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# BARHAM LEVEE UPGRADE STRATEGY SUMMARY PAPER

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## 1. Introduction

This Summary Paper documents levee management issues at Barham. It is intended to provide a summary of the work undertaken since 2011 in the form of the 2014 Flood Study followed by the 2017 Floodplain Risk Management Plan, and its subsequent implementation to date focusing on the levee management aspects of the Plan.

Under the NSW State Government's Flood Policy, the management of flood liable land and flood mitigation infrastructure is the responsibility of local government. It is a Council responsibility that flood protection levees are in a state of continual readiness.

With significant financial assistance provided by the NSW Government via its Floodplain Management Program, Council has been able to have a Flood Study completed in 2014 and subsequently a Floodplain Risk Management Study and Plan completed in 2017. The completion of these projects makes it much more likely that Council will be successful in accessing further NSW Government grants for the implementation of any future levee improvements.

This Summary Paper has been prepared at a time when Council is having detailed design plans prepared for the upgrade of the River Estate Levee which seeks to bring the levee up to current urban levee design standards.

This Paper also covers the other levees at Barham, summarising the previous work which has been done, providing an updated discussion of management considerations and the current implementation strategy for future levee upgrades.

The author of this Summary Paper is Trevor Clark. Trevor previously worked for consultants GHD Pty Ltd and was the project manager for most of the previous reports prepared by GHD between 2011 and 2019.

The term annual exceedance probability (AEP) is used in this Summary Paper. The AEP of a flood is the long-term probability between floods of a certain size. The 1% AEP flood is also referred to as the 100 year average recurrence interval (ARI) flood. Other events are listed below:

- 2% AEP flood event – equivalent to 50 year ARI event
- 5% AEP flood event – equivalent to 20 year ARI event
- 10% AEP flood event – equivalent to 9.5 year ARI event
- 20% AEP flood event – equivalent to 4.5 year ARI event

A 1% AEP flood is a flood that has a 1% chance of occurring or being exceeded once in a year. A 20% AEP flood is a flood that has a 20% chance of occurring or being exceeded once in a year.

## 2. Overview of Murray River Flooding Conditions at Barham

### 2.1 Description of Flooding Influences

Riverine flooding conditions at Barham have some notable characteristics. It is important to understand these characteristics in order to fully appreciate the flooding risks posed by the Murray River on the Barham township area.

The key characteristics are (refer to Figures 1 and 2):

- Flooding at Barham is not sensitive to Murray River inflows upstream of the Barmah Choke. The key Murray River tributary inflows influencing flooding at Barham are the Goulburn and Campaspe Rivers.
- A significant portion of the Murray River flows downstream of Echuca bypass to the north of Barham via Thule Creek and the Koondrook Forest into the Wakool River system.
- The Murray River channel at Barham is perched. This condition coincides with ground level elevations generally falling away from the river channel.

The above natural conditions result in a very narrow range of flood heights at Barham for increasing flood size. The design flood levels at the Barham streamflow gauge located on the downstream side of the Barham-Koondrook bridge as determined by the 2014 Flood Study (GHD, 2014) are:

- 20% AEP – 6.00 metre (m)
- 10% AEP – 6.08 m
- 5% AEP – 6.13 m
- 2% AEP – 6.17 m
- 1% AEP – 6.20 m
- Extreme – 6.40 m

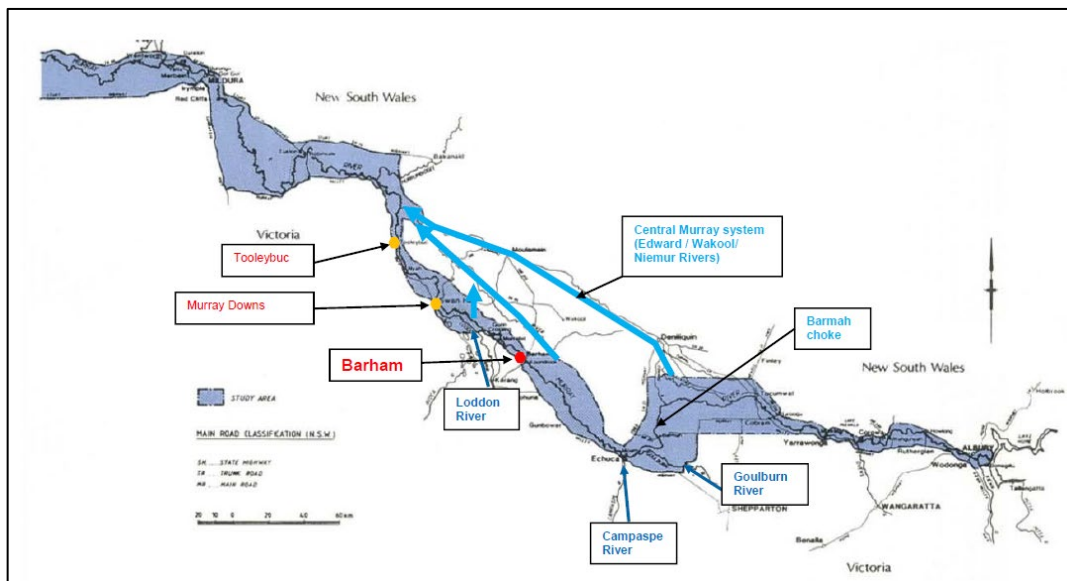
The 0.2 m differential between the 1% and 20% AEP flood levels is extremely narrow relative to most floodplains. It is narrow at Barham because of the natural floodplain conditions present (i.e. discharge of majority of flows into the bypassing Wakool River system and the perched floodplain conditions).

The 1% AEP flood level of 6.20 m at the Barham gauge is based on statistical analysis of the recorded flood heights at Barham since 1914. The maximum recorded height of 6.22 m occurred in 1917.

