CLIENTS | PEOPLE | PERFORMANCE

RiverLife Property Group

Report for RiverLife Estate, Barham

Flood Risk Assessment

4 March 2011

INFRASTRUCTURE | MINING & INDUSTRY | DEFENCE | PROPERTY & BUILDINGS | ENVIRONMENT

This RiverLife Estate, Barham – Flood Risk Assessment Report:

1. *has been prepared by GHD Pty Ltd for RiverLife Property Group;*
2. *may only be used and relied on by RiverLife Property Group;*
3. *must not be copied to, used by, or relied on by any person other than RiverLife Property Group without the prior written consent of GHD;*

GHD and its servants, employees and officers otherwise expressly disclaim responsibility to any person other than RiverLife Property Group arising from or in connection with this Report.

To the maximum extent permitted by law, all implied warranties and conditions in relation to the services provided by GHD and the Report are excluded unless they are expressly stated to apply in this Report.

The services undertaken by GHD in connection with preparing this Report:

- *were limited to those specifically detailed in section 1 of this Report;*
- *did not include an assessment of cultural heritage impacts associated with the development.*

The opinions, conclusions and any recommendations in this Report are based on assumptions made by GHD when undertaking services and preparing the Report ("Assumptions"), including (but not limited to):

- *various available flood related data sourced for this assessment is representative of actual flooding conditions for Barham and its surrounds.*

GHD expressly disclaims responsibility for any error in, or omission from, this Report arising from or in connection with any of the Assumptions being incorrect.

Subject to the paragraphs in this section of the Report, the opinions, conclusions and any recommendations in this Report are based on conditions encountered and information reviewed at the time of preparation and may be relied on until three years from the date of issue of the Report, after which time, GHD expressly disclaims responsibility for any error in, or omission from, this Report arising from or in connection with those opinions, conclusions and any recommendations.

Contents

Table Index

Figure Index

1. Introduction

This report documents the results of investigations into flooding risks associated with the proposed residential development of land adjoining the Murray River on the eastern outskirts of Barham (refer Figure 1).

Barham and the development site are protected from Murray River flooding via a levee system that has been in place for many decades, parts of which date back to the early 1900s. The levee network varies markedly in terms of height and condition. The levee was close to being overtopped in the most recent significant flood event of October 1993.

The development site was identified by the Wakool Shire Council in their 2009 Land Use Strategy Report prepared as part of their Local Environmental Plan (LEP) review process, as a prospective residential development area at Barham. A rezoning proposal was subsequently submitted by Council to the Department of Environment, Climate Change and Water (DECCW) in 2010.

DECCW's response to the rezoning proposal in October 2010 advised Council that either of the following two options needed to be implemented to ensure that adequate protection from flooding was in place for the development site:

- Option 1 - Council to prepare a Floodplain Risk Management Plan for Barham and its environs and implement any resulting recommendations: or
- Option 2 - Council to protect the site in isolation, to town levee standard.

– and prepare a FPRMP ?

Given the substantial time and cost associated with Option 1, Council and the developers (RiverLife Property Group) have opted to pursue Option 2. This report addresses the issues nominated by DECCW in their letter to Council of 1 October 2010 as requiring assessment to demonstrate that the development site is adequately protected from flooding. The issues nominated by DECCW in their advice to Council are as follows:

- Appropriate level of freeboard above the 1% flood;
- Appropriate construction standard;
- Type of levee construction and associated footprint;
- Dealing with internal drainage;
- Access in times of flood, particularly those larger than design;
- Impact on neighbours;
- Impact on the local environment;
- Land management issues;
- Potential back flooding from Eagle Creek; and
- Ongoing operation and maintenance.

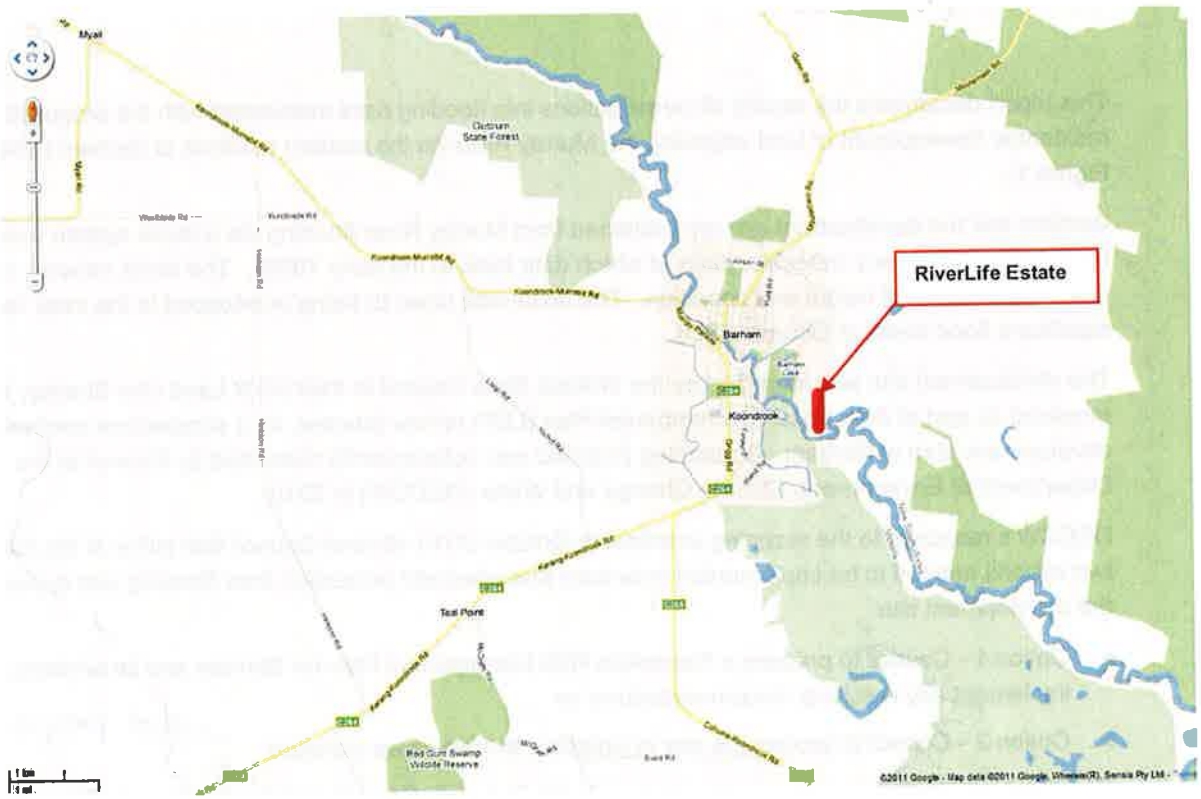


Figure 1 Locality Plan

2. Background / Previous Studies

2.1 Murray River

Barham is located on the NSW side of the Murray River, opposite the Victorian side township of Koondrook. Barham is the largest town within the Wakool Shire with a population of 1,100. The township includes a hospital, primary school, secondary school, dual water supply and an augmented sewerage system.

Approximately 65% of the Wakool Shire is classified as flood liable land. This includes flooding associated with the Murray River, the Wakool River and the numerous creek systems within the Shire.

The following factors influence Murray River flooding characteristics at Barham:

- Barmah choke. The Barmah choke is a natural floodplain constriction located in the vicinity of Barmah, upstream of Echuca. This natural constriction results in the majority of Murray River flood flows upstream of Barmah being directed northwards into the Edward River system;
- Koondrook-Perricoota Forest. In Murray River flood events, flows downstream of Echuca inundate the adjoining Gunbower Forest, Perricoota Forest and Koondrook Forest. Outflows from the NSW side forests occur into the Wakool River system to the north via the Thule Creek and Barbers Creek floodways. This release of flow into the Wakool River system significantly reduces the flow carried by the Murray River at Barham / Koondrook; and
- Levees on both the NSW and Victorian side banks funnel the remaining river flow past Barham and Koondrook.

As a result of the above influences, the peak Murray River flow at Barham is relatively insensitive to the size of the flood event in the upstream Murray River catchment as evidenced by the small differences in recorded flood levels at Barham for a range of historic events as further discussed in Section 3.

2.2 Town Levee System at Barham

The levee system protecting Barham is understood to have been constructed in the early 1900s following the establishment of the township in the late 1800s.

The levee system protecting the township consists of a series of levee segments which provide protection from both Murray River and Barbers Creek flooding. The levee is effectively a large ring levee enclosing an area of 44 km^2. The Barham urban area occupies only a small proportion of the total area enclosed.

The development site which is the subject of this assessment is located within the levee enclosed protected area as shown on Figure 2.

