation.

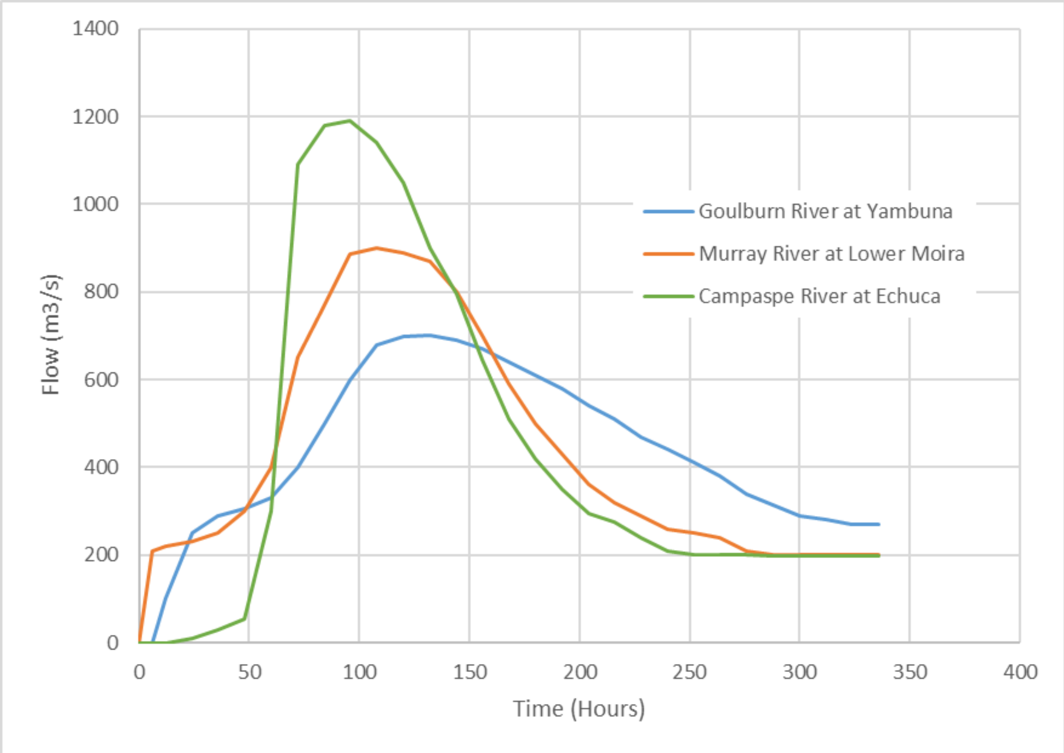


FIGURE 3-1 1% AEP DESIGN FLOWS EXTRACTED FROM ECHUCA MOAMA FLOOD STUDY[1]

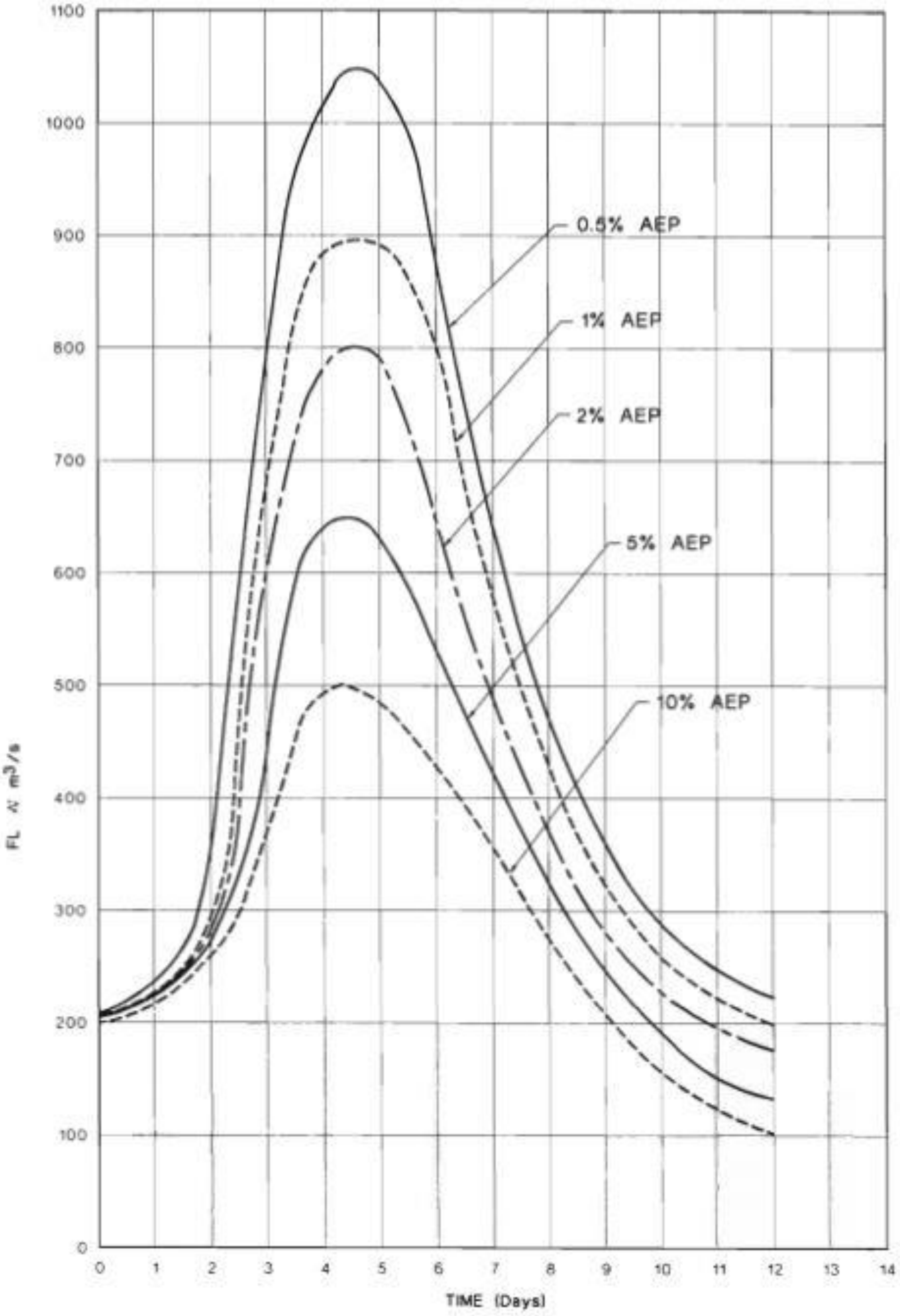


FIGURE 3-2 DESIGN FLOWS FOR MURRAY RIVER AT LOWER MOIRA[1]

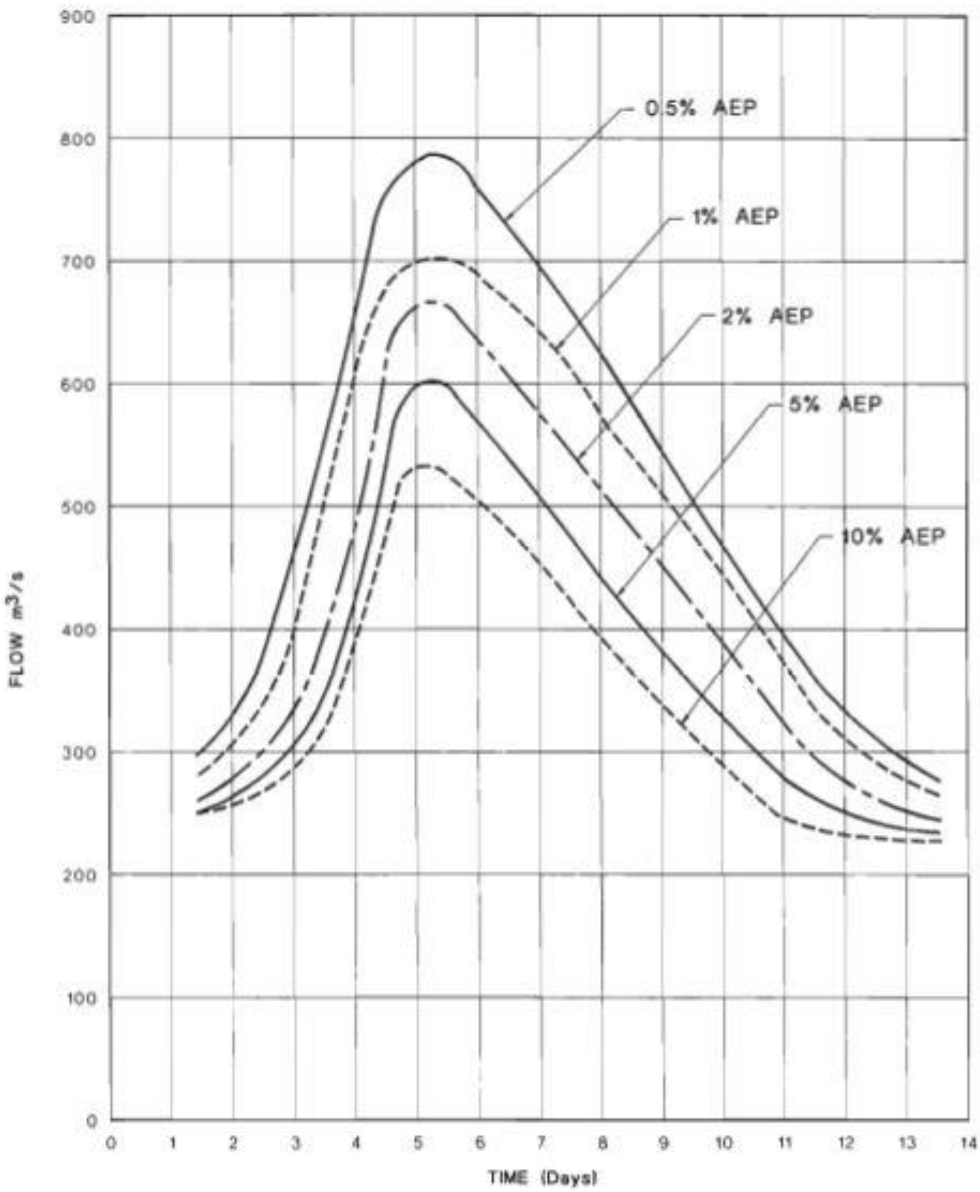


FIGURE 3-3 DESIGN FLOWS FOR GOULBURN RIVER AT YAMBUNA[1]

