

NUMURKAH FLOODPLAIN MANAGEMENT STUDY  
COMMUNITY REFERENCE GROUP

# NUMURKAH FLOODPLAIN MANAGEMENT STUDY AND PLAN

## SUMMARY REPORT





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# COMMUNITY REFERENCE GROUP SUMMARY & RECOMMENDATION

The Numurkah Floodplain Management Study and Plan was initiated in October 2012 after a major rainfall event in late February and early March 2012 which severely impacted on the town of Numurkah. This event saw some 200 to 300 mm of rain fall across the Broken, Muckatah and Nine Mile Creek Catchments, an area of approximately 2,500 square kilometres which stretches from the Midland Highway to the south, across to the Warby Ranges and Peechelba in the east and to Yarrawonga and Cobram to the north.

The topography of the catchment naturally flows to the west, with an estimated 200,000 to 250,000 megalitres of flood water runoff, all having to pass through and around the township of Numurkah, on its route to the Murray River.

As the main bridge on the Broken Creek, the Melville Street Bridge in Numurkah is restricted by a design capacity of just 800 megalitres per day. It was no match for the peak flow of 25,000 to 30,000 megalitres of water per day; subsequently the bridge structure and creek banks were rapidly overtopped. When floodwater from the east combined with flood water entering the town from the south, via the Hospital Depression, it resulted in unprecedented flood levels and extensive damage being recorded across what were previously considered by the community as "safe residential areas".

In the absence of prior safeguards in place, the ultimate casualty was the inundation of the Numurkah Hospital in the early hours of Sunday the 4th of March. This traumatised both staff and patients alike. Many community residents and business houses were also severely impacted and paid a heavy price both emotionally and financially, many of them still struggling to recover.

A lingering consequence of this is that any reports of a major rainfall event in any of the upper catchments immediately raises the stress and anxiety levels of the Numurkah community to a state of high alert for the days following as they grapple with the possibility of another major flood event heading towards the town.

As a result of extensive community feedback, the Community Reference Group resolved that anything short of permanent protection for both north and south Numurkah would not be acceptable.

To that end, extensive studies of up to 15 different options have been modelled ranging from a small floodway through the Train Park to a large whole town levee and Box Creek bypass.

The Community Reference Group, and the supporting agencies involved, are determined to finally overcome Numurkah's long-term vulnerability to major floods which have occurred almost every second decade.

Working through the results of each option modelled made it quite clear that with Numurkah's relatively flat topography finding a practical solution would be challenging and difficult.

Mitigation Option (A), which is explained in greater detail within the attached report was by design, the final model run. After detailed assessment it has been determined by the Community Reference Group that this option best meets the needs of the Numurkah community and your endorsement of Mitigation Option (A) is favourably encouraged.

## Mitigation Option Package (A) - A brief overview:

- Offers protection to all homes, businesses and community facilities within the Levee system, both north and south of the Broken Creek. The larger residential blocks in south Numurkah, between Corke Street and Powell Road are not included within the Levee system because the flood passage through these blocks needs to be maintained. The homes on these blocks, and other houses outside the levee system but being deemed at risk will be part of the Operating Flood Plan and will be individually protected as the need dictates. The planning and design of protection for these properties such as the quantity and placement of sandbags and other infrastructure, will need to be part of the Moira Shire Municipal Emergency Flood Sub Plan. This Plan will be assisted by the permanent installation of "In Stream Monitoring Stations" placed upstream of Numurkah, which will provide for more informed and timely management of future events.
- The Numurkah Recreation Reserve and a portion of the Numurkah Golf Course are inside the levee system as a result of the need to take the Southern Residential Levee to its north eastern tip in order to act as a 'Diversion Levee' in this area and to maximise flow through the creek itself.
- Permanent levees are a necessity as Numurkah has limited time available to prepare for any rapidly approaching flood event.
- Flood water passing through the central town area will be contained within the creek reserve.
- The northern levee in the initial mitigation package presented to the Community in June of 2015 and rejected by both the community and the Community Reference Group as a "Stand Alone" package, is an important component of the recommended package.
- The Community Reference Group believes that dry road access to south Numurkah and thus the Numurkah and District Health Service and Ambulance Victoria Station needs to be maintained. Access will be via Katamatite Road and the Goulburn Valley Highway or possibly an improved Melville Street Bridge however, how this is achieved is to be determined in the planning and design phase.
- A large portion of the levees would not be constructed in 'built up' areas and generally where possible would follow the creek reserves.
- Although not a component of this Flood Study, the Community Reference Group would like to see the old Numurkah Cemetery's flood protection reinstated to cope with a 1974 type flood event. Larger events would require the flow path to remain open through this area.

We present this report to the community and urge your support of package (A).

The Community Reference Group wish to acknowledge Water Technology Consultants, Moira Shire Staff, Government Support Agencies and our local politicians, both State and Federal, for their expertise, assistance and encouragement throughout this project.

As Chairman, and Councillor Representative, I would like to extend my sincere thanks to the Numurkah Community for supplying information and taking ownership of this plan.

My sincere thanks and gratitude also goes to the relatively small but very dedicated team of the Numurkah Flood Study Community Reference Group, who have spent many hundreds of hours of researching, fact finding and negotiation in order to reach this very comprehensive and positive outcome.

**Cr Kevin Bourke**  
**Chairman, Numurkah Floodplain Management Study and Plan Community Reference Group**

# 1. GLOSSARY OF TERMS

## **Annual Exceedance Probability (AEP)**

Refers to the probability or risk of a flood of a given size occurring or being exceeded in any given year. A 90% AEP flood has a high probability of occurring or being exceeded; it would occur quite often and would be relatively small. A 1% AEP flood has a low probability of occurrence or being exceeded; it would be fairly rare but it would be of extreme magnitude.

## **Australian Height Datum (AHD)**

A common national surface level datum approximately corresponding to mean sea level. Introduced in 1971 to eventually supersede all earlier datums.

## **Average Recurrence Interval (ARI)**

Refers to the average time interval between a given flood magnitude occurring or being exceeded. A 10 year ARI flood is expected to be exceeded on average once every 10 years. A 100 year ARI flood is expected to be exceeded on average once every 100 years. The AEP is the ARI expressed as a percentage.

## **Cadastre, cadastral base**

Information in map or digital form showing the extent and usage of land, including streets, lot boundaries, water courses etc.

## **Catchment**

The area draining to a site. It always relates to a particular location and may include the catchments of tributary streams as well as the main stream.

## **Design flood**

A design flood is a probabilistic or statistical estimate, being generally based on some form of probability analysis of flood or rainfall data. An average recurrence interval or exceedance probability is attributed to the estimate.

## **Discharge**

The rate of flow of water measured in terms of volume over time. It is to be distinguished from the speed or velocity of flow, which is a measure of how fast the water is moving rather than how much is moving.

## **Existing Conditions**

Refers to modelling of the current situation in Numurkah with respect to topography (lay of the land) and key structures such as bridges and culverts.

## **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 overland runoff before entering a watercourse and/or coastal inundation resulting from elevated sea levels and/or waves overtopping coastline defences.

## **Flood frequency analysis**

A statistical analysis of observed flood magnitudes to determine the probability of a given flood magnitude.

## **Flood hazard**

Potential risk to life and limb caused by flooding. Flood hazard combines the flood depth and velocity.

## **Floodplain**

Area of land which is subject to inundation by floods up to the probable maximum flood event, i.e. flood prone land.

## **Flood storages**

Those parts of the floodplain that are important for the temporary storage, of floodwaters during the passage of a flood.

## **Geographical information systems (GIS)**

A system of software and procedures designed to support the management, manipulation, analysis and display of spatially referenced data.

**Hydraulics**

The term given to the study of water flow in a river, channel or pipe, in particular, the evaluation of flow parameters such as stage and velocity.

**Hydrograph**

A graph that shows how the discharge changes with time at any particular location.

**Hydrology**

The term given to the study of the rainfall and runoff process as it relates to the derivation of hydrographs for given floods.

**Intensity frequency duration (IFD) analysis**

Statistical analysis of rainfall, describing the rainfall intensity (mm/hr), frequency (probability measured by the AEP), duration (hrs). This analysis is used to generate design rainfall estimates.

**LiDAR**

Spot land surface heights collected via aerial light detection and ranging (LiDAR) survey. The spot heights are converted to a gridded digital elevation model dataset for use in modelling and mapping.

**Peak flow**

The maximum discharge occurring during a flood event.

**Probability**

A statistical measure of the expected frequency or occurrence of flooding. For a fuller explanation see Average Recurrence Interval.

**Probable Maximum Flood**

The flood that may be expected from the most severe combination of critical meteorological and hydrologic conditions that are reasonably possible in a particular drainage area.

**RORB**

A hydrological modelling tool used in this study to calculate the runoff generated from historic and design rainfall events.

**Runoff**

The amount of rainfall that actually ends up as stream or pipe flow, also known as rainfall excess.

**Stage**

Equivalent to 'water level'. Both are measured with reference to a specified datum.

**Stage hydrograph**

A graph that shows how the water level changes with time. It must be referenced to a particular location and datum.

**Topography**

A surface which defines the ground level of a chosen area.

## 2. OVERVIEW

North-East Victoria and the New South Wales Riverina was subject to widespread heavy rainfall and flood events in March 2012. Numurkah was one of the towns hit hardest during this period, with large parts of the township inundated in that event. It is estimated that over 90 residential and commercial properties were inundated above floor level in the March 2012 event.

The Moira Shire Council, in conjunction with Goulburn Broken CMA and the community, has developed the Numurkah Floodplain Management Study and Plan. This study builds on the work that Water Technology previously completed during the Numurkah Flood Study (Water Technology, 2011).

### 2.1 COMMUNITY CONSULTATION AND FEEDBACK

A key objective of the Plan was to ensure community engagement and to demonstrate community support for the final Plan. A key aspect of all community engagement was to provide information to ensure community understanding and then to seek feedback verbally at meetings and one-one-sessions and through more formal feedback methods such as surveys.

A community based reference group (CRG) was involved in all stages of the study, including the development of flood mitigation options for testing in the flood modelling. Feedback from the period of community consultation guided the development of the Plan and the final recommended package of mitigation works.

