LEETON SHIRE COUNCIL

ENGENY WATER MANAGEMENT

LEETON SHIRE COUNCIL

Leeton Shire Floodplain Risk Management Study and Plan

Report




June 2019

M9500_003

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M9500_003 LEETON SHIRE FLOODPLAIN RISK MANAGEMENT STUDY					
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EXECUTIVE SUMMARY

The Leeton Shire Floodplain Risk Management Study (FRMS) has been undertaken subsequent to the Leeton Shire Flood Study (Engeny, 2015). A key objective of the Leeton Shire FRMS was to develop a detailed understanding of the flood risks and develop a Floodplain Risk Management Plan (FRMP or Plan) that outlines the proposed management measures to address existing, future and continuing/residual risk. Specifically, the Plan identifies flood mitigation measures to reduce the likelihood and consequence of flooding, control future development within floodprone areas and improve emergency planning and response to future flood events. The Plan also aims to increase the community's awareness and resilience to flood risks. Outcomes from the FRMS and FRMP are outlined as follows.

Floodplain Risk Management Study

The FRMS identified that Landsdowne Estate and properties surrounding McCaughey Park and east Yanco were considered to be the major flooding hotspot areas. Three houses in Landsdowne Estate were predicted to experience above floor inundation in a 1 % AEP event and two houses surrounding McCaughey Park (Hebden Street) were predicted to experience above floor inundation in a 1% AEP.

Flood hazard classification and hydraulic categorisation maps were prepared. The flooded areas in Leeton and Yanco were considered to be of low hazard category however the open drains surrounding Leeton and Yanco along with a few pockets of deep water where flood depths of greater than 1 m were predicted are considered to be of high hazard due to the excessive depths. It was determined that the drainage channels were floodways with much of the remaining areas of inundation being flood storage areas. The floodways are also considered to be high hazard due to the greater flood depths, whilst the flood storage areas were generally considered to be low hazard apart from areas of significant ponding and greater flood depths.

Regarding isolation and evacuation, no properties were predicted to become isolated during floods in Leeton and Yanco. Evacuation of properties predicted to be inundated may be possible during a flood (i.e. low flood hazard of flooded road) and assessment of flood depth over roads indicated that roads were generally considered to be trafficable (<300mm) therefore isolation and evacuation is not considered to be an issue.

Based on an understanding of the flood risk, an extensive list of flood risk management measures was considered and potential flood behaviour modification measures for the major hotspot areas were incorporated into the TUFLOW hydraulic model for assessment (refer Section 3.7).

A multi-stage assessment procedure was applied to potential floodplain risk management measures, comprising property modification measures, response modification measures and flood behaviour modification measures. A list of measures was considered for applicability to the flood characteristics and associated risk, from which a short list of options was assessed both qualitatively and quantitatively (where possible). Options to increase drainage capacity were investigated for the system between Almond Road and Fivebough Road and increased flood storage was investigated for McCaughey Park.

Th e feasibility and effectiveness of quantitatively assessed options was evaluated using a simplified cost-benefit analysis, the outcomes of which are summarised below.

Table 0-1 Simplified Cost / Benefit Evaluation

Mitigation Measure	Estimated Cost	Number of Dwellings Potentially Protected	Evaluation Outcome ($/Dwelling)
Landsdowne Estate Mitigation Option	$585,000	3	$195,000
McCaughey Park Pond Water Level Reduction and Additional Pond Storage	$360,000	2	$180,000

A flood damage assessment was also undertaken for the preferred mitigation options for Leeton (Landsdowne Estate) and Yanco (McCaughey Park Pond). The assessment identified that the Landsdowne Estate Mitigation Option presented the only viable solution based on the resultant benefit/cost ratio (1.07).

Table 0-2 Flood Damage Assessment Outcomes

Scenario	Averaged Annual Damages	Net Present Value of Damages	Cost of Option	Option Benefit	Benefit/ Cost Ratio
Leeton - Base Case	$71,981	$1,602,933			
Leeton - Landsdowne Estate Mitigation Option	$29,529	$436,052	$585,000	$626,881	1.07
Yanco – Base Case	$18,215	$268,980			
Yanco - McCaughey Park Pond Water Level Reduction and Additional Pond Storage	$16,254	$240,020	$360,000	$28,960	0.08

Floodplain Risk Management Plan

The recommended flood risk management measures are summarised below.

Table 0-3 Recommended Measures

Measure	Description
Landsdowne Estate Drainage Upgrade	Consider feasibility of the proposed works and undertake further investigation and design if deemed potentially viable.
McCaughey Park Pond Expansion	Consider feasibility of the proposed works and undertake further investigation and design if deemed potentially viable.
Zoning and Development Control	Consider recommended development control measures and incorporate into LEP.
Community Flood Awareness and Preparedness	Develop a tailored community Flood Awareness and Preparedness Program in consultation with the communities at risk and the NSW State Emergency Service (NSW SES).
Flood Predictions and Warnings	Develop an Flood Warning System for the Leeton Shire in conjunction with the Australian Bureau of Meteorology (BOM) and the NSW SES. Consider the installation of flood depth indicators at key locations.
Flood Emergency Response	Develop an Flood Emergency Response Plan for the Leeton Shire in consultation with the community, NSW SES and all relevant stakeholders including Murrumbidgee Irrigation (MI).

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1. INTRODUCTION

Subsequent to the completion of the Leeton Shire Flood Study (Engeny, 2015), Engeny Water Management (Engeny) was engaged by Leeton Shire Council (LSC) to undertake the Leeton Shire Floodplain Risk Management Study (Leeton Shire FRMS) and develop a Floodplain Risk Management Plan. The Locality Plan is presented in Figure 1-1.

The essential best practice principle of flood risk management is the adoption of a well-considered pro-active response to the identified flood problem that first recognises the various flood risks and then moves to address the risks before they develop to or are experienced at extreme levels. Based on this fundamental principle, the project has been undertaken in two phases which are described as follows:

- Phase 1: Floodplain Risk Management Study – utilising outputs from the Leeton Shire Flood Study, the purpose of Phase 1 was to develop an understanding of the flood risks in order to determine potential flood mitigation measures to address the defined risks.

- Phase 2: Floodplain Risk Management Plan – based on the understanding established from Phase 1, the purpose of Phase 2 was to develop a plan of recommended flood risk mitigation measures to be considered by LSC for implementation.

1.1 Project Objectives

The key objectives of the Leeton Shire FRMS were to:

- Establish a detailed understanding of the existing flooding behaviour using the output from the flood study to define flood risk characteristics and confirm the critical hot spot areas surrounding Leeton and Yanco.

- Determine and assess potential flood risk management options to address the identified flood risks based on social, ecological and economic factors.

- Develop a Floodplain Risk Management Plan (FRMP) that outlines the proposed management measures to address existing, future and continuing/residual risk. Specifically, the plan identifies flood mitigation measures to reduce the likelihood and consequence of local and regional flooding, control future development within floodprone areas and improve emergency planning and response to future flood events. The plan also aims to increase the community's awareness and resilience to flood risks.