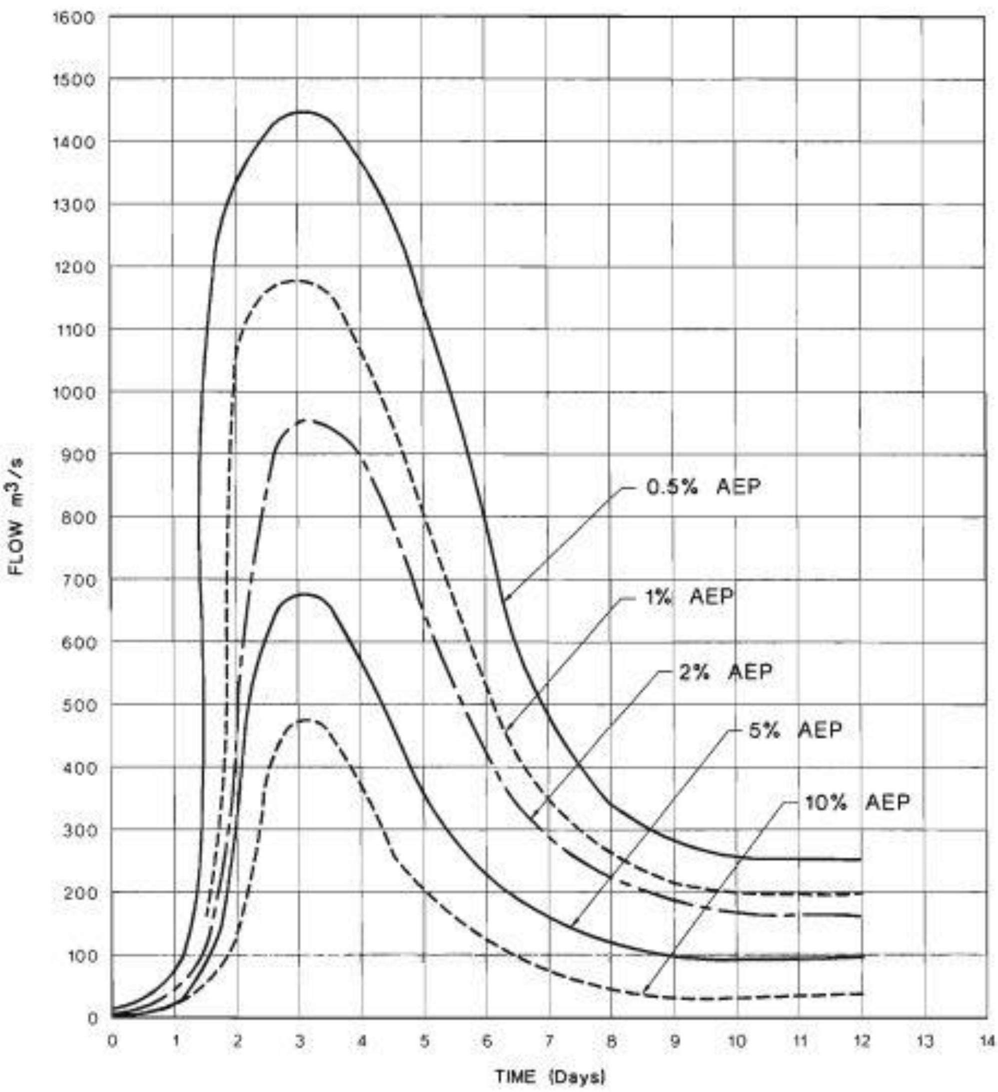


FIGURE 3-4 DESIGN FLOWS FOR CAMPASPE RIVER AT ROCHESTER[1]

A two-dimensional TUFLOW model was developed which utilised existing topographic datasets available from various sources. Four LiDAR sets that covered the study area were used to develop a mosaic of the topography.

- Floodplains LiDAR from Goulburn Broken CMA
- Floodplains 3 LiDAR from Goulburn Broken CMA
- MDBC 2001 LiDAR from the Murray Darling Basin Authority
- Floodplains LiDAR from the North Central CMA

The Floodplains 3 dataset was used in preference as it best represented the river channels. LiDAR is an aerial laser survey technique that allows accurate survey of large areas. The lasers used to collect LiDAR data do not penetrate water with high sediment content. This results in the LiDAR not surveying the bathymetry below the waterline. To ensure the capacity along the Murray River was being accurately represented, the Murray

River channel was stamped in to the model using bathymetry survey extracted from State Rivers Plans from the 1980s. The Goulburn River was also stamped in based on bathymetry developed for a previous model of the Goulburn River developed by Water Technology for Goulburn Broken CMA. An example of the difference in the Goulburn River cross-section using raw LiDAR and with the developed bathymetry is shown in Figure 3-5.

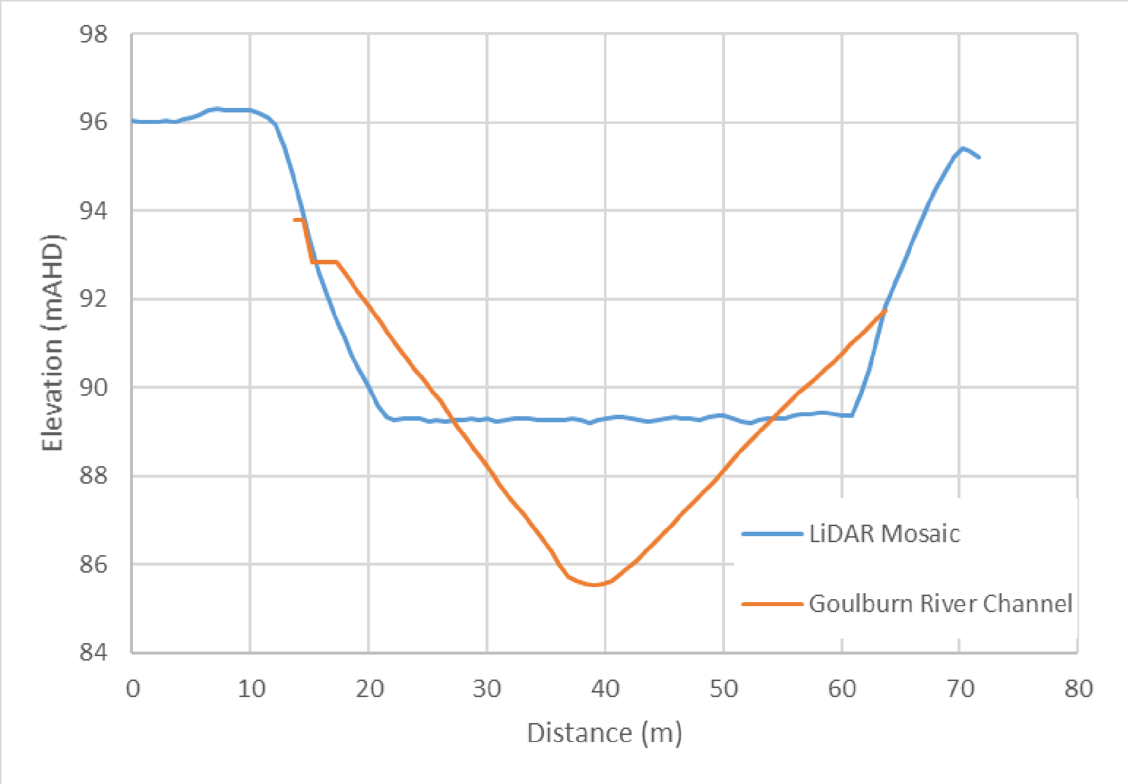


FIGURE 3-5 GOULBURN RIVER CHANNEL COMPARISON

Four key levees were built into the model to ensure they were being represented accurately in the model topography. The Echuca levee height and alignments were provided by the Campaspe Shire Council. Two major levees, one along the Murray River and one along the Campaspe River, were included. The Moama town levee alignment was sourced from the Murray Shire Development Control Plan with levels estimated by comparing the LiDAR to the levee heights outlined in the Moama Floodplain Study[2]. These crest levels were later checked against a plan received from the Murray River Council and were almost identical. Levee locations and elevations around the Kooyong Park site were provided by the landowner.

The extent of the TUFLOW model with the underlying topography and included levees is shown in Figure 3-6. A 30x30 m resolution grid was adopted for the model, covering approximately 325 km^2.

The Manning's 'n' roughness parameter has important effects on flood velocities, flow paths, flood depths and extents. Manning's 'n' roughness values were derived from aerial photography and appropriate industry standard literature such as Australian Rainfall and Runoff, Chow (1959), etc. The final Manning's 'n' roughness is shown in Figure 3-7. Given the broad flat floodplain and slow velocity, the flood levels on the floodplain are likely to be relatively insensitive to the Mannings 'n' roughness.

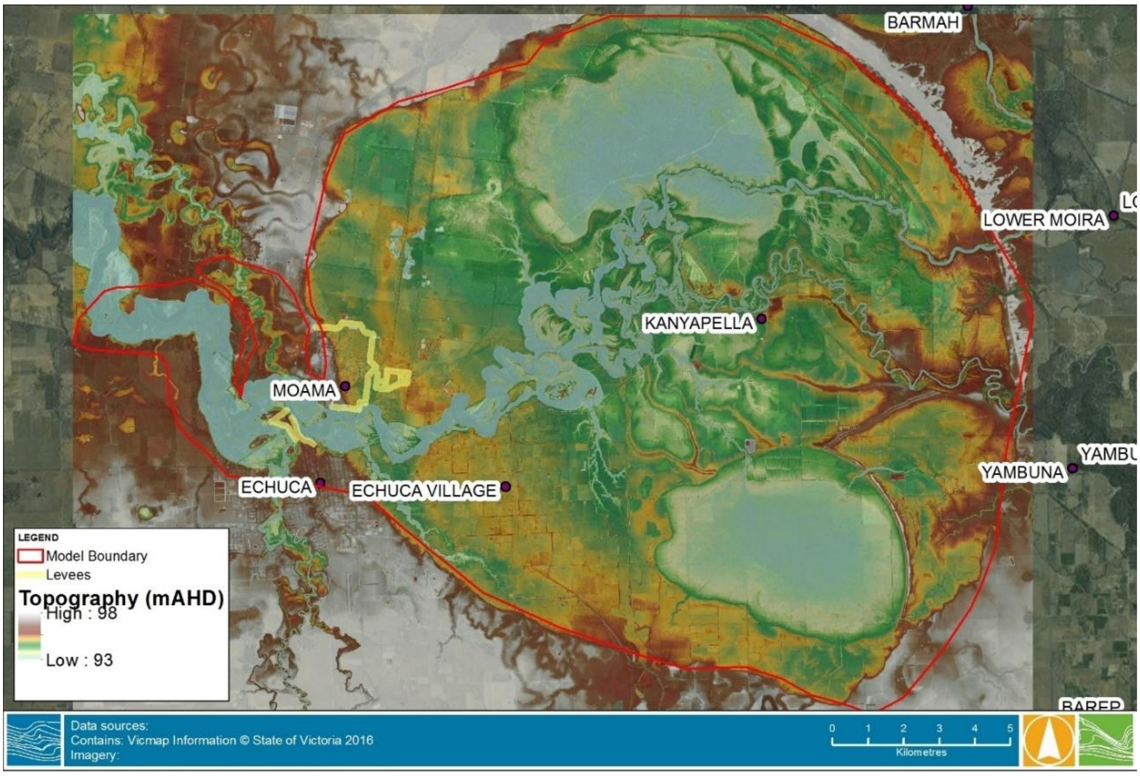
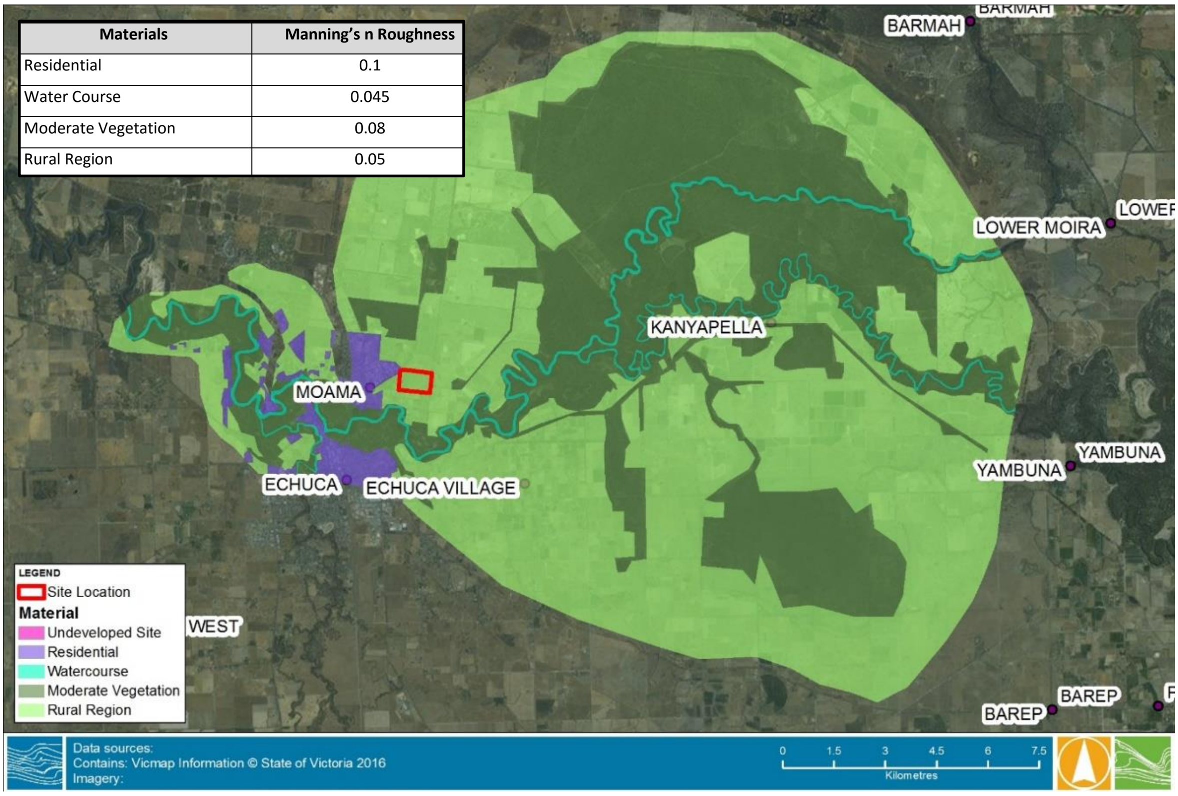