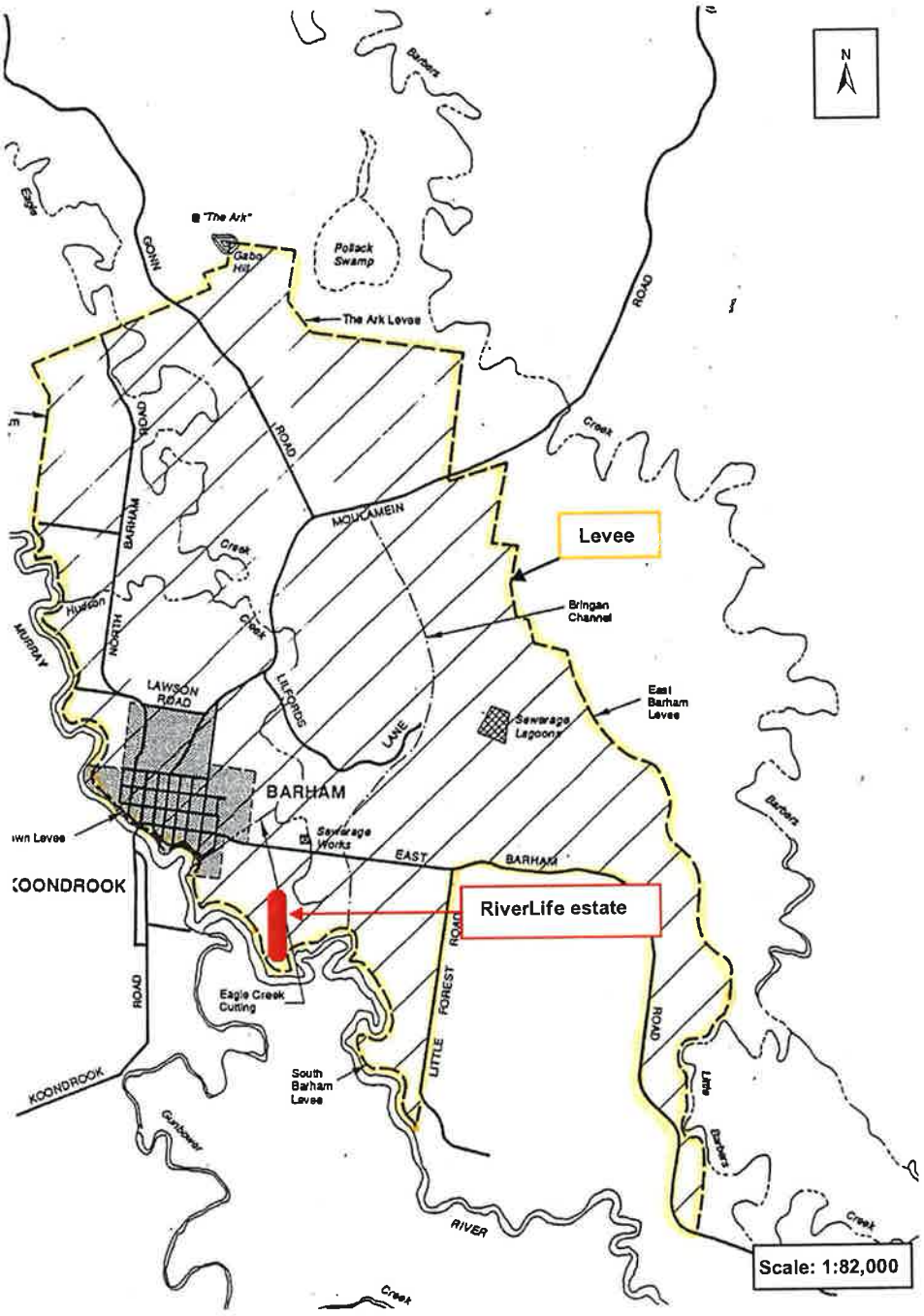


Figure 2 Existing Barham Levee

(extract from the 1995 Barham Town Levee Investigation report)

2.3 Relevant Reports

The current study draws substantially on investigations carried out as part of the following previous studies.

- Murray River Flood Plain Management Study (Gutteridge Haskins & Davey et al, 1986). This report provides an overview of flooding characteristics and management issues for the Lake Hume to South Australia border reach of the river.
- Barham Town Levee Investigation (Gutteridge Haskins & Davey, 1995). This report provides a detailed assessment of the levee protection system at Barham.
- Flood Data Transfer Project – Murray River Basin Report and the Shire of Gannawarra Flood Mapping Report (Egis Consulting, 2000). These reports were prepared as part of the Victorian statewide Flood Data Transfer Project commissioned by the Department of Natural Resources and Environment.
- Edward, Wakool and Niemur Rivers – Stages 1, 2 and 3 Areas – Floodplain Risk Management Study (Earth Tech, 2008). This report was prepared for DECCW and documents a rural floodway network within the Wakool Shire Council.
- Floodplain Management Plan – Wakool River Stage 2 – Moama-Moulamein Railway to Gee Gee Bridge (DECCW, 2011). The gazetted floodplain management plan for the area north of Barham.

In addition to the above, the Wakool Shire Council has a Local Disaster Plan (Displan,1997) setting out responsibilities and actions associated with preparedness, response and recovery measures for disasters within the Wakool Shire.

The Displan makes reference to a series of sub-plans including a Local Flood Plan (2007). The Local Flood Plan sets out in detail responsibilities and actions associated with preparedness, response and recovery measures in relation to flood events impacting on the Wakool Shire Council area.

2.4 Development Proposal

The development proposal is supported by the Wakool Shire Council. Council's current local environment plan (LEP) review process has included the preparation of a Land Use Strategy Report (Collie Pty Ltd et al, 2009). This report identifies Barham as the township with the most potential for residential development within the Shire. This is based on analysis of dwelling applications in the period 1997-2007. The report identifies that there is currently only a limited supply of residential opportunities at Barham.

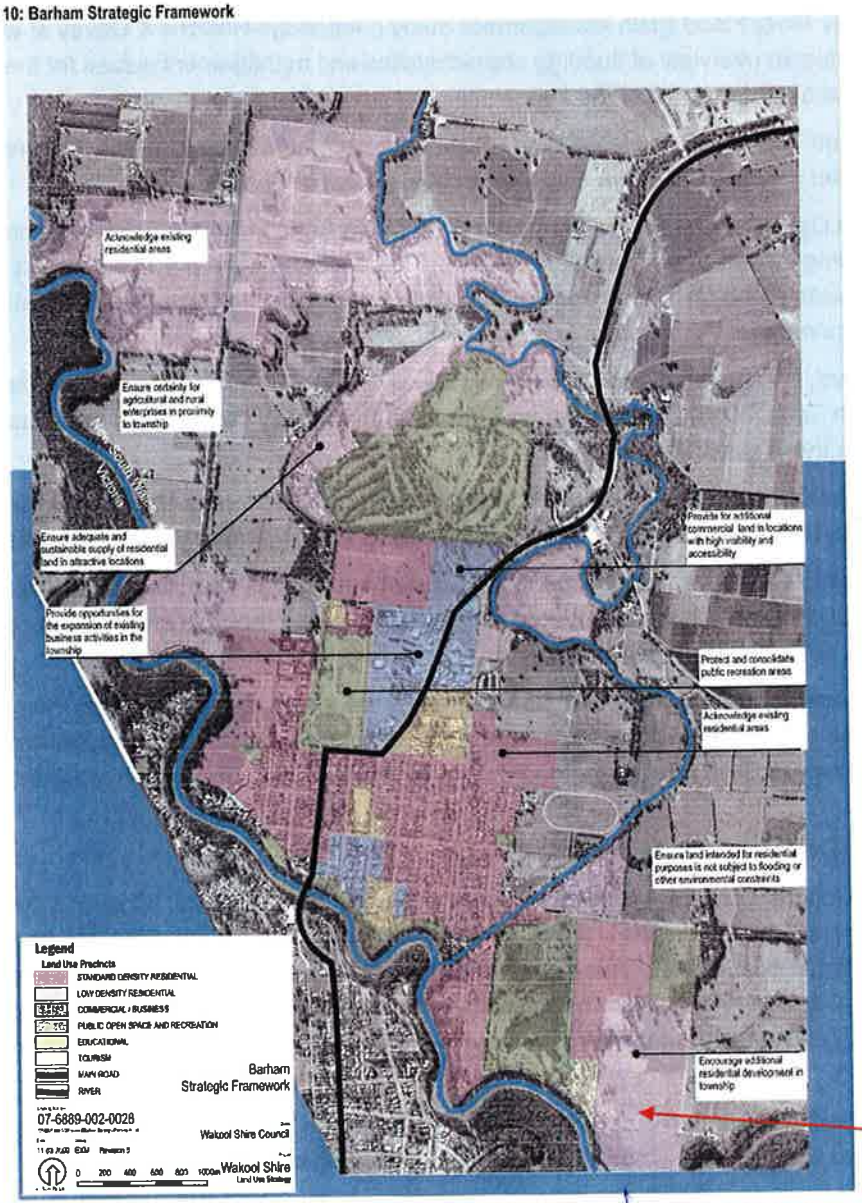
In order to capitalise on the potential growth opportunities available within the Barham township, the 2009 Land Use Strategy Report nominates principles which include the following:

- Ensure appropriate supply of residential land in attractive and serviceable locations; and
- Ensure land intended for residential purposes is not subject to flooding or other environmental purposes.

The 2009 report includes a land use framework strategy for Barham which identifies additional residential

land east of Barham Lakes (refer Figure 3). This includes the RiverLife estate development site which is the subject of this report.

Figure 10: Barham Strategic Framework



RiverLife Estate

Did not show extent of lot + therefore flood risk

Figure 3 2009 Land Use Strategy Report – Barham Township

(extract from 2009 Wakool Shire LEP Review – Land Use Strategy Report)

3. Flooding Conditions Description at Barham

3.1 Catchment Description

The Murray River at Barham has a catchment area of 43,400 km^2. The major river tributaries are the Upper Murray River, Mitta Mitta River, Kiewa River, Ovens River, Goulburn River and the Campaspe River.

Flooding at Barham is most sensitive to inflows from the Goulburn River and Campaspe River systems as these two tributary inflows are downstream of the Barmah choke.

A record high flood in the Campaspe River in January 2011 did not lead to major flood concerns at Barham with the flood peaking well below the town levee crest. Only minor flooding occurred in the Murray River tributaries upstream of the Campaspe River in January 2011. Major inflow contributions from the Goulburn River in addition to the Campaspe River are required to induce flood levels at Barham similar to those experienced in major flood events such as those listed in Table 1.

3.2 Past Flood Events

A streamflow gauge has operated at Barham since 1905. The station (409005) is located on the downstream side of the Barham-Koondrook bridge which itself was constructed in 1904.

A summary of the highest flood levels recorded at the Barham bridge streamflow gauge is provided in Table 1. The 1870 flood is widely accepted as the largest flood to have occurred for which records are available on the broader Murray River system. A flood height for this event was not recorded at Barham. The 1870 flood height recorded at upstream Echuca and downstream Euston was higher than 1917.

The recent flood event in January 2011 resulted in a peak river height of 77.26 m AHD at the Barham gauge.

Table 1 Highest Floods Recorded at Barham since start records in 1905

Event Rank	Date	Peak Flood Height (m)	Peak Flow (ML/day)
1	1917	77.66	36,000
2	1916	77.59	34,900
3	1956	77.56	34,400
4	1975	77.56	34,400
5	1993	77.54	34,000

Note: Levels and flows are at the Barham streamflow gauge 409005.

3.3 Barham Levee

The Barham levee alignment is shown on Figure 2. The total levee circumference is 45 km enclosing an area of approximately 44 km^2 which includes Barham and the development site.

The various segments which make up the Barham levee are described in the 1995 Barham Town Levee Investigation report. The 1995 report indicates that the levee segments vary markedly in terms of height, cross section and condition.

The Murray River levee segment located immediately adjacent to the Barham township area referred to as the 'Town Levee' by the 1995 report, has a crest height varying from 77.7 to 78.2 m AHD based on survey information documented in the 1995 report. This section of levee is described by the 1995 report as being well maintained.