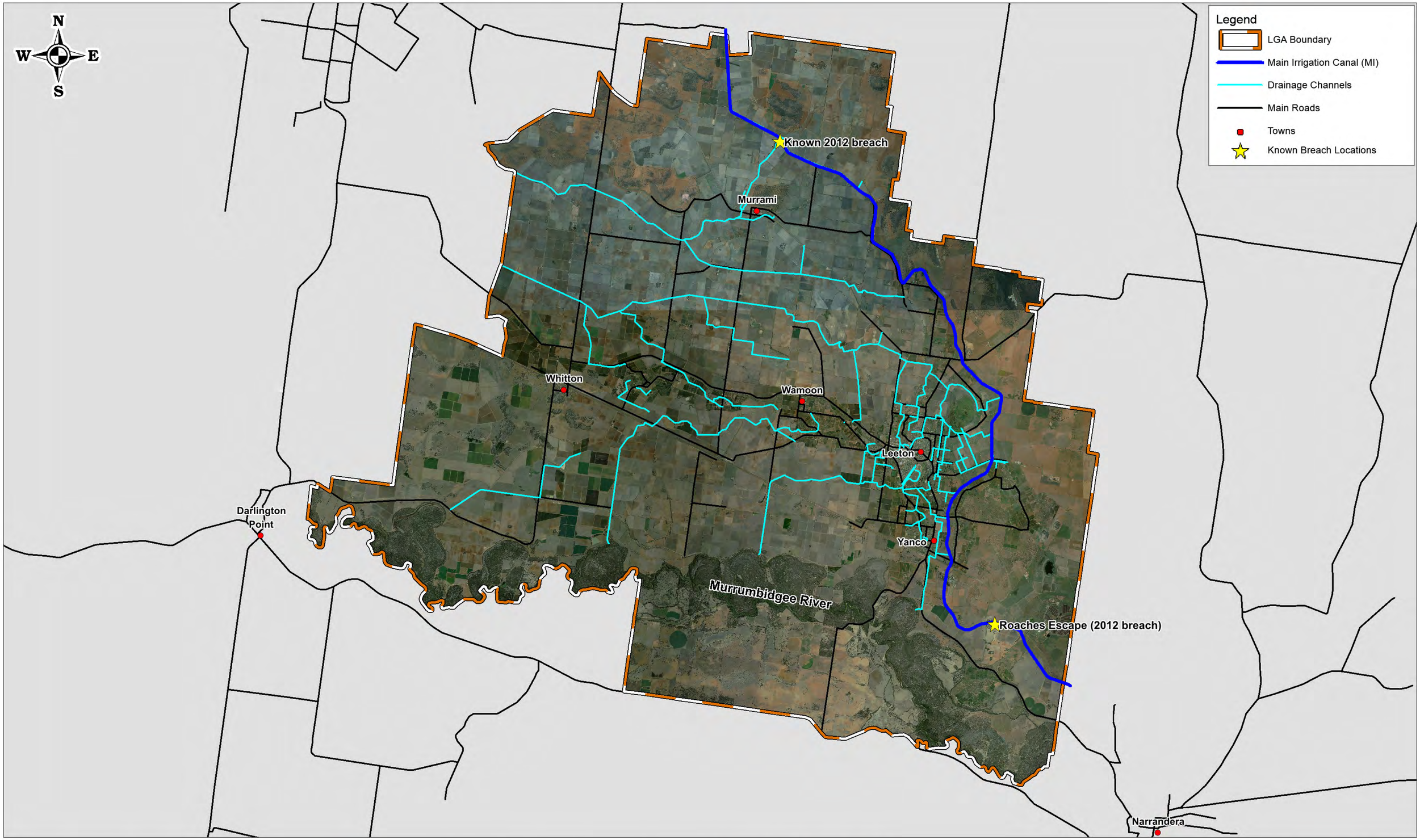
1.2 Project Scope

The scope of works for the Leeton Shire Floodplain Risk Management Study has consisted of the following:

1. Hydraulic model refinement for assessment of mitigation options.
2. Floodplain risk management study including:

a. Analysis of flood behaviour including review of hot spots.
b. Flood risk assessment.
c. Identification of floodplain risk management measures.
d. Hydraulic assessment of flood risk management measures.
e. Presentation of hydraulic assessment results to LSC.
f. Determination of preferred mitigation options in consultation with LSC.
g. Cost estimation of preferred mitigation options.
h. Determine benefit of preferred mitigation options in terms of buildings potentially protected.

3. Development of floodplain risk management plan.



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Scale in Kilometres (1:200,000 @ A3)

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Leeton Flood Study

Study Area

Figure 1.1

Job Number: M9500_003
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Drawn: KJM
Date: 22 MAY 2018

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1.3 Input Data and Available Information

Available information for the Leeton Shire FRMS included the following:

- Leeton Shire Flood Study Report (Engeny, 2015).
- Leeton Shire Flood Study TUFLOW models (Engeny, 2015).
- Murrumbidgee Irrigation Flood Management Plans for:
  - Narrandera to Darlington Point.
  - Roaches.
  - Fivebough.
  - Leeton Rainfall Hotspots.
- Griffith Flood Risk Management Study and Plan (BMT WBM, 2015).
- Narrandera Flood Risk Management Study (SKM, 2009).
- Narrandera Flood Risk Management Plan (SKM, 2009).
- Narrandera Flood Study Review and Levee Options Assessment (Lyall & Associates, 2015).

2. HYDRAULIC MODEL REFINEMENT

Comments from the Leeton Shire Flood Study (Engeny, 2015) included a review of the hydraulic models to ensure a more detailed hot spot analysis is undertaken to develop a greater understanding of the constraints and opportunities in managing flood risk.

A review of the urban flood model extents was undertaken in order to refine the model extents to ensure the flood models represent current conditions as accurately as possible for mitigation option assessment purposes. Three models were developed using the inputs from the Flood Study. The revised model extents are presented in Figure 2-1. The urban model was extended east of the main irrigation canals to ensure the volume of water passing through each of the sub drains was more accurately represented (i.e. previously was modelled with a channel cut through the embankment which provided a conservative estimation of the volume of water passing through the sub drain).

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Legend

- Model 1 Extent
- Model 2 Extent
- Model 3 Extent
- Culvert
- Pipe
- Open Drain
- Main Canal
- Road

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Leeton Shire Floodplain Risk Management Plan

Figure 2.1

Revised Model Extent

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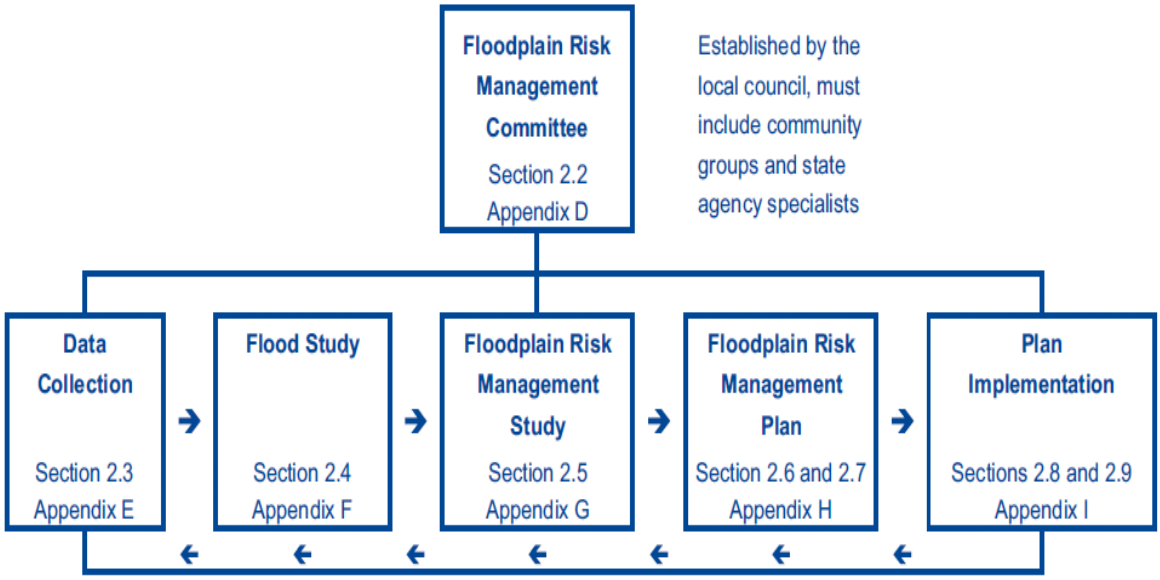
3. FLOODPLAIN RISK MANAGEMENT STUDY

3.1 Overall Approach

This study has been undertaken in accordance with the Floodplain Development Manual (DIPNR, 2005). The Leeton Shire Floodplain Risk Management Study comprises Stage 2 of the Floodplain Risk Management Process which comprises of the following components:

- Stage 1 Flood Study - completed in 2015.
- Stage 2 Floodplain Risk Management Study.
- Stage 3 Floodplain Risk Management Plan.

The Process as outlined in the Floodplain Development Manual is illustrated in the diagram below.



3.2 Flood Behaviour in the Study Area

Flooding around the Leeton and Yanco townships has been discussed for five (5) areas of particular interest which are defined as the study area. These study or hotspot areas include:

- Corbie Hill Road to Fivebough Road.
- Petersham Road.
- Leeton Township (CBD).

- Wattle Hill.
- Yanco.

Flooding between Corbie Hill Road and Fivebough Road is primarily caused by runoff generated from the Colinroobie Ranges and Corbie Hill situated to the east of the Murrumbidgee Irrigation (MI) main irrigation canal. The irrigation canal acts as a levee during flood events and has the ability to detain a significant volume of runoff behind the channel embankment. Flood waters pass through the irrigation canal via sub drains located at Corbie Hill Road and approximately 1.5 km north of Corbie Hill Road. The sub drains are essentially pipes underneath the channel where the capacity is largely determined by the upstream hydraulic head. Open drains convey flood water from the irrigation canal generally in a northerly direction towards and around Fivebough Wetlands. The flat gradients of the open drains result in limited conveyance capacity and widespread flooding across the area.

Flooding along Petersham Road is primarily caused by runoff generated from the main urban area of the Leeton township to the west. Relatively informal open drains convey flood water from the township along Petersham Road towards and around Fivebough Wetlands.

Flooding within the Leeton CBD area is caused by direct rainfall runoff within the relatively small sub catchments. Flows are conveyed via underground stormwater pipes and kerb and channel prior to discharging into open drains that convey water in a generally north direction towards and around Fivebough Wetlands. Nuisance flooding may be experienced within the CBD due to minor drainage deficiencies; however, results indicated that no major flood risks are evident in the area.

Wattle Hill has similar flooding characteristics as the Leeton CBD. However, the open drains located in Wattle Hill convey water in a southerly direction before travelling west away from Leeton. Nuisance flooding may be experienced in Wattle Hill; however, results indicated that no major flood risks are evident in the area.