FIGURE 3-6 MODEL TOPOGRAPHY AND LEVEE ALIGNMENTS



Materials	Manning's n Roughness
Residential	0.1
Water Course	0.045
Moderate Vegetation	0.08
Rural Region	0.05

FIGURE 3-7 MANNING'S 'N' ROUGHNESS MAP

3.1 Developed Site

The hydraulic model was modified to represent developed conditions to determine the flood impacts of development on the surrounding area. The current rural levees surrounding the site were upgraded as per the design supplied by the EDM Group. A ring levee designed to protect the site from the 1% AEP flood event was modelled, the alignment of this, with existing levees still in place, is shown in Figure 3-8. The developed levee crest was set well above the flood level to ensure it was not overtopped. In this developed scenario, the internal levees are not required and do not offer any additional protection. These would most likely be removed to accommodate the proposed development layout.

Roughness values for the developed case were not altered to incorporate increased urban development. The levee protects the site from flood waters and therefore the roughness within the levee is not important to the hydraulic model results.

FIGURE 3-8 PROPOSED DEVELOPMENT LEVEE ALIGNMENT

4 FLOOD MODELLING RESULTS

4.1 Existing Conditions

The 1% AEP flood event was modelled using a 30x30 m grid cell resolution using the two-dimensional hydraulic modelling software TUFLOW. The model completed in this investigation assumed 1% AEP inputs on all three rivers. This assumption is conservative, and analysing the results of the 1% AEP flood levels against the adopted 1% AEP design contours from the Echuca Moama Flood Study shows that the new two-dimensional modelling with the conservative hydrology assumption over estimates the flood levels. This could be revised with different assumptions for the design flows. Water Technology have adopted a pragmatic approach to this investigation. The adopted design flood elevation contours were used and subtracted from the latest aerial laser survey of the floodplain to develop a detailed depth map of the 1% AEP flood event.

The two-dimensional hydraulic model was then used to provide information regarding flow velocity and timing of the flood wave as it progresses across the floodplain, this provides a better understanding of flood hazard and flood function.

Water surface contour levels for the 1% AEP flood event, developed during the Echuca Moama Flood Study[1], are shown in Figure 4-1. The corresponding depth grid developed by subtracting the 1% AEP flood level contours from the aerial laser survey is provided in Figure 4-2. It is noted that the 1% AEP flood level contours provided in the Echuca Moama Flood Study (1997) and the Moama Floodplain Management Study (2001) are slightly different. The latest study in 2001 was used for the adoption of the Flood Planning Level. Figure 4-2 shows that the flood extent for the 1% AEP event as provided in the Moama Floodplain Management Study (2001) is slightly different to that generated using the currently available LiDAR. This is a bit different along the northern extent of the floodplain and along the levee alignment to the north-east of town. This is because of the limited available topographic survey used at the time of the 2001 study and because the current levee alignment slightly differs from that proposed in Figure 1.1 of the Moama Floodplain Management Study (2001).

The Moama Floodplain Management Study (2001) estimated the 1% AEP flood levels at the proposed development site as ranging between 95.58 at Old Deniliquin Road to 95.50 m AHD closer to Moama Street. Depths surrounding the site to the north and east are generally below 0.5 m, with depths to the south and west of the site generally between 0.5 and 1 m deep. A low depression on the south-western corner of the site running back to the Murray River is deeper, with depths to 1.3 m.

> *The Echuca Moama Flood Study (1997) 1% AEP flood contours were used to develop a flood depth map of the study area using the latest LiDAR information.*
>
> *The Moama Floodplain Management Study (2001) 1% AEP flood levels at the proposed development site were used as the basis for determining the Flood Planning Level for the site (1% AEP flood level plus 0.5 m).*

By adopting the flood levels from the previous studies of Moama, this investigation ensures that the flood levels used are entirely consistent with those used to make past planning decisions within Moama. An attempt was made to compare these flood levels to those generated for the Echuca-Moama Bridge Environmental Effects Statement (2015), however flood levels were only quoted in that report at locations downstream of the mapping produced in this investigation.

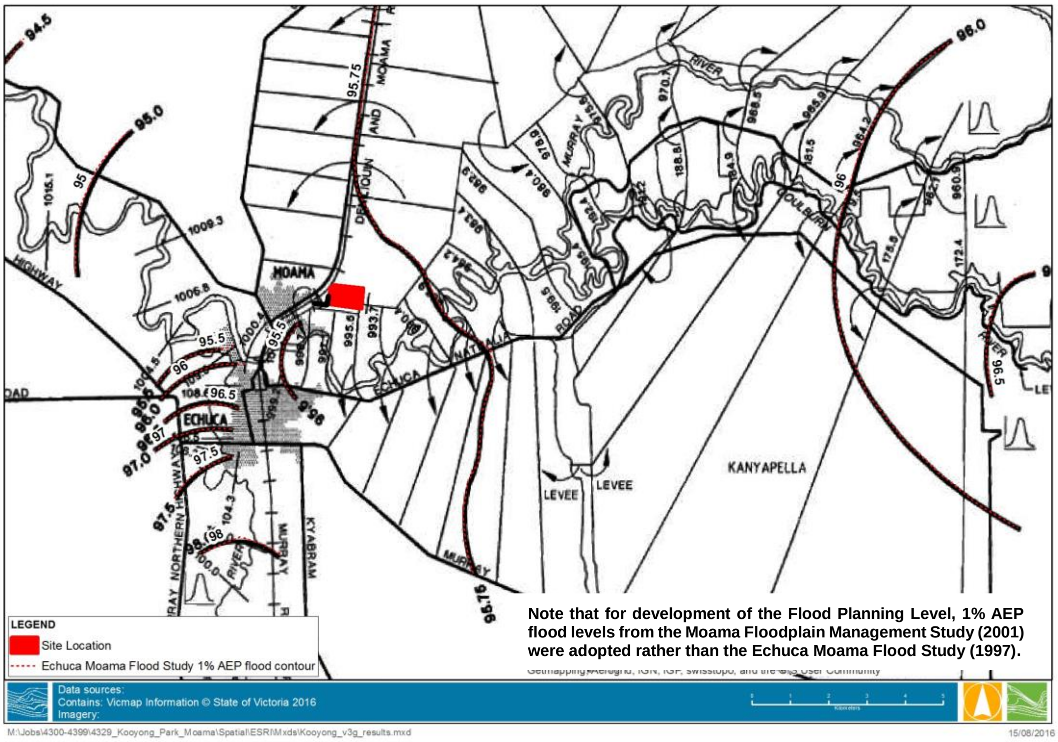


FIGURE 4-1 ECHUCA-MOAMA FLOOD STUDY (1997) 1% AEP CONTOURS USED IN THIS INVESTIGATION

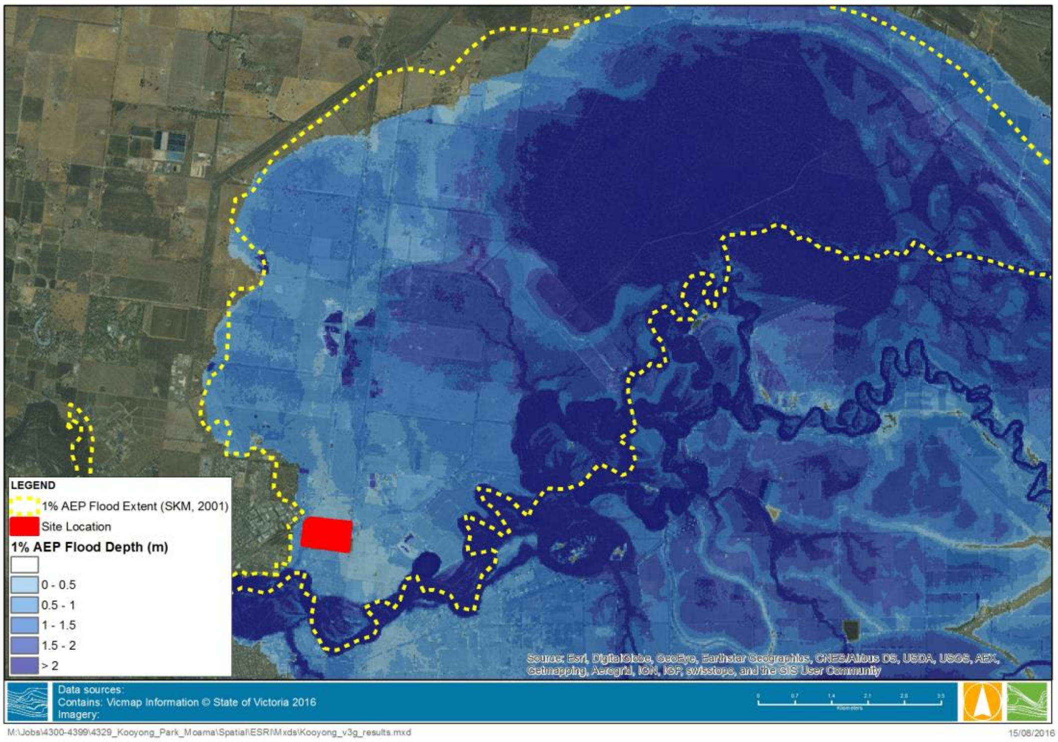


FIGURE 4-2 1% AEP FLOOD DEPTH MAPPING AND COMPARISON EXTENT TO THE MOAMA FLOODPLAIN MANAGEMENT STUDY (2001)

4.2 Developed Conditions

The two-dimensional hydraulic model was run under both existing conditions and upgraded levee conditions to test the impact of the proposed levee upgrade on flood behaviour. The upgraded levee around the site was modelled with a crest level well above the 1% AEP flood level to ensure no overtopping. The levee design is discussed in more detail in Section 7 of this report. Whilst the property is shown to be dry due to protection from riverine flooding provided by the levees, it is important to note that localised flooding could occur on the development site due to local rainfall. The impacts of this local stormwater flooding will depend on the drainage systems constructed within the site, and will be managed through appropriate design.