The 'South Barham Levee' extends upstream of the Town Levee past the proposed development site. The 1995 report indicated this levee segment has a crest height varying from 78.0 to 79.0 m AHD. The embankment height varies from zero to 0.8 metres high.

3.4 Past Flood Frequency Analysis

Flood frequency analysis for the Barham streamflow gauge (409005) has previously been carried out as part of a number of studies. The resulting design flood level and flows at Barham are given in Table 2.

The terms annual exceedance probability (AEP) and average recurrence interval are used in Table 2. Both terms reflect the probability of a flood occurring. The AEP is the probability (chance) of a flood occurring in a given year expressed in percentage terms. The ARI is the long term average number of years between a flood of a certain size. The 1% AEP flood is equivalent to the 100 year ARI flood. The remainder of this report uses the term ARI, the term used by Council's Local Flood Plan.

The design flows in Table 2 have a very narrow range reflecting the throttling of the flow carried by the immediate Murray River floodplain at Barham to approximately 36,000 ML/day. Flows in excess of this capacity discharge into the Wakool River system via the Barbers Creek and Thule Creek floodways.

There have not been any major flood events for the Barham reach of the Murray River since 1995. The five highest events during this period are as follows:

- January 2011 – peak stage 77.26 m AHD;
- 1996 – peak stage 77.22 m AHD;
- 1995 – peak stage 77.12 m AHD;
- 2000 – peak stage 77.04 m AHD; and
- 2003 – peak stage 76.36 m AHD.

All of the above events are equivalent to less than a 20 year ARI event as defined by the 1995 report.

Table 2 Design Flood Levels and Flows at Barham

AEP (%)	ARI (years)	1986 RWC Murray River Study		1992 PWD Levee Audit		1995 Council Town Levee Investigation	
		Level (m AHD)	Flow (ML/day)	Level (m AHD)	Flow (ML/day)	Level (m AHD)	Flow (ML/day)
5	20	77.56	34,400	-	-	77.55	34,000
2	50	77.58	34,800	-	-	77.60	35,000
1	100	77.59	34,900	77.61	-	77.65	36,000
0.5	200	-	-	-	-	77.68	37,500
0.2	500	-	-	-	-	77.72	38,000

Note: Levels and flows are at the Barham streamflow gauge 409005.

3.5 Flood Heights

3.5.1 1995 Town Levee Investigation Report

The 1995 Town Levee Investigation report lists the following three observed flood levels for the October 1993 flood event:

- 77.54 m AHD at the Barham bridge gauge;
- 78.33 m AHD towards the southern end of the East Barham levee adjoining Little Barbers Creek; and
- 77.56 m AHD on the East Barham levee adjoining the Barbers Creek floodway.

To define the variation in 100 year ARI flood levels in the vicinity of Barham, the 1995 Town Levee Investigation used the following approach:

- Used the above three 1993 recorded flood heights;
- Identified a further four 1993 flood heights based on locations where the flood height relative to the levee crest is known through local resident observation accounts. The freeboard was deducted from the surveyed levee crest elevation to provide the 1993 flood height at these four locations;
- The difference of 0.11 metres at the Barham bridge gauge between the adopted 100 year ARI flood level and the 1993 flood level was then added to the four approximated 1993 flood heights to provide a total of seven 100 year ARI flood heights at point locations; and
- The seven point location 100 year ARI flood levels were used to produce interpolated 100 year ARI flood height contours at 0.2 metres intervals.

The 1995 report indicates that based on the developed 100 year ARI flood profile, the Barham levee system would be overtopped in a 100 year ARI flood at the following locations:

- Town Levee near the bridge;
- South Barham Levee approximately 500 metres upstream of Eagles Creek Cutting;
- East Barham Road near Little Forest Lane and at several locations to the east of this point;
- East Barham Levee near the Barham Moulamein Road; and
- Isolated sections along the North Barham Levee and its junction with Gonn Road.

The 1995 report concludes that the levee system at Barham provides protection up to at least a 17 year ARI flood event, which is equivalent to the 1993 flood event.

3.5.2 Victorian Designated Flood Levels

Victorian government floodplain management authorities officially declared 1% flood levels for the Murray River between Lake Hume and the South Australian border in 2004. The officially declared flood heights at Koondrook are as follows:

- 77.9 m AHD at the Barham bridge; and
- 78.2 m AHD adjoining the RiverLife estate development site.

The basis of the Victorian flood levels at Koondrook are described by a report covering the Gannawarra Shire area prepared as part of the Flood Data Transfer Project (FDTP). This project was a Victorian government project initiative to digitise and attribute all flood data into a GIS database. The FDTP Gannawarra Shire report states that:

- 1% flood levels are based on a river flood profile derived by the Rural Water Commission of Victoria for the 1975 flood; and
- 0.25 metres was then added to the 1975 flood profile to produce the estimated 1% flood profile and flood levels.

The FDTP Gannawarra Shire report comments that the above methodology might be considered as producing conservative flood levels.

3.6 Warning Times / Rates Rise / Duration Flooding

The duration of Murray River flood events can be vary significantly depending on the characteristics of the particular flood events.

The recent January 2011 event was primarily induced by major flooding within the Campaspe River with only minor flooding within the other upstream Murray River tributaries. The flood level peaked at Barham on the 28 January 2011, approximately two weeks after the flood inducing rainfall occurred. Over the two week period, the flood level at Barham rose by only 0.3 metres however, reflecting the relative insensitivity of flooding characteristics within this reach of the Murray River to the flow downstream of Echuca.

Data on travel times for various historical floods documented in the 1986 study report indicates that the average time difference between Murray River floods peaking is as follows based on known time differences for a range of historical floods:

- Albury to Echuca – typically seven days; and
- Echuca to Barham – typically a further four to six days.

The available warning time at Barham in advance of a flood peak is therefore typically one to two weeks.

The flooding duration at Barham is typically quite protracted, remaining close to the peak for extended periods lasting weeks. The October 1993 event which peaked at 77.54 m AHD (approximately a 20 year ARI event) remained above 77.2 m AHD for approximately 10 weeks. Protracted ongoing flooding of rural properties in the vicinity of Murrabit downstream of Barham following the January 2011 flood event is continuing to impact on properties in mid February 2011, more than three weeks after the peak flooding occurred.

3.7 1995 Investigation Levee Upgrade Options

The 1995 Town Levee Investigation report documents the results of investigations for six ring levee options at Barham. Five of the six route options enclose the RiverLife Estate development site. The remaining option which excluded the RiverLife Estate was not assessed in detail given that it did not encompass all of the existing (as at 1995) urban development at Barham.

Of the five routes assessed in detail, the so-called Route 1 (refer Figure 4) was preferred based on it being the lowest cost, second highest benefit cost ratio and also a high assessed likelihood of it being accepted by the approving authorities.

Other notable recommendations made by the 1995 report are as follows:

- Recommends the adoption of an upgraded levee crest design level of the 100 year ARI flood level plus 0.6 metres of freeboard. The report notes that this is less than the default nominal freeboard of 1.0 metre for urban areas in NSW. The justification for the reduced freeboard is based on the relatively small increase in flood level with increasing flood severity (e.g. 500 year ARI flood level at Barham assessed by the 1995 report as being only 0.07 metres higher than the 100 year ARI flood level); and

- 1995 report concludes that based on limited geotechnical investigations, that the local soils at Barham are generally suitable for use as levee embankment material provided proper attention is paid to moisture content, compaction and dispersion potential during construction.

Contrary to other advice?

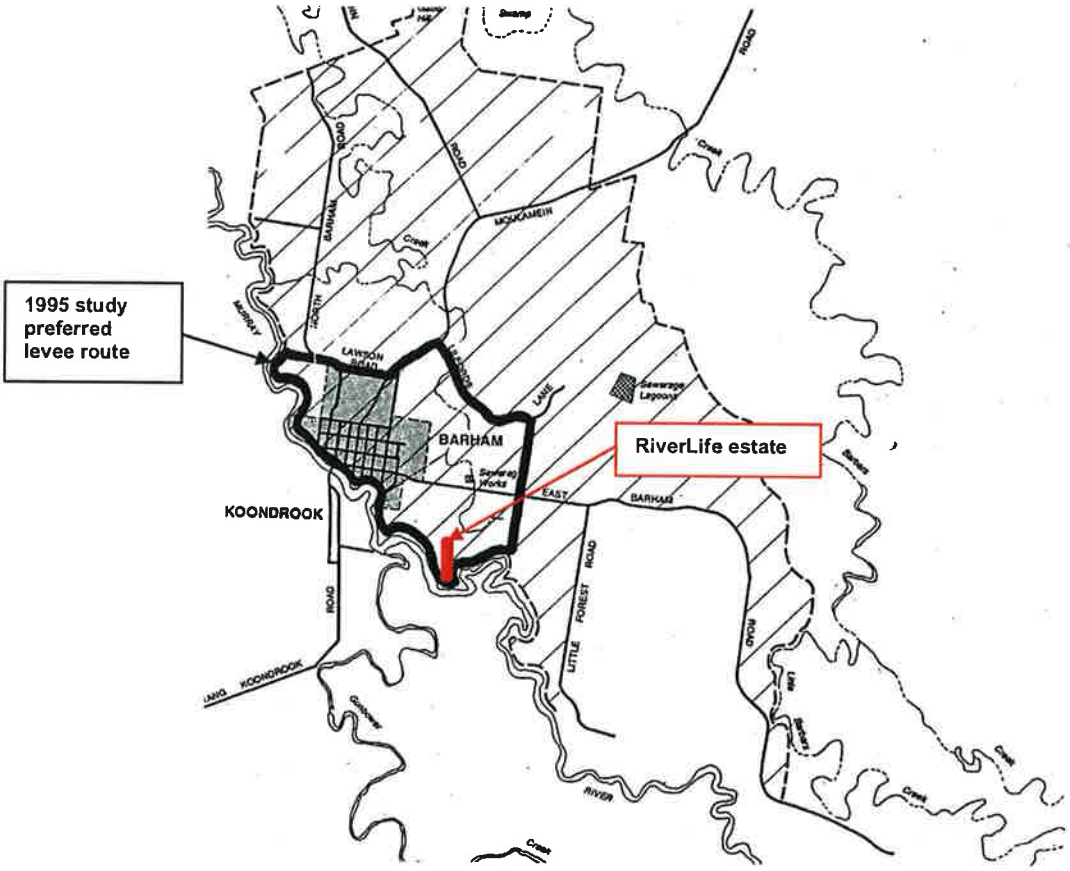


Figure 4 Preferred Levee Route – 1995 Town Levee Investigation

(extract from the 1995 Barham Town Levee Investigation report)

3.8 Koondrook-Perricoota Flood Enhancement Works

Construction of works to allow for managed flooding of the Koondrook-Perricoota Forests is currently being undertaken. The works include channels, regulators and levees. The aim of the enhancement works is to allow for more control over flooding of the forest and to therefore improve the forest's environmental health.