Flooding in Yanco occurs from two different sources (east and west of Main Avenue). The catchment west of Main Avenue drains towards the pond located to the west of town (adjacent to Binya Street). Flows within the pond are then pumped into an open drain and conveyed in a northerly direction towards Leeton. Runoff generated from developed areas east of Main Avenue and west of Davis Road is conveyed via open drains in a northerly direction towards Leeton. The MI main irrigation canal acts as a levee during flood events in this area that detains runoff generated from the Merungle Hill catchment to the east. Flood water is conveyed through the irrigation canal via a sub drain located approximately 600 m north of Regulator Road. The open drain located at the outlet of the sub drain conveys floodwater from Merungle Hill south through Regulator Road and ultimately into the Murrumbidgee River.

Reference should be made to the Leeton Shire Flood Study (Volume 2) for flood mapping.

3.2.1 Historical Flood Behaviour

The 3rd/4th March 2012 rainfall event was the biggest rainfall/flooding event to have occurred within the Leeton LGA. Approx. 170 mm fell within a 24-hour period from 9 am on 3/3/2012. Approx. 30% of the rainfall fell between 9 am and 3 pm on 3/3/2012 with the majority falling between the 12-hour period of 3 pm 3/3/2012 until 3 am 4/3/2012 (approx. 70% of the rainfall). In the week preceding this event, around 100 mm of rainfall fell across the catchment (measured at Yanco Agricultural Institute by BOM gauge 074037).

Anecdotal information was provided by the NSW SES that during the rainfall event, the Main Canal bank overtopped and the canal banks at Roaches Regulator had to be breached to allow the water to escape and flow overland to the Murrumbidgee River. The storm's impacts throughout Leeton and other towns as well as neighbouring agricultural land, was considered to be caused by flash flooding rather than Murrumbidgee River flooding, with the river peak occurring 6 days after the storm (i.e. 3rd March rainfall event, 9th March flood peak at gauges).

Widespread flooding occurred throughout the Leeton and Yanco townships during the event mainly due to significant rainfall and runoff volumes from the mountain ranges surrounding the townships that occurred in a short time period.

Murrumbidgee Irrigation (MI) provided Emergency Response Guides for their infrastructures. Information relating to the March 2012 flood event was included in the document. According to the document; the heavy rain event meant MI's system was full and needed draining through the River drains. Usually, MI would have drained longer and earlier, but in this scenario, because the River was in flood as well, it impacted MI's ability to drain the system especially in the Gogeldrie area. MI blocked off the drainage points to avoid River flood water entering MI's system, which limited MI's ability to drain the rain flood waters.

3.2.2 Design Flood Analysis

Flood depths through properties between Corbie Hill Road and Fivebough Road are typically up to 0.6 m outside of the open drains in a 1% AEP event. Flows are generally contained within the open drains in the 50% AEP with flood depths predicted to be typically less than 0.2 m in areas outside of the open drains. Due to the flat gradients in this area flood velocities are typically less than 0.2 m/s in both the 50 and 1% AEP events.

Flood depths through properties along Petersham Road are typically less than 0.3 m in the 1% AEP event. Flooding through properties along Petersham Road is considered to be local flooding issues due to topographic constraints (i.e. majority of properties lower than roads).

Flood depths through properties in Yanco west of Main Avenue are typically less than 0.25 m in the 1% AEP event. Flood depths greater than 1 m were predicted in the 1% AEP event behind the main irrigation canal, the railway, Binya Street, the McCaughey Park pond in Yanco and the large storage area adjacent Golf Club Drive. Flooding through private

properties in Yanco are considered to be local flooding issues due to topographic constraints (i.e. majority of properties lower than roads).

Flood depths of typically less than 0.5 m are predicted outside of open drains in the 1% AEP event east of Main Avenue.

Flood evacuation via major roads during the 1% AEP is predicted to be possible due to the low flood hazards predicted on roads throughout the Leeton and Yanco townships.

3.2.3 Hydraulic Controls

There are a number of major key hydraulic controls around Leeton and Yanco. These are illustrated in Figure 3.1 and include the following:

- Main Irrigation Canal (Leeton):
  - The main irrigation canal acts like a flood protection levee for Leeton.
  - Runoff from the mountain ranges (Corbie Hill and Collinroobie Ranges) ponds behind the canal embankment prior to entering downstream open drains via sub drains under the embankment.
  - Without the main canal, flooding of properties between Corbie Hill Road and Fivebough Road would be significantly worse to the west of the canal (particularly properties in Landsdowne Estate).
- Open Drains and Road Crossings between Corbie Hill Road and Fivebough Wetlands:
  - Results of the modelling indicate that the combination of flat longitudinal gradients of the open drains (less than 0.5%) and small dimension culvert crossings ensures water ponds behind roads and back up into private properties once capacity of the open drains is reached.
- Main Irrigation Canal (Yanco):
  - The main irrigation canal acts like a flood protection levee for Yanco.
  - Runoff from the mountain ranges (Merungle Hill) ponds behind the canal embankment prior to entering downstream open drains via sub drains under the canal.
  - Without the main canal, flooding of properties east of Main Avenue are likely to be significantly worse to the west of the canal.
- Open Drains (Yanco):
  - The flat longitudinal gradients of the open drains (less than 0.5%) downstream of the pond limits the outlet capacity of the pond pump.
  - Water is predicted to travel backwards towards the pond from the downstream open drain. This was confirmed by a property owner on Hebden Street. As such, drainage capacity is significantly restricted by the flat grades.

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Legend

- Road Culvert Crossing
- Open Drain
- Main Irrigation Canal

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Leeton Shire Floodplain Risk Management Plan

Figure 3.1

Key Hydraulic Controls

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3.3 Flood Risk Assessment

3.3.1 Hotspot Analysis

The location, nature and source of flooding issues for the major hotspots in the Leeton and Yanco townships are presented in Appendix A. Refer to Figure 3-2 showing hotspot areas and 1% AEP flood depth.

The major hotspot areas were considered to be:

- Landsdowne Estate:
  - Widespread flooding occurs around development and neighbouring farms/properties in frequent flood events (i.e. 50% and 20% AEP).
  - A number of properties and houses are predicted to be inundated in the 20% AEP and larger events with 1 house predicted to experience above floor inundation in the 20% and 10% and 3 houses in the 1% AEP event. This is based on modelled flood depth results and surveyed house floor levels provided by LSC.
  - Water ponds behind bund on adjacent property to the west before entering site.
  - Detention basin is lower than downstream drainage channels with limited pump capacity (15L/s).
  - Downstream drainage channel capacity is limited due to very flat longitudinal grade. Cross drainage culvert capacity at each road crossing is also limited with road crossings and road embankments acting as a significant hydraulic control.
- McCaughey Park & East Yanco:
  - Up to 4 properties along Hebden Street were predicted to be at risk of experiencing flooding from two sources; one being the drain that conveys water to the pond between Cudgel Street and Hebden Street, the other source being rainfall pooling within property boundaries due to land being lower than the top of drain.
  - Flow enters properties east of Main Avenue/Irrigation Way in large events due to overtopping of the drain as well as properties being lower than the road.
  - Based on modelled flood depth results and surveyed house floor levels provided by LSC, 2 houses are predicted to experience above floor inundation in the 1% AEP event.
  - Ponding in 26 Hebden Street overtops the drain bund wall in a 10% AEP event.
  - Widespread flooding of properties west of the drain occurs in the 1% AEP event as Hebden Street has 1% AEP flood immunity.

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Flood Depth (m)

- 0.0 to 0.3
- 0.3 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 4.0
- > 4.0

Legend

- Flooding Hot Spot
- Main Irrrigation Canal (MI)

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Leeton Shire Floodplain Risk Management Plan

Figure 3.2

Flooding Hot Spots

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3.3.2 Flood Hazard Classification

The Floodplain Development Manual defines flood hazard as follows:

- High Hazard – possible danger to personal safety; evacuation by trucks is difficult; able-bodied adults would have difficulty wading to safety; potential for significant structural damage to buildings.
- Low Hazard – should it be necessary, trucks could evacuate people and their possessions; able-bodied adults would have little difficulty in wading to safety.

The provision of a flood hazard classification is often determined based on the predicted flood depth and velocity results. High flood depths will cause a hazardous situation whilst a low depth may only cause an inconvenience. High flood velocities are dangerous and have potential to cause structural damage whilst low velocities are generally considered to have no major threat. Figures L1 and L2 in the Floodplain Development Manual were used to determine the hazard categories within the Leeton and Yanco townships. The provisional hazard categories are considered to reflect the true flood hazard as other risks including evacuation or isolation have not been identified. The rate of rise of floodwaters is also considered to be slow based on historical and modelled flood behaviour.