Three final mitigation packages are presented in this summary report and it is recommended that these options are presented to the community through an additional period of community consultation. This will aim to seek feedback on the options and determine a preferred package. It is imperative that the adopted package of mitigation works has strong community support.

### 2.2 FLOOD MAPPING AND INTELLIGENCE

A hydrologic analysis determined design flows for the waterways in the study area using a combination of flood frequency analysis and RORB modelling.

Peak flows and hydrographs were calculated at the hydraulic model inflow boundaries. A 1D/2D Mike FLOOD hydraulic model was constructed and calibrated to the March 2012 and October 1993 historic events. The modelling demonstrated that the events were quite different in nature which correlates with observations that the March 2012 was a much larger and more damaging event. Overall the hydraulic models provided a very good representation of the historic events which impacted Numurkah and was subsequently used to model a full range of design flood events. The key findings from the hydraulic modelling were:

- Under existing conditions approximately 125 commercial and residential properties are flooded above floor in the 1% AEP event.
- Approximately 25% of flow passes through the central township in the 1% AEP event while the remainder flows through the hospital depression and across the floodplain to the south of Numurkah.
- It is not until the 2% AEP flood event and greater, that significant numbers of properties are flooded above floor.
- The 1% AEP event is slightly smaller in magnitude than the March 2012 event, with flood levels generally 20 to 30 mm lower around central Numurkah.
- The modelling has confirmed that the irrigation channel banks which run parallel to Kinnaird's Road have an important role in protecting properties in the northern residential areas of Numurkah in large flood events particularly when combined with temporary measures such as sandbagging.
- The modelling demonstrated that the railway line and Goulburn Valley Highway embankments have a local impact on upstream flood levels but this impact only extends as far upstream as Melville St.
- It was found that increasing the culvert capacity on Broken Creek under the railway and Goulburn Valley Highway had a very minor impact in reducing upstream flood risk. It had a local impact on reducing upstream flood levels but that impact only extended for a short distance upstream and not to residential and commercial areas.



Figure 2.1: 1% AEP Flood Extent and Key Hydraulic Features

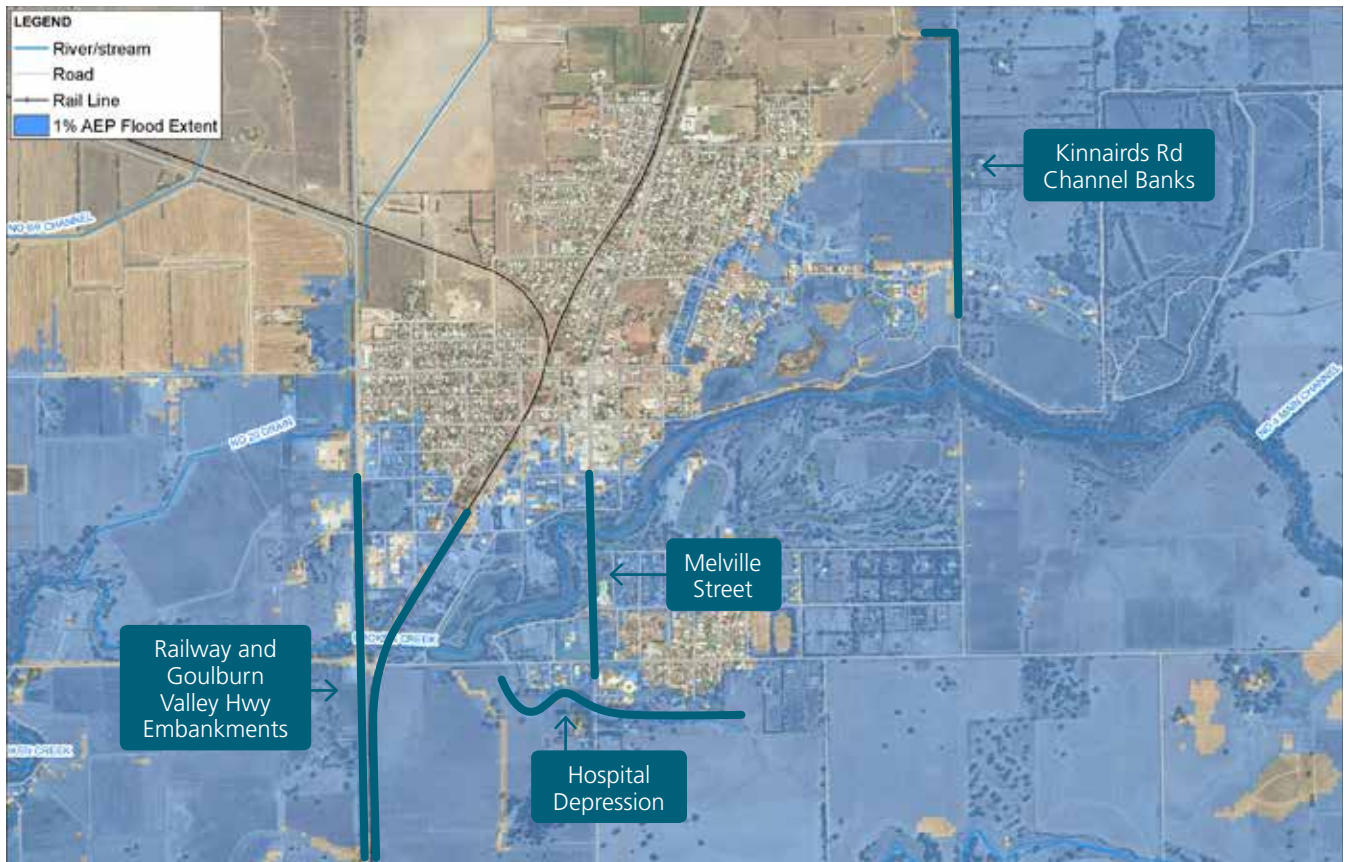
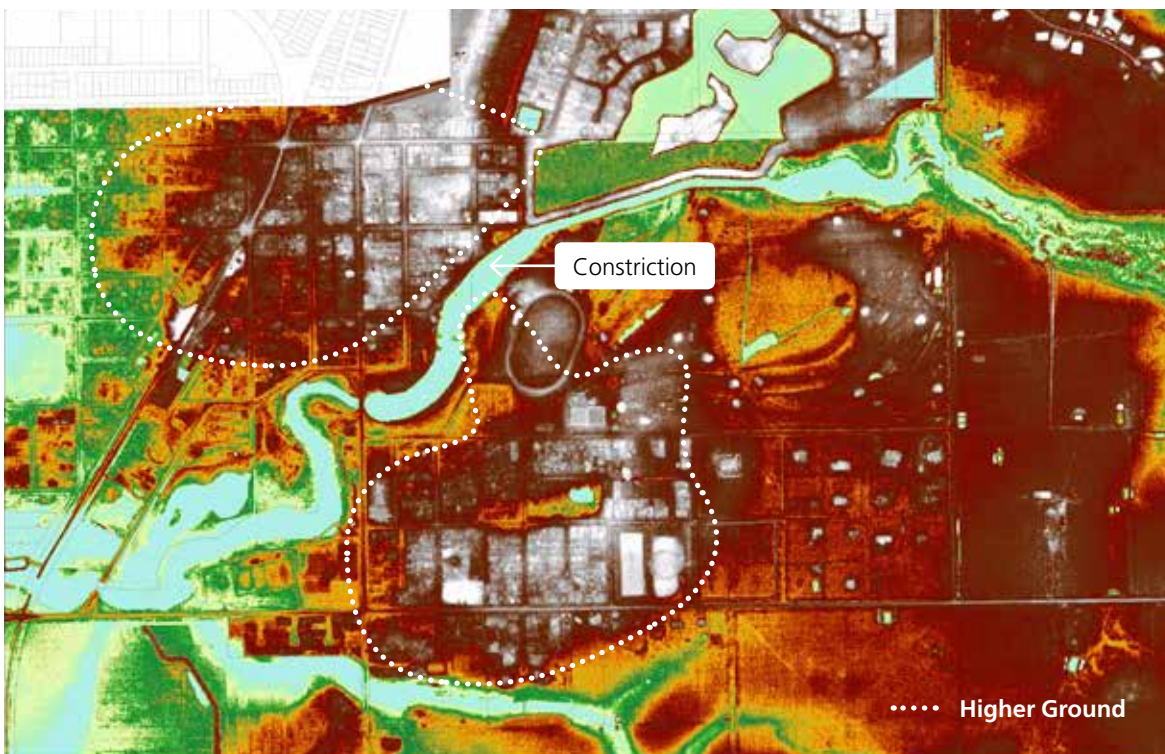
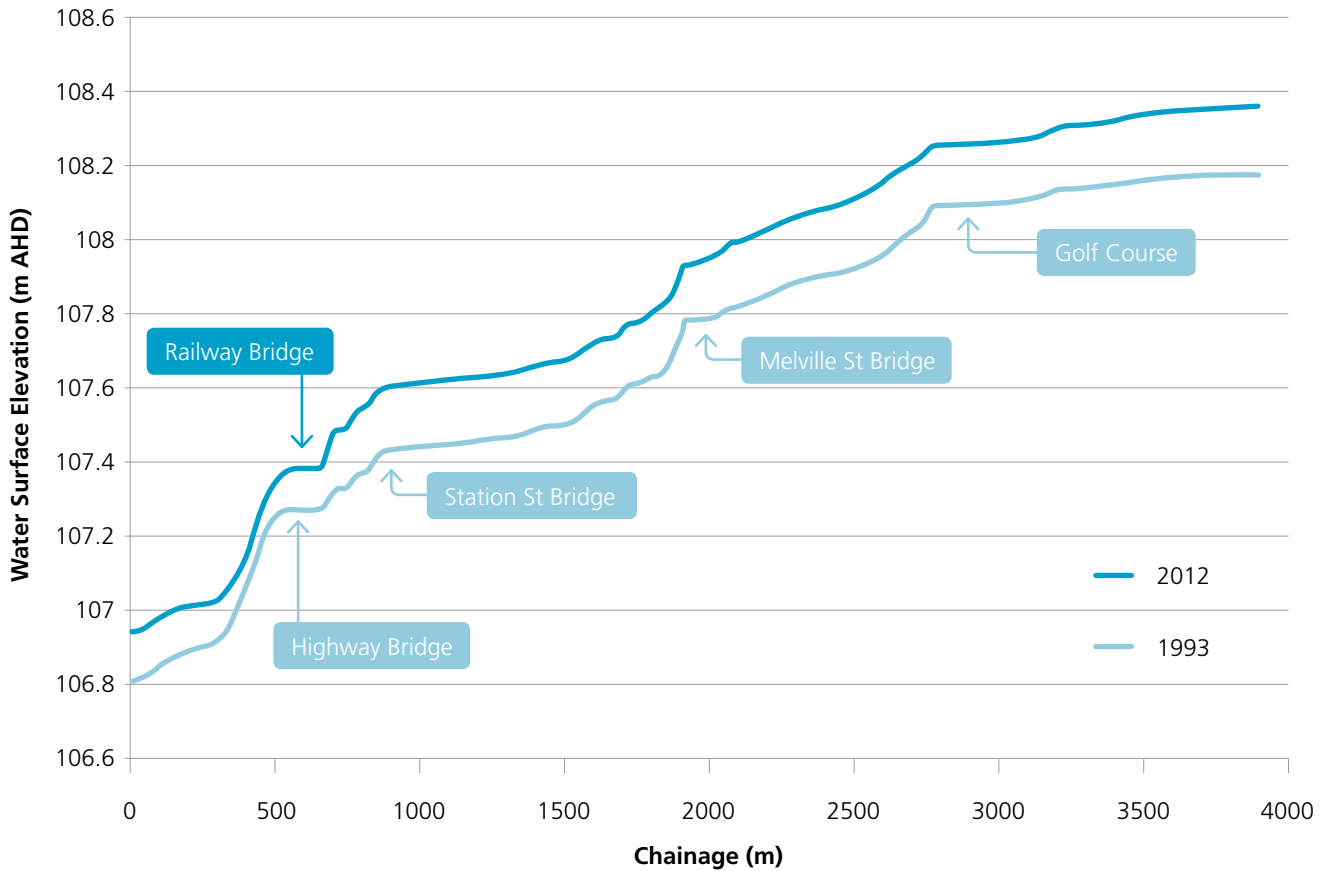