The existing levee which encloses the Koondrook Forest and the Barbers Creek floodway to the east of Barham is to be upgraded as part of the enhancement works. It is understood that the upgraded levee will have a design crest level 1.0 metre above the 100 year ARI flood level.

3.9 Koondrook Township Levee Works

The North Central Catchment Management Authority advised that a crest level survey of the levee protecting the Koondrook township was undertaken in the early 2000's. The survey identified that the levee crest was marginally below the 100 year ARI flood level in a number of places. The levee was subsequently raised to the 100 year ARI flood level.

No other known studies or modifications to flood mitigation works have been carried out at Koondrook since the early 2000s.

3.10 Wakool Shire Council Local Flood Plan

The Local Flood Plan sets out roles and responsibilities associated with preparing for, responding and recovering from a flood event. The lead role is performed by the SES with support from a large number of government agencies, infrastructure authorities and local community groups.

Notable aspects of the Local Flood Plan are commented on as follows:

- Plan indicates that township evacuations should only be required in the event of potential or actual levee failure, with the primary means of evacuation by private transport, with those requiring assistance evacuated by public buses;
- Plan specifies that SES is responsible for the coordination of the supply of foodstuffs and medical supplies to areas that become isolated;
- The Local Flood Plan document refers to Barham flood heights in metres relative to the gauge zero height, as distinct from gauge heights in metres relative to AHD;
- Roads in the vicinity of Barham listed as being potentially affected by flooding are the Gonn Road and Sandy's Bridge Road; and
- Plan states that the Barham township is protected by a levee system which withheld the 1956 flood, the second highest recorded flood since 1906. It further states that the town levee system was upgraded in 1984, with the levee crest level raised to 0.6 metres higher than the 1956 flood. The plan warns that overtopping or failure of the levee system could result in inundation of the whole of the Barham township area.

4. Development Site

4.1 Description

The proposed RiverLife residential estate is located on the upstream side of Barham as shown on Figure 5. Adjoining land use / features are as follows:

- The southern end of the estate property borders the Murray River channel. The existing levee is located adjoining the river channel;
- The mid portion of the estate's western boundary adjoins the Barham Lakes Caravan Park; and
- The remaining land use adjoining the development site consists of rural farmland to the north and east of the development property.

The development property has an internal irrigation channel and drainage channel network. This includes a supply channel which crosses the property in an east-west direction towards the southern end of the property as shown on Figure 5. This particular section of supply channel has a number of large trees adjoining its route.

A natural depression is located towards the northern end of the property. This depression drains into the upper reaches of Eagle Creek.

A corridor of riparian vegetation fringes the Murray River channel on the subject property. The flood protection levee is located within this riparian vegetation corridor. A farm channel is located on the dry side of the levee, also within the same vegetation corridor.

A survey undertaken by David Laughlin Land Surveys dated January 2009 provides ground level elevations over the development site. Ground level elevations vary as follows:

- The crest level of the existing levee adjoining the Murray River within the estate property varies from 77.8 to 78.2 m AHD;
- The existing levee height relative to ground levels on the protected side of the levee generally varies from 0.4 to 0.6 metres;
- Ground levels vary from 77.2 to 77.6 m AHD inside the levee at the southern end of the development property; and
- The lowest portion of the site is located in the north eastern corner at approximately 76.7 m AHD. The north western corner is slightly higher at approximately 77.1 m AHD.

Flood prone

Flood height 1993 77.54

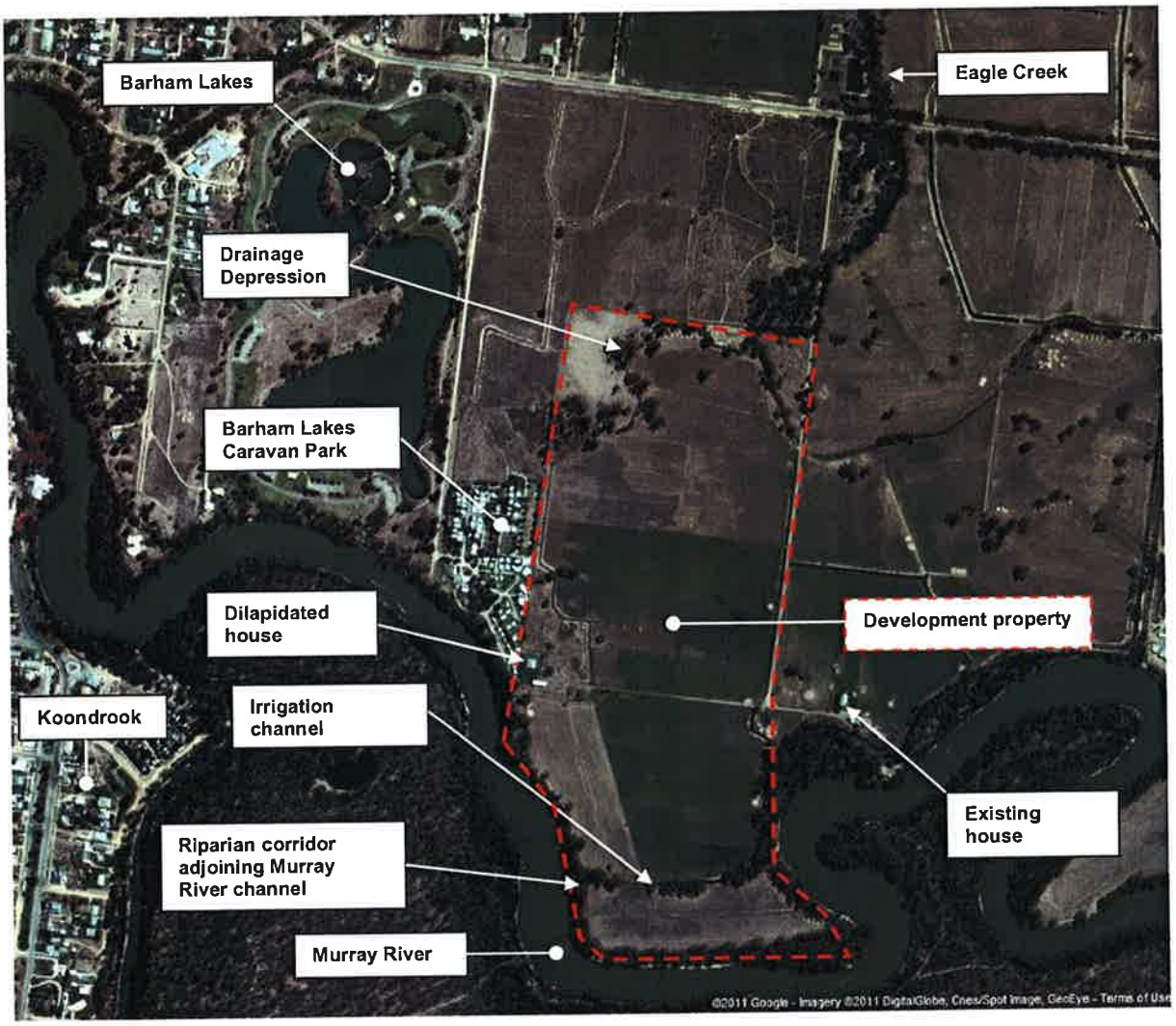


Figure 5 Local Area Features Plan

4.2 100 Year ARI Flood Levels for Development Site

4.2.1 Barham Bridge Gauge

Previous estimates of the 100 year ARI flood level at the streamflow gauge (409005) located immediately downstream of the Barham –Koondrook bridge are as follows:

- 1986 Murray River Floodplain Management Study report – 77.59 m AHD;
- 1995 Town Levee Investigation report – 77.65 m AHD; and
- 2000 Victorian Flood Data Transfer Project approximately 77.9 m AHD.

The Victorian assigned flood level of 77.9 m AHD is considered to be a conservatively high estimate given that it is based on adding 0.25 metres to the 1975 flood profile. This approach may be valid for other reaches of the Murray River, however the local reach at Barham clearly does not reflect this approach as evidenced by the narrow range of historic event recorded flood heights.

The recorded 1975 flood level at the Barham bridge gauge is 77.56 m AHD (refer Table 1). This is 0.10 metres lower than the highest flood level on record of 77.66 m AHD (1917 event). It would also imply a 100 year ARI flood level closer to 77.8 m AHD derived from an approach which adds 0.25 metres to the 1975 flood level.

Based on the above, a 100 year ARI flood level of 77.7 m AHD at the Barham bridge gauge is considered appropriate.

4.2.2 Development Site

The development property is located approximately 2.5 km upstream of the Barham-Koondrook bridge. Previous estimates of the 100 year ARI flood level at the development property are as follows:

- 1995 Town Levee Investigation report – 77.85 to 77.90 m AHD; and
- 2000 Victorian Flood Data Transfer Project - approximately 78.2 m AHD.

As discussed above, the approach of adding 0.25 metres to the estimated 1975 flood profiler to give a 100 year ARI flood level, as per the Victorian study approach, is considered overly conservative for the Barham reach of the Murray River.

Observation accounts indicate that the existing levee at the development site was not overtopped by the 1993 flood. The recorded 1993 flood level at the Barham bridge (77.54 m AHD) is within 0.12 metres of the highest flood level on record (1917 at 77.66 m AHD). The existing levee crest varies upwards from a low of 77.8 m AHD.

Based on this, a 100 year ARI flood level of 78.0 m AHD at the development property is considered appropriate. The corresponding height at the Barham bridge gauge is 77.7 m AHD.

4.3 Extreme Flood Levels

The 100 year ARI event is a flood that will occur on average once every one hundred years. It is commonly adopted as the reference flood from which to base planning and building controls, with a factor of safety (e.g. freeboard) commonly added.

The future occurrence of a larger flood than the 100 year ARI event is inevitable. The consequences of an extreme event need to be assessed and flood emergency plans put in place to prepare for, respond to and recover from the effects of extreme floods.