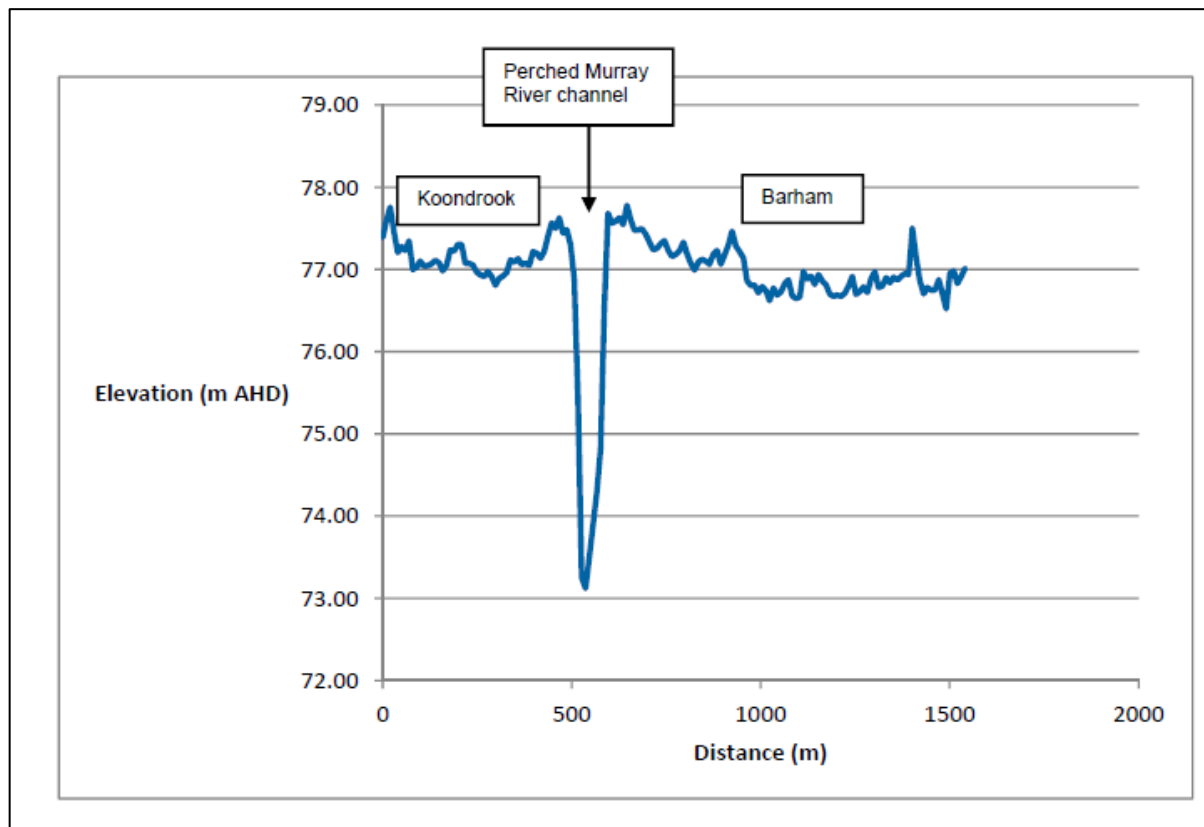
The natural floodplain conditions are also a key reason why Barham township has not experienced any significant river flooding in living memory. The other non-natural influence is the flood protection levees present within the floodplain surrounds.

Peak flood levels have exceeded 6.00 m at the Barham gauge on the following occasions:

- 2016 – 6.08 m
- 1993 – 6.10 m
- 1981 – 6.10 m
- 1975 – 6.12 m
- 1974 – 6.07 m
- 1973 – 6.05 m
- 1956 – 6.13 m
- 1955 – 6.02 m
- 1939 – 6.13 m
- 1931 – 6.05 m
- 1920 – 6.10 m
- 1918 – 6.03 m
- **1917 – 6.22 m (highest)**
- 1916 – 6.16 m



**Figure 1 Murray River Floodplain Features**



**Figure 2 Typical Floodplain Cross Section at Barham**

## 2.2 Impacts of Flooding on Barham Township

Flooding impacts at Barham are not well documented for floods prior to the 1950s, including for the highest flood on record in 1917.

Previous reports indicate the levees present combined with sandbagging efforts in the floods of 1956, 1975 and 1993 were successful in protecting the town from flooding.

In 1956, anecdotal accounts indicate that the then rural Koondrook Forest levee was breached. The Bringin Channel banks on the east side of Barham were subsequently used as de facto levee banks to protect the township.

Anecdotal accounts from long term Barham residents support that there has not been any significant river flooding within the township in living memory.

A recent flood peaked at 6.08 m in October 2016. The 2016 flood was equivalent to a 10% AEP flood and is the highest flood recorded at Barham since 1993. Information suggests that there was no river flooding impacts during the October 2016 flood. There were no apparent concerns that the existing levees were at risk of breaching at any stage of the 2016 flood, with no seepage issues reported.

Community consultation undertaken during the 2014 and 2017 projects identified that the predominant view of the local community at Barham is that the risk of river flooding impacting on the town is extremely low. Many residents may not acknowledge that there is any risk. Local community support for a costly upgrade of the levee system is therefore likely to be low.

The reason why Barham has not been significantly affected by river flooding over a long period is due to:

- Natural flooding characteristics which limit the river flow and therefore flood level in the river channel opposite the town.
- The presence of the levees. Although the older levees are not engineered levees, natural compaction of the banks over a long period of time combined with the limited depth of floodwater on the river side of the levee has not generally lead to any serious levee breaches during past flood events.