Figure 2.2: Topography around central Numurkah demonstrating the natural constriction that occurs through the township



**Figure 2.3: Long Section of flood levels during the 1993 and 2012 flood events**

## 2.3 FINAL MITIGATION PACKAGES

These packages were developed following extensive consultation with the community-based reference group (CRG) and agency stakeholders, and represent three different levels of protection for the town. The three final mitigation packages were modelled in detail to fully understand the benefits, costs and impacts of each. The three packages consist of:

### Final Mitigation Package A

Formalisation of the northern levee combined with a large southern ring levee and hospital depression levee protecting the northern and southern residential areas excluding the larger, residential lots and sections of the golf club. This package results in a very significant reduction in flood damages. The scheme has some moderate impacts upstream of the levee systems which extend for several kilometres across the floodplain. This package of works has been costed at slightly less than \$17 million and has a low benefit-cost ratio of 0.3.

This option also includes channel enlargement works along Broken Creek. This package reduces the number of properties flooded above floor in the 1% AEP event from 125 to 6. This package is the preferred package of the community-based reference group (CRG).

### Final Mitigation Package B

Formalisation of the northern levee combined with a southern ring levee and three smaller ring levees in the south of Numurkah thus providing protection to both the northern and southern residential areas of Numurkah, excluding the larger, southern, residential lots. This package results in a very significant reduction in flood damages. The scheme has some moderate impacts upstream of the levee systems. This package of works has been costed at slightly more than \$23 million and achieves similar benefits to Package A.

### Final Mitigation Package C

Formalisation of the northern levee combined with a southern ring levee and three smaller ring levees in the south of Numurkah thus providing protection to both the northern and southern residential areas of Numurkah, including the larger, southern, residential lots. This package results in a very significant reduction in flood damages. The scheme has some very significant impacts upstream of the levee systems which extend for several kilometres across the floodplain and are more severe than Packages A and B. This package of works has been costed at slightly less than \$25.5 million and achieves slightly more benefit than Packages A and B in that the larger, southern residential lots are also protected by the southern ring levee.

The above mitigation packages all include removal of some earthen embankments to the east of Numurkah near the Numurkah Go Kart track, channel enlargement works on Broken Creek, non-return valves on stormwater infrastructure which intersect the levees and environmental and cultural heritage management plans.

Mitigation Package A was found to have a low benefit-cost ratio of 0.3. This is a reflection of the high costs associated with levee construction, particularly sections likely to require retaining or flood walls, as well as very significant acquisition costs. The low benefit cost ratio is also due to the benefits of the schemes not being realised until relative large flood events. Package B and C did not undergo full benefit cost analysis but given they are more expensive to construct and achieve similar benefits they would have a lower benefit-cost ratio than Package A.

## 2.4 ORIGINAL MITIGATION PACKAGE

The original mitigation package below was presented to the community at a period of community consultation in February 2016. One of the key areas of feedback from the community option was that it did not include any structural mitigation for the southern residential areas of Numurkah. Based on this feedback the additional modelling was undertaken which led to the final packages described above. It should be noted that this option does not have the support of the CRG and generally received poor feedback from the broader community.

### Original Mitigation Package

Formalisation of the northern levee in order to provide protection to properties located to the north of Broken Creek. This package predominately benefits the northern portion of the township and results in a significant reduction in flood damages. This package reduces the number of properties flooded above floor in the 1% AEP event from 125 to 31.

## 2.5 NEXT STEPS

It is recommended that The Numurkah Floodplain Management Study and Plan now be presented to the community through a period of consultation in order to present the final mitigation packages and allow a preferred package to be determined.

Following this process, and the determination of a preferred scheme, the Plan will seek endorsement from both the Goulburn Broken Catchment Management Authority and the Moira Shire Council prior to sending to the Victorian Government for consideration for funding in a staged manner. Initial funding requests will comprise functional and detailed design of the proposed structural mitigation works. Other actions will include updating of the Emergency Response Plan, implementation of updated planning scheme layers, and implementation of the flood warning recommendations.

## 2.6 ACKNOWLEDGEMENTS

The Numurkah Floodplain Management Study and Plan was led by the Numurkah Floodplain Management Study and Plan Community Reference Group. The study team would like to thank the community members which volunteered their time to be on the Community Reference Group, and all others who contributed to the Plan, for their commitment to what has been a long study, but which offers solutions to reduce the flood risk for the Numurkah community.

## 3. FINAL MITIGATION PACKAGES

Following extensive consultation with the community reference group and key agency stakeholders, three flood mitigation packages were modelled in the extended hydraulic model and the key components of the modelling and results are described in this section.



## 3.1 FINAL MITIGATION PACKAGE A

### Northern Levee and Southern Ring Levee (which protects the smaller southern lots and football and golf clubrooms)

#### 3.1.1 OVERVIEW

The key components of the final Mitigation Package A are shown in Figure 3.1 and consist of:

- Construction of a northern levee extending from the Goulburn Valley Highway, along the northern bank of Broken Creek, across Melville Street near the central township and along the alignment of the existing irrigation channel banks adjacent to Kinnairds Road to the east of the township. The Brooke Court area is included within the levee. The northern levee would be constructed with 300 mm (30 cm) of freeboard above the 1% AEP water level. The irrigation channel banks to the east, which currently provide a level of protection in large events, would need to be replaced and/or upgraded to new design standards. The constructed levee would be 4.5 km in length and have an average height of 0.8 metres. Moira Shire Council would be the construction authority for the levee, which includes management of the operation and maintenance plan.
- A southern ring levee which encompassed the smaller lots in the southern residential area, the football clubrooms and football ground and approximately half of the golf course. The levee extends as far east as Corke Street. The ring levee was assumed to be predominantly an earthen levee with some sections of raised road along Tunnock Road, Corke Street and Katamatite Road.
- An earthen ring levee protecting several properties in the hospital depression.
- Broken Creek channel enlargement in the vicinity of the caravan park, Melville Street, skate park and football club to reduce the hydraulic constriction that occurs through that area.
- Floodways across the Katamatite-Nathalia Road at two locations - at the lower end of the Hospital Depression and at the upper end of the depression 400 metres to the east of the intersection with Kinnaird's Road. In order to ensure safe access to the southern residential areas during flood event, a culvert/bridge structure may replace the western floodway and this will be determined during detailed design. Safe access will be required to ensure the Numurkah District Health Service and Ambulance Station are accessible during flood events.
- There are a total of nine locations where the northern and southern levees would cross minor roads or access tracks and a system of headwalls and drop boards, flood gates or raised trafficable crossings would be required at those points. Removal of earthen embankments to the east of Numurkah in the vicinity of the Go Kart Track.
- Installation of non-return valves on all major stormwater outlets into Broken Creek from the northern and southern sections of the township. This is to ensure flood water does not back up in large flood events resulting in flood water on the protected side of the levee.

This package of works has been costed and the total capital cost is estimated to be \$16,935,000 (ex. GST) (inclusive of land acquisition, contingencies, admin and engineering). The cost excludes any local mitigation measures that might be required as a result of the increased water levels upstream and downstream of Numurkah.