The Moama township levee was represented as accurately as possible based on information provided by Council[6], Figure 4-3. The small section along Chanter Street where the road crest is lower than the levee crest was infilled, as it is likely that in a significant flood event this known low spot in the levee would be sandbagged. It is likely that this section of levee has been left purposefully low so to allow for ordinary traffic in non-flood times. The Moama township levee crest is 96.02 m AHD for the concrete wall close to the Murray River, drops down to 95.72 m AHD along Chanter Street, increases to 96.32 m AHD through to the railway line, increasing to 96.52 m AHD north of the railway line. A number of road crossings are lower at 96.17 m AHD and the railway line top of ballast is at 95.43 m AHD.

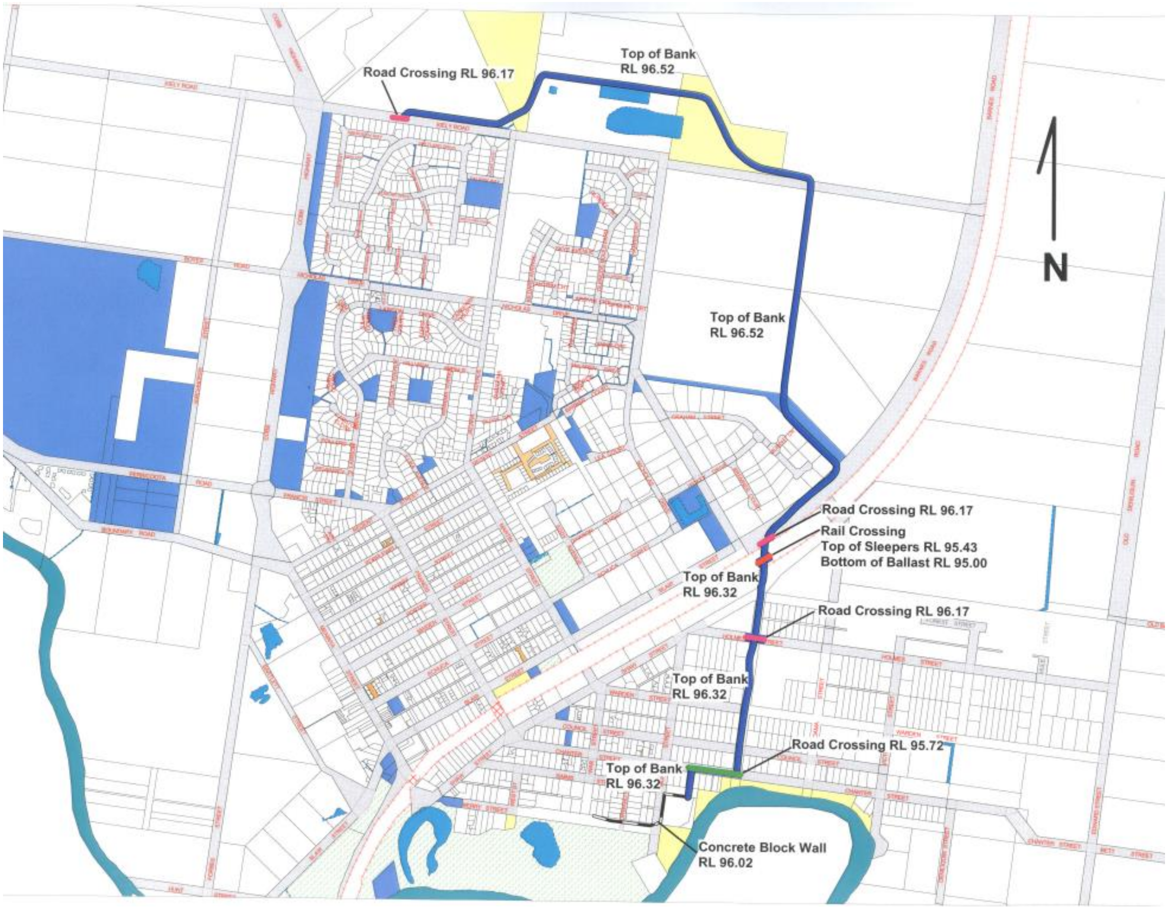


FIGURE 4-3 LEVEE HEIGHTS FOR THE MOAMA TOWNSHIP LEVEE (SOURCE: COUNCIL)

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[6] Murray River Council (2002), *Moama Levee,* Earth Tech; additional pdf maps supplied by Murray River Council (GIS export, no reference available)

The current development layout crosses a floodway as defined by the Moama Floodplain Management Study (2001), Figure 4-4. This floodway definition was based on limited information at the time of the study. The subject property already has an authorised rural levee surrounding its perimeter, and the floodway should be redefined to reflect that. The site has approval to upgrade this rural levee to an urban levee standard, the upgraded levee will not encroach further on the floodway. The floodway as it is currently defined represents a point in the floodplain upstream where water breaks out and it represents a low drainage line south of the proposed development site that drains back to the river, but the area in between does not accurately represent what is considered a floodway under today's definition. The floodway crosses the railway line at the north-west corner of the proposed development in a location where there is no culvert under the railway line. This railway line would impact on flow behaviour in this area. The flooding across the floodplain north of the development location occurs over a broad flat area with no concentration in flows along a defined floodway. It is suggested that the floodway definition in this area be redefined.

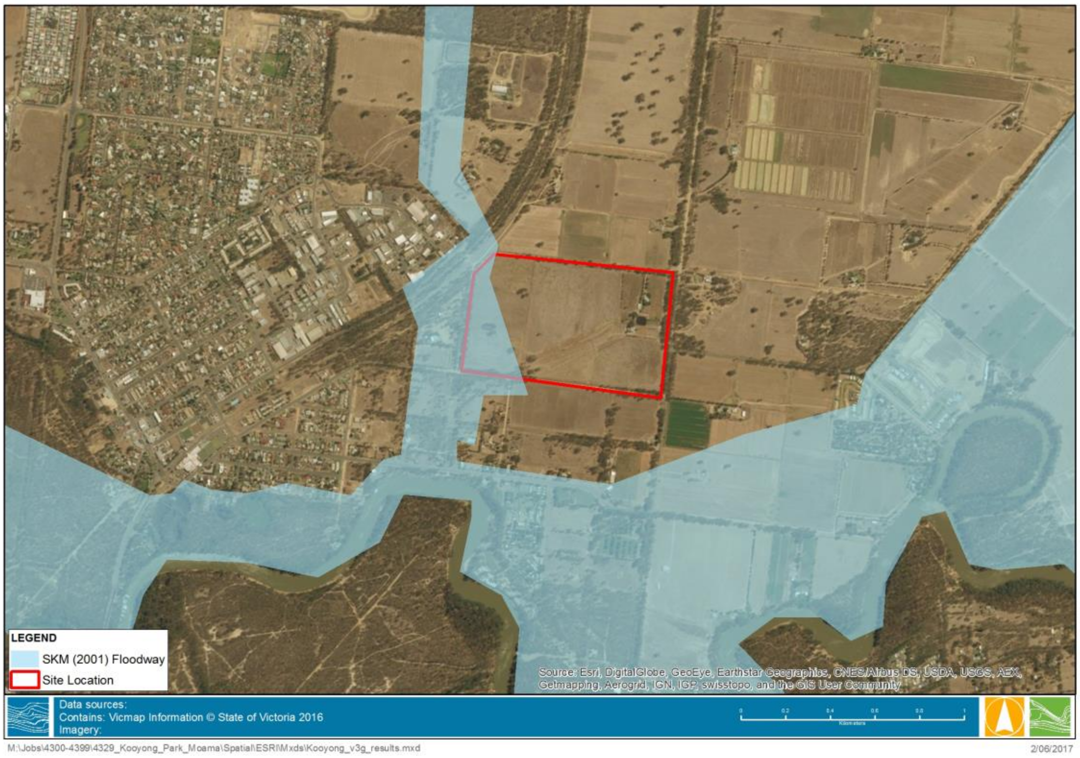

FIGURE 4-4 MOAMA FLOODPLAIN MANAGEMENT STUDY FLOODWAY DEFINITION

Further to the discussion regarding the floodway, modelling results have been compared to test the impact that the development would likely have on a 1% AEP flood event. Water levels under existing conditions were subtracted from those under developed conditions to show the difference in flood levels resulting from the proposed levee upgrade at the site. Localised impacts were identified around the site, with no change to water levels across the broader floodplain, as is shown in Figure 4-5. The results show that the ring levee will decrease the water level along the southern and western boundaries of the site by between 0.02 to 0.03 m. Increases of between 0.02 to 0.03 m are observed to the north of the site, impacting nearby parcels of land, detailed in Figure 4-6.

The results show that the proposed development does not significantly impact flood levels within the floodplain, further demonstrating that the floodway as currently defined requires amendment.