An excerpt from this manual is provided in Figure 3-3. The flood hazard categorisation for the 1% AEP flood event for Leeton and Yanco is provided in Figure 3-4. Hydraulic results have indicated that most of flooded areas in Leeton and Yanco are considered to be of low hazard category. The open drains surrounding Leeton and Yanco along with a few pockets of deep water where flood depths of greater than 1 m were predicted are considered to be of high hazard due to the excessive depths.

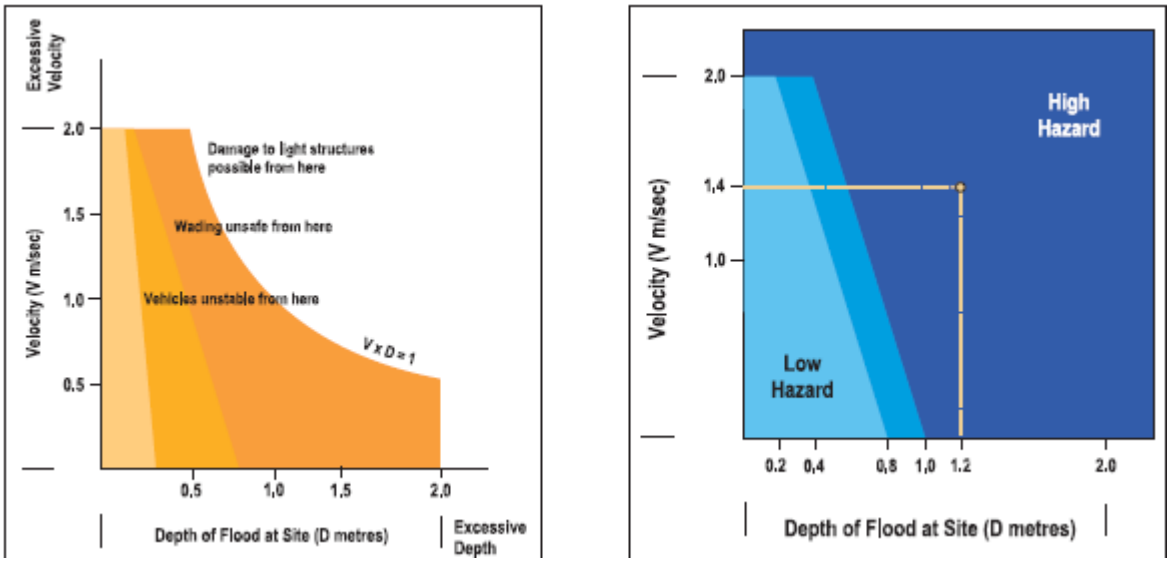

Figure 3-3 Provisional Flood Hazard Categorisation

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Hazard Category

- Low Hazard
- Medium Hazard
- High Hazard
- Extreme Hazard

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Leeton Shire Floodplain Risk Management Plan

Figure 3.4

Hazard Categorisation

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3.3.3 Hydraulic Categorisation

The Floodplain Development Manual recognises three categories of flood prone land, these being:

- Floodways.
- Flood storage.
- Flood fringe.

Floodways are defined as those areas where a significant volume of water flows during floods and are often aligned with obvious natural channels. They are generally flow conveyance areas as such have deeper flow and or higher velocities. Flood storage areas are generally defined as those parts of a flood plain that are important for the temporary storage of floodwaters during the passage of a flood. Flood fringe is the remaining area of land affected by flooding, after floodway and flood storage areas have been defined.

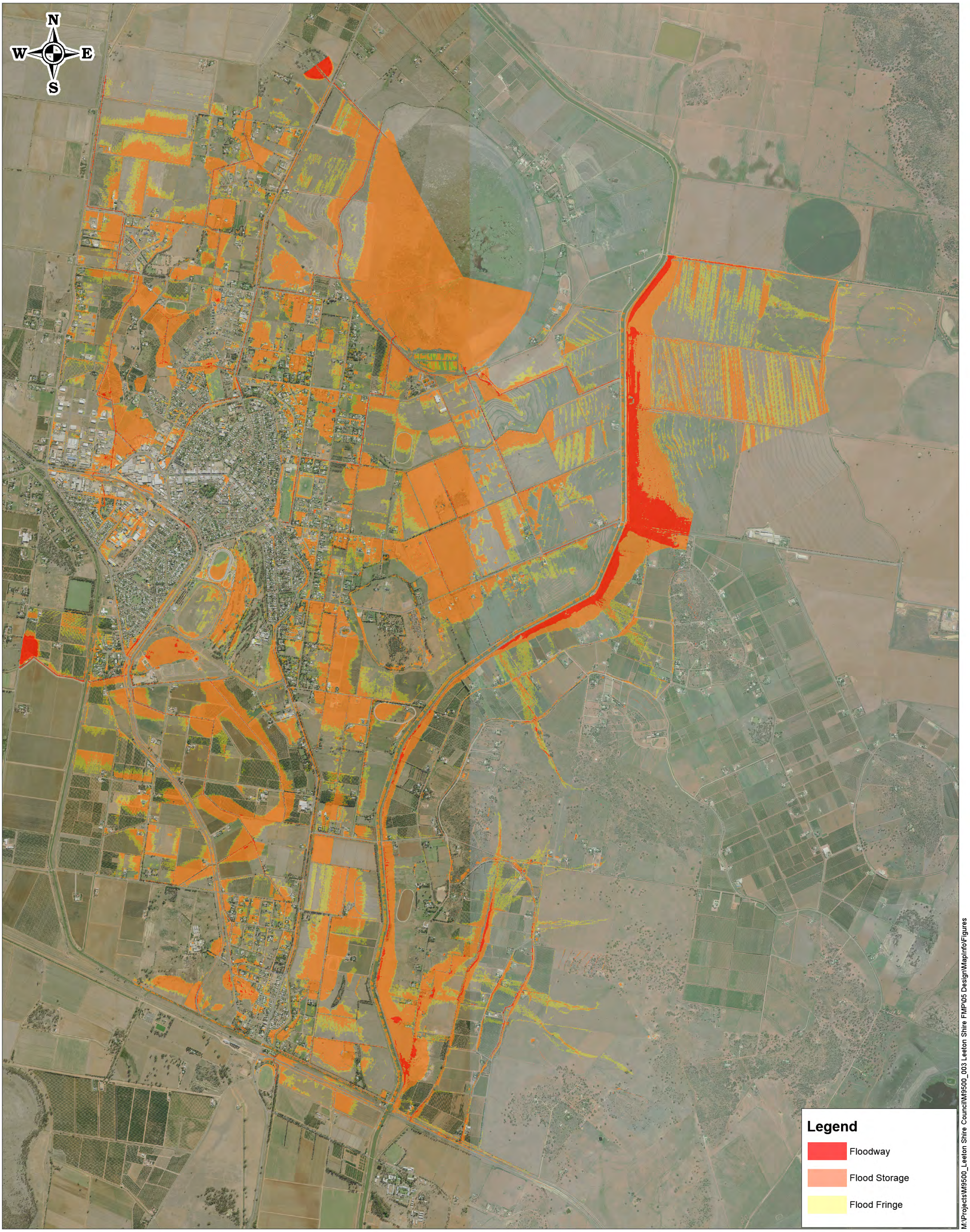
The following criteria were developed in order to better define the hydraulic categories within the Leeton and Yanco Township areas:

- Floodways: Depth velocity product > 0.1 at the 1% AEP.
- Flood storage: Depth velocity product < 0.1 and Depth > 0.1 m at the 1% AEP.
- Flood Fringe: 1% AEP flood extent.

It was determined that the drainage channels were floodways with much of the remaining areas of inundation being flood storage areas. The floodways are also considered to be high hazard due to the greater flood depths, whilst the flood storage areas were generally considered to be low hazard apart from areas of significant ponding and greater flood depths.

Two different flood storage criteria were tested to ensure there were no flood fringe areas identified as flood storage. Depths of > 0.3 m and > 0.1 m (combined with depth velocity product values < 0.1) were assessed by filling potential future development sites (residential land use in the Leeton Local Environmental Plan) to determine flood impacts. It was determined that depths > 0.1 m and with a depth velocity product < 0.1 predicted to align to the definition of flood storage.

Revised hydraulic categorisation maps for Leeton and Yanco are presented in Figure 3-5 and are based on the revised local hydraulic models for each township. It should be noted that the Whitton mapping was unchanged from the 2015 Flood Study.



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0 0.7 1.4
Scale in kilometres (1:35,000 @ A3)

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994. (GDA94)
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

Leeton Shire Floodplain Risk Management Plan

Figure 3.5

Hydraulic Categorisation

Job Number: M9500_003
Revision: 0
Drawn: KJM
Date: 22 MAY 2018

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3.3.4 Flood Warning Time

In the lead up to a flood, warning times play a critical role in reducing the risks to property damage and potentially life. Small warning times represent a greater risk to the community as there is less opportunity to respond effectively and implement risk reducing measures. Minimal warning times present a risk that emergency services are unlikely to be able to mobilise and provide any assistance or direction to affected communities.

To assess flood warning times for the study area, consideration has been given to the flood warning classification presented in Table 3-1.