Figure 3.1: Final Mitigation Package A Options

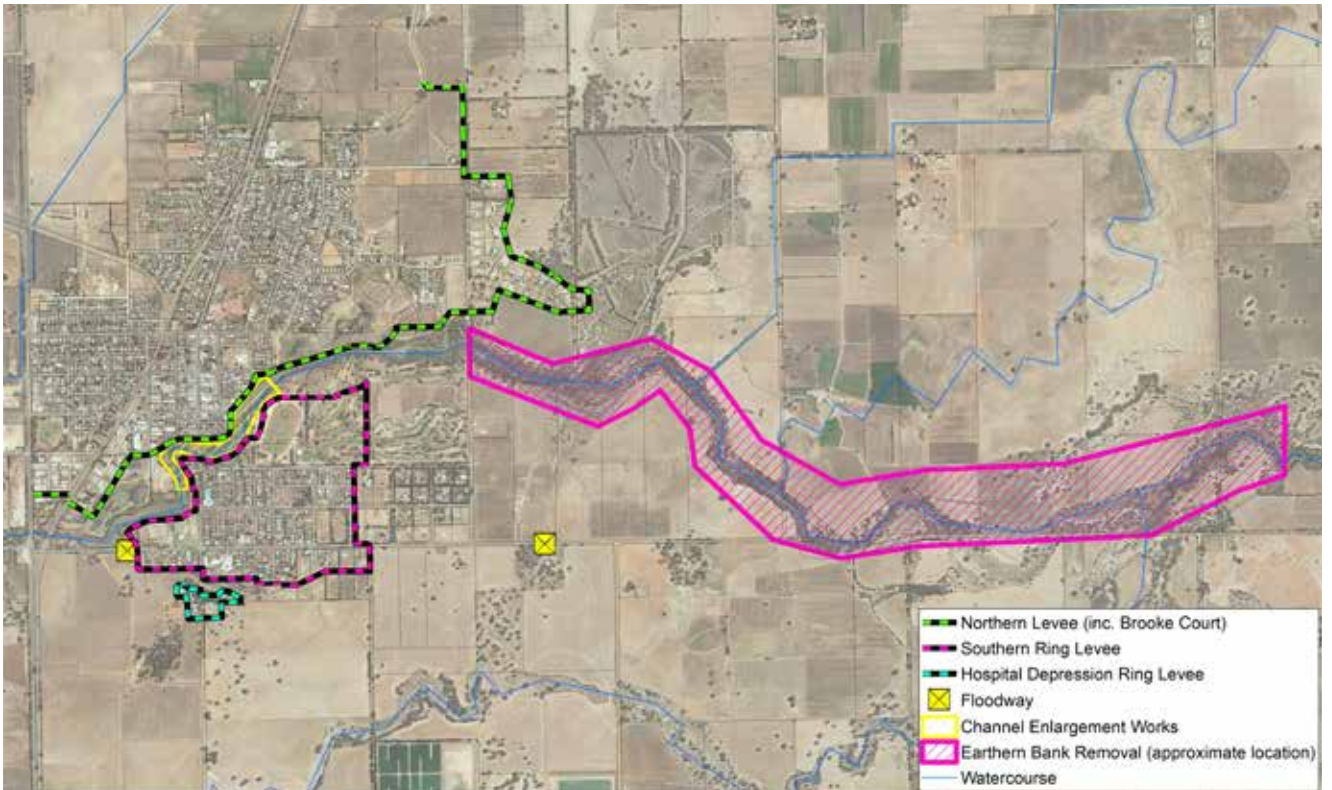
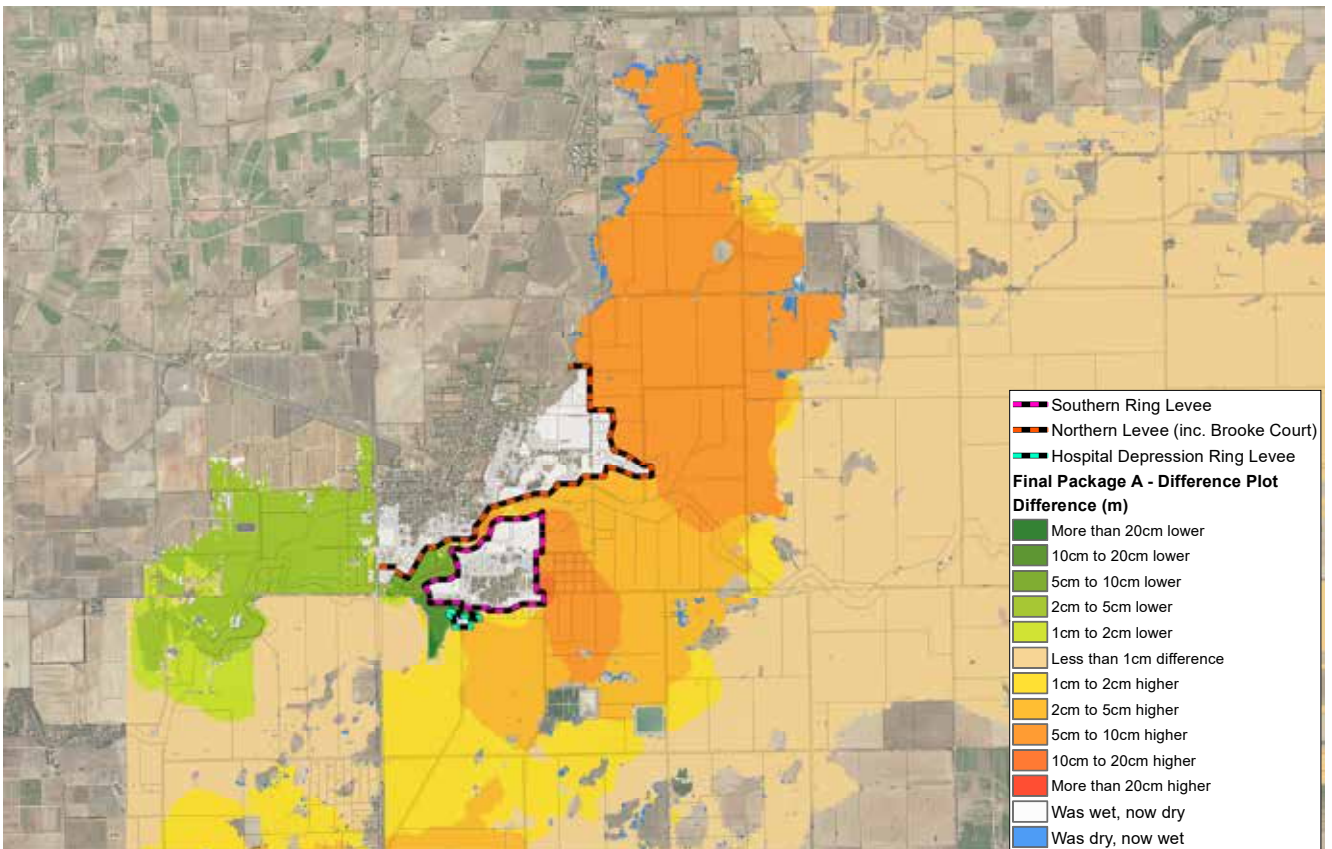


Figure 3.2: Final Mitigation Package A - 1% AEP Difference Plot



### 3.1.2 FINAL MITIGATION PACKAGE A RESULTS

The scenario was modelled for full range of design events. The results for the 1% AEP event are shown below in Figure 3.2. It can be seen that:

- The levees offer 1% AEP protection to all blocks inside the levee system which includes all of the smaller southern residential lots and all properties in Numurkah township to the north of Broken Creek including those on and around Brooke Court.
- Water levels upstream of the levee systems are increased by generally 50 to 65 mm (5-6.5 cm). These impacts extend for approximately 2.8 km to the east and 5.2 km to the north up into the Muckatah Depression. Water levels also increase across the floodplain to the south of Numurkah with increases of more than 10 mm likely to extend to Wunghnu.
- Increased water levels of up to 100 mm within Numurkah immediately to the east of the southern levee through the larger, southern residential lots. Most buildings through this area are built up, however there is one property at 2547 Katamatite-Nathalia Road which would flood above floor with this scenario but doesn't under existing conditions. Local measures would be required to mitigate the impact to this property. In addition, the Municipal Flood Emergency Plan (MFEP) will need to include specific actions for this property and others in this area impacted by inundation.
- Moderate increases in water levels of 10 to 50 mm (1-5 cm) between the north and south levees upstream of Melville Street including through the golf course.
- Lower flood levels through the hospital depression and immediately downstream of the southern levee with reductions of up to 200 mm (20 cm). This is partly due to the southern levee limiting flow and the removal of the disused channel banks to the south-west of the levee.

- Reduction in flood levels of 20 to 50 mm (2-5 cm) downstream of the Goulburn Valley Highway extending for approximately 2 km.
- 10 to 50 mm (1-5 cm) increase in flood levels downstream of the Goulburn Highway south of Sampsons Road.

During a 1% AEP event, the package reduces the total number of properties inundated from 834 properties to 74 properties, with the number of properties flooded above floor reduced from 125 to 6.

### 3.1.3 FINAL MITIGATION PACKAGE A SUMMARY

Overall it can be seen that the final Mitigation Package A protects a significant proportion of residential properties through Numurkah but with moderate impacts to the south, east and north-east of the levee systems which extend for more than 5 kilometres.

The increased water levels are marginally greater than final Mitigation Package B and extend for a greater distance across the floodplain. One additional property would become flooded above floor within Numurkah at 2547 Katamatite-Nathalia Road. Flooding would be made worse for several properties within Numurkah as well as properties in outlying areas. Further analysis and consultation with landholders would be required to fully understand these impacts to outlying areas.

Detailed costings for this package are provided in Section 14 of the complete study report and Appendix B.

## 3.2 FINAL MITIGATION PACKAGE B

### Northern Levee and Southern Ring Levees (which protects the smaller southern lots)

#### 3.2.1 OVERVIEW

The key components of the final Mitigation Package B are shown in Figure 3.3 and consist of:

- The northern levee as per Final Mitigation Package A with Brooke Court included within the levee.
- A southern ring levee which encompasses all of the smaller residential lots in the southern residential area. The levee alignment generally follows existing roads and so it has been assumed that much of the levee would occur from the raising of roads. Other options such as temporary flood barriers placed along the roadways could also be considered. The larger, southern residential lots to the east were excluded from the levee. Most of these houses are built up and did not flood above floor in the March 2012 event.
- Ring levee protecting several properties from 160-172 Melville Street and the caravan park residence. This ring levee will allow the flow of water to continue across Melville Street and through the train park and reduces the constriction that occurs at the Melville Street Bridge. The unoccupied house at 174 Melville Street has been excluded from this ring levee and it is assumed in this scenario that the property would be acquired and form part of the flow path across Melville Street.
- An earthen ring levee protecting several properties in the hospital depression.
- Ring levee or flood wall around the football club clubrooms
- Broken Creek channel enlargement in the vicinity of the caravan park, Melville Street, skate park and football club to reduce the hydraulic constriction that occurs through that section of Broken Creek.
- Floodways across the Katamatite-Nathalia Road at two locations - at the lower end of the Hospital Depression and at the upper end of the hospital depression 400 metres to the east of the intersection with Kinnairds Road. In order to ensure safe access to the southern residential areas during flood event, a culvert/bridge structure may replace the western floodway and this will be determined during detailed design. Safe access will be required to ensure the Numurkah District Health Service and Ambulance Station are accessible during flood events.
- There are a total of nine locations where the northern and southern levees would cross minor roads or access tracks and a system of headwalls and drop boards, flood gates or raised trafficable crossings would be required at those points.
- Removal of earthen embankments to the east of Numurkah in the vicinity of the Go Kart Track.
- Installation of non-return valves on all major stormwater outlets into Broken Creek from the northern and southern sections of the township. This is to ensure flood water does not back up in large flood events resulting in flood water on the protected side of the levee.