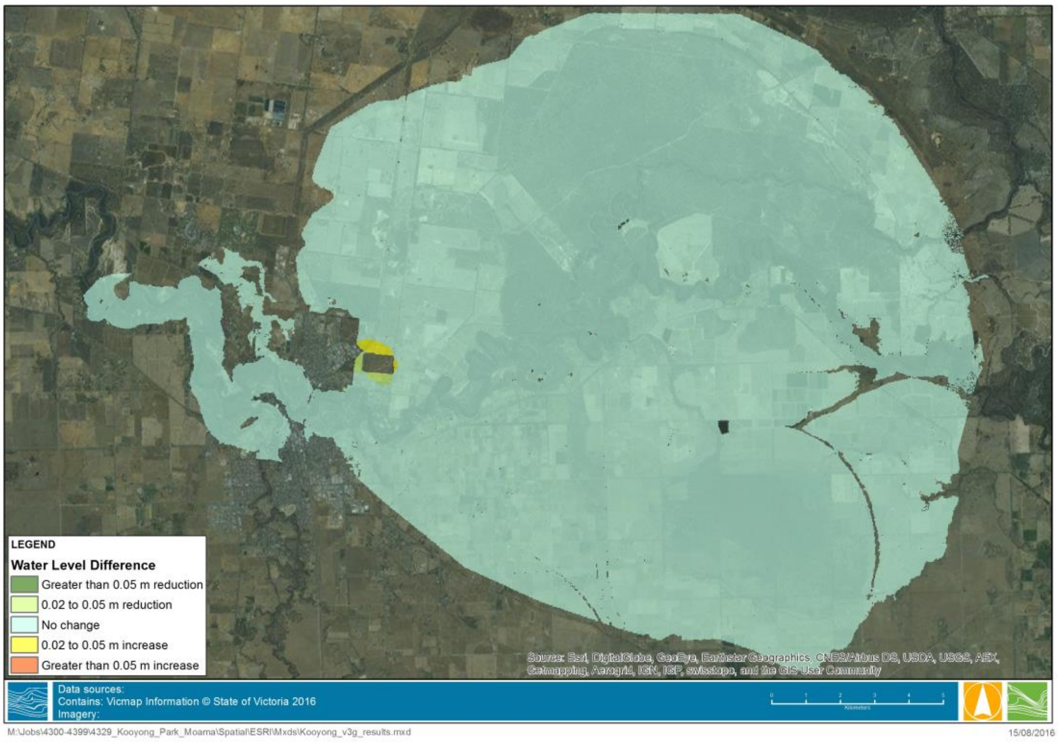

FIGURE 4-5 WATER LEVEL DIFFERENCES FROM PROPOSED DEVELOPMENT

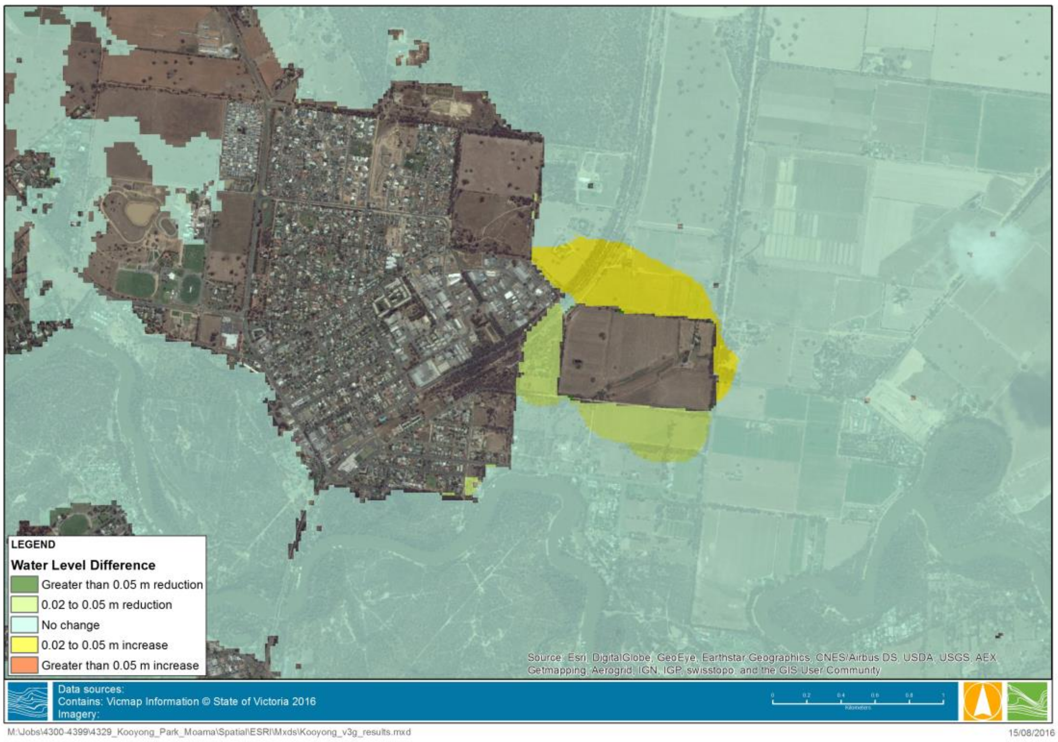

FIGURE 4-6 WATER LEVEL DIFFERENCES FROM PROPOSED DEVELOPMENT

5 FLOOD BEHAVIOUR

5.1 Flood Probability

As the site is outside of the Moama township levee it is important to understand how a large flood behaves. In the event of a large flood water will first spill out of the Murray River channel and will inundate the large low-lying forest area upstream of Moama. At the same time, the river will begin to flood out into the low-lying billabongs and wetlands along the river channel. In a 1% AEP flood event, flood waters will overtop the Old Barmah Road near Webb Road approximately 3 days after spilling out of the river channel. Another 12 hours later and Old Deniliquin Road will be overtopped north of Gregory Road. At around the same time the river may begin to back up into a low-lying drainage path that extends from the corner of Holmes and Victoria Streets through to Chanter Street and the Murray River. After another 6 hours, the proposed development site would be inundated along the southern and the western boundaries of the site. After another 12 hours, the site may be inundated along its northern boundary. The peak of the flood may then arrive another 3 to 4 days later. As this demonstrates Moama has significant warning time in which to prepare for large flood events.

The Echuca Moama Flood Study investigated a wide range of flood events. From an analysis of the earlier work the evacuation route along Moama and Holmes Street would be inundated at shallow depths in events larger in magnitude than a 10% AEP event. As the site is protected by a levee, which is proposed for upgrade, the site will not be inundated by events larger than a 1% AEP. It would take an extremely rare event to overtop the levees and inundate the site.

The Echuca Moama Flood Study showed that the design flood levels at the Echuca Wharf are very dependent on the adopted stage-discharge relationship at the river gauge. This relationship is highly dependent on the impact of the Campaspe River on Murray River flood levels. The final adopted stage-discharge relationship for the Echuca Wharf indicates that the 0.5% AEP event increases by 0.15 m as compared to the 1% AEP event. An extreme event was also considered, with twice the magnitude flow of the 1% AEP flows, with the water levels increasing by approximately 1.5 m. This extreme event would have a very low probability, with the previous report suggesting a probability of 0.01% AEP. The flood levels at the Echuca Wharf and at the proposed development site from the Moama Floodplain Management Study[2] are summarised below.

TABLE 1 ADOPTED DESIGN FLOOD LEVELS (SKM, 2001)2

Design AEP (%)	Adopted Design Flood Level at Echuca Wharf (m AHD)	Adopted Design Flood Level at Proposed Development (m AHD)
Extreme	96.81	96.92 to 96.90
0.5%	95.58	95.80 to 95.74
1%	95.34	95.58 to 95.50
2%	95.11	95.36 to 95.28
5%	94.79	95.14 to 95.03
10%	94.34	94.68 to 94.58

Note: Proposed development site located at MIKE11 Murray River chainage 995.50 to 997.10

The Murray Local Environmental Plan (2011) has set the Flood Planning Level as the 1% AEP level from the Moama Floodplain Management Study[2] plus 0.5 m freeboard. It also defines flood prone land in the Flood Planning Map (Sheet FLD_006) as indicated by the shaded area defined as the Flood Planning Area, Figure 5-1. The Flood Planning Level at Echuca Wharf is therefore 95.84 m AHD, and is 96.00 to 96.08 m AHD at the proposed development site.

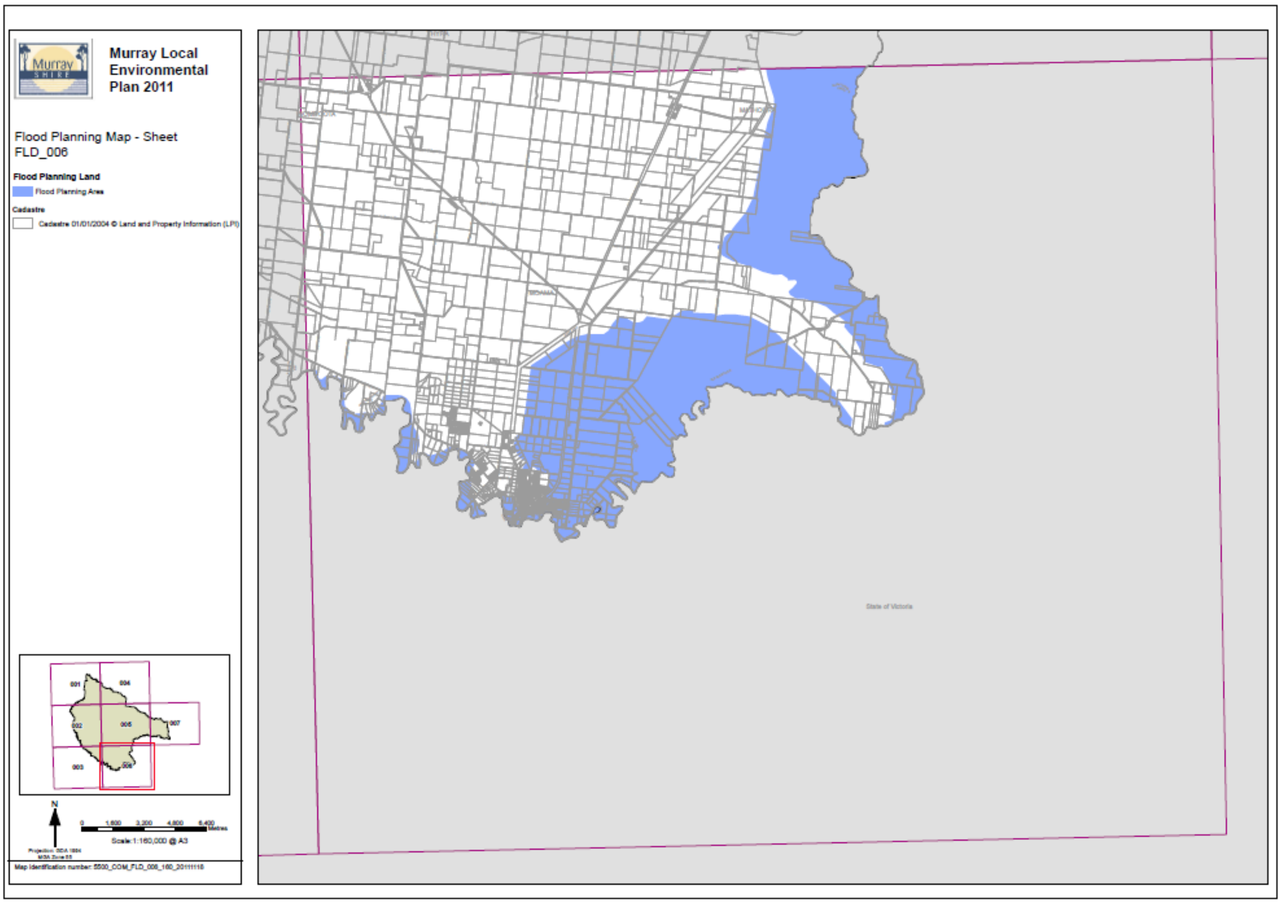

FIGURE 5-1 FLOOD PLANNING AREA (MURRAY LOCAL ENVIRONMENTAL PLAN 2011)

5.2 Flood Function

The NSW Floodplain Development Manual discusses the identification of flood function otherwise known as hydraulic categories. The categories of Floodway, Flood Storage and Flood Fringe are described. It is important to note that these hydraulic categories have a degree of subjectivity in their definitions. A proposed map of the hydraulic categories was included in the Moama Floodplain Management Study[2]. This was based on limited flood mapping and topography information. Hydraulic categories were developed in this investigation and are discussed further below.

Similar to the past Moama Floodplain Management Study[2], the Floodway category can be aligned with the Murray River banks. This is generally equivalent to fast flowing and deep water with a velocity and depth product greater than 1. In the Murray River floodplain upstream of Moama, the Kanyapella Basin is wide, flat and deep. The majority of the remaining area can be considered Flood Storage, where depths are often 1 to 2 m deep and velocities are less than 0.2 m/s in a 1% AEP flood event. Note that a portion of the land proposed for development sits on slightly elevated land, with 1% AEP depths of only 0.3 m.

5.3 Flood Hazard

The NSW Floodplain Development Manual[3] defines hazard using two categories, High and Low. In the Low hazard category, a truck would be able to evacuate people and able-bodied adults could wade to safety with little difficulty. In the High hazard category, there would be possible danger to personal safety, evacuation by trucks would be difficult, able bodied adults would have difficulty wading to safety and there would be potential for significant structural damage to buildings.