## 2.3 Levee System

Parts of the existing levee system date back to the early 1900s following the establishment of the township in the late 1880s. The existing levees consist of a series of levee segments as follows:

- Murray River east (NSW) side bank – includes the Town Levee segment opposite the township and other segments upstream and downstream of the town.
- River Estate Levee – ring levee enclosing a residential estate constructed in 2014
- Koondrook Forest Levee – ring levee enclosing the Forest constructed between 2009 and 2013 to confine environmental floodwater and natural floodwater within the Forest.

Apart from the 2014 River Estate Levee, a 600 m north side extension to the Town Levee constructed in 2008 and the Koondrook Forest Levee, the levees at Barham are not engineered levees. This means that they have not been formally designed or constructed in accordance with current or recent industry practice for water retaining embankments.

The levees at Barham are mostly relatively low height levees. This is due to the perched nature of the river channel, with the levees located on the higher ground close to the river channel.



The existing levee directly opposite the township (Town Levee) has freeboard relative to the 1% AEP flood level varying from 0.3 to 0.6 m. The outer town rural levees generally have little or no freeboard relative to the 1% AEP flood level. Freeboard guards against a number of factors including uncertainties in the estimation of flood level, local hydraulic effects, wind and wave action, settlement of the levee over time, defects in the levee and climate change.

Levee segments at Barham, as referred to in previous reports, are shown on Figure 3.



**Photograph 1 Town Levee opposite the Bowling Club**



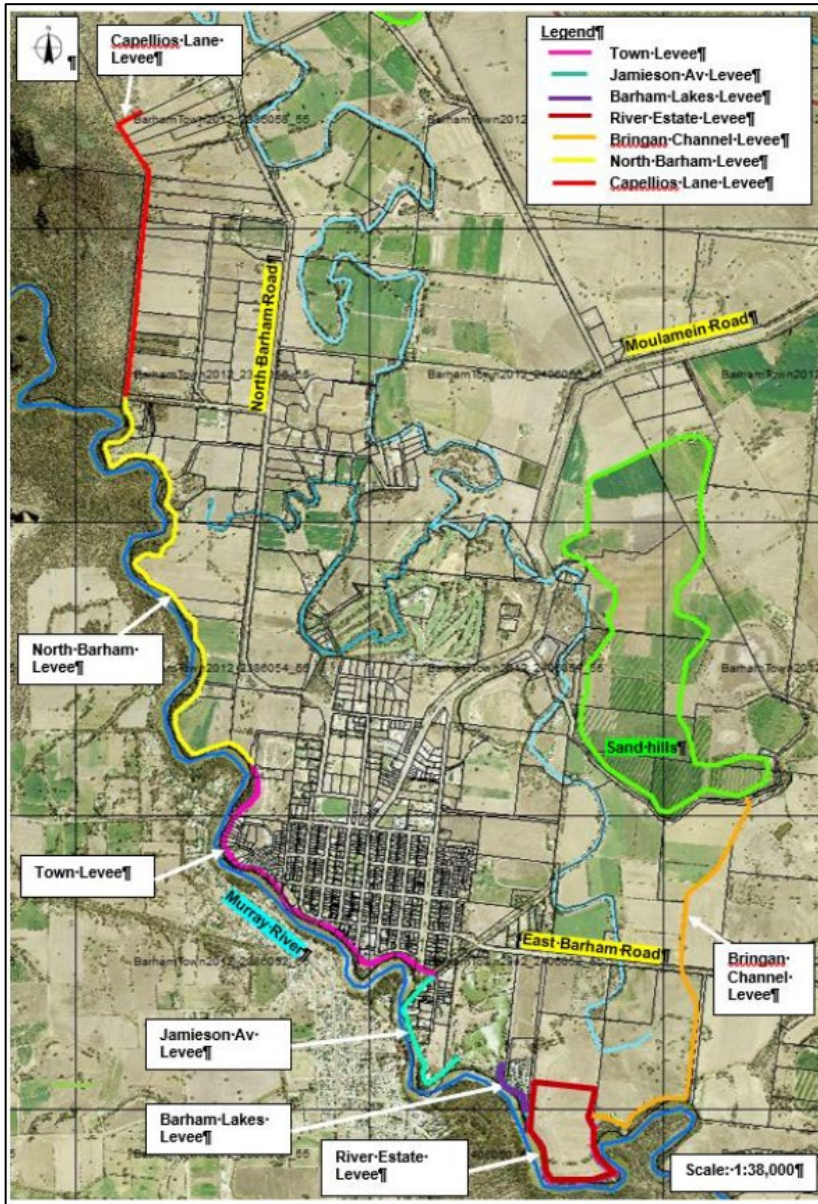


Figure 3 Barham – Levee Segments

## 3. Levee Upgrade Strategy Discussion

### 3.1 Introduction

Under the NSW State Government's Flood Policy, the management of flood liable land is the responsibility of local government, both in relation to mitigating the risk of flooding to existing development and enforcing development controls that are designed to ensure that future development is compatible with the flood risk.

Mitigating the flood risk to existing development should not be pursued by local government without first taking into account the economic, environmental and social impacts associated with the mitigation measures under consideration.

If a mitigation measure is cost prohibitive relative to the reduction in future flood damages achieved, then it should generally be discarded.

If a mitigation measure results in excessive adverse environmental impacts, then this may also be sufficient reason to discard the measure. An example of this could be the need to remove a large amount of high value native vegetation for the works to proceed.

If a mitigation measure results in excessive adverse social impacts, then this may also be sufficient reason to discard the measure. An example of this could be the removal of large mature trees along a river bank adjoining an urban area, thereby dramatically altering the aesthetic appearance of the river frontage.

Local government has an obligation to take into account the views of the local community when making decisions in regards to infrastructure which impacts on that community. If the local community is not supportive of the proposals (e.g. flood mitigation infrastructure for example) then this is cause for Council to consider whether or not to proceed with the proposal.