This package of works has been costed and the total capital cost is estimated to be \$23,102,000 (ex. GST) (inclusive of land acquisition, contingencies, admin and engineering). The cost excludes any local mitigation measures that might be required as a result of increased water levels upstream and downstream..



Figure 3.3: Final Mitigation Package B Options

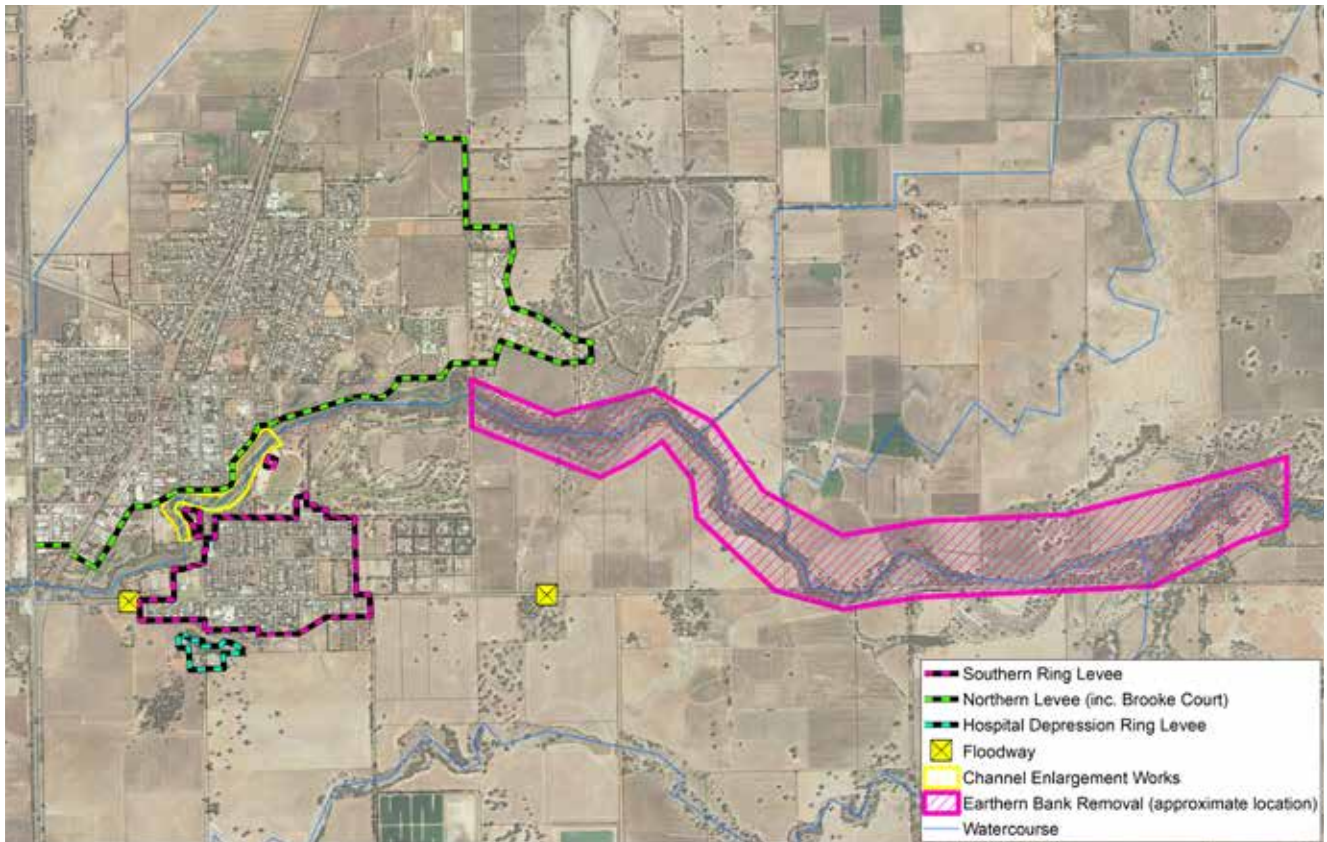
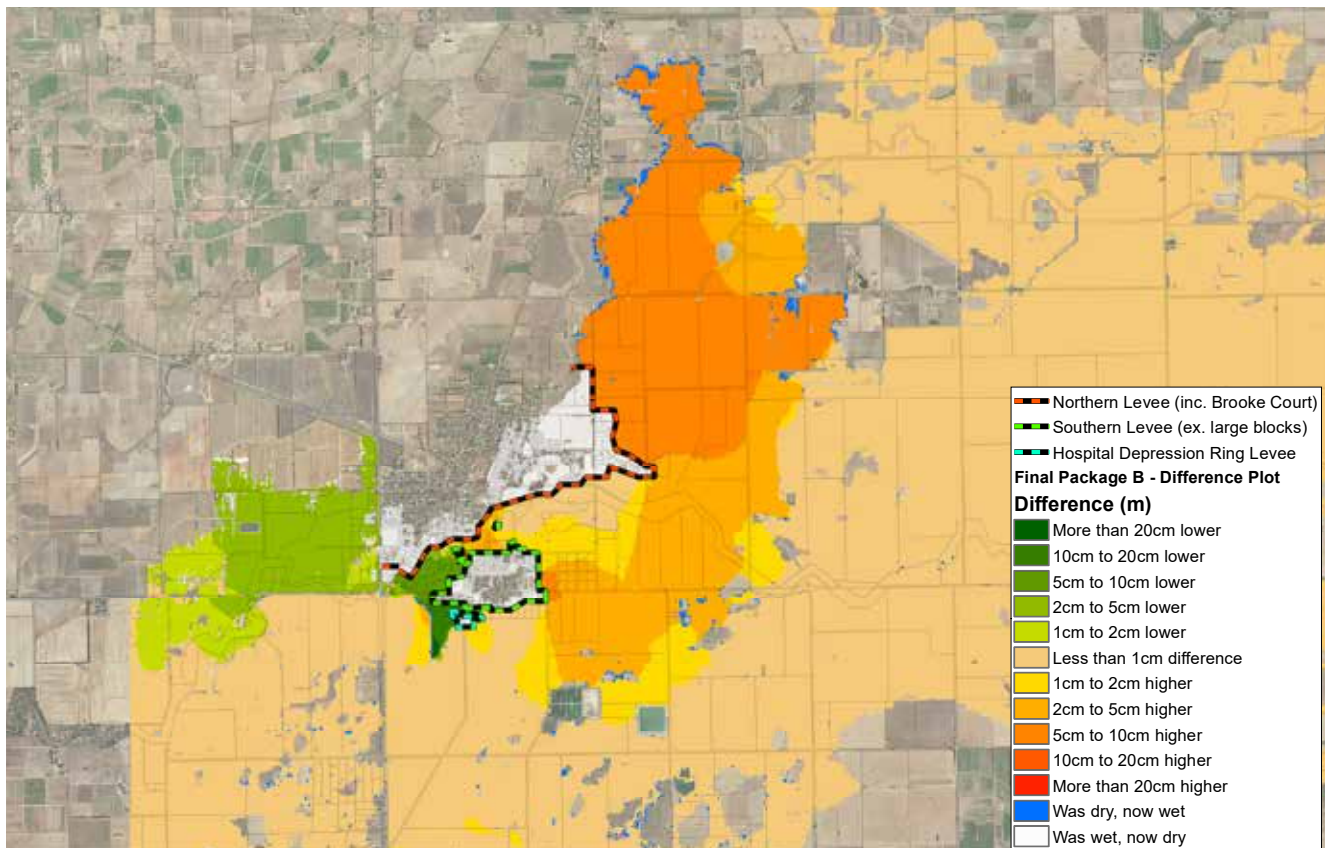


Figure 3.4: Final Mitigation Package B - 1% AEP Difference Plot



### 3.2.2 FINAL MITIGATION PACKAGE B RESULTS

The scenario was modelled for the 1% AEP event and the results are shown in Figure 3.4. It can be seen that:

- The levees offer 1% AEP protection to all blocks inside the levee system which includes all of the smaller, southern residential lots and all properties in Numurkah township to the north of Broken Creek excluding those at Brooke Court. It is of note that whilst outside of the levee the larger southern residential properties have floor levels built up and there would be no above floor flooding at these properties under existing or Package B mitigated conditions. Nonetheless, the Municipal Flood Emergency Plan (MFEP) will need to include specific actions for properties in this area which are impacted by inundation.
- Water levels upstream of the levee systems are increased by generally 20-50 mm (2-5 cm) with the largest impacts to the north of the Brooke Court levee. These impacts extend for approximately 2.8 km to the east and 5.2 km to the north up into the Muckatah Depression. Water levels increase for approximately 1.3 km across the floodplain to the south of Numurkah. The impacts to the south are considerably less than Package A.
- Minor increases in water levels of 10-30 mm (1-3 cm) between the north and south levees upstream of Melville Street including through the golf course and football oval areas. The impacts through this area are considerably less than Package A.
- Lower flood levels through the hospital depression and immediately downstream of the southern levee with reductions of up to 200 mm (20 cm). This is partly due to the southern levee limiting flow and the removal of the disused channel banks to the south-west of the levee.
- Reduction in flood levels of 20-30 mm (2-3 cm) downstream of the Goulburn Valley Highway extending for approximately 3.2 km.