Flood frequency analysis for the available period of record at the Barham bridge gauge (409005) as part of the 1995 Town Levee Investigation identified the following extreme event flood levels:

- 200 year ARI – 77.68 m AHD; and
- 500 year ARI – 77.72 m AHD.

The above flood levels are less than 0.1 metres above the 100 year ARI flood level of 77.65 m AHD adopted by the 1995 study. The narrow range of flood levels is due to the Murray River floodplain characteristics for this reach of the Murray River floodplain. In very large flood events, the majority of the flow conveyed by the Murray River downstream of Echuca discharges into the Wakool River system via the Thule Creek and Barbers Creek floodways. The Murray River itself with the levee systems in place appears to have an upper limiting capacity of less than 40,000 ML/day past Barham. The balance of the flow downstream of Echuca discharges into the Wakool River system.

In even larger flood events, the levees on either side of the Murray River along the length of the Murray River will be overtopped. In these circumstances, notably the reach between Cobram and the Barmah Choke, and the reach between Echuca and Barham, the extent of inundation outside the levee system will cover huge areas given the relative flatness of the terrain conditions. Although the area inundated will be very large, this in turn limits the potential for increases in flood height. The flood depth at Barham in an extreme event is therefore unlikely to be significantly higher than what occurs when the levees are first overtopped.

5. Flood Risk Assessment

5.1 Proposed Levee Protection

we want them to commit to a flood study.

The development property presently relies on protection from flooding by the existing levee scheme. This includes the levee which parallels the Murray River channel and the levee to the east which confines floodwaters to the Barbers Creek floodway (refer Figure 2).

In the long term, it is likely that an upgraded levee protection scheme will be implemented to provide protection for the Barham township and adjoining areas. The extent of the area protected by a future upgraded levee scheme is uncertain. It may or may not encompass the RiverLife development site. The preferred levee scheme identified by the 1995 Town Levee Investigation report does encompass the RiverLife development site (refer Figure 4). ?

The upgraded town levee scheme will not be implemented for at least three years and possibly much longer. Given this, it is proposed that a new levee be provided to protect the proposed development from flooding in isolation to the appropriate urban protection standard. This was nominated as an option in a letter dated 1 October 2010 from DECCW to the Wakool Shire Council in response to Council's rezoning proposal for the subject land.

The following sections of this report document an assessment of issues associated with both the levee design and impacts arising from the levee, including the following:

- Levee route, height;
- Levee type / shape;
- Levee construction standards;
- Levee management issues including maintenance;
- Internal drainage issues;
- Access during floods;
- Levee impacts on floods (i.e. hydraulic impacts);
- Levee impacts on the local environment; and
- Levee impacts on adjoining properties, Barham township and Wakool Shire.

approval

5.2 Levee Route

RiverLife Property Group has advised that the portion of the property to be subject to residential property development is to be limited to that south of the existing access track leading to the existing dilapidated house as shown on Figure 6. This is a change from that initially considered by the Gakuscy.

Most of the levee route will therefore parallel the Murray River channel. The levee is proposed to be positioned on the inside of the riparian (treed) corridor, not on the existing levee alignment which is generally adjacent to the river bank and among the treed zone. The precise levee route will be identified during detailed design. The alignment will be curved to skirt around the inside of the tree line.

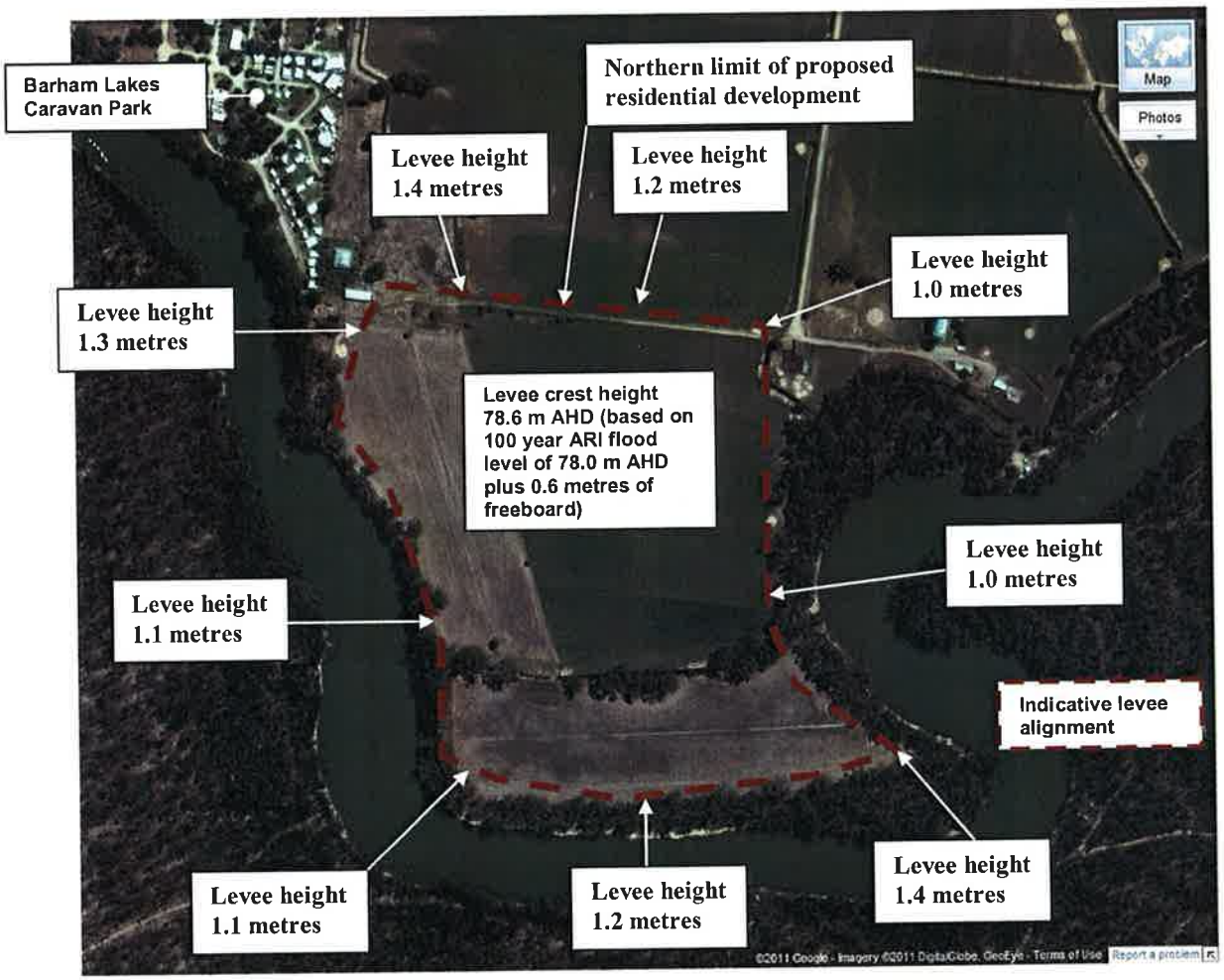


Figure 6 Levee Alignment / Heights

5.3 Levee Height

The 2005 NSW Floodplain Development Manual indicates that the height or crest level of a levee is determined by a variety of factors that include:

- The economics of the situation including the nature of development requiring protection;
- The physical limitations of the site;
- The level to which floods can rise relative to the ground levels in the area and the associated safety implications; and
- The visual impact of the levee.

The actual levee height or crest level depends on two properties as follows:

- 100 year ARI flood level given that this is almost always selected as the level of protection sought for urban areas.
- Design freeboard which represents a factor of safety to protect against influences such as wave action, localised hydraulic behaviour and possible future settlement of levees.

5.3.1 100 Year ARI Flood Level

The 100 year ARI flood level applicable to the site is 78.0 m AHD as per Section 4.2. This level has been determined based on a review of previous flood investigation studies at Barham. The adopted flood level would coincide with a flood level at the Barham bridge gauge of approximately 77.7 m AHD, which is higher than the highest recorded flood level in the 105 years of available record.

5.3.2 Freeboard

The freeboard appropriate to the development property has been discussed with DECCW. These discussions have suggested that a freeboard of 0.6 metres above the 100 year ARI flood level may be considered appropriate.

The primary reason why this level of freeboard may be appropriate is due to the flood level in the Murray River adjoining Barham being relatively insensitive to the upstream river flow. This hydraulic characteristic is due to a large proportion of flood flows bypassing to the north of Barham via the Barbers Creek flood system as discussed in Section 3. Flood levels for a range of historical flood events are therefore 'bunched' (refer Table 1). The highest flood on record (1917 – 77.66 m AHD) is only 0.12 metres higher than the fifth highest flood on record (1993 – 77.54 m AHD).

Additionally the terrain on either side of the Murray River channel at Barham Koondrook is relatively flat. This results in only a small increase in flood height with increasing flow.

Ultimately the decision for the appropriate level of freeboard is a matter for DECCW and Council. This decision should consider the information presented in this report and the level of risk accepted by the local community.

5.3.3 Resulting Crest Heights

Levee heights based on 0.6 metres of freeboard above the adopted 100 year ARI flood level are shown on Figure 6. The resulting levee height varies from 1.0 to 1.4 metres above the surveyed ground levels.

Based on the flood height characteristics at Barham (refer Sections 3 and 4), the 0.6 metres of assumed freeboard is expected to be sufficient to protect against overtopping to well in excess of the 500 year ARI event.

5.4 Levee Type / Shape

Much of the information below has been sourced from the publication 'Levee Design Construction Maintenance' (Sing Pty Ltd, 2002). This publication although prepared targeting issues in regional Victoria is equally applicable to Barham.

5.4.1 Type

Flood protection levees are generally constructed as earthen banks where space is not a limiting factor. In some instances, notably within existing urban areas, space within which to construct the levee may be limited. In these circumstances vertical walls may be utilised.

Space is not a limiting factor for the Barham development site. The intention is therefore to construct the proposed levee as an earthen embankment. The embankment will be grassed to allow for rainfall infiltration, assist in stabilising the batters and crest and to soften the aesthetic impact of the levee.

5.4.2 Form

Stripping

The stripping of topsoil below the levee footprint is critical to ensure that the levee bonds to the underlying material. Where the top soil is shallow, a stripping depth of 300 mm is proposed to be adopted to ensure all surface roots and vegetation is removed.

Crest Width

The crest width proposed for the levee is 3.0 metres. This coincides with the width required to safely accommodate a vehicle.