In some circumstances, it may be appropriate for local government to adopt a floodplain risk management strategy which rather than attempting to fully mitigate the flood risk to development, tolerates the flood risk, accepting that at some point in the future there will inevitably be flood property damage. This approach may be justified where:

- Mitigation is problematic due to significant adverse impacts resulting from the measures.
- Not supported by the majority of the local community.
- Past flood history does not include major property damage or loss of life.

Increasingly, insurance premium costs for properties which have a moderate to high flood risk are becoming cost prohibitive. Flood protection infrastructure can significantly reduce the flood risk to properties which in turn substantially lowers their flood insurance premiums. Property valuations can also be expected to rise if the risk of flooding to those properties is mitigated.

The Levee Owners Guideline (NSW Public Works, 2014) requires that levee owners in NSW:

- Maintain the levee in an adequate state for its intended purpose.
- Consider the adequacy of the levee to protect the community and the need to rehabilitate or upgrade the levee where necessary.
- Respond to changes in accepted flood protection standards, engineering standards and industry practices.
- Develop and maintain an effective levee management program, including operation, maintenance, surveillance and where necessary, contingency planning.

Most local governments in rural NSW do not have sufficient finances in order to cover the cost of flood mitigation infrastructure without having access to support funding. Primary considerations for Councils in relation to the implementation of flood mitigation infrastructure are:

- Council's having access to NSW Government grant funding. In the case of a regional council like Murray River Council, NSW Government funding of \$6 for every \$1 contributed by Council is potentially available.
- For NSW Government funding to be available, current urban levee design standards have to generally be met. One of the key design standards is the design height of the levee which in the case of Barham is the 1% AEP flood level plus the appropriate design freeboard.
- The cost of future levee maintenance activities are wholly borne by Council.

## 3.2 Flood Risk at Barham

An overview of flooding conditions and risks at Barham was given in the preceding Section 2.

The most likely failure for the levees at Barham with the exception of the River Estate Levee will be due to some local weakness, with failure triggered by either river bank erosion undermining a levee, a structure penetration (e.g. pipe) triggering internal erosion, or a tree within a levee falling over.

Given the non-engineered nature of most of the local levees, it is difficult to be definitive in terms of the risk of flooding at Barham. The following considerations would however appear to be pertinent:

- A recent flood event in October 2016 equivalent to a 10% AEP flood did not impact on Barham.
- The local Murray River flooding conditions prevent significant flood level rises above a 20% AEP event (1% AEP flood level only 0.2 m above the 20% AEP flood level).
- The Town Levee currently has a minimum of 0.3 metre of freeboard above the 1% flood level. Given the flooding conditions at Barham, the height of the existing Town Levee segment is arguable sufficient to conclude that the flood risk due to overtopping is extremely small.

Flooding impacts are documented in the Barham Floodplain Risk Management Study and Plan report (GHD, 2017). It nominates an average annual flood damage of \$620,000 based on the modelled flood levels and

indicative building floor levels. This outcome would appear to represent an over estimation of the actual past flood damages, given the low levels of flood damage incurred in recent floods.

The slow rates of rise of and fall of river flood levels at Barham mean that if a levee is breached or overtopped, the resulting flooding could be quite protracted, potentially lasting for a period of weeks. The property and economic impacts of this should not be underestimated.

The application of integrity assessment guidelines which have been prepared for engineered levees are arguably not applicable for the non engineered levees at Barham, which have been present in some cases for 100 years, and through natural consolidation are in a condition which appear not particularly vulnerable to breaching during floods, as evidenced by the recent 2016 event observations.

The 2019 Barham Levees System IFCL report (NSW Public Works Advisory, 2019) concludes that an assessment of the consequences of levee failure at Barham revealed that the potential loss of life to be theoretically zero, notwithstanding that substantial property damage would result.

### 3.3 Current (2019) Levee Upgrade Strategy

The Barham Levee Options Assessment report (GHD, 2019) documents a discussion of upgrade considerations in light of the Structural Integrity Audit outcomes.

Points raised by the 2019 Options Assessment report include:

- Progressing with rectification measures for the three external levee segments (North Barham Levee, Capelios Lane Levee and Bringan Channel Levee) should be given low priorities given that Council is not responsible for these levees, and their failure won't necessarily result in serious flooding of the Barham township area.
- The River Estate Levee rectification works appear to clearly warrant the highest priority given that development is progressing adjoining the levee. The longer the River Estate Levee upgrade works are deferred, the greater the disturbance to existing developed adjoining properties when the works are undertaken.
- Progressing with rectification measures for the three internal levees (Town Levee, Jamieson Avenue Levee and Barham Lakes Levee) is viewed as a lower priority compared to the River Estate Levee.
- The Town Levee has an existing minimum freeboard of 0.3 m. It is therefore at extremely low risk of overtopping and has performed well in recent floods.
- The most critical levee (Town Levee segment) is located in a native tree corridor opposite the bank of the river channel. A levee upgrade will be extremely difficult to implement without having a major adverse impact on this tree corridor from an environmental and social impact perspective. The local community is likely to strongly oppose this.



- The Barham Lakes Levee will provide protection to a large caravan park. The natural high ground along the levee route is extremely close to the 1% AEP flood level. There is no existing levee as such.
- The Jamieson Avenue Levee protects R1 and R5 zoned development. There is development activity within the levee protected area. The existing minimum freeboard is 0.1 m.

The upgrade strategy recommended by the 2019 report is shown below in Table 1. The 2019 report states that monitoring of the levee performance should be a focus in future floods and that if there are indications that the levees are showing signs of structural weakness, then this should give cause to revisit the implementation timeframes.