### 3.2.3 FINAL MITIGATION PACKAGE B SUMMARY

Overall it can be seen that this option protects a significant proportion of residential properties through Numurkah with less impacts than Package A but more impacts than Package C. Upstream water levels are generally 30-50 mm (3-5 cm) higher to the east and north-east of Numurkah. The impacts do not extend as far across the floodplain to the south of Numurkah as Package A. Above floor flooding would not be made worse for properties within Numurkah however there are some properties in outlying rural areas that would be impacted. Further analysis and consultation with landholders would be required to fully understand these impacts to outlying rural areas.

The impacts upstream of the township are significant and local mitigation options would need to be further investigated if this option was to be implemented. This would occur as part of a functional and detailed design phase.

Detailed costings for this package are provided in Section 14 and Appendix B of the full study report.

## 3.3 FINAL MITIGATION PACKAGE C

### Northern Levee and Southern Ring Levees (which protects all southern residential lots)

#### 3.3.1 OVERVIEW

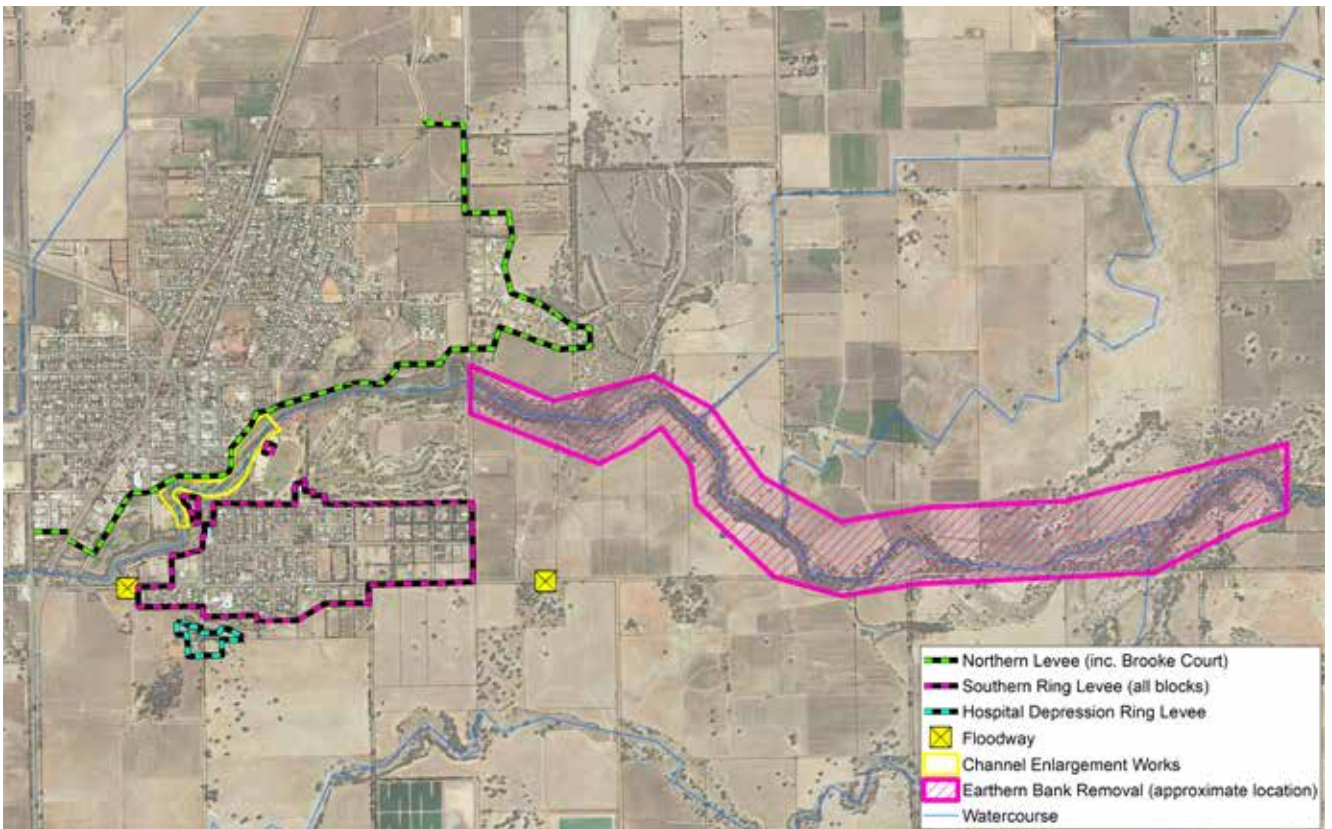
The key components of the final Mitigation Package C are shown in Figure 3.5 and consists of:

- The northern levee as per Mitigation Package A with Brooke Court included within the levee.
- A southern ring levee which encompasses both the smaller and larger residential lots through the southern residential area. The levee alignment generally follows existing roads and so it has been assumed that much of the levee would occur from the raising of roads. Other options such as temporary flood barriers placed along the roadways could also be considered.
- Ring levee protecting several properties from 160-172 Melville Street and the caravan park residence. This ring levee will allow the flow of water to continue across Melville Street and through the train park and reduces the constriction that occurs at the Melville Street Bridge. The unoccupied house at 174 Melville Street has been excluded from this ring levee and it is assumed in this scenario that the property would be acquired and form part of the flow path across Melville Street.
- An earthen ring levee protecting several properties in the hospital depression.
- Ring levee or flood wall around the football club clubrooms
- Broken Creek channel enlargement in the vicinity of the caravan park, Melville Street, skate park and football club to reduce the hydraulic constriction that occurs through that section of Broken Creek.
- Floodways across the Katamatite-Nathalia Road at two locations - at the lower end of the Hospital Depression and at the upper end of the hospital depression 400 metres east of the intersection with Kinnairds Road. In order to ensure safe access to the southern residential areas during flood event, a culvert/bridge structure may replace the western floodway and this will be determined during detailed design. Safe access will be required to ensure the Numurkah District Health Service and Ambulance Station are accessible during flood events.
- There are a total of nine locations where the northern and southern levees would cross minor roads or access tracks and a system of headwalls and drop boards, flood gates or raised trafficable crossings would be required at those points.
- Removal of earthen embankments to the east of Numurkah in the vicinity of the Go Kart Track.
- Installation of non-return valves on all major stormwater outlets into Broken Creek from the northern and southern sections of the township. This is to ensure flood water does not back up in large flood events resulting in flood water on the protected side of the levee.

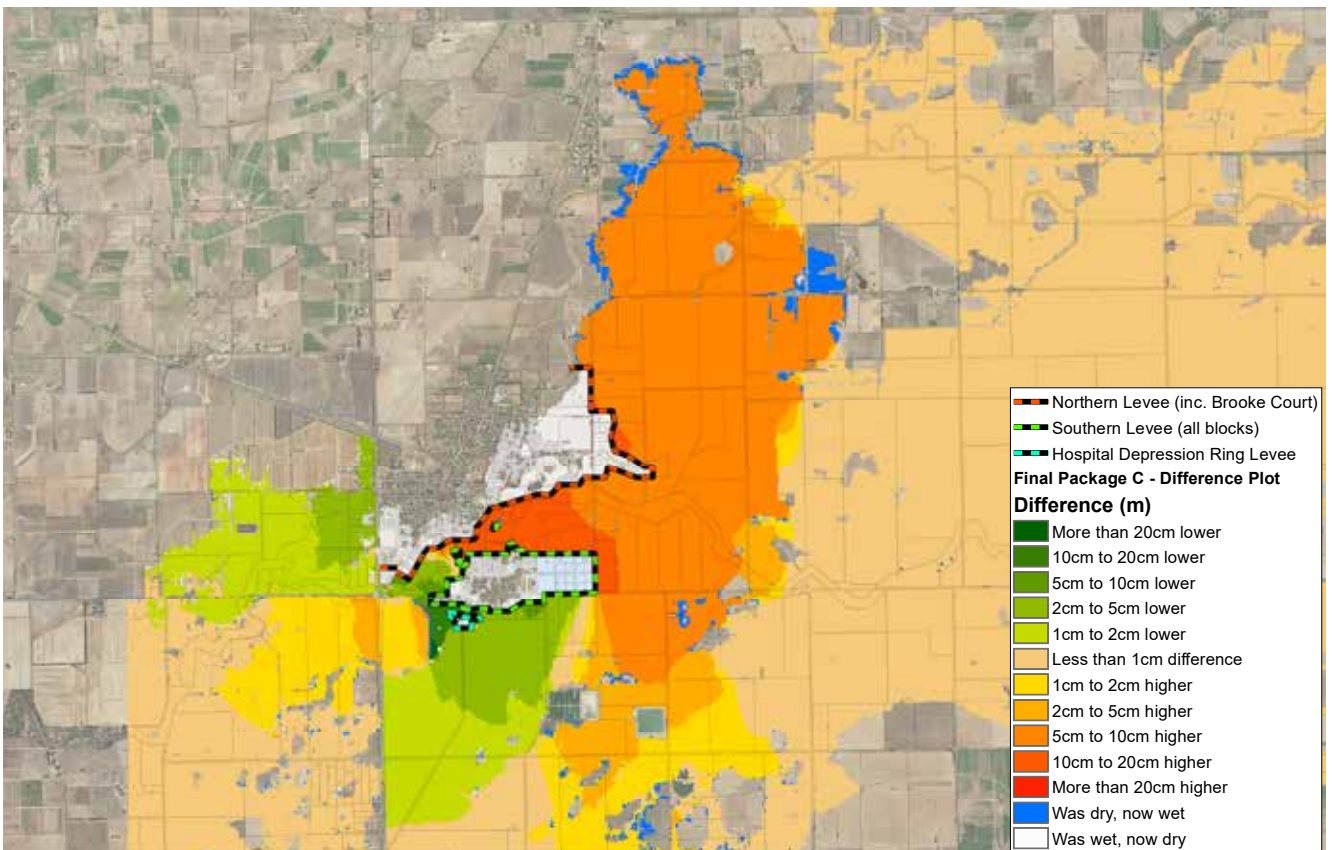
This package of works has been costed and the total capital cost is estimated to be \$25,487,000 (ex. GST) (inclusive of land acquisition, contingencies, admin and engineering). The cost excludes any local mitigation measures that might be required as a result of increased water levels upstream and downstream.