Vehicular access is desirable along the levee crest. It allows for patrol access during flood events. The 3.0 metres crest width also makes it less likely that localised low points will develop, such as can occur on narrow crested levees.

Batters

The most appropriate bank slopes for a levee depend on a consideration of the soil type, access arrangements, construction methods and maintenance arrangements.

Levees adjoining residential areas will generally require mowing of the batters. This requires a batter slope of no steeper than 4 (horizontal) to 1 (vertical). Where mowing is not a requirement, batter slopes

of 2.5:1 on the wet side and 2:1 on the dry side are generally adopted as the steepest permissible batter slopes.

The following considerations are applicable to the batter slopes for the proposed levee on the RiverLife estate:

- Mowing of the levee is likely to be required. The steepest batter slope used will therefore be 4:1; and
- The proposal for the river side of the levee is to utilise a gentle flat batter to lessen the engineered appearance of the levee.

5.4.3 Source Levee Material

A limited geotechnical investigation was undertaken as part of the 1995 Barham Town Levee Investigation (Gutteridge, Haskins & Davey, 1995). The investigations involved the excavation of 12 test pits adjacent to the existing levee network to depths of 3.0 metres. Samples at each test pit were subsequently laboratory tested. One of the 12 test pits is located at the southern end of the Barham Lakes property, a short distance downstream of the RiverLife development property.

Most of the test pits revealed that below the topsoil, a layer of Silty Clay of high plasticity is commonly present with some Sandy Silty Clay layers of medium plasticity. Silty sand was also found in a number of the test holes, but not the test hole closest to the development site.

The testing of the silty clay found it to be highly to extremely dispersive. The 1995 report indicates that this conflicts with the field observation and anecdotal accounts that the levees at Barham have generally weathered reasonably well. Dispersive soils used to form a levee bank tend to be more vulnerable to erosion during flooding.

Detailed design and associated documentation will identify the source of material proposed to be used for the levee construction.

5.5 Levee Construction Standards

Although levees are only required to perform during a flood event, it is critically important that they are constructed to a high standard given the severe consequences if they fail during a flood event, particularly when relied upon for the protection of urban areas.

Levees are if anything more prone to beaching than embankments for semi permanent water bodies as they are more susceptible to drying out and cracking leaving them potentially vulnerable to seepage and breaching when infrequent flood events occur.

An appropriate specification will need to be prepared for the RiverLife estate levee construction. A sample specification is included in the 2002 publication and covers detailed requirements for:

- Clearing and grubbing;
- Stripping;
- Foundation treatment;
- Borrow pits (if applicable);

- Placing and compaction including moisture control requirements;
- Topsoil placement; and
- Finished surface level and dimension tolerances.

5.6 Levee Management Issues

5.6.1 Maintenance

Levees are an important asset. They can remain unused and untested for long periods between floods. Appropriate maintenance is important between flood events to reduce the risk of levee failure. Activities necessary to provide appropriate levee maintenance are as follows:

- Retain design / as-constructed plans. This will allow any settlement of levee crest heights to be identified by referring future surveyed crest heights with the design crest height;
- Retain design and operations details for internal drainage systems, particularly systems which rely on pumping (if applicable). A back-up pump system should be maintained in working order to guard against the event of the primary system failing. The primary system also needs to be adequately maintained;
- Scheduled condition inspections and post flood condition inspections. In the case of Barham, the amount of available warning time will also allow for inspections prior to a flood with a period of one week or more typically available for any repair works to be done. Scheduled inspections, say annually, would identify maintenance works required to be undertaken prior to the next scheduled inspection;
- Batter maintenance will generally occur in response to damaged areas observed during inspections. Slumped areas / sections should be fully excavated and reconstructed rather than superficial patching. Mowing activities will depend on the local circumstances. Trees should not be allowed to grow on levee banks as they can increase the risk of breaching due to cracking and direct damage due to falling in high winds. Trees should be removed at the sucker stage. Larger trees should be removed, roots and all; and
- Crest maintenance should have the primary goal of maintaining the design crest level. This may require topping from time to time to rectify any localised lowering.

5.6.2 Ownership

The arrangements for the construction and maintenance of the levee is a matter for the developer and the Wakool Shire Council.

A possible outcome could involve the developers being responsible for maintaining the levee for a specified period of time with Council responsible for maintenance after this date. The changeover could coincide with the estimated time at which an upgraded levee system for the broader Barham township is expected to be established. The RiverLife estate levee could form part of the broader upgraded town levee, with any redundant segments decommissioned.

The responsible owner of the levee will need to have right of access to the levee in order to carry out maintenance works. To this extent the owner responsible for the levee needs to either have direct ownership of the land or adequate rights through the establishment of an easement over the levee to ensure the role of maintaining the levee can be carried out.

5.7 Internal Drainage

The ground survey over the subject property indicates that the area enclosed by the proposed levee (refer Figure 7) drains to the following two low points:

- South eastern corner of the site where ground levels fall to approximately 77.2 m AHD; and
- Area east of the existing house and farm buildings located adjacent to the south side of the access track where ground level elevations fall to approximately 77.2 m AHD. This area drains into a farm drain aligned northwards through the remainder of the development property and ultimately into Eagle Creek.

The area enclosed by the proposed levee is approximately 18 hectares. Internal drainage arrangements are likely to involve the discharge of most of the site northwards into the Eagle Creek system (i.e. retention of existing drainage characteristics). The system would be gravity operated, possibly discharging into a constructed wetland on the north side of the levee bank, east of the existing dilapidated house.

Consideration would need to be given for a back up pump out system. This pump out system would only be required in the event of a failure of the broader existing levee system around Barham resulting in the inundation of the area outside the estate protected levee. In these circumstances, it would no longer be possible to gravity discharge internal runoff from within the levee enclosed area.

Backwater Murray River Flooding via Local Creeks

A significant portion of Barham and its immediate surrounds drain into Eagle Creek. The upper reaches of Eagle Creek extend to the northern side of the development property. The Eagle Creek route is aligned northwards to the east of Barham, eventually crossing the northern limits of the levee system, 6 km north of the Barham-Koondrook bridge.

The 1995 Barham Town levee Investigation report identifies a 100 year ARI flood level at the Eagle Creek levee crossing of 76.6 m AHD. The lowest point in the levee enclosed RiverLife estate area is 77.2 m AHD. The possibility of Murray River backwater flooding via Eagle Creek has therefore little or no implications for impacting on the development property.

The Hudson Creek levee crossing located 3 km north of the Barham-Koondrook bridge has a 100 year ARI flood level of 77.0 m AHD as identified by the 1995 study report. This is also below the lowest land within the RiverLife estate levee protected area and as such poses little risk.

The Eagle Creek Cutting is not a threat as it is not required to be kept open for the drainage of internal runoff into the river system. The Cutting is only present to discharge pumped water from the Murray River into Eagle Creek for irrigation purposes. It is otherwise closed to flow in both directions.

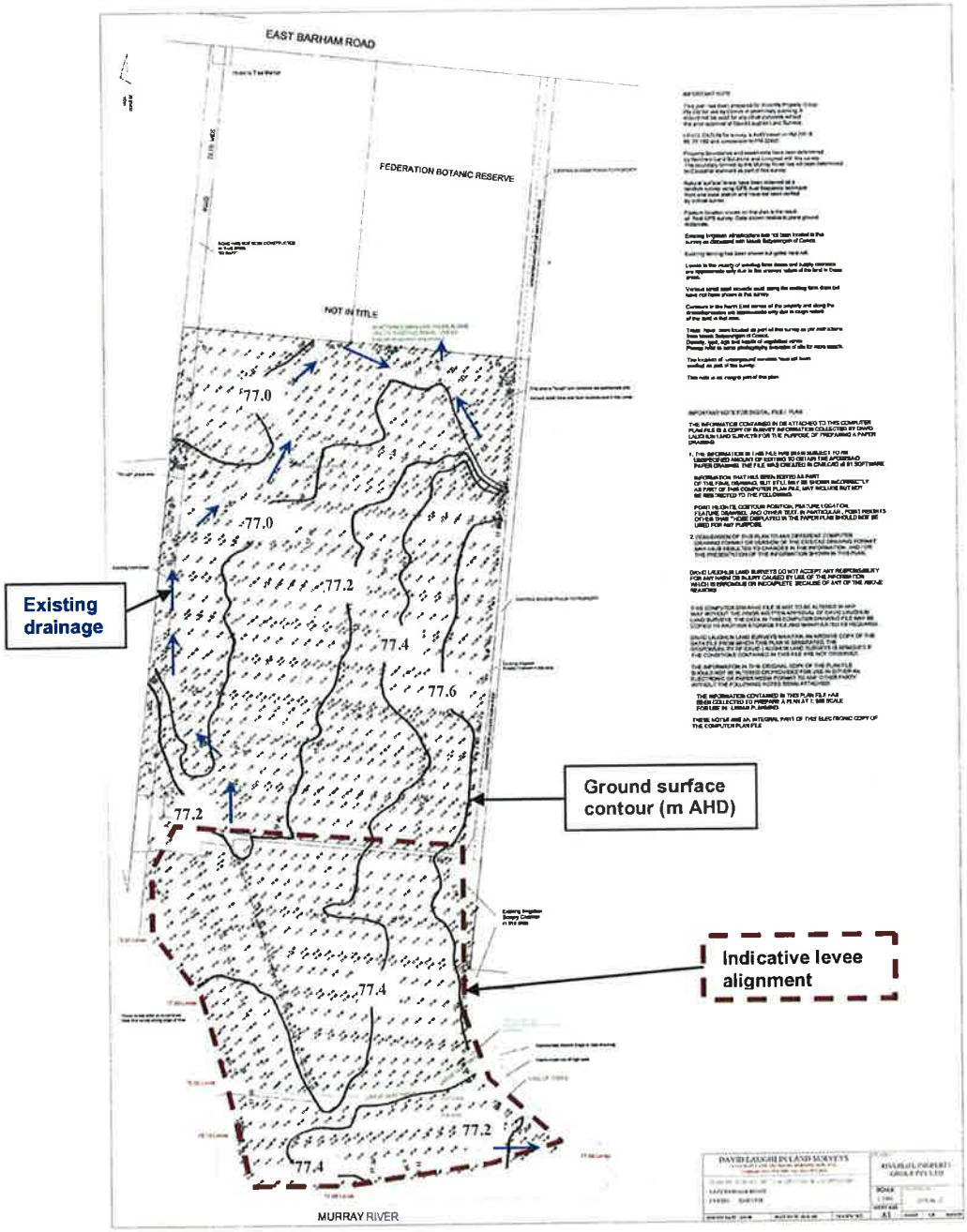


Figure 7 Local Runoff Drainage – Existing Conditions

(modified plan extract David Laughlin Surveys)

5.8 Access During Floods

Past reports on flooding at Barham (GHD, 1995) have indicated that the township area itself has not experienced flooding for more than 50 years and possibly going back to the 1917 flood. Most major flood events appear to have included sandbagging to top up sections of levee bank to guard against overtopping. Where outer levees have been breached, the town has been protected by inner levees (e.g. Bringham Channel Levee).