**Table 1      2019 GHD Levee Options Assessment Report – Upgrade Strategy Priorities & Timeframes**

Action	Priority	Implementation Timeframe
Develop an Operation and Maintenance Manual for the existing levee system	High	Prior to 2021
Upgrade the River Estate Levee to the adopted freeboard and structural standard	High	Prior to 2023
Upgrade the Jamieson Avenue Levee to the adopted freeboard standard	Moderate to High	2028
Upgrade the Town Levee to the adopted freeboard standard	Moderate	2035
Upgrade Barham Lakes Levee to the adopted freeboard standard	Low	2035 - 2050
Pending any subsequent reviews, upgrade the North Barham Levee to the adopted freeboard standard	Low	2035 - 2050
Pending any subsequent reviews, upgrade the Capellios Lane Levee to the adopted freeboard standard	Low	2035 - 2050
Pending any subsequent reviews, upgrade an east side levee (e.g. Bringian Channel) to the adopted freeboard standard	Low	2035 -2050

## 3.4 Current State of Play

As at May 2022, Council are progressing with the implementation of the Barham Floodplain Risk Management Plan. Since the Plan's completion and adoption in 2017, implementation activities have consisted of:

- In 2018, Council commissioned the Structural Integrity Audit and Levee Rectification Strategy Review. This project was completed in 2019. The resultant recommended actions, priorities and timeframes are as per Table 1. These priorities are what is currently governing the implementation approach.
- Barham Levee Owner's Manual was prepared by Council in 2019.
- In 2022, Council engaged consultant's (Dryside Engineering) to prepare detailed designs for the River Estate Levee Upgrade and the Jamieson Avenue Levee. Design drawings have now been prepared for the River Estate Levee Upgrade (April 2022) and are in the process of being prepared for the Jamieson Avenue Levee upgrade works.

Consultation with the directly affected community residents has been undertaken as part of the design process for the River Estate Levee upgrade. Feedback from River Estate residents has been negative in relation to the proposed River Estate Levee upgrade works. Details in regards to this matter are discussed more fully in Section 4 of this document. The main concerns of residents are summarised as follows:

- Observations of flooding conditions in October 2016 may have led some residents to conclude that raising the levee to meet the required 0.5 m of freeboard above the 1% flood level is overly conservative and not necessary.
- Concerns that the upgrade works will have a significant disruptive impact on their properties.
- Doubts that the levee structural deficiencies are sufficient reason to proceed with a major upgrade of the levee.

Further consultation with the residents of the River Estate is scheduled for the 4 May 2022.

## 3.5 Review of 2019 Strategy

The current Levee Upgrade Strategy is documented in GHD's September 2019 report – Barham Levee Options Assessment.

There have been no significant flood events since September 2019 (highest flood level recorded 5.38 m). There is therefore no additional data relating to the performance of the existing levee system during flood events which would give cause to revise the 2019 Upgrade Strategy. The most recent significant flood remains the October 2016 flood which peaked at 6.08 m during which no serious levee issues were observed.

Recent community consultation undertaken as part of the preparation of detailed designs for the River Estate Levee and the Jamieson Avenue Levee upgrade works has highlighted that many residents at Barham



perceive that there is little or no risk from river flooding. Given the lack of past impacts on the town, this is to be expected.

Geotechnical investigations undertaken as part of the River Estate Levee detailed design project in 2022 has concluded that the upgrade of the levee is necessary for it to be compatible with urban standards, consistent with the conclusions of the 2019 Structural Integrity Audit report and the 2019 Levee Systems IFCL report.

The issue which is currently causing considerable angst to all parties (relevant NSW Government departments, Council and the local community) is the conflicting expectations of the respective parties.

In the case of the local community, views and opinions are based largely on past experiences which amount to little or no property flood damage in living memory. Consequently and unsurprisingly, most residents consider that flooding poses very little risk, and therefore to proceed with a costly upgrade of the levee system is not needed and to be opposed given the significant disruptive impacts associated with the upgrade works (e.g. disturbance to property grounds, impacts on trees, visual impacts associated with higher levees).

In the case of Council, the need for upgrading the levees to a higher standard is not something that is being specifically sought by Council. Council is simply complying with the standards which apply to urban levees as developed by the NSW Government. The local flooding conditions at Barham are however such that it could be argued that the standards are higher than needs to be the case, as is the argument coming from sections of the community. To be financially able to maintain the levees in the long term, Council requires access to NSW State Government grant funding, which in turn requires a commitment to maintain them to the current urban standards.

The State Government authorities are compelled to enforce the adopted state wide floodplain management policies. These are naturally very risk averse which they need to be. Nothing is worse than a levee which has been constructed with public funds then fails in a future flood, having made matters worse by giving those protected a false sense of security.

Moving forward, the following levee upgrade strategy approach is nominated.

## **Barham Lakes, North Barham, Cappellios Lane and Bringan Channel Levee Segments**

The 2019 GHD report advises that the future upgrade of the Barham Lakes Levee segment, the North Barham Levee segment, the Cappellios Lane Levee segment and the Bringan Channel Levee segment be treated as Low Priority actions, given that none of the four levees is critical for the protection of the town area. The report states that pending community support levels and issues encountered in future flood events, an actual upgrade of these four levee segments may be deferred indefinitely.

This review considers that this approach remains appropriate for these four levee segments. If observations in future floods determine that there is a case for upgrading one of all of these four levees, then Council

should then proceed with the implementation of upgrades. In the absence of any such observations, the upgrade of these levees can be deferred indefinitely.

## **Town Levee Segment**

The 2019 GHD report advises that the future upgrade of the Town Levee segment be treated as a medium priority action. An indicative timeframe for its completion of 2035 is nominated. The report also states that pending community support levels and issues encountered in future flood events, an actual upgrade of the Town Levee segment may be deferred indefinitely.

This current review considers that Council should focus on monitoring the Town Levee until implementation of the River Estate Levee and Jamieson Avenue Levee upgrade works are fully complete. If concerns arise during monitoring activities, then this may give cause to proceed with design activities for an upgrade of the Town Levee.