**Figure 3.5: Final Mitigation Package C Options**



**Figure 3.6: Final Mitigation Package C - 1% AEP Difference Plot**



### 3.3.2 FINAL MITIGATION PACKAGE C RESULTS

The scenario was modelled for the 1% AEP event and the results are shown in Figure 3.6. It can be seen that:

- The levees offer 1% AEP protection to all blocks inside the levee system which includes all southern residential lots (small and large) and all properties in Numurkah township to the north of Broken Creek including those at Brooke Court.
- Water levels upstream of the levee systems are increased by generally 80-100 mm (8-10 cm). These impacts extend for approximately 2.8 km to the east and 5.8 km to the north up into the Muckatah Depression. Water levels also increase across the floodplain to the south of Numurkah with increases of more than 10 mm (1 cm) likely to extend to Wunghnu.
- Significant increases in water levels of 100-200 mm (10-20 cm) between the north and south levees upstream of Melville Street including through the golf course and football oval areas.
- Lower flood levels through the hospital depression and immediately downstream of the southern levee with reductions of up to 200 mm (20 cm). This is partly due to the southern levee limiting flow and the removal of the disused channel banks to the south-west of the levee.
- Reduction in flood levels of 10-20 mm (1-2 cm) downstream of the Goulburn Valley Highway extending for approximately 2 km.

Overall it can be seen that this option protects a significant proportion of residential properties through Numurkah but with more impacts than Packages A and B. The increases in upstream water levels are significantly greater and extend further to the north and south of Numurkah than the other packages. Above floor flooding would not be made worse for properties within Numurkah however there are properties in outlying rural areas that would be impacted. Further analysis and consultation with landholders would be required to fully understand these impacts to outlying rural areas.

### 3.3.3 FINAL MITIGATION PACKAGE C SUMMARY

Overall it can be seen that the final Mitigation Package C protects a significant proportion of residential properties through Numurkah, including those located in the southern residential area. Brooke Court and the larger southern residential blocks remain inside the levee with this package. The package is associated with very significant impacts upstream of the levees which are worse than both Package A and Package B.

The impacts upstream of the township are significant and local mitigation options would need to be further investigated if this option was to be implemented. This would occur as part of a functional and detailed design phase.

Detailed costings for this package are provided in Section 14 and Appendix B of the full report.

## 3.4 COMPARISON OF IMPACTS

Scenario	Final Mitigation Package A	Final Mitigation Package B	Final Mitigation Package C
<b>Description</b>	Northern levee including Brooke Crt area and Southern ring levee protecting the smaller residential lots	Northern levee including Brooke Crt area and Southern ring levee protecting the smaller southern residential lots	Northern levee including Brooke Crt area and Southern ring levee protecting all southern residential lots
<b>Impact on upstream water levels</b>	Increases by 50-65mm, and extending 2.8km east and 5.2km north	Increases by 20-50mm, and extending 2.8km east and 5.2km north	Increases 50-100mm, and extending 2.8km east and 5.2km north
<b>Impact on the Brooke Court area</b>	Protected by levee	Protected by levee	Protected by levee
<b>Impact upstream of Melville Street</b>	Increases of 8-50 mm between the northern and southern levees	Increases of 10-30 mm between the northern and southern levees	Increases of 100-200 mm between the northern and southern levees
<b>Impact on larger southern residential blocks</b>	Increases by 100 mm, one additional property flooded above floor level	Increase by 20-70 mm	Protected by levee
<b>Impact to the south of Numurkah</b>	Increase water levels more than 10mm extending to Wunghnu	Increase water levels for 1.3km and significantly less than Scenario 2	Increase water levels more than 10mm extending to Wunghnu
<b>Impact on Hospital Depression</b>	Reductions up to 200mm	Reductions up to 200mm	Reductions up to 200mm
<b>Impact downstream of GVH</b>	Reductions up to 20-50mm	Reductions up to 20-30mm	Reductions up to 10-20mm

## 3.5 ORIGINAL MITIGATION PACKAGE

### Northern Levee

#### 3.5.1 OVERVIEW

The package below was presented to the community at a period of community consultation in February 2016. One of the key areas of feedback from the community option was that it did not include any structural mitigation for the southern residential areas of Numurkah. Based on this feedback the additional modelling was undertaken which led to the final packages described above. It should be noted that this option does not have the support of the community reference group and generally received poor feedback from the broader community

The key components of Original Mitigation Package (Northern Levee) are shown in Figure 3.7 and consists of:

- Construction of a Northern Levee extending from the Goulburn Valley Highway, along the northern bank of Broken Creek, across Melville Street near the central township and along the alignment of the existing irrigation channel banks to the east of the township. The Brooke Court area would be excluded from the levee. It is known that a flow path exists across Brooke Court and that no above floor flooding occurred on Brooke Court in the March 2012 event. There are however two older, low-lying houses near to Brooke Court which would flood in the 1% AEP event. The northern levee would be constructed with 300 mm (30 cm) of freeboard above the 1% AEP water level. The irrigation channel banks to the east, which currently provide a level of protection in large events, would need to be replaced and/or upgraded to new design standards. The constructed levee would be 4.5 km in length and have an average height of 0.8 metres. Moira Shire Council would be the construction authority for the levee, which includes management of the operation and maintenance plan.
- There are six locations where the northern levee would cross minor roads or access tracks and a system of headwalls and drop boards would be required at those points.
- Removal of earthen embankments to the east of Numurkah in the vicinity of the Go Kart Track.
- Installation of non-return valves on all major stormwater outlets into Broken Creek from the northern section of the township. This is to ensure flood water does not back up in large flood events resulting in flood water on the protected side of the levee.

This package of works has been costed and the total capital cost is estimated to be \$3,491,000 (ex. GST) (inclusive of land acquisition, contingencies, administration and engineering). The cost excludes any local mitigation measures that might be required as a result of the increased water levels downstream.



Figure 3.7: Original Mitigation Package Options

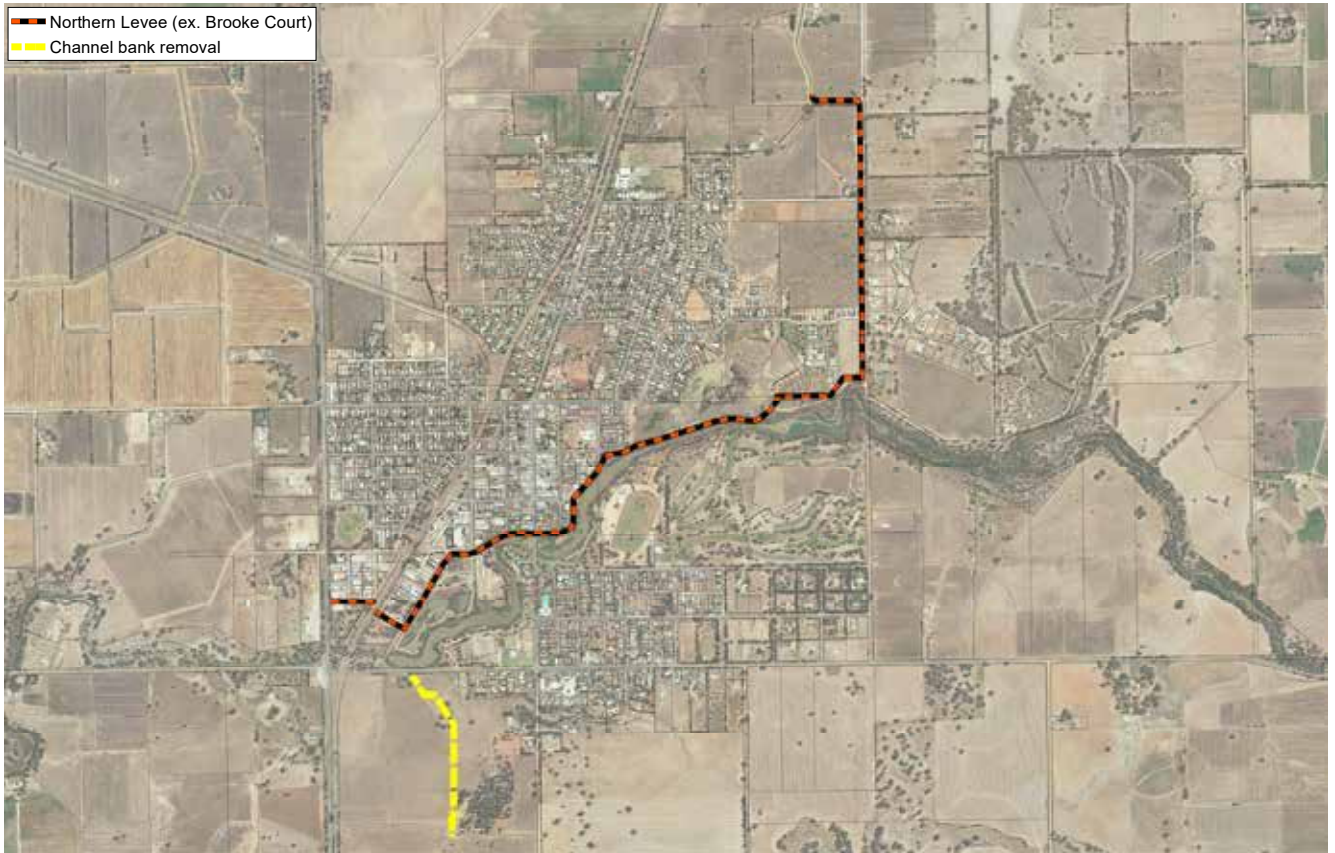
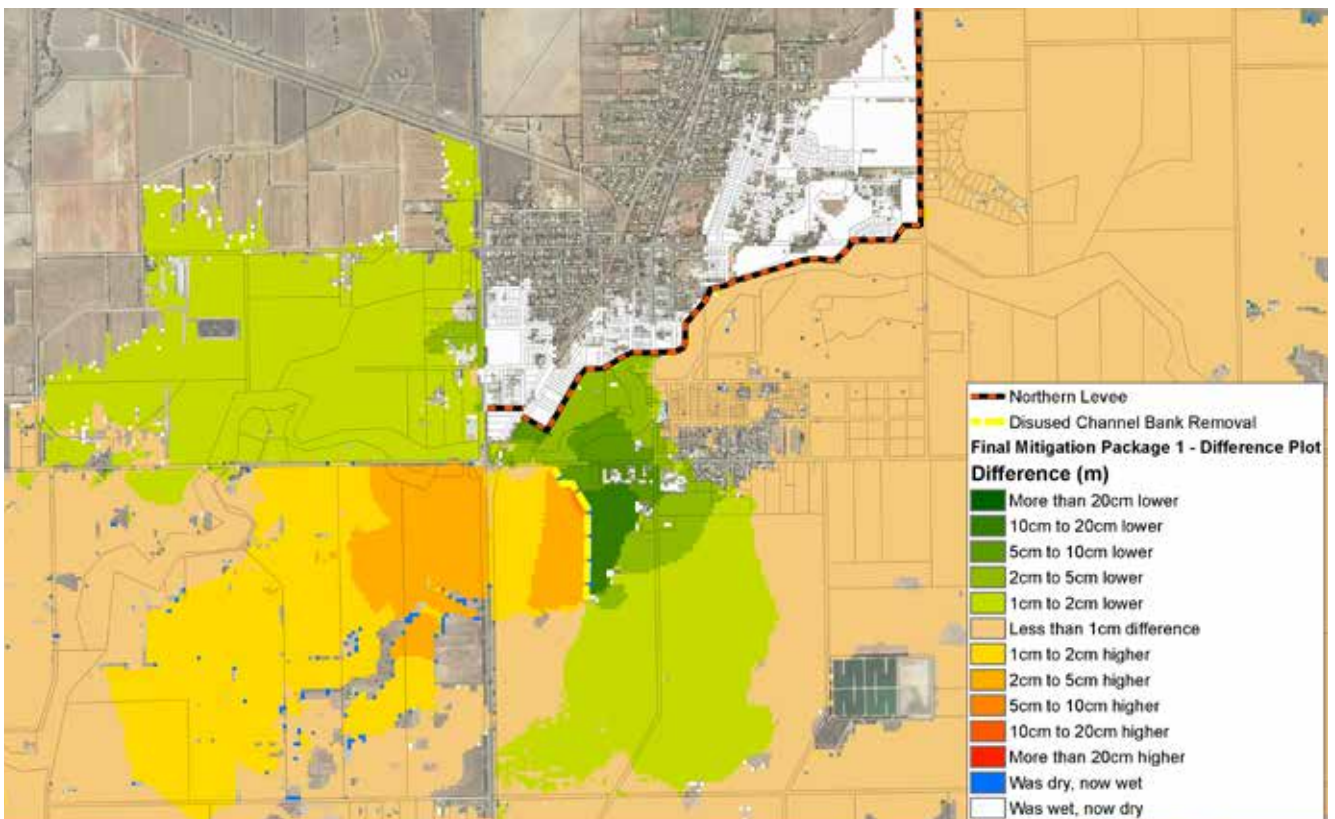