As described previously the depths on the wider floodplain for a 1% AEP event are generally between 1 and 2 m, with velocities generally very low, less than 0.2 m/s. 1% AEP depths surrounding the site are lower than in the general floodplain, with depths less than 1 m to the south and west, and depths around 0.3 m to the north and east. Figure 5-2 below shows the depth map, with Figure 5-3 showing the velocity map, and Figure 5-4 showing the Hazard Categories using the NSW Floodplain Development Manual definition.

With low velocities on this floodplain, the hazard definition is dominated by the depth of flood water, and as can be seen in Figure 5-4 the hazard is generally defined as low, near the proposed development.

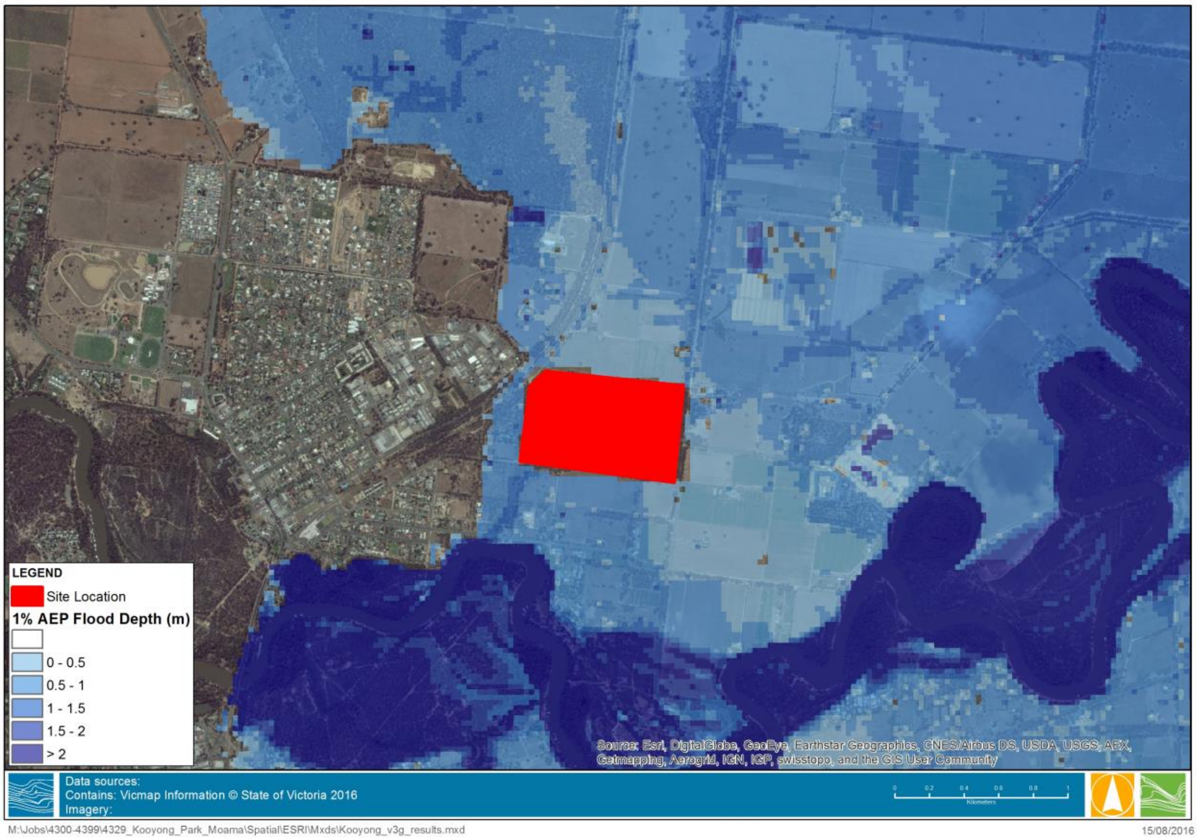

FIGURE 5-2 1% AEP FLOOD HAZARD - DEPTH

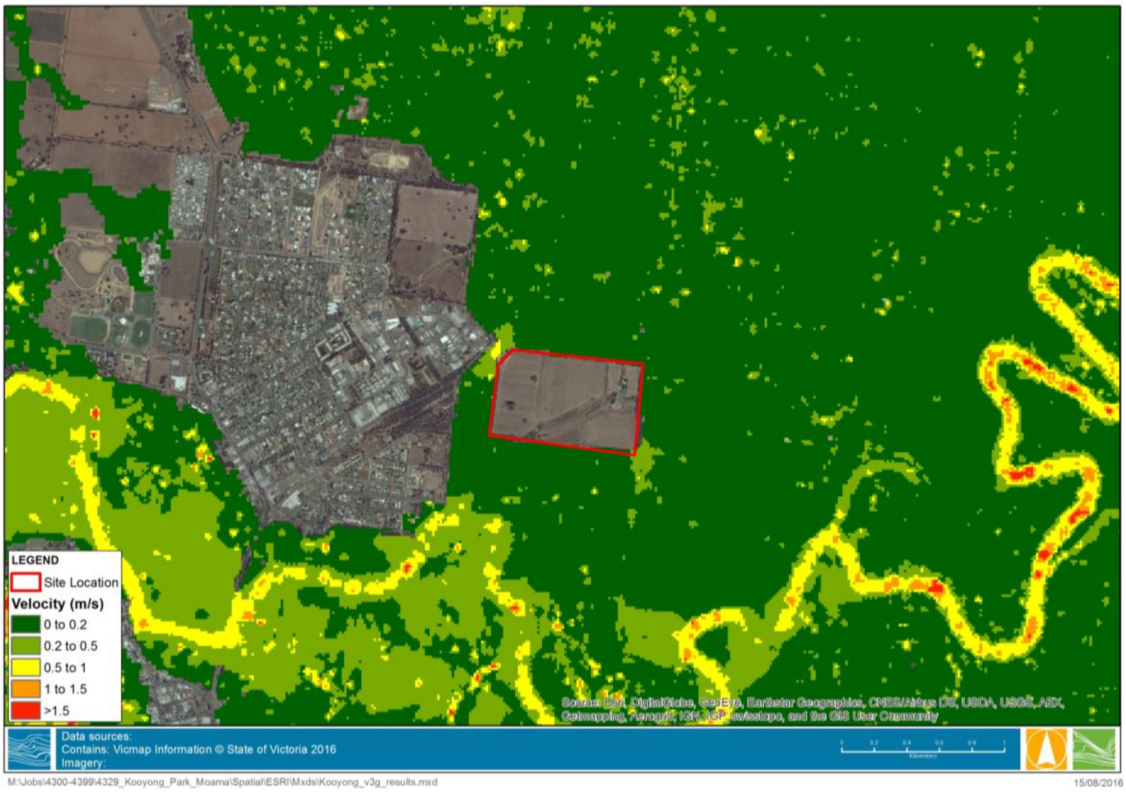

FIGURE 5-3 1% AEP FLOOD HAZARD - VELOCITY

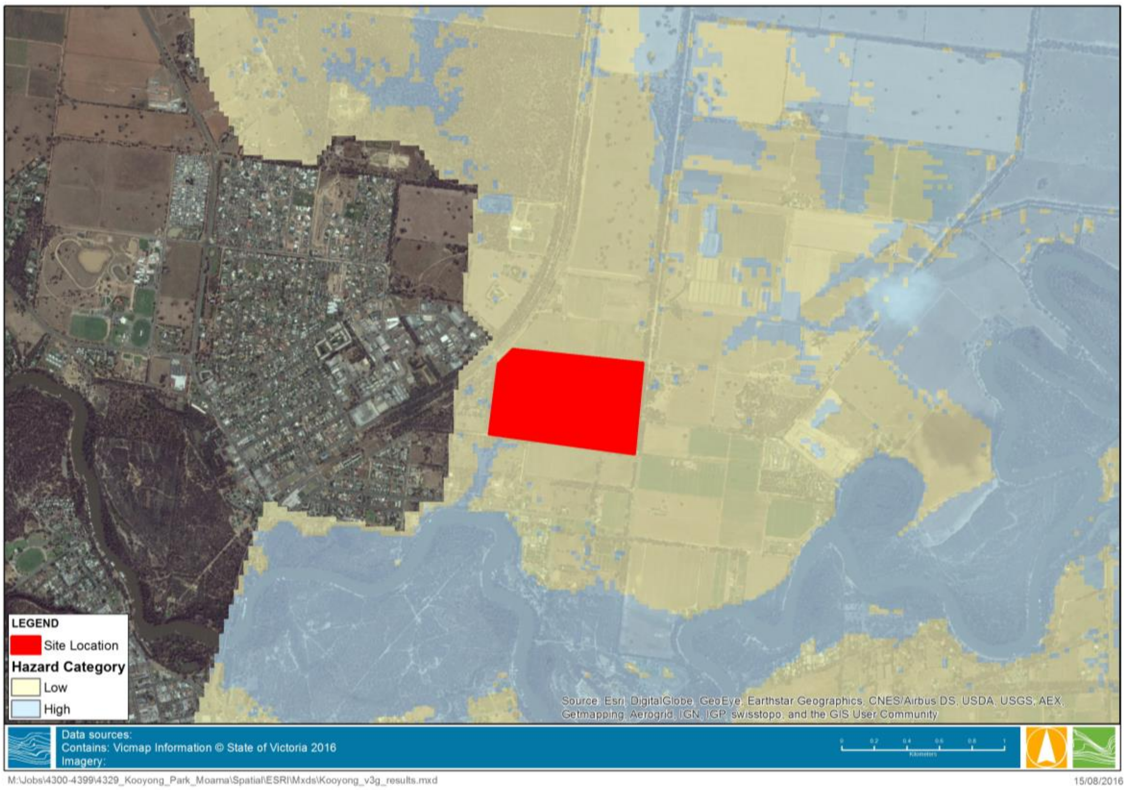

FIGURE 5-4 1% AEP FLOOD HAZARD CATEGORIES FROM NSW FLOODPLAIN DEVELOPMENT MANUAL[3]

5.4 Access and Egress Considerations

Access to the proposed development site is to be located off Moama Street. The evacuation route from the site during a flood would be south along Moama Street, west on Holmes Street, over the levee and into the protected area behind the levee. The route is shown in the inset in Figure 5-5. The road surface and 1% AEP flood level are shown in Figure 5-5. This demonstrates that the depth during a 1% AEP flood would be a maximum of 0.7 to 0.9 m deep over a length of 350 m. The velocity along the evacuation path is less than 0.2 m/s. This places the evacuation path within the low hazard definition within the NSW Floodplain Development Manual[3].