Once the River Estate Levee and Jamieson Avenue Levee upgrade works are complete, Council should revisit whether or not to proceed with an upgrade of the Town Levee. It is envisaged that to proceed, this would require a reasonable level of community support. In the absence of observations in future floods suggesting that an upgrade of the Town Levee is needed (e.g. overtopping or threatening to overtop, seepage or breaching), then the upgrade of the Town Levee can be deferred indefinitely.

## **Jamieson Avenue Levee**

Once the detailed designs have been prepared and adopted for the Jamieson Avenue Levee upgrade, Council should progress to seeking NSW State Government funding assistance for construction and upon securement of sufficient funding, proceed with the construction of the works.

The actual implantation timeframe will be dependent on how soon Council is successful in securing NSW Government grant funding.

## **River Estate Levee**

Pending the outcome of further consultation activities which are planned in May 2022, Council should progress to seeking NSW State Government funding assistance for construction, and upon securement of sufficient funding, proceed with the construction of the upgrade works.

The actual implantation timeframe will be dependent on how soon Council is successful in securing NSW Government grant funding.

Section 4 of this report provides a more detailed account of issues relating the River Estate Levee upgrade. This is provided given the focus on this levee at the current time, as a result of the detailed design project which is in-progress.

# Barham Levee Upgrade Strategy Summary Paper

**Table 2      2022 Updated Barham Levee Upgrade Strategy**

Action	Priority	Timeframe
River Estate Levee segment upgrade	High	2022 - 2025
Jamieson Avenue Levee segment upgrade	Moderate to High	2022- 2025
Town Levee segment upgrade	Low to Moderate	Indefinite – pending future performance
Barham Lake Levee segment upgrade	Low	Indefinite – pending future performance
North Barham Levee segment upgrade	Low	Indefinite – pending future performance
Callelios Lane Levee segment upgrade	Low	Indefinite – pending future performance
Bringan Channel Levee segment upgrade	Low	Indefinite – pending future performance

## 4. River Estate Levee Review

### 4.1 Pre Construction Background

The site which is now occupied by the River Estate was identified as a prospective residential development area by the Wakool Shire Council's 2009 Land Use Strategy report.

A rezoning proposal was subsequently submitted by Council to the NSW Government Department of Environment, Climate Change and Water (DECCW) in 2010. DECCW responded to the rezoning proposal by advising Council that they would need to either:

- Option 1 - Prepare a town wide Floodplain Risk Management Plan and implement any resulting flood protection recommendations.
- Option 2 - Provide flood protection infrastructure meeting current urban flood protection standards to protect the development site in isolation.

Given the substantial time and cost associated with Option 1, the developers (RiverLife Property Group) chose to pursue Option 2.

A Flood Risk Assessment report was subsequently completed in 2011 for the parcel of land which is now occupied by the River Estate. The report was prepared by consultant's GHD for the RiverLife Property Group.

The 2011 Flood Risk Assessment report recommends the following:

- New ring levee enclosing the estate, aligned such that it skirts around the fringe of the riparian vegetation, thereby limiting any environmental impacts, and also providing a buffer to the river channel to guard against any future river bank erosion.
- Height of levee to be at the 1% AEP flood level plus the level of freeboard required by DECCW and Council.
- Levee to be constructed in accordance with the techniques and materials appropriate for urban flood protection levees.

The 2011 report identifies a 1% AEP river flood level of 78.0 m AHD at the proposed levee site. The report indicates that DECCW advised in discussions with GHD that a freeboard of 0.6 m above the 100 year ARI flood level may be considered appropriate.

It is noted that the 2011 report does refer to design flood levels given in previous reports prepared prior to 1998. AHD flood levels quoted in reports prepared prior to 1998 are based on a survey datum which is 0.15 m lower than post 1998. In 1998, the gauge zero datum at the Barham gauge was lowered from 71.435 m AHD to 71.28 m AHD (i.e. lowered by 0.155 m). The physical location and elevation of the gauge has not

changed since it was set up in 1905. A recorded flood height of say 6.00 m in 2022 is at the same height (elevation) as a recorded flood height of 6.00 m in 1922.

The highest recorded flood height at the Barham gauge was 6.22 m in 1917. The correct AHD elevation of the 1917 flood height is 77.50 m AHD, which differs from the 77.66 m AHD quoted in reports prepared prior to 1998.

The 2011 report notes that the then existing levee opposite the River Estate site located close to the river bank within the riparian vegetation varies in height between 77.8 and 78.2 m AHD. The reliance on this levee for flood protection to a future residential estate was not acceptable to DECCW given it did not meet urban design standards.

## 4.2 Construction

The River Estate Levee was constructed during 2014. A concept design plan of the levee provided to GHD in 2015 shows a design crest level for the levee of 78.25 m AHD.

In January 2016, Murray River Council engaged the surveying firm Northern Land Solutions to complete a crest height survey of the River Estate Levee. This survey identified that the constructed levee height varies from 78.12 m AHD to 78.30 m AHD along its length.

Based on the 2014 Flood Study hydraulic modelling, the 1% AEP Murray River flood level varies from 77.9 m AHD to 78.1 m AHD opposite the River Estate Levee. The resultant as-constructed levee freeboard above the 1% AEP flood level therefore varies from 0.1 to 0.3 m.

A significant flood occurred in October 2016 peaking at 6.08 m (equivalent to 10% AEP event) at the Barham gauge, 0.12 m below the 1% AEP flood level. Comparisons of a photograph taken of the 2016 flood near its peak opposite the River Estate with ground survey data indicate that 2016 flood levels peaked at approximately 77.8 m AHD opposite the Estate. This suggests that the 1% AEP modelled flood levels are in good agreement with the actual 2016 flood levels opposite the River Estate.