Figure 3.8: Original Mitigation Package Difference Plot





### 3.5.2 ORIGINAL MITIGATION PACKAGE RESULTS

A difference plot is provided in Figure 3.8 for the original mitigation package under the 1% AEP event. The results demonstrate that the works are effective in protecting much of the northern township in the 1% AEP event. The key observations from the modelling results are:

- The results demonstrate that the levee is effective at protecting the northern part of Numurkah in the 1% AEP event with 94 properties protected from above floor flooding and 466 properties protected from below floor flooding. The levee does not cause any impacts to upstream water levels.
- Removal of the south-west disused channel banks has resulted in lower water levels to properties near the hospital depression of between 15 and 65 mm (1.5 and 6.5 cm). Two properties in that area would be protected from above floor flooding while several would be protected from below floor flooding.
- The results demonstrate that removal of the channel banks causes increased water levels to agricultural areas downstream of the banks, as well as one residential and one commercial property. At both properties water levels are increased by approximately 25 mm (2.5 cm).
- During a 1% AEP event, the package reduces the total number of properties inundated from 834 properties to 368 properties, with the number of properties flooded above floor reduced from 125 to 31.

### 3.5.3 ORIGINAL MITIGATION PACKAGE SUMMARY

The results show that the Original Mitigation Package significantly reduces flood risk in Numurkah with the northern section of the town protected in a 1% AEP flood event as shown in Figure 3.8.

The works are more effective for residents living north of Broken Creek however there is some benefit to properties in the south of Numurkah who are located within close proximity to the hospital depression, as a result of removal of the disused irrigation channel banks. Impacts downstream of the south-west disused channel banks are noted, and local mitigation options for these downstream properties would need to be further investigated as part of a functional and detailed design phase if this package of works was implemented.

## 4. KEY FINDINGS AND RECOMMENDATIONS

### The following points detail the key findings and recommendations of the study:

- Design flood levels were determined and can be used to guide future planning decisions in Numurkah.
- Three final packages of mitigation works have been identified which significantly reduce flood risk for Numurkah. The packages consist of:
  - **Mitigation Package A** consists of formalising the northern levee, a larger southern ring levee and hospital depression levee as well as channel enlargement of Broken Creek. This package benefits both the northern and southern portions of the township and results in a very significant reduction on flood damages. The scheme has some moderate impacts upstream of the levee systems which extend for several kilometres across the floodplain. This package of works has been costed at slightly less than \$17 million and has a low benefit-cost ratio of 0.3.
  - **Mitigation Package B** consists of formalising the northern levee as well as a southern ring levee and three other smaller ring levees. This package benefits both the northern and southern portions (excluding the larger southern residential lots) of the township and results in a very significant reduction in flood damages. The scheme has some moderate impacts upstream of the levee systems. This package of works has been costed at slightly more than \$23 million.
  - **Mitigation Package C** consists of formalising the northern levee as well as a southern ring levee and three other smaller ring levees. This package benefits both the northern and southern portions (including the larger southern residential lots) of the township and results in a very significant reduction in flood damages. The scheme has some significant impacts upstream of the levee systems which extend for several kilometres across the floodplain and are worse than Packages A and B. This package of works has been costed at slightly less than \$25.5 million.
- It is recommended that the three final mitigation packages are presented to the community through a period of community consultation in order to seek community feedback on the preferred mitigation package.
- If any of the above packages of works are implemented the next step will be for the package to undergo functional and detailed design. Some of the packages have been noted to have impacts on a significant number of upstream and downstream properties and local mitigation works where appropriate will need to be investigated as part of the functional and detailed design phase.
- The Original Mitigation Package has also been presented in this report and consists of formalising the northern levee as well as a number of other minor works. This package predominately benefits the northern portion of the township and results in a significant reduction in flood damages. This package of works has been costed at slightly less than \$3.5 million and has a low benefit-cost ratio of 0.4. It should be noted that this option does not have the support of the community reference group and received low levels of support during the last period of community consultation.
- It is recommended that any future decommissioning of irrigation channels must consider the impact on flood risk to Numurkah and surrounds. In particular, the study has highlighted the importance of the irrigation channel to the east of Numurkah which runs parallel to Kinnairds Road and has a significant role in protecting the township in large flood events. Any future decommissioning works of the Kinnairds Road channel must consider these impacts and replace the channel banks with a formal levee.

- The CRG requests that culverts along Broken Creek are upgraded in the future to improve drainage around Numurkah. In particular, when funding permits, the committee wishes to see the Goulburn Valley Highway and Railway culverts be upgraded with increased capacity to reduce water banking up on the upstream side in large flood events. It is acknowledged by the committee that funding is unlikely to be available in the short-term but it is recommended that the works be implemented as part of a long-term drainage plan for Numurkah. In the short-term it is recommended that the culverts undergo maintenance to ensure they are cleared of debris and sediment and are operating at full capacity.
- The CRG requests that VicTrack be notified that damage to the railway line in the vicinity of Numurkah from large flood events is likely to continue periodically into the future. The committee would like VicTrack to consider that, when funding permits, the culverts under the railway line be upgraded with either an increased number of culverts or bridged sections to increase the capacity of flow under the line. Such works will reduce the frequency of overtopping and are likely to reduce the long-term cost associated with flood damage to the railway line along with the associated economic losses to the greater community. It is acknowledged that funding is unlikely to be available in the short-term but it is recommended that the works be implemented as part of a long-term drainage plan for Numurkah. A copy of the draft report will be forwarded to VicTrack at the completion of the project with these points highlighted to them.
- It is recommended that future road maintenance and upgrade programs by both Council and VicRoads must consider the impact of flooding in completing such works. It is noted that roads can have a significant impact on floodplain behaviour, particularly in areas of flat terrain such as Numurkah. Floodplain behaviour must not be altered or made worse around Numurkah through the raising of road crest levels that often occurs in road maintenance programs.
- VICSES, Moira Shire Council and Goulburn Broken CMA should explore further the recommendations for enhanced flood response through utilising the flood inundation maps and flood intelligence tools included in the Municipal Flood Emergency Plan (MFEP).
- The study has recommended a flood warning system for Numurkah which includes additional permanent rainfall and streamflow gauges. A firm commitment has been made by Goulburn Broken CMA, DELWP, BOM and Moira Council to implement the recommendations and planning for the warning system has commenced. The flood warning system should be utilised in conjunction with the flood maps and flood intelligence produced from this study to form an effective flood warning system.
- The CRG strongly support permanent gauges being installed on the Broken Creek between Katamatite and Numurkah and in the Muckatah Channel. They feel that this would reduce the reliance on temporary gauges that may not be available in a flood situation. It is recommended that Moira Shire Council and Goulburn Broken CMA explore the opportunity with Bureau of Meteorology what the benefit of permanent gauges would be for any future flood warning system upgrade, and identify locations that would be suitable. As part of this process consultation should also occur with Goulburn Murray Water who also have some preferred permanent gauging sites.

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