Table 3-1 Flood Warning Classification

Warning Level	Warning Time (hr)	Description
No effective warning	< 1	No time for pro-active and systematic organization of flood mitigation, evacuation, emergency response etc. Individuals would be self-directed in regard to emergency response.
Minimal warning	1-6	Limited assistance and direction likely from emergency services. Measures requiring minimal time for implementation may be appropriate for flood management.
Moderate warning	6-12	Potential assistance and direction from emergency services, depending on time of day. Measures requiring moderate time, or less, for implementation may be appropriate for flood management.
Good warning	12 +	Significant assistance and direction from emergency services may be available, including assistance with evacuation. Most measures requiring some form of on-demand implementation would be appropriate for flood management.

As there are no formal warning systems in place for local rainfall/flooding events at Leeton and Yanco townships, the only warnings available are from the BOM. BOM provides 3 day and 10-day rainfall forecasts. These 3 to 10-day forecasts are rainfall totals only and may not give a true reflection of how the rainfall will be distributed over the period. 24-hour rainfall forecasts are updated twice daily on the BOM website (at 8 am and 8 pm EST). Given the inaccuracy of the longer forecasts from the BOM, it is likely that warning times for Leeton and Yanco townships (and the entire Leeton LGA) would be in the minimal warning time category.

There are currently no formal warning systems (BOM or other) in place for local events within the Leeton and Yanco townships. There is currently a NSW SES 'Flood Intelligence Card' (Appendix B) that indicates which properties in Yanco (south of the irrigation canal

and Regulator Road) may experience flooding based on Murrumbidgee River gauge levels at Narrandera. The levels (at Narrandera gauge) and locations identified include:

- Cudgel Creek starts to flow at 4.87 m gauge height at Narrandera gauge.
- Euroley Creek starts to flow at 6.03 m gauge height at Narrandera gauge (5.46 m downstream Yanco weir gauge).
- Flooding overtops bank at Baulches farm (Yanco weir rd) at 6.70 m downstream Yanco weir gauge).
- Euroley Bridge Road cut at 7.39 m gauge height at Narrandera gauge.
- Flooding on Murrays farm 1725 at 7.42 m gauge height at Narrandera gauge.
- Flooding Yanco Brickworks at 8.03 m gauge height at Narrandera gauge.
- Flooding over road near aerodrome at 8.07 m gauge height at Narrandera gauge.
- Water crosses YAHS school entrance Rd at 8.20 m gauge height at Narrandera gauge.
- Consider evacuation of YAHS at 8.99 m gauge height at Narrandera gauge.

A formal warning system is in place for Murrumbidgee River flooding. According to Murrumbidgee Irrigation Emergency Response Guide (Flood Management Plan), MI receives flood warnings 5 to 7 days in advance prior to River flooding. A flood will occur at levels in excess of 8.5 meters at the Narrandera gauge for the Main Canal and drainage outfalls to the river. This scenario is exacerbated when it coincides with heavy rainfall runoff causing flooding into MI's Main Canal.

3.3.5 Duration of Flooding

Longer durations of flood inundation result in greater potential impacts in terms of damages and disruptions to the community. The 2012 event was evident of this scenario, with widespread and lengthy flood inundation experienced across the entire LGA for days following the rainfall event (in particular Landsdowne Estate). In general, due to the flat topographic characteristics of the Leeton Shire and limited drainage capacity, major flood events are likely to cause longer durations of inundation across the shire.

In the event of a long duration rainfall event, ponding throughout the Leeton and Yanco townships may occur for prolonged periods of time (>24 hours). This can be attributed to the flat open channel grades and significant storage available within farms/properties.

3.3.6 Depth and Velocity of Floodwaters

Flood waters through Leeton and Yanco travel very slowly (typically less than 0.3 m/s) with flood depths typically less than 0.5 m outside of drainage channels.

3.3.7 Isolation and Evacuation

No properties are predicted to become isolated during floods in Leeton and Yanco. Evacuation of properties predicted to be inundated may be possible during a flood (i.e. low flood hazard of flooded road), however no systems are in place to guarantee safe passage along roads (i.e. cannot see roads through floodwater, cannot guarantee roads haven't been washed away). Care should be given to driving through floodwaters.

Assessment of flood depth over roads which indicated that roads were generally considered to be trafficable (<300 mm) and as such isolation and evacuation is not considered to be an issue.

Figure 3.6 presents potential flood evacuation routes which have been identified based on low flood hazard or flood free roads.

3.3.8 Land Development Risks

Areas identified as residential land use in the Leeton Local Environmental Plan (LEP) were investigated to assess the impacts of potential development (i.e. land filling which removes flood storage). As shown in Figure 3-7, hydraulic analysis showed that the majority of the 'future residential areas' were observed to impact existing developments.

An area along Petersham Road (north of Fivebough Road) may have the potential to develop as this is outside of the flood storage zone. However, potential developments are to ensure free draining of stormwater runoff and ensure drainage connectivity to a downstream channel.

Should development within the flood storage zone be proposed, land development controls should be implemented to ensure no impacts external to the site. Land development controls may include:

- Minimise risk to life and damage to property by controlling development on flood prone land.
- Ensure the impacts of the full range of flood sizes up to and including the PMF are considered when assessing development on flood prone land.
- Ensure that development does not have a significant impact on flood behaviour, people's safety, surrounding properties and structures, and the natural environment.
- Ensure that the effects of climate change are considered when assessing development on flood prone land.
- Ensure that development on the floodplain is consistent with the NSW Flood Prone Land Policy and NSW Floodplain Development Manual.

- Ensure that developers and the community are conscious of the potential flood hazard and consequent risk associated with the use and development of land within the floodplain.
- Ensure that all land uses and essential services are appropriately sited and designed in recognition of all potential floods.
- Ensure that development on flood prone land does not place an unacceptable financial burden on landowners or the community.
- Ensure the type, scale and location of development on a site is responsive to the nature and risk of flood hazard present.

Further discussion regarding consideration of an appropriate freeboard for Leeton Shire is provided in Appendix C.

Development control objectives and measures for Council to consider are outlined in Appendix D.

N
W
E
S

Legend

Evacuation Routes

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Leeton Shire Floodplain Risk Management Plan

Figure 3.6

Evacuation Routes

Job Number: M9500_003
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N
W
E
S

Flood Impact

- <-0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- 0.30 to 0.50
- >0.50

Legend

- Cadastre
- Potential Development Area
- Not Potential Development Area

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Leeton Shire Floodplain Risk Management Plan

Figure 3.7

Potential Areas for Filling and Associated 1% AEP Flood Impacts

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Drawn: KJM
Date: 22 MAY 2018

3.4 Identification of Flood Risk Management Measures

Managing flood risk is important to improve community resilience to flooding and limiting flood risk growth (from increased floodplain development, and changes to climate and floodplain topography). Achieving effective management involves encouraging or promoting the:

- Management of existing, future and residual flood risk for local communities using the range of treatments available.
- Engagement with, and active participation of, the local community in managing the flood threat they face.
- Inclusion of flood risk management outcomes in policies, planning instruments and forward plans.
- Strategic planning and use of floodplains as valuable and sustainable resources capable of multiple uses of benefit to the community. These uses should be compatible with the flood function and flood hazard and aim to limit the impacts of flooding on damage to property and infrastructure, and the wellbeing, health and safety of the future floodplain community. Strategic planning should consider long-term climate, cumulative land-use and demographic changes that are expected to influence risk.
- Identification, assessment and implementation of feasible, practical and effective options to treat intolerable risks to the existing community, considering their social, environmental and economic benefits and costs, and their sustainability.
- Sustainable emergency management practices that consider long-term climate variation, and cumulative land-use and demographic changes.
- Management of flood risk to infrastructure and the design of new infrastructure to limit its impacts on flood behaviour; key infrastructure for emergency response and recovery needs to be fit-for-purpose when required.
- Continued aid to the community in recovering from the impacts of floods.

Flood risk management opportunities can be broadly separated into three (3) categories; property modification measures, response modification measures and flood behaviour modification measures. Table 3-2 summarises potential flood risk management opportunities under each of the three categories whilst Table 3-3, Table 3-4 and Figure 3-8 summarise the applicability of each opportunity in relation to property medication measures, response modification measures and flood behaviour modification measures respectively. It is noted that the focus of flood risk management is on localised flooding within Leeton Shire and therefore does not consider mitigation of flooding impacts from the Murrumbidgee River.