## 4.3 2019 Structural Integrity Report and Options Assessment Report

A Structural Integrity Audit was completed for the existing levees at Barham in 2018 / 2019. The audit is documented in the Barham Levee Structural Integrity Audit Final Report (GHD, March 2019). In light of the audit outcomes, options for progressing with an upgrade of the levee system at Barham are documented in the Barham Levee Options Assessment Final Report (GHD, 2019).

In regards to the River Estate Levee, the audit report identified the following issues:

- Levee height confirmed to provide an equivalent freeboard above the 1% AEP flood level varying from 0.1 to 0.3 m.

- High probability of leakage through the levee bank structure during a flood event, and subsequent internal erosion due to the dispersive and poorly compacted nature of the fill.
- No particular structural defects associated with the foundation material identified that would increase the probability of erosion through the foundation during a flood event.
- Likely to be a poor bond between the levee embankment fill and the foundation.
- Tree roots present in the embankment fill which upon breaking down over time will create preferential seepage paths which can result in internal erosion.

In light of the above issues, the audit report preliminary recommendations for rectification measures to the levee are for:

- A structural upgrade of the existing levee to address the deficiencies in the levee.
- Structural upgrade approach is to involve the addition of a new impervious zone layer on the river side batter, and raising of the levee to its required design height.
- Modifications to a stormwater pipe through the northern section of the levee.
- Removal of inappropriate works within the levee easement.
- Remediation of a number of local issues identified by the audit including two sink holes and localised batter erosion.

The Barham Levee Options Assessment report (GHD, September 2019) documents a freeboard assessment for the Barham Levees. The resulting recommendation is for a design freeboard allowance of 0.5 m to be adopted for the Barham levee system (i.e. design crest height of levees at the 1% AEP flood level plus 0.5 m).

The 0.5 m design levee freeboard adopted recommended for Barham is at the lower end of the freeboard scale currently adopted for urban levees in NSW. Freeboard is more typically in the range of 0.5 to 1.0 m. Levees at Moama and Swan Hill for example have an adopted design freeboard of 0.6 m.

The 2019 Options Assessment report documents four alternative arrangements for upgrading the River Estate Levee. The recommended option is for the construction of a raised impervious earthfill zone on the river side of the existing levee on the basis that it minimises the capital cost of the upgrade and it limits the disturbance to the existing developed lots by limiting the works to the river side of the levee.

## 4.4 2022 Detailed Design of Levee Upgrade

The consulting firm Dryside Engineering has recently prepared detailed design drawings for the upgrade of the River Estate Levee following their engagement by Council in late 2021. They are currently in the process of preparing detailed design plans for the Jamieson Levee upgrade.

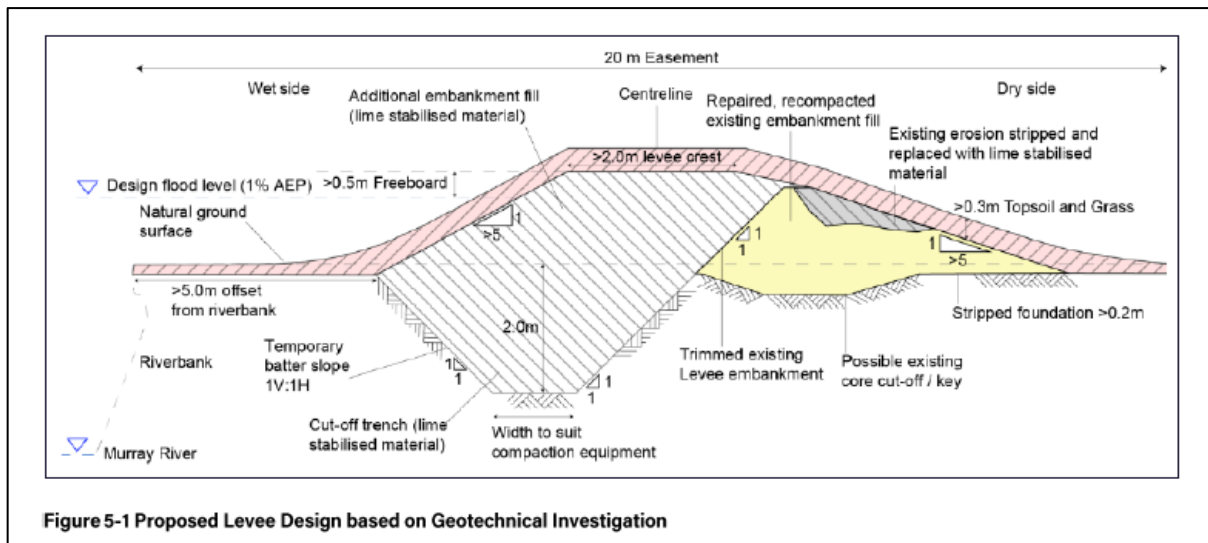
The River Estate Levee design upgrade is documented in a report dated 1 April 2022 – River Estate Levee Upgrade Design Report. The engineering drawings are included as Appendix A to the report.



Based on an independent review of the design freeboard assessment in GHD's 2019 report, the 2022 Dryside report recommends that a design freeboard of 0.5 m be adopted, consistent with the GHD 2019 recommendation.

Following an assessment of options, the option adopted for the design has the following features (refer to Figure 4 below):

- Minimum setback of 5 m from the edge of the river bank to the wet side levee toe.
- A 2 m deep cut-off trench on the wet side of the levee.
- 0.3 m of topsoil covering the batters and crest of the levee.
- Finished surface level of the topsoil at the 1% AEP flood level plus 0.5 m.
- Fill materials for cut-off trench and remainder of levee except for topsoil layer to be lime stabilised in order to control the dispersive and erodible properties of the site-won alluvium material.
- Maximum batter slope of 1V:5H.
- Permanent vegetation (grass) cover to be established over the levee including suitable watering infrastructure.
- Emergency spillway facility at the Riverview Drive crossing site.