Topping up of levee banks at Barham in past flood events has been possible due to the substantial flood warning time available. The available warning time at Barham in advance of a flood peak is typically in the vicinity of one to two weeks (refer Section 3.6).

Evacuation access has not therefore been required at Barham in any flood events in living memory. The rate of rise of floodwaters is sufficiently slow such that the potential overtopping of the levee bank network will be known well in advance. To this extent, the threat to residents from overtopping of the levee system poses only a relatively low risk given that substantial time will be available to evacuate residents prior to overtopping.

Access from the immediate floodplain at Barham will potentially occur via the following route options:

Climate change?

- Local access road (i.e. East Barham Road) is within the town levee system enclosed protected area.
- Victorian side evacuation route. Road routes available are either the Koondrook Cohuna Road or the Koondrook Kerang Road. This road route is not expected to be overtopped unless a flood exceeding the 100 year ARI event is experienced given the status of the Koondrook town levee as advised by the North Central CMA; and
- NSW side evacuation route. Road routes available are either the Barham Moulamein Road or the Barham Deniliquin Road. The Barham Moulamein Road (Main Road 319) is not listed by the Shire of Wakool Local Flood Plan as one of the roads affected by Wakool River flooding.

The access route nominated by response personnel in a flood event warranting evacuation would depend on the circumstances (e.g. status of flooding on the NSW side particularly the Wakool, Niemur and Edward Rivers, and flooding conditions on the Victorian side particularly the Loddon and Campaspe Rivers).

Access issues in potential flood scenarios are discussed as follows.

5.8.1 Scenario 1 - Barham evacuated, RiverLife estate protected

The levee protecting the RiverLife estate will have a crest height 600 mm above the 100 year ARI flood event. This level of protection is well in excess of the level of protection afforded to the Barham township area by the existing levee system.

A possible scenario involves the event of an impending future flood where the forecast flood level is such that the appropriate emergency response is to evacuate the township of Barham due to the potential for the town levee system to be overtopped. At the same time the forecast flood level is not sufficiently high to threaten to overtop the RiverLife estate levee. Relevant considerations for this scenario are as follows:

- If the levee system protecting the township of Barham is overtopped or breached, this will result in the isolation of the RiverLife estate; and
- A flood isolating the RiverLife estate may do so for a period of a number of weeks.

In view of these conditions, it is considered the most appropriate course of flood response action for this scenario would be for the RiverLife estate to be wholly evacuated at the same time as the Barham township to avoid protracted isolation and the risk of the RiverLife levee breaching through structural failure.

Given the above response, it may be queried as to why the need for an internal levee protecting the RiverLife estate if evacuation is to occur at the same time as the Barham township in circumstances where the peak forecast flood level is well below the crest level of the RiverLife Estate levee. The reason is that flooding of Barham is more likely to occur through unexpected breaching of the existing levee system. In these circumstances, evacuation is unlikely to have taken place prior to the floodwaters entering the township area. In these circumstances the RiverLife estate levee will provide protection to residents and property within the estate.

5.8.2 Most Extreme Event (e.g. PMF, dam-break failure of Lake Hume)

A probable maximum flood (PMF) Murray River flood event will result in overtopping of the levee systems along much of the length of the Murray River. Widespread inundation would occur in vast areas not previously flooded since European settlement.

In these circumstances, sufficient warning time permitting, mass evacuation of whole towns would be necessary, including towns such as Koondrook and Barham.

The depth of flooding in a PMF event at Barham is difficult to predict. The magnitude of the event may be up to ten times the size of the 100 year ARI event, or higher if dam failure released flows contribute (e.g. Eildon Dam, Hume Dam, Dartmouth Dam).

Such an event is likely to overtop a levee with 600 mm of freeboard located at Barham. This will cause substantial property damage due to inundation above floor level of dwellings protected by the RiverLife levee. Velocities are not expected to be sufficiently high to cause severe structural damage (e.g. movement) of most modern buildings given the flat hydraulic gradient of the floodplain in the vicinity of Barham (approximately 1 in 11,000).

The most important consideration in relation to extreme events is the amount of warning time. Even with an extreme event induced by a Campaspe River flood, the amount of warning time at Barham will be in the vicinity of one week. This amount of warning time should be sufficient to:

- Avoid any loss of life through prior evacuation; and
- Limit property damage through removal of high value items.

Significant property damage will still occur in an extreme Murray River event, however avoiding this is neither practicable nor rational given the low probability of occurrence.

6. Impacts of Proposed Levee

6.1 Flood Impacts

Levee can provide an effective means of protection against flooding. In doing so, this can also impact on flooding conditions in adjoining and downstream areas due to:

- Obstructing the flow of floodwaters leading to higher flood levels and increased velocities in the adjoining floodplain areas; and
- Reducing the amount of floodplain storage available. Floodplain storage can be important in dampening the flood peak as it travels downstream, resulting in reduced peak flooding.

The development site is located in an area which forms part of the broader area protected against flooding by the existing levee system around Barham This existing levee system encloses an area of approximately 44 km^2. The proposed RiverLife estate levee will enclose an area of approximately 18 hectares (0.18 km^2).

6.1.1 Impacts in Floods up to and including the 100 Year ARI Flood Event

The outer levee system enclosing Barham and the surrounding farmland has a crest height at least as high as the 1993 flood level based on observation accounts from that event. This equates to at least a 17 year ARI flood event as documented within the 1995 Town Levee Investigation report. The 1993 recorded flood level at Barham (77.54 m AHD) is within 0.12 metres of the highest flood on record (1917). It is therefore reasonable to expect that given the amount of warning time available (one to two weeks), protection against overtopping in a 100 year ARI event could be achieved through raising of low points in the levee system if and when required.

Given the above, the proposed levee is not in an active flow conveyance area or an active flood storage area up to at least the 17 year ARI event, and more than likely up to at least the 100 year ARI event. Under these circumstances, the proposed RiverLife levee will have no impact on flooding conditions in events up to and including the 100 year ARI event.

6.1.2 Impacts in Floods more severe than the 100 year ARI Flood Event

Extreme Murray River floods are likely to result in overtopping of the levees which adjoin much of the river route downstream of Echuca. Levees adjoining the Murray River vary significantly in terms of their overtopping threshold. Levees constructed on the NSW side by government agencies in recent decades have included up to 1.0 metre of freeboard above the 100 year ARI flood level. The risk of these levees being overtopping is very low.

Other older levee systems tend to be lower and less structurally sound. The risk of these older, lower levees failing through overtopping or breaching is far greater. Notwithstanding this, these older levees have often proved to be effective, as has been the case at Barham. This is in part however due to a relatively low required levee height at Barham, and therefore low water pressures on the levee. This characteristic reduces the risk of breaching.

In extreme events at Barham, it is very likely that the existing levee system will be either overtopped or breached. This will result in the proposed levee protecting the RiverLife estate being isolated, due to the increased height and structural strength of the estate levee compared to the other older existing levees protecting Barham.

Under these conditions, the expected impact of the proposed RiverLife estate levee on flooding due to conveyance obstruction in extreme events is as follows:

- Levee may lead to slightly higher localised flood levels upstream. Any increase in flood level is expected to be small and dissipate with increasing distance upstream of the levee, as is the case with all afflux impacts in subcritical flow regimes; and
- Given that the above impact will only occur in the event of the existing Barham levee system being overtopped or breached resulting in inundation of the surrounding land adjoining the RiverLife estate, including much of the Barham township area, the impact of any slightly higher flood level due to the RiverLife levee in terms of increased property damage is expected to be negligible.

The expected impact of the proposed RiverLife estate levee on flooding due to floodplain storage loss in extreme events is as follows:

- Storage volume within the RiverLife estate levee enclosed area assuming an average depth of 1.2 metres is 220 ML;
- The peak 100 year ARI flow at Echuca is in excess of 120,000 ML/day. A storage volume of 220 ML would fill in approximately three minutes at this rate; and
- Given this, the impact of lost storage in extreme events, which will only come into effect if the existing levee scheme at Barham is breached, is expected to be minimal.

6.2 Environmental Impacts

Levees can lead to environmental impacts brought about by the following:

- Direct impacts associated with the construction of the levee. Flora / vegetation along the route of the established levee footprint is destroyed as well as the habitat value of this vegetation; and
- Levees exclude floodwater access to the dry side of the levee. Any flood dependent ecosystems (flora and fauna) which depend on periodic access to floodwater to remain healthy will be adversely impacted as a result.

The scope for this flood risk assessment did not include a detailed assessment of flora and fauna impacts associated with the establishment of the proposed levee around the RiverLife estate or for that matter the estate itself. The following description is therefore an overview of impacts based on a field inspection of site conditions and taking into account the levee alignment and type.

6.2.1 Vegetation Conditions

The development site (refer Figure 6) has previously been predominantly cleared of native vegetation and regraded for irrigation. Areas of significant vegetation remaining on the development site are limited to the following:

- Continuous riparian vegetation corridor of varying age trees, mostly river red gums, along the Murray River channel frontage (refer Photographs 1 to 3). This riparian corridor varies in width from approximately 25 metres wide up to 60 metres wide in the south eastern corner of the site. The riparian zone includes some disturbance, in the form of the existing levee which is typically located within 10 metres of the river bank line, and an excavated now redundant farm supply channel;
- Some large mature trees have been retained along the route of an east west aligned excavated farm channel located 150 metres from the sites southern boundary (refer Photograph 4). This redundant supply channel corridor partly occupied by retained mature trees can be seen on Figure 6 and is up to 35 metres wide;
- To the north outside the proposed levee protected area, scattered trees have been retained within two natural drainage lines which converge just inside the sites northern boundary (refer Figure 5). Low flow farm drainage channels have been established within the depressions to improve surface drainage of rainfall runoff and irrigation surplus runoff. These drainage lines are located within the upper reaches of the Eagle Creek catchment; and
- A small number of scattered mature trees in the vicinity of the dilapidated homestead are present outside the proposed levee protected area.