Option type	Existing developed areas			Future development areas		
	Existing risk		Residual risk	Future risk		Residual risk
	Safety	Damage	Safety	Safety	Damage	Safety
Measures to modify property						
Zoning and development control				High	High	Low[a]
Voluntary purchase	High	High	High			
Voluntary house raising	Low	Medium	Negative[c]			
Flood proofing of buildings	Low	Low				
Access during flood events	High	Low[e]	High	High	Low[e]	High
Measures to modify response						
Community flood awareness & readiness[b,d]	Low[b]	Low[b]	Low[b]	Low[b]	Low[b]	Low[b]
Flood predictions and warnings[a]	Medium[b]	Low[b]	Medium[b]	Medium[b]	Low[b]	Medium[b]
Emergency response planning for floods[b]	Medium[b]	Low[e]	High[b]	Medium[b]	Low[e]	High[b]
Measures to modify flood behaviour						
Levees	High	High	Negative[c]	High	High	Negative[c]
Detention/retarding basins	Medium	Medium	Negative[c]	Medium	Medium	Negative[c]
Flood mitigation dams	Medium	Medium		Medium	Medium	
Bypass flow conveyance	Medium	Medium		Medium	Medium	
Channel improvements	Medium	Medium		Medium	Medium	
Enhance environment						

a. Depends upon consideration of emergency response management issues in strategic planning.

b. These options all rely on each other to be effective.

c. Measures such as house raising and levees reduce risk to property but are known to have an adverse impact on perceived risk to life because people incorrectly assume that property protection measures have eliminated flood risk.

d. There is little qualitative evidence showing community awareness and education campaigns are effective to reliably and perpetually reduce risk.

e. Have no impact on structural damage. However, in some cases, where response times and conditions allow may permit some reduction in contents damage.

Notes: Existing risk: events up to the design flood for mitigation works or the main defined flood event (DFE) for land-use planning

Residual risk: events rarer than the design flood for mitigation works or the main DFE for land-use planning.

Future risk: events up to the design flood for mitigation works or the main DFE for land-use planning.

The ratings in this table are a guide only as the effectiveness will vary dependent upon the individual situation and should be assessed accordingly.

Blank squares may be not applicable or options have nil affect.

High/medium/low relate to positive effects.

Negative relates to potential adverse impacts.

Figure 3-8 Summary of Potential Flood Risk Mitigation Measures (Source: AIDR, 2013)

3.5 Overview of Potential Flood Risk Management Measures

A number of potential flood risk management measures were identified and recommendations for further consideration or implementation were made where the measures were deemed to be applicable.

Table 3-2 Property Modification Measures

Measure	Pros	Cons	Applicability to Leeton Shire	Recommendation
Zoning & Development Control	• Very effective in managing future flood risk. • Relatively low cost to Council. • Effective planning controls may allow appropriate development in constrained areas.	• Little impact on existing flood risk. • Heavily reliant on suitable planning and development assessment.	Flood risk to future development within the Leeton LGA is managed through the Flood Planning Area Overlay in the Leeton LEP as well as the Development Control Plan (DCP). The hydraulic modelling outputs from the Leeton Shire Flood Study (Engeny, 2015) was being used by LSC to identify and manage risks associated with future development and land use zoning.	It is recommended that development controls are identified and implemented through the DCP to properties located within the Flood Planning Area Overlay.
Voluntary Purchase	• Completely removes population from the flood risk. • Effective in managing current and future flood risk.	• Can be a costly mitigation measure and sets a precedence for other flood affected properties. • Voluntary purchase program can take significant time to implement.	Landsdowne Estate and other houses around Leeton were inundated in 2012 and whilst a number of houses are predicted to experience flooding in frequent events (i.e. 50% AEP & 20% AEP events), the cost to implement this measure is unlikely to be feasible. As such, voluntary purchase is not considered to be a viable mitigation measure and alternative measures should be considered.	Not recommended

Measure	Pros	Cons	Applicability to Leeton Shire	Recommendation
Voluntary House Raising	• Can be relatively low cost. • Improves flood immunity to houses and therefore reduces flood damage. • Can improve property value.	• Only mitigates risk to population up to a certain flood level. • Generally, more effective in reducing flood damages rather than overall risk. • Can increase residual risk due to perceived increase in safety. • Restricted to certain construction types, i.e. stumps.	Whilst floor level survey was not available for all houses, a large number of houses (including those in Landsdowne Estate) are believed to be slab on ground structures. Voluntary house raising is generally considered to be a private matter that property owners would likely need to consider and fund privately.	Not recommended. LSC could provide relevant information to assist interested property owners.
Flood Proofing of Buildings	• Relatively low cost. • Improves flood resilience.	• Only effective in reducing flood damages rather than overall risk.	Flood proofing of buildings is considered to be a private matter that property owners would likely need to consider and fund privately.	Not recommended. LSC could provide relevant information to assist interested property owners.
Access During Flood Events	• Allows better flood event response. • Generally, only requires works within local/state government areas. • Reduces flood risk to roads. • Potentially reduces recovery cost post-event in terms of road repair.	• Upgrading of infrastructure can be costly. • Does not directly reduce flood hazard to properties. • Can increase flood hazard and risk to existing properties as majority of properties are lower than the main access roads.	No properties were predicted to become isolated. Access roads around Leeton, Yanco and the greater Shire in general were predicted to have low hazard due to the low velocities and relatively low flood depths. Additionally, raising access roads around the Shire could result in increased flood risk and hazard to existing properties.	Not recommended.

Table 3-3 Assessment of Response Modification Measures

Measure	Pros	Cons	Applicability to Leeton Shire	Recommendation
Community Flood Awareness & Readiness	• Relatively low cost. • Encourages 'ownership' of risk in the community. • Increases flood resilience of the community.	• Does not necessarily reduce flood hazard. • Reliant on community buy-in and ownership.	Increasing community flood awareness and readiness is considered applicable to all Leeton Shire residents however specific flood readiness or response planning should be focused on specific properties vulnerable to flood impacts. General flood information could be placed on the council website, NSW SES website, social media sites and relevant notice boards.	It is recommended to develop a Community Flood Awareness & Readiness Program in conjunction with the NSW SES, which not only provides general flood risk management information to the wider community but focuses on providing information to assist protect properties considered vulnerable to flood impacts. The program should also specifically focus on increasing awareness of the flood impacts associated with land filling.
Flood Predications & Warnings	• Allows for activation of flood response. • Can reduce flood damage costs.	• Requires a reliable and maintained ICT system and therefore can be costly. • Reliant on accurate rainfall forecasting. • Reliant on waterway system with gauging network. • Does not necessarily reduce flood hazard.	Severe rainfall warning is considered applicable to Leeton Shire to the overland flow nature of flooding however traditional flood predictions and warning are not considered applicable to Leeton Shire due to the lack of a waterway system.	Flood predictions and warnings would need to be based on forecast and recorded rainfall and therefore it is recommended that LSC investigate the implementation of a flood prediction and warning system in conjunction with the Australian Bureau of Meteorology (BOM) and the NSW SES.

Measure	Pros	Cons	Applicability to Leeton Shire	Recommendation
Emergency Response Planning for Floods	• Relatively low cost. • Can enhance community engagement.	• Does not necessarily reduce flood hazard. • Reliant on effective planning and implementation.	LSC is reliant on NSW SES guidance during floods. A Flood Emergency Response Plan would provide a benefit to high risk residents and the community in general and allow for response planning including property protection and evacuation (if required).	That the NSW SES develop an Flood Emergency Response Plan which may include a list of flood prone properties that need to be protected (i.e. sand bagging) and or evacuated in a flood event. Vulnerable residents at risk of flooding should also be identified and included in the plan so that assistance can be provided. It is recommended that the NSW SES works with the community and LSC to develop a Flood Emergency Response Plan.

Table 3-4 Assessment of Flood Behaviour Modification Measures

Measure	Pros	Cons	Applicability to Leeton Shire	Recommendation
Levees	• Completely mitigates flood risk up to the design level. • Could provide developable land inside the levee which	• High construction costs (as well as flood assessment and design costs). • Significant ongoing operation and maintenance costs. • By nature, will increase flood risk outside the levee.	Currently the MI main irrigation canal acts as a flood protection levee. No locations were identified as ideal for flood levees, without causing adverse impacts.	Not recommended.

Measure	Pros	Cons	Applicability to Leeton Shire	Recommendation
	would otherwise be flood prone.	• Can increase residual flood risk due to perception. • Often challenges in managing local drainage inside the levee.		
Detention/Retarding Basins	• Can mitigate flood risk up to the design flowrate/volume.	• Can potentially lead to negative impacts through catchment timing affects. • More suited to smaller creek systems. • High construction costs, particularly for larger waterways. • Potential classification as a referable structure with associated regulatory requirements.	It is not considered that detention or retarding basins are relevant due to the widespread extent of inundation and significant flood storage volumes already present outside of the drainage channels.	Not recommended, however increasing the available storage within McCaughey Park should be further investigated.
Flood Mitigation Dams	• Can mitigate flood risk up to the design flowrate/volume. • Can provided integrated flood mitigation/water supply solutions.	• Significant construction costs. • Significant ongoing operation and maintenance costs. • Potential environmental impacts due to changed flow regimes. • Potential classification as a referable structure with associated regulatory requirements.	The McCaughey Park pond and Fivebough Wetlands currently provide some flood mitigation storage benefits, however unlikely to be applicable due to the widespread extent of inundation and the significant storage volume that would be required to provide flood mitigation.	It is recommended that further investigation be undertaken on increasing flood storage within McCaughey Park.
Bypass Flow Conveyance	• Can reduce flood risk up to the design standard.	• Potential significant construction costs. • Potential environmental impacts due to changed flow regimes. • May require continual maintenance due to changing geomorphology.	One opportunity was identified for upstream bypass flow conveyance. The sub drain under the MI main irrigation canal (Corbie Hill Rd) could be blocked to	Bypass flow conveyance not recommended as MI unlikely to accept increased water levels on the upstream side of the main

Measure	Pros	Cons	Applicability to Leeton Shire	Recommendation
			convey water to the sub drain to the north (Grevillea Rd).	irrigation canal (i.e. increased structure failure risk).
Channel Improvements	• Can reduce flood risk due to flood level reduction.	• Likely to need approval from State regulatory agencies. • Can result in flood impacts beyond the area of channel improvement works (usually downstream).	Channel widening from Corbie Hill Rd to Fivebough Wetlands is likely to improve conveyance and reduce flood risk to Landsdowne Estate.	Channel improvements are recommended for further investigation as there may be opportunities for drainage improvement. It is recommended that a hydraulic assessment be undertaken for channel improvement measures.