**Figure 4 April 2022 Design Upgrade Arrangement for River Estate Levee**

## 4.5 Benefits of River Estate Levee Upgrade

The River Estate Levee upgrade will provide the following benefits:

- Mitigate the risk of future flooding within the estate.
- Reduce flood insurance premiums for properties within the estate.
- Increase the valuations of properties within the estate.

## 4.6 Response to River Estate Resident Concerns

Community consultation during the preparation of the detailed designs of the River Estate Levee upgrade has identified that some residents have concerns about the levee upgrade. Information aimed at addressing some of these concerns is provided below.

### Issue 1 – Why the need for the levee?

The levee was a condition of the rezoning approval imposed by the NSW Government authority (DECCW) in 2011/2012. The rationale for the need for the levee was that:

- The then existing levee located within the riparian vegetation zone was not an urban standard levee due to its limited height and structural deficiencies.
- The estimated 1% AEP river flood level at the time (78.0 m AHD) was higher than ground levels within the estate which varied at the time from 77.2 to 77.6 m AHD, and also higher than parts of the existing levee.

### Issue 2 – Is the 1% AEP design flood level correct?

The design height of the levee coincides with the 1% AEP flood level plus the necessary freeboard.

The 1% AEP flood level was estimated to be 78.0 m AHD in 2011. The 2014 Flood Study modelling places the 1% AEP flood level at 78.06 m AHD at the upstream most point opposite the Estate and 77.91 m AHD at the downstream most point opposite the estate.

In October 2016, flooding peaked at 6.08 m at the Barham gauge, 0.12 m below the 2014 Flood Study defined 1% AEP flood level of 6.20 m. Photographs of 2016 flood levels close to the peak adjacent to the River Estate suggest a peak 2016 flood level of approximately 77.8 m AHD when compared to ground survey data. Adding 0.12 m to this height results in a flood level which is in good agreement with the 2014 Flood Study modelled 1% AEP flood levels.

### **Issue 3 – Is the 0.5 m design freeboard appropriate?**

The 2019 GHD project and the current 2022 Dryside Engineering project have identified that an appropriate design freeboard for the River Estate Levee and other levees at Barham is 0.5 metre. Freeboard accounts for uncertainties in the estimation of the 1% AEP design flood level, wind and other generated waves, local disturbance / turbulence, levee settlement and climate change effects.

The 0.5 m freeboard adopted is at the lower end of the freeboard typically required for urban levees in NSW. Levees at Moama and Swan Hill have 0.6 m design freeboard.

### **Issue 4 – Is the need for a structural upgrade of the levee justified?**

All levees at Barham were subject to a structural integrity audit in 2018/2019 (GHD project), including the River Estate Levee. Geotechnical samples taken from the River Estate Levee and subject to laboratory testing identified that the levee structural integrity did not meet urban standards and that a structural upgrade was needed to address the deficiencies. Details are provided in the Structural Integrity Audit report (GHD, 2019).

Geotechnical consultants engaged by Dryside Engineering in early 2022 (Senversa) reviewed the previous GHD geotechnical work. This review confirmed the River Estate Levee to be in need of a structural upgrade to address deficiencies. Details are provided in the River Estate Levee Upgrade Design Report (Dryside Engineering, 2022).

### **Issue 5 – What will be the consequences if the River Estate Levee fails / breaches**

The consequences will vary depending on the circumstances (i.e. river flood level when levee breach occurs, where the breach occurs).

Floodwater entering the estate through a breached opening in the levee will continue to flow into the estate until the water level in the estate is equal to the river flood level opposite the breach point. Assuming a breach in the levee close to the upstream most point, the water level within the estate will rise to 78.06 m AHD if the river flood level is at the 1% AEP flood level. The lowest ground levels within the estate based on pre-development survey data were at approximately 77.2 m AHD in the south eastern corner of the estate. The maximum depth of flooding would therefore reach 0.86 m for this scenario. The average depth of flooding within the estate would be expected to be closer to 0.6 m.

## **Issue 6 – Why has the upgrade of the River Estate Levee been assigned the highest priority compared to the other levees at Barham?**

The River Estate Levee was an approval condition which supported the rezoning of the estate site to General Residential. Council will be responsible if the levee is found to fail due to reasons associated with it not being constructed to the necessary standard.

The 2019 GHD investigations confirmed that the levee in its current form does not meet the necessary standards for urban levees. Council is therefore compelled to take action to bring the levee up to standard, both from an obligation to adequately protect those within the levee, and an obligation to meet its own local government responsibilities.

The upgrade works will significantly disrupt the already development properties within the estate which back onto the levee. If the upgrade works are deferred, this will lead to more and more disruption as more of the lots are occupied. The sooner the upgrade works are complete, the better in this respect.

## **Issue 7 – Why is the 2022 detailed design arrangement different to the 2019 concept design arrangement?**

The levee upgrade arrangement adopted by Dryside Engineering has been selected on the basis that it will provide the most reliable, structurally sound levee in the aftermath of the upgrade, minimising the risks of any further issues.

Going with a lesser approach from the perspective of minimising costs and disruption impacts to landholders such as the concept design approach put forward by GHD in 2019 has been discarded on the basis that a scenario where there are ongoing risks associated with the upgraded levee cannot be tolerated (i.e. upgrade needs to be done once and properly).

The worst possible outcome would be to proceed with a costly and disruptive upgrade and still end up with a levee that has ongoing problems.

## 5. References

Dryside Engineering (Aust) Pty Ltd (1 April 2022). *River Estate Levee Upgrade Design Report*. Prepared for Murray River Council.

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GHD Pty Ltd (October 2014). *Barham Flood Study*. Prepared for Wakool Shire Council (Final Report).

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