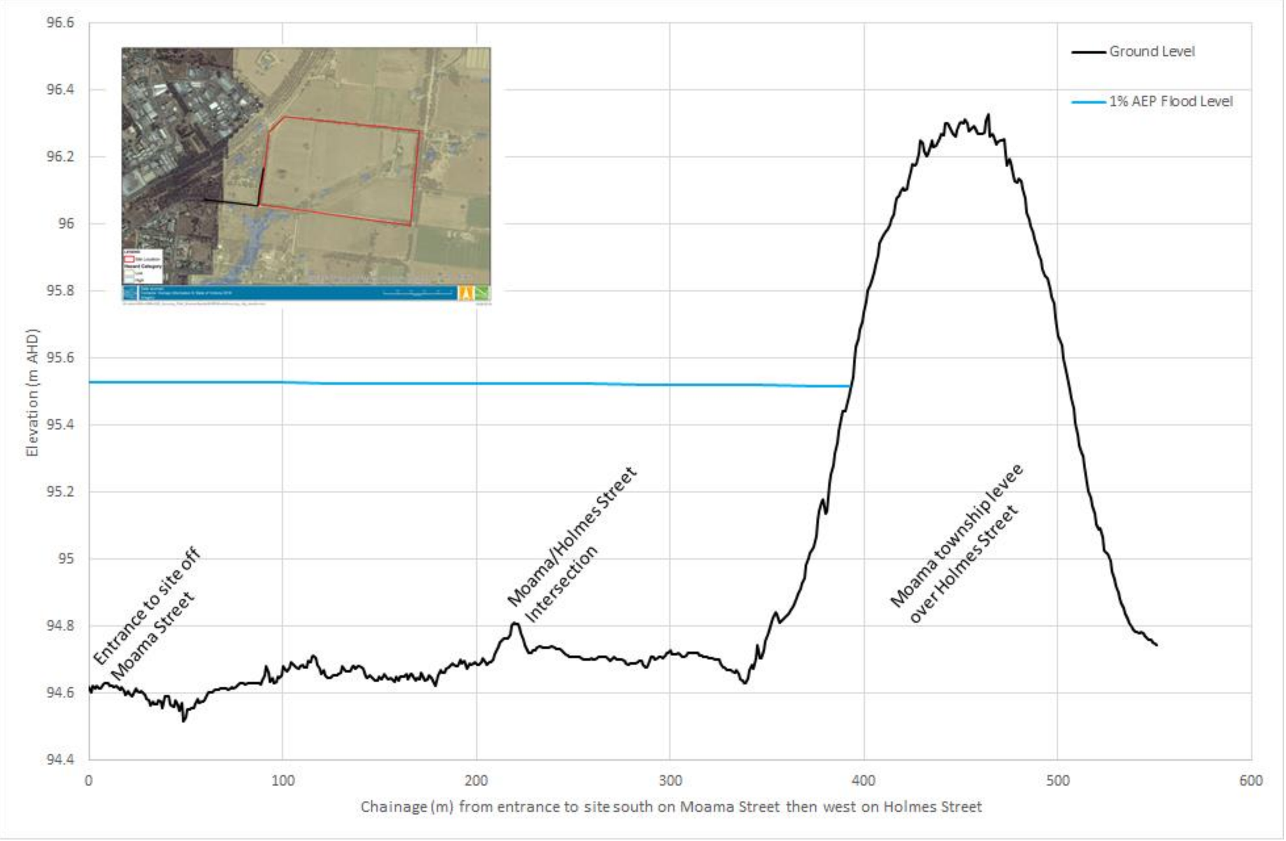

FIGURE 5-5 HAZARD CATEGORY LIMITS AND SITE ACCESS ROUTE

It is noted that the flood warning time is significantly long enabling effective evacuation if required. Given the long duration of large floods on the Murray River it is likely that should an event occur many residential properties outside of the town levee would be evacuated. The houses themselves would remain protected by the proposed upgraded levees. Access to and from these properties would not pose a significant risk as shown by the low velocity and depth of between 0.7 and 0.9 m along the evacuation route.

It is suggested that as part of future flood awareness campaigns in Moama and surrounds, all residents outside of the town levee be encouraged to develop an evacuation plan, including consideration of evacuation routes, triggers for evacuating, etc. Council and SES are well placed to assist residents in this regard.

6 PLANNING CONSIDERATIONS

At the time of completing this investigation, the Local Government (Council Amalgamations) Proclamation 2016 under the Local Government Act 1993, was implemented. The Murray Shire Council and Wakool Shire Council were amalgamated, with the subject site now under the jurisdiction of the Murray River Council.

6.1 Murray Local Environmental Plan (2011)

The relevant flood planning maps were still contained in the Murray Shire Council Local Environmental Plan (2011). Part 7, Clause 7.8 contains the following relevant flood related planning information.

7.8 Flood planning

(1) The objectives of this clause are as follows:

(a) to minimise the flood risk to life and property associated with the use of land,

(b) to allow development on land that is compatible with the land's flood hazard, taking into account projected changes as a result of climate change,

(c) to avoid significant adverse impacts on flood behaviour and the environment.

(2) This clause applies to:

(a) land that is shown as "Flood planning area" on the Flood Planning Map, and

(b) other land at or below the flood planning level.

(3) Development consent must not be granted to development on land to which this clause applies unless the consent authority is satisfied that the development:

(a) is compatible with the flood hazard of the land, and

(b) is not likely to significantly adversely affect flood behaviour resulting in detrimental increases in the potential flood affectation of other development or properties, and

(c) incorporates appropriate measures to manage risk to life from flood, and

(d) is not likely to significantly adversely affect the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses, and

(e) is not likely to result in unsustainable social and economic costs to the community as a consequence of flooding.

(4) A word or expression used in this clause has the same meaning as it has in the Floodplain Development Manual (ISBN 0 7347 5476 0), published in 2005 by the NSW Government, unless it is otherwise defined in this clause.

(5) In this clause, flood planning level means the level of a 1:100 ARI (average recurrent interval) flood event plus a minimum 0.5 metre freeboard.

Flood Planning Map – Sheet FLD_006 clearly shows the subject site within the Flood Planning Area. This investigation has clearly demonstrated that the site will be flood free during an event due to the levee surrounding the site. This development is compatible with the Low Hazard Storage category as defined in the NSW Floodplain Development Manual[3]. The very low velocities ensure no erosion issues are likely at this site.

6.2 Murray Development Control Plan (2012)

The Murray Shire Council Local Environmental Plan (2011), should be considered in conjunction with the Murray Shire Council Development Control Plan (2012). Section 7.10 Natural Hazards of the DCP (2012) states that on flood prone land identified in the Moama Floodplain Management Study (1999), compliance is required to clause 7.8 of the LEP (as described above), and the NSW Floodplain Development Manual[3]. Section 7.10 Natural Hazards of the DCP (2012) also requires that development in flood prone areas remain consistent with the recommendations of the Moama Floodplain Management Study (1999).

Section 11 Flood Prone Land of the DCP (2012) includes guidance on development in flood prone areas, which it describes as areas inundated in a Probable Maximum Flood (PMF). The PMF is the largest flood that could conceivably occur. It is generally not feasible to provide complete protection against this event and consequently the PMF is identified for the purpose of flood awareness and emergency response rather than development control. The site is protected by a levee but is surrounded by inundation in a 1% AEP event, which is significantly smaller than a PMF event.

Table 1: Guidance & Controls Applicable to Types of Development in FPA 1 of the DCP (2012), provides a good practical summary of the development principles to be implemented on the floodplain.

Nature of Flooding – The description of flooding in the Low Hazard Flood Storage category is consistent with that found in this investigation, confirming that this category is the correct category to apply to this development application. The site will be flood free in a 1% AEP event with surrounding land and the access road classified as Low Hazard Flood Storage.

Flooding Implications – The investigation has demonstrated that the impact of the proposed development is minimal to surrounding properties, with no impact on the wider floodplain.

General – The Kanyapella Basin has a very large storage volume; this development has no real impact on flood storage volumes or flood behaviour.

Flood Control Works – The proposed development site is currently protected by an Authorised Levee (Department of Water reference 50CW805701). The levee is currently constructed to a rural levee standard with no restrictions on height and width. The intent is that this rural levee would be upgraded to an urban levee standard as part of the development.

Residential, Commercial & Industrial Development – The DCP (2012) states that floor levels will be set at the Flood Planning Level (FPL). The NSW Floodplain Development Manual[3] in Appendix K3.2 suggests that if a development is protected by an appropriate standard levee then the appropriate planning level for setting floor levels may need to just consider overland flow behind the levee. This would most likely significantly reduce the required floor level. As described in Section 5.1, the FPL of the site has been determined to be 96.08 to 96.0 m AHD, this is generally 0.5 to 1.5 m above the existing ground level. As the site is surrounded by levee which will be constructed with a crest level equal to the Flood Planning Level of 96.0 to 96.08 m AHD, it is suggested that the dwellings be constructed above the ground level with consideration given to local stormwater issues only. This will require that the levee be maintained regularly. It is recommended that consideration be given to levee ownership and a maintenance program agreed.

7 UPGRADED LEVEE

The existing Authorised rural levee surrounding the site will be upgraded to an urban standard. There are no restrictions placed on the approved levee alignment with regards to height and width. The approved alignment is shown below in Figure 7-1.

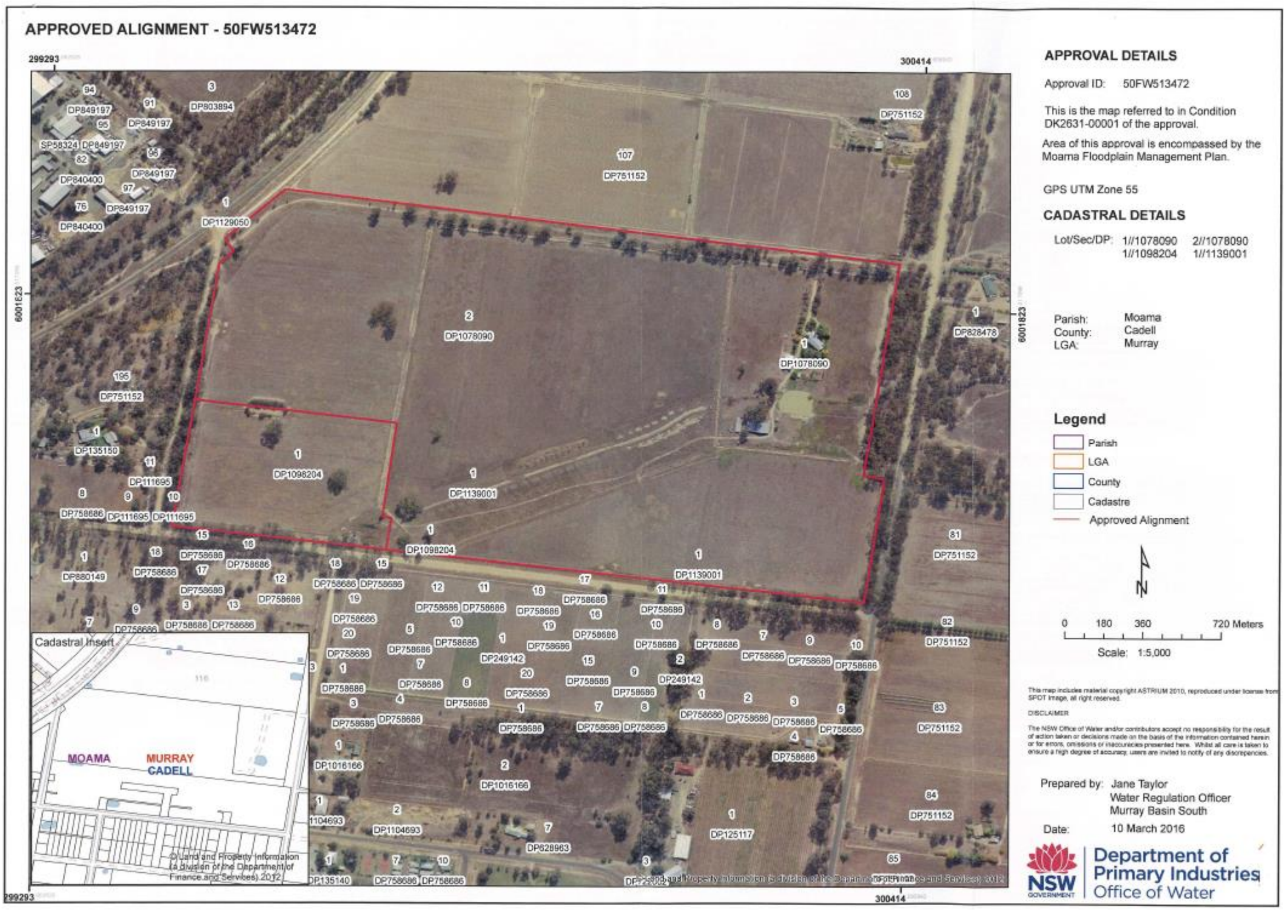

FIGURE 7-1 APPROVED LEVEE ALIGNMENT

In discussion with Office of Environment and Heritage it was advised that the levee crest should be designed using the same approach as that undertaken for the Barham Floodplain Management Study (GHD, 2016) should be completed. The levee crest was designed based on the 1% AEP flood level plus freeboard. The freeboard considered the following factors:

- Uncertainty associated with the estimation of the 1% AEP flood level
- Local factors such as waterway blockage
- Wave action associated with wind, water craft and vehicles
- Settlement of the levee or defects in the levee
- Climate change affects

In NSW, a levee freeboard typically ranges between 0.5 m (same as the freeboard applied to set the Flood Planning Level) and 1 m. In Victoria 0.6 m has been the typical freeboard used for large rural levees, with more recent studies of urban townships applying 300 mm where excessive freeboard would have detrimental impacts on the amenity of the town.

Uncertainty in design level

The difference in the flood level between the 0.5% and 1% AEP events and the 1% and the 2% AEP events can be used as a measure of the uncertainty in flood levels. Table 1 provides the design flood levels at Echuca Wharf, which shows that the difference between the 0.5% and 1% AEP events and the 1% and 2% AEP events is approximately 0.23 m in both cases. This shows that the flood levels are not overly sensitive to flow in rare events, this is because the river and floodplain are very wide and because of the impact of Barmah-Millewa Forest upstream attenuating the Murray River flows.

Local factors such as blockage

On a large floodplain such as the Murray River floodplain upstream of Moama, blockages are not expected to have a significant impact on the flood levels, this could be expected to have a negligible impact on flood levels at the site.

Wave action

The largest waves impacting on the levee would be generated from wind in this case as there are no trafficable roads when flood levels approach the top of the levee. The size of wind waves on open water can be estimated by the following:

$H_s = 0.00178\ U\ \sqrt{F}/\sqrt{g}$

Where H_s is the significant wave height in metres (height of the highest 1/3rd of the waves in a wave field); U is the design wind speed in m/s; F is the fetch length in metres; g is the acceleration due to gravity (9.81ms^{-2}). The highest wind speed on record at the nearest gauge was recorded as 85 km/h from the NNW direction in May 2014. The average wind speed was just 9 km/h. The fetch was estimated at around 500 m. A longer fetch across the Kanyapella Basin does exist but it is interrupted by the flowing river, heavily treed forest, roads, wind breaks etc.

Using the above approach, a wave height of 0.3 m was estimated using the highest wind speed on record. If a slightly more conservative fetch of 1 km is adopted the wave height is increased to 0.42 m. Using the average wind speed a wave height of 0.06 m was estimated. This demonstrates that wind induced waves are potentially the largest factor in determining freeboard.

Settlement

A levee has the potential to settle over time. This can be minimised through good construction techniques using the correct materials, and maintaining the levee over time. Settlement is likely to be a lower order factor compared to uncertainty in flows, climate change and wind waves.

Climate change

The impact of climate change on design flows for the Murray River at Moama is a complex issue given the potential impact on the Murray, Goulburn and Campaspe Rivers. With all these rivers having major storages on them, the impact of climate change on peak design flow is difficult to determine and is likely to be of the same order of magnitude as the uncertainty in design flows documented above. In a few flood studies that Water Technology has undertaken in Victoria, under climate change with increased rainfall intensity the climate change 1% AEP flow is similar to the current 0.5% AEP flow. An allowance of 0.2 to 0.3 would be reasonable to make for climate change.

Adopted design freeboard

The levee design crest will be based on the adopted 1% AEP flood level of 95.5 to 95.58 m AHD at the proposed development location plus an appropriate freeboard.

Of all the factors discussed above that go into a freeboard assessment, it is suggested that wind waves are likely to have the largest impact. The estimated wave height using the maximum recorded wind speed was 0.3 to 0.42 m for fetch distances of 500 and 1,000 m respectively. It is proposed to adopt a freeboard of 0.6 m, which easily accommodates for the various sources of uncertainty. This is also the same freeboard that was determined in the Barham Floodplain Management Plan, is equivalent to the Moama township levee, is what is typically adopted in Victoria for a rural earthen levee, and is within the bounds of what is typically accepted in NSW. It is suggested that a freeboard of 0.6 m be adopted.

Adding the above 0.6 m freeboard to the 1% AEP flood level gives a design levee crest level is 96.1 to 96.18 m AHD. This levee height is similar to that of the existing Moama township levee, with the crest level of this proposed levee being over 0.1 m higher than the crest level of the concrete wall at the southern end of the Moama township levee. The proposed levee would require a levee height of around 1 to 1.6 m above ground level. A levee height of this magnitude would not look out of place in Moama.

The rural levees currently surrounding the site typically have a crest of 95.65 m AHD. The proposed levee upgrade would raise the levee crest by around 0.5 m to the proposed design crest level. A newly constructed levee in the south western corner of the development site has been constructed to a crest level of 95.9 m AHD. It is recommended that this be raised to meet the proposed levee crest level.

If the levee is built of a typical earthen construction method the width of the levee will be approximately 8 to 11 m at its base, assuming 3:1 batters on the outside, a 3 m crest width and a 2:1 batter slope on the inside. If Council wish for the levee to be mowed then batter slopes of 4:1 are more appropriate, but this will extend the width of the levee at its base out to 16 m at its highest point. The levee should be constructed with an impervious core, with 300 mm deep stripping and an impermeable foundation laid as its base. Other construction methods could be considered, but earthen levees are typical in rural townships where space is not limiting. The earthen material used to construct the levee needs to be of good quality to ensure that the levee weathers appropriately reducing maintenance costs into the future. Geotechnical investigations are required on site to test the suitability of local material. If these tests show that the material is not suitable for levee construction, then clay material will need to be brought to site.

A levee as described above will ensure that the development behind the levee remains flood free in events larger than a 1% AEP event. The levee would likely be overtopped in an extreme event like the Probable Maximum Flood. Floods of this extreme nature are very rare and would require evacuation of many townships along the Murray River. There is no requirement in planning terms to protect to these extreme flood events.

The levee surrounds the full development site. Access through the levee for road connections will be required. As the levee is to be between 1 to 1.5 m high, roads will need to cut through the levee. As is the case with the Moama township levee, these locations would most likely be designed below the levee crest. It is recommended that the road surface through the levee be no lower than the 1% AEP flood level of 95.5 m AHD. During a flood which exceeds the 1% AEP flood level, sandbags could then be placed across the road entrance to increase the level of protection. Alternatively, if a road crest level of 95.5 m AHD could not be achieved due to physical constraints with the road grade, then headwalls with drop structures would be required on the levee either side of the road, like those in the concrete wall component of the Moama township levee. The issue with this approach is that once these structures are in, no traffic can pass along the access route.

An appropriate civil engineer with experience in designing levees should be utilised for the detailed design of the levee to urban levee standard. The following documents are highly relevant and provide good references for levee management.

- Levee Management Guidelines (Department of Environment, Land, Water and Planning, 2015)
- Levee Owner's Guideline (NSW Public Works, 2015)
- International Levee Handbook (CIRIA, 2013)

The Levee Owner's Guideline is a NSW document and is probably the most relevant for this development. It outlines the history of levees in NSW, ownership, principles for levee design, maintenance, emergency response and communications. This document should be used in developing the design for upgrading the existing levee. The issues of levee ownership and responsibilities for maintenance will need to be discussed and agreed upon, with a set program for inspections and maintenance established. Community education and a flood response plan would also be required.

Internal drainage will need to be considered as part of the design of the site. A stormwater management plan should be prepared. This should include consideration for how internal stormwater interacts with the levee and exists the site. The south-west corner of the development site is the lowest point. A drainage path flows from this point to Chanter Street, under a large culvert and back to the Murray River. This seems to be the logical point for stormwater to exit the site. It is recommended that a passive culvert under the levee with a flap valve or penstock gate be installed. This would allow free drainage of stormwater in non-flood times. When a flood occurs and stormwater can't exit the site freely, a pumping system will be required to pump over the levee into this drainage path.

Levee Recommendations for Design and Maintenance Consideration

- Levee crest to be designed to 96.1 to 96.18 m AHD (1% AEP flood level plus 0.6 m freeboard).
- Earthen levee design is appropriate.
- Road entrances be carefully considered, if possible adopt 95.5 m AHD as road crest level, with sandbags or drop structures to make up the remaining freeboard in a flood event. These emergency measures would need to be documented in the Councils flood response plan.
- Experienced civil engineer with levee design to follow appropriate levee design standards.
- As constructed survey to be obtained after levee construction.
- Levee ownership and maintenance plan discussed between the developer and Council, with an agreement reached on ownership and maintenance prior to construction.
- Stormwater management plan developed including consideration for a pumping system to deal with stormwater during flood events.

8 SUMMARY

This report documents a flood assessment of proposed development site at Kooyong Park, Moama, and the impacts of upgrading the rural ring levees surrounding the property to an urban levee standard. The approved alignment of the levee has no restrictions in relation to width and height. It is recommended that the levee crest be designed at 96.1 to 96.18 m AHD, which is based on the 1% AEP flood level plus 0.6 m freeboard. This freeboard has been developed based on assessing the various levels of uncertainty that go into design flood level estimation. A freeboard of 0.6 m is appropriate. The assessment has shown that depending on batter slope assumptions of an earthen levee, the width of the levee will typically be 8 to 11 m wide and 1 to 1.6 m high. This is typical of an earthen levee in a rural area such as Moama.

The flood modelling results were assessed against appropriate NSW planning policy and best practise floodplain management principles, providing information which supports the application for the proposed development. The assessment shows that the floodplain surrounding the proposed development can be categorised as low hazard storage in a 1% AEP flood event. Depths in a 1% AEP flood event are lower than 1 m to the south and west of the site, and around 0.3 m to the north and east. The velocities in a 1% AEP flood event are low, less than 0.2 m/s.

With the proposed levee constructed the site will be protected during a large flood. Flood modelling has demonstrated that the proposed levee upgrade does not significantly alter flood levels and flood behaviour in the surrounding floodplain.

In an extreme flood event evacuation may be necessary. Evacuation routes have been assessed and have been shown to be low hazard during a 1% AEP flood event. When considering the long flood warning time afforded to Moama, safe evacuation of the proposed development site can be achieved if necessary.

There is expected to be very little, if any, environmental, social and economic adverse issues associated with the proposed development.

The proposed development meets the required performance criteria of NSW floodplain management policy. There are no floodplain related issues which should impact on Council's decision to accept this development proposal.

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