3.6 Potential Flood Behaviour Modification Measures

As part of the study, a number of flooding hotspot areas have been identified in the Leeton and Yanco township areas. The location, nature and source of flooding issues for the major hotspots in the Leeton and Yanco townships are presented in Appendix A. Appendix A also outlines the comprehensive list of engineering options considered for each hotspot area. A number of the options listed were eliminated for reasons presented in the table. A summary of potential flood behaviour modification measures or engineering options that were considered and further investigated are provided in the following section.

The majority of flooding issues experienced by properties were identified to be local stormwater drainage issues associated with properties being lower than the roads or drainage channels. These local stormwater drainage issues were excluded from the hydraulic assessment and were not considered and addressed in the Floodplain Risk Management Plan.

3.6.1 Potential Flood Behaviour Modification Measures for Landsdowne Estate

The following flood behaviour modification measures were considered in the identification of measures with potential to provide protection to properties within Landsdowne Estate:

- Mitigation Option 1: Bunding on Lot 21 on DP/SP 1107447 to prevent water entering Landsdowne Estate from the south. This option was not considered to be viable due to the adverse impacts that would likely be caused to properties south including Lot 21 on DP/SP 1107447. As such, this option was not assessed any further.

- Mitigation Option 2: Increasing pump capacity (from 15 L/s to 2,000 L/s) within detention basin, increase downstream drainage channel grade (approximate average) from 0.03% to 0.08% as shown in Table 3-5 and upgrade Almond Road and Grevillea Road culverts to 4/900 mm RCPs (3 additional pipes) to increase discharge from Landsdowne Estate. This option was considered potentially viable and therefore warranted a hydraulic assessment.

- Mitigation Option 3: Increasing pump capacity (from 15 L/s to 2,000 L/s) within detention basin, increase downstream drainage channel grade (approximate average) from 0.03% to 0.08% as shown in Table 3-6 and increase channel base width to 10 m and upgrade Almond Road and Grevillea Road culverts to 4/900 mm RCPs (3 additional pipes) to increase discharge from Landsdowne Estate. Additional easement width would be required from Corbie Hill Road to Fivebough Road. This option was considered potentially viable and therefore warranted a hydraulic assessment.

- Mitigation Option 4: In order to limit the runoff volume at Landsdowne Estate, this option would involve removal of the sub drain under main canal near Corbie Hill Road and regrade the drainage channel to redirect flow in a northerly direction to the sub drain near Grevillia Road. Given the approvals that would be required from Murrumbidgee

Irrigation and affected property owners, it is advised that discussions between relevant stakeholders (i.e. LSC, MI and affected property owners) be held to determine whether this option could be achieved and whether further investigated is warranted. As such, a hydraulic assessment has not been undertaken however it is recommended that this is undertaken depending on the outcome from stakeholder discussions.

Table 3-5 Proposed Change in Channel Invert Level (Mitigation Options 2 & 3)

Location	Channel Invert Level Upstream of Road (m AHD)		Channel Invert Level Downstream of Road (m AHD)	
	Existing Scenario	Mitigation Scenario	Existing Scenario	Mitigation Scenario
Almond Road	134.8	134.69	134.7	134.65
Grevillia Road	134.6	133.87	134.6	133.82
Fivebough Road	134.5	133.30	134.3	133.25

Table 3-6 Easement Details from Corbie Hill Road to Fivebough Road (Mitigation Option 3)

Location	Existing Easement Width (Approx.) (m)	Required Channel Width (Approx.) (m)
Corbie Hill Rd – Almond Rd	10	14
Adjacent Almond Road	12	14
Almond Rd – Grevillia Rd	19	17.8
Adjacent Grevillia Rd	12	18
Grevillia Rd – Fivebough Rd	14	19.2
Fivebough Rd - Channel	14	19.2

Of these options, it was considered that Mitigation Options 2 and 3 warranted hydraulic assessment as it was thought that a bund upstream of Landsdowne Estate (Options 1) would likely result in unacceptable impacts to properties to the south including Lot 21 on DP/SP 1107447 and the redirection of flow upstream of the Main Canal (Option 4) required consultation with relevant stakeholder before assessing the viability of this option.

The hydraulic assessment was undertaken using the Urban Models and results for Mitigation Options 2 and 3 are outlined in Section 3.7.

3.6.2 Potential Flood Behaviour Modification Measures for Yanco

Based on the flood model results and house floor level survey supplied by LSC, two houses (26 and 28 Hebden Street) were predicted to potentially experience above floor flooding in the 1% AEP event. A number of additional properties surrounding McCaughey Park are at risk from flooding in large to extreme events. As such, the following flood behaviour modification measures were considered in the identification of potential measures to provide protection to properties at risk within Yanco:

- Mitigation Option 1: Increase pipe capacity under Binya Street to decrease flooding on private property west of McCaughey Bicentennial Park. During the site inspection the existing 450 mm RCP was observed to be blocked due to sediment build-up and therefore an increase in pipe capacity was considered to reduce the extent of inundation within the property. Given that the inundation was related to a single property and that the flood depth was largely influenced by the water level within the pond, it was considered that this option did not warrant further investigation.

- Mitigation Option 2: Reduce flooding in eastern Yanco by increasing the capacity of culverts between Short Street and Irrigation Way (along Davis Road) from various 450 to 750 mm RCPs to 3/675 mm RCPs. The red lines in Figure 3-11 show the culvert upgrade locations. This option was considered potentially viable and therefore warranted a hydraulic assessment.

- Mitigation Option 3: Reduce starting water level in the pond by 0.5 m (135.6 m AHD) and increase pump capacity to 2 m^3/s. The pond is at a depression in the local catchment and therefore the majority of the catchment drains to the pond however there is limited existing pump and channel capacity to discharge flow and manage the volume and levels within the pond before impacting surrounding properties in moderate to major storm events. This option was considered potentially viable and therefore warranted a hydraulic assessment.

- Mitigation Option 4: Increase pond storage volume and 0.5 m lowered pond starting water level (135.6 m AHD) with existing pump capacity. The additional storage was gained from approximately 1 hectare of open space land immediately south of the pond between the drainage channel and properties on Binya Street. The additional storage was based on excavating up to 1.6 m (136.4 m AHD base level) to determine whether additional storage would provide a tangible benefit. This option was considered potentially viable and therefore warranted a hydraulic assessment.

- Mitigation Option 5: Increase capacity of drainage channel from Hebden Street to Racecourse Road. This was investigated in terms of channel grade and extent of works including potential upgrade to existing road crossing culverts including railway culverts downstream of Racecourse Road. The preliminary investigation determined that due to the lack of grade, extent of downstream works and potential downstream impacts, the option was not considered to warrant further assessment at this stage.

Of these options, it was considered that Mitigation Options 2, 3 and 4 warranted further hydraulic assessment. The hydraulic assessment was undertaken using the Urban Models and results for Mitigation Options 2, 3 and 4 are outlined in Section 3.7.

3.7 Hydraulic Assessment of Flood Behaviour Modification Measures

3.7.1 Hydraulic Assessment of Landsdowne Estate Mitigation Option 2: Pump Upgrade, Channel Regrade and Culvert Upgrade

The existing case TUFLOW hydraulic model was modified to increase the pump capacity to 2 m^3/s, regrade the drainage channel between Almond Road and Fivebough Road and upgrade the Almond Road and Grevillea Road culverts to 4/900 mm RCPs.