6.2.2 Proposed Levee Direct Impacts

The existing levee is located within the treed riparian corridor immediately adjoining the river bank (refer Photographs 1 and 2). Modifying this levee to the required standard is not proposed given that it would have a major impact on the riparian vegetation.

The proposed levee route is to skirt around the outside line of the riparian corridor. This will enable most, if not all of the mature trees to be retained. The batter toe of the levee located closest to the river will approach some of the tree trunks located furthest from the river. The levee form is described in Section 5.4.

The estate concept design plan incorporates an open space reserve straddling the redundant water supply channel located 150 metres from the estate's southern boundary (refer Photograph 4). The intention is to retain most of the trees that adjoin this channel. A small number of trees may be lost at the eastern river end of the channel to allow for the levee to be constructed as it crosses the channel.

Photograph 1 Riparian vegetation zone adjoining Murray River - view north west towards old homestead and Barham Lakes Caravan Park

Photograph 2 View looking west towards riparian vegetation and river on the site's western boundary

Photograph 3 View east from the south western corner of the site adjoining the Murray River – riparian vegetation on right, river unsighted due to vegetation

Photograph 4 View looking west along the redundant irrigation supply channel – open space reserve to be retained over this corridor post development

6.2.3 Other Impacts

The remainder of the site on the inside of the river riparian corridor and away from the redundant supply channel corridor has been completely cleared of native vegetation and irrigation farmed for an extended period. Environmental impacts associated with developing this area are therefore expected to be minimal.

It is possible that a small winery may be established in the north western corner of the development site. This will not involve any habitable buildings and as such does not require any additional protection from flooding.

The remainder of the development property north of the levee protected area will not be developed in the short to medium term. Depending on demand and the future refinement of the Barham township levee scheme, development of the northern portion of the site may occur in the longer term, particularly if government standard levee protection is secured for the Barham township and includes protection of the RiverLife site. If this was to occur in the future, most of the proposed RiverLife estate levee would become redundant, with only the section paralleling the river needing to be maintained.

6.3 Social Impacts

Levees can lead to adverse social impacts as a result of:

- Increasing the flood risk to adjoining landholders (e.g. through higher flood levels due to levees obstructing the passage of floodwater); and
- Altering the aesthetic appearance of the landscape (e.g. levee may block or partially block the view from an adjoining property).

In relation to the proposed levee enclosing the RiverLife estate, the levee is expected to have minimal adverse impact on the adjoining properties. The reasons for this are as follows:

- The surrounding land is not subject to flooding due to the presence of the existing levee system at Barham. The existing levee system funnels the flow between the Victorian side and NSW side levees at Barham / Koondrook. The proposed levee will not result in any further constriction of the floodplain as the proposed levee is located within the area already excluded from flooding, unless there is a breach or overtopping of the existing levee. Hydraulic conditions for floods events not overwhelming the existing levee system will therefore remain unchanged;
- In extreme flood events which will result in overtopping of the existing levee scheme at Barham, the surrounding land adjoining the proposed RiverLife levee will be inundated regardless of the presence of the proposed levee. The proposed levee may lead to slightly higher localised flood levels upstream, however the impact of this is expected to be negligible;
- Local runoff from parts of the adjoining west and east side properties drains through the northern portion of the RiverLife property on route to Eagle Creek. The proposed extent of the RiverLife levee is to be restricted to the southern portion of the property and will not therefore impact on the drainage of the adjoining west and east side rural properties;

- Similarly the limited extent of the proposed levee will not result in it directly bordering the Barham Lakes Caravan Park. The levee is therefore expected to have little or no impact on views from the caravan park; and
- The existing farm house on the adjoining east side property is located 100 metres from the estate boundary. River views and flood risk for this property are not expected to be significantly affected.

The Wakool Shire Council is supportive of the development proposal as it is consistent with its recently adopted Land Use Strategy Report (Collie Pty Ltd et al, 2009). Attracting new residents by among other things providing attractive areas for residential development is an important factor in ensuring the future viability and sustainability of the Shire.

The proposed RiverLife estate will provide substantial benefits to the Shire in the form of increasing the area of available for new residential development at Barham. The estate area is directly referenced by the 2009 Land Use Strategy Report as an area suited to future residential development, particularly given the current limited available vacant land to meet demand.

7. Summary and Conclusions

Background

The proposed RiverLife estate development site is located on land currently protected from Murray River flooding by a network of levees which protect the Barham township and surrounding rural areas. The levee system protects against both Murray River flooding and Barbers Creek flooding enclosing a total area of 44 km^2.

The existing levees do not meet expected standards in relation to flood protection levees for urban areas and consequently are at an excessive risk of being overtopped or breached. This report has subsequently been prepared documenting issues associated with the construction of a proposed new levee for protecting the RiverLife estate site in isolation, consistent with Option 2 identified in letter correspondence from DECCW to the Wakool Shire Council dated 1 October 2010.

Proposal

The development proposal involves residential development on the southern portion of the property only (refer Figure 6). Details of the proposed levee are as follows:

- The indicative levee route is shown on Figure 6 and encloses approximately 18 hectares (0.18 km^2);
- The levee crest will be constructed to the 100 year ARI flood level plus the level of freeboard required by DECCW and Council. A freeboard of 0.6 metres results in a levee which varies in height from 1.0 to 1.4 metres;
- The levee route will follow the inside line of the remnant riparian vegetation adjoining the Murray River channel. The existing levee will not be altered as it is located within the riparian vegetation adjoining the river;
- The levee will be constructed in accordance with techniques and materials appropriate for urban flood protection levees (refer Section 5); and
- The majority of internal runoff within the levee protected area will continue to be gravity discharged to the north as occurs under existing conditions.

Hydraulic Impacts

The proposed RiverLife estate levee is located within the area currently protected by the existing levee network and will not therefore impact on broader floodplain hydraulics in events that do not overtop or breach the existing levee scheme. This is not known to have occurred at Barham in living memory.

In extreme Murray River flood events which will result in the inundation of Barham and the surrounding protected areas, the proposed RiverLife development is expected to have a negligible impact on flooding conditions and flood risks for the following reasons:

- The available flood warning time for Barham is expected to be at least one week allowing for evacuation of both the existing township and the RiverLife estate to take place if predicted flood levels warrant;

- The proposed RiverLife estate levee crest is to be elevated approximately 0.6 metres higher than the existing town levee system providing protection in the event of the existing levees breaching; and
- The reduced conveyance and lost floodplain storage associated with the levee enclosed estate area is not likely to have a measurably impact on flooding conditions given the severity and extent of floodwaters in such extreme events.

Environmental Impacts

The environmental impacts associated with the construction of the proposed levee and the internal development is expected to be minimal for the following reasons:

- The proposed levee route is to be positioned such that it skirts around the fringe of the Murray River riparian vegetation. Minimal, if any, mature tree losses to this riparian zone will therefore result;
- The development layout incorporates an open space reserve over the redundant irrigation channel route towards the southern end of the property which will allow for the retention of most of the large trees present within this reserve area; and
- The only other potential environmental sensitive areas are located outside the proposed levee protected area towards the northern end of the site. The development is not expected to therefore impact on these other areas which include drainage depressions with light to moderate density scattered tree coverage.

Social / Economic Impacts

The proposed RiverLife estate including the flood levee is expected to have minimal adverse social and economic impacts. Adjoining rural farmland will not be affected given that drainage through the northern portion of the development property will not be impeded.

The existing farm house on the adjoining east side property is located 100 metres from the estate boundary. River views and flood risk for this property are not expected to be significantly affected.

The limited extent of the proposed levee will not result in it directly bordering the Barham Lakes Caravan Park. The levee is therefore expected to have little or no impact on views from the caravan park.

The proposed residential development will provide positive social and economic impacts for Barham and the broader Wakool Shire by attracting new residents and the benefits that come with this. Council's 2009 Land Use Strategy document directly identifies the development property as an area where additional residential development for Barham is to be encouraged.

Conclusion

Given the above, it is concluded that the proposed RiverLife estate residential development can proceed without causing significant adverse impacts on surrounding flooding conditions, the local environment, and the social and economic conditions of the adjoining landholders. The development will provide positive social and economic impacts for Barham and the broader Shire.

8. References

Collie Pty Ltd, Ivey ATP, Geolyse and Groupwork (April 2009). *Wakool Shire LEP Review – Land Use Strategy Report*. Prepared for Wakool Shire Council.

Earth Tech Pty Ltd (2008). *Edward, Wakool and Niemur Rivers – Stages 1, 2 and 3 Areas – Floodplain Risk Management Study*. Prepared for DECC.

Egis Consulting (17 April 2000). *Flood Data Transfer Project – Flood Mapping Report – Shire of Gannawarra*. Prepared for the Department of Natural Resources and Environment.

Egis Consulting (1 May 2000). *Flood Data Transfer Project – River Basin Report – Murray River Basin*. Prepared for the Department of Natural Resources and Environment.

Gutteridge Haskins & Davey Pty Ltd, Cameron McNamara Pty Ltd, and Laurie Montgomerie & Pettit Pty Ltd (December 1986). *Murray River Flood Plain Management Study*. Summary Report, Detailed Report and Atlas prepared for the Rural Water Commission of Victoria and the Water Resources Commission of NSW.

Gutteridge Haskins and Davey Pty Ltd (February 1995). *Barham Town Levee Investigation*. Prepared for Wakool Shire Council.

Sing Pty Ltd (2002). *Levee Design Construction & Maintenance*. Prepared for Victoria Department of Natural Resources and Environment.

NSW Department of Environment, Climate Change & Water (March 2010). *Draft Floodplain Management Plan – Wakool River Stage 2 – Moama-Moulamein Railway to Gee Gee Bridge*.

NSW Government (April 2005). *Floodplain Development Manual: The Management of Flood Liable Land*.

GHD

105 Hume Street
Wodonga VIC 3690 Australia
T: 61 2 6043 8700 F: 61 2 6043 8711 E: abxmail@ghd.com.au

Document Status

Rev No.	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
0	T Clark	J Ellwood		J Ellwood		24/2/11
1	T Clark	J Ellwood		J Ellwood		4/3/11