The model was simulated for the 1% AEP events. Model results showed that the assessed mitigation option provided an average flood depth reduction of approximately 190 mm at Landsdowne Estate and 80 mm within the properties/farms east of the channel between Almond Road and Fivebough Road in the 1% AEP. As expected, an increase in flood depth was observed downstream of Grevillea Road due to the increased culvert and channel conveyance, however these impacts are fairly constrained to the existing channels. House floor levels within Landsdowne Estate were predicted to have flood immunity of the 1% AEP, depending on floor level, with three predicted to be protected in the 1% AEP event, that were not previously protected. It should be noted that the accuracy of these predictions is limited as they are based on hydraulic modelling results and associated assumptions. The option also resulted in a reasonable reduction in the extent of inundation within properties/farms between Landsdowne Estate and Grevillia Road in the 1% AEP events. A reduction in flood depth of approximately 16 mm was observed at Almond Road in the 1% AEP flood event. Almond Road is predicted to be trafficable in the 1% AEP event.

A summary of the mitigation outcomes for Option 2 to houses within and surrounding Landsdowne Estate that were predicted to experience above floor inundation is provided in Table 3-7. In the 1% AEP event, Option 2 is shown to provide protection to all 3 houses predicted to experience above floor inundation in the existing scenario and is therefore the preferred option for the Landsdowne Estate area. Houses considered to have the greatest risk of above floor flooding were surveyed, however floor level survey was not captured for all houses within this specific area or Leeton Shire. As such, therefore there may be additional houses that experience above floor inundation that have not been identified. It should also be noted that the reported results are based on flood model results and supplied floor level survey.

The flood impact for the 1% AEP is shown in Figure 3-9.

Table 3-7 House Flood Impact Summary – Landsdowne Estate

Property Address	Floor Level (mAHD)	Existing 1% AEP Flood Level (mAHD) (Flood Immunity)	Existing 1% AEP Depth of Inundation above Floor (mm)	Mitigation Result
20 Lansdowne Road	136.34	136.36 (10% AEP Immunity)	22 mm	House Protected
4 Lansdowne Road	136.32	136.36 (10% AEP Immunity)	34 mm	House Protected
130 Almond Road	136.35	136.36 (10% AEP Immunity)	10 mm	House Protected

N
W
E
S

Re-grade channel. Base width 1m

Re-grade channel. Base width 1m

Upgrade culvert to 4 / 900 RCPs

Re-grade channel. Base width 1m

Upgrade culvert to 4 / 900 RCPs

Pump to 2000 L/s

Re-grade channel. Base width 1m

Flood Impact (m)

- <0.50
- -0.50 to -0.25
- -0.25 to -0.10
- -0.10 to -0.05
- -0.05 to -0.025
- -0.025 to -0.01
- -0.01 to 0.01
- 0.01 to 0.025
- 0.025 to 0.05
- 0.05 to 0.10
- 0.10 to 0.25
- 0.25 to 0.50
- > 0.50

Legend

- Cadastre
- Pump Upgrade
- Channel Upgrade
- Culvert Upgrade

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0 0.2 0.4
Scale in kilometres (1:10,000 @ A3)

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994. (GDA94)
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

Leeton Shire Floodplain Risk Management Plan

Figure 3.9

Landsdowne Estate
Mitigation Option 2 - Flood Impacts

Job Number: M9500_003
Revision: 0
Drawn: KJM
Date: 22 MAY 2018

3.7.2 Hydraulic Assessment of Landsdowne Estate Mitigation Option 3: Pump Upgrade, Channel Regrade and Widening, and Culvert Upgrade

The existing case TUFLOW hydraulic model was modified to increase the pump capacity to 2 m^3/s, regrade and widen (to 10m) the drainage channel between Almond Road and Fivebough Road to approximately 0.08% and upgrade the Almond Road and Grevillea Road culverts to 4/900 mm RCPs.

Hydraulic model results in approximately 270 mm reduction in flood depth in the 1% AEP event at Landsdowne Estate. A significant reduction to flood extent for properties in Landsdowne in the 1% AEP flood event was also observed. House floor levels within Landsdowne Estate were predicted to have flood immunity of the 1% AEP, depending on floor level, with three houses predicted to be protected in the 1% AEP event, that were not previously protected. It should be noted that the accuracy of these prediction are limited as they are based on hydraulic modelling results and associated assumptions.

Model results also showed a significant reduction in the extent of inundation to land downstream of Landsdowne Estate with properties west of the drainage channel (downstream of Almond Road) predicted to experience a flood depth reduction of 260 mm. No changes to property flood depths were predicted downstream of Grevillia Road. A reduction in of flood depth of approximately 80 mm was observed at Almond Road in the 1% AEP flood event. Almond Road is predicted to be trafficable in the 1% AEP event.

A summary of the mitigation outcomes for Option 3 to houses within and surrounding Landsdowne Estate that were predicted to experience above floor inundation is provided in Table 3-8. In the 1% AEP event, Option 3 is shown to provide protection to all 3 houses predicted to experience above floor inundation in the existing scenario. Given that this option is considered to provide the same level of immunity as Option 2, but will require greater excavation and easement acquirement, it is not the recommended mitigation option for the Lansdowne Estate. Houses considered to have the greatest risk of above floor flooding were surveyed, however floor level survey was not captured for all houses within this specific area or Leeton Shire. As such, therefore there may be additional houses that experience above floor inundation that have not been identified. It should also be noted that the reported results are based on flood model results and supplied floor level survey.

Table 3-8 House Flood Impact Summary

Property Address	Floor Level (mAHD)	Existing 1% AEP Flood Level (mAHD) (Flood Immunity)	Existing 1% AEP Depth of Inundation above Floor (mm)	Mitigation Result
20 Lansdowne Road	136.34	136.36 (10% AEP Immunity)	22 mm	House Protected
4 Lansdowne Road	136.32	136.36 (10% AEP Immunity)	34 mm	House Protected
130 Almond Road	136.35	136.36 (10% AEP Immunity)	10 mm	House Protected

The flood impact for the 1% AEP is shown in Figure 3-10.

N
W
E
S

Re-grade channel. Base width 10m

Upgrade culvert to 4 / 900 RCPs

Re-grade channel. Base width 10m

Upgrade culvert to 4 / 900 RCPs

Pump to 2000 L/s

Re-grade channel. Base width 10m

Re-grade channel. Base width 1m

Flood Impact (m)

- <0.50
- -0.50 to -0.25
- -0.25 to -0.10
- -0.10 to -0.05
- -0.05 to -0.025
- -0.025 to -0.01
- -0.01 to 0.01
- 0.01 to 0.025
- 0.025 to 0.05
- 0.05 to 0.10
- 0.10 to 0.25
- 0.25 to 0.50
- > 0.50

Legend

- Cadastre
- Pump Upgrade
- Channel Upgrade
- Culvert Upgrade

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0 0.2 0.4
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Leeton Shire Floodplain Risk Management Plan

Figure 3.10

Landsdowne Estate
Mitigation Option 3 - Flood Impacts

Job Number: M9500_003
Revision: 0
Drawn: KJM
Date: 22 MAY 2018

3.7.3 Hydraulic Assessment of Yanco Mitigation Option 2: Culvert Upgrade between Short Street and Irrigation Way (east Yanco)

Existing hydraulic modelling results indicated flooding of existing houses in events greater than the 10% AEP. Stormwater also ponds in private property in the east Yanco region as there is commonly a bund between property boundaries and drainage channels and supply channels which restricts property drainage.

The hydraulic assessment of the culvert upgrades between Short Street and Irrigation Way showed minor reductions (less than 100 mm) in flood depth within the drainage channels upstream of Irrigation Way in the 50% AEP event. Reductions of up to 30 mm were observed within properties either side of Davis Road in the 10% and 1% AEP events. As expected, a minor increase (less than 30 mm) in flood depth was observed in the drainage channel downstream of Irrigation Way in the 50% AEP event. Typically flood depth increases of 30-60 mm were observed within the channels and properties downstream of Irrigation Way to McQuillan Road in the 10% and 1% AEP events. In the 10% and 1% AEP events, flood depth increases of 10-30 mm were observed within the large basin downstream of the Golf Club Estate due to the minor increased flows and flood levels in the drainage channel at Racecourse Road. Stormwater generally overtops the drainage channel and flows east to the basin.

Due to the extent of works and associated costs to upgrade the existing culverts as well as the potential downstream impacts, this option was not considered viable however further investigation could be undertaken should LSC seek to mitigate flood impacts within the east Yanco region.

The flood impact for the 1% AEP is shown in Figure 3-11.

N
W
E
S

Upgrade culvert to 3 / 675 RCPs
Upgrade culvert to 3 / 675 RCPs
Upgrade culvert to 3 / 675 RCPs
Upgrade culvert to 3 / 675 RCPs
Upgrade culvert to 3 / 675 RCPs

Flood Impact (m)
- <0.50
- -0.50 to -0.30
- -0.30 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- 0.30 to 0.50
- > 0.50

Legend
- Cadastre
- Culvert Upgrade

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0 0.7 1.4
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Grid: Map Grid of Australia, Zone 55

Leeton Shire Floodplain Risk Management Plan

Figure 3.11

Yanco
Mitigation Option 2 - Flood Impacts

Job Number: M9500_003
Revision: 0
Drawn: KJM
Date: 22 MAY 2018

3.7.4 Hydraulic Assessment of Yanco Mitigation Option 3: Pond Water Level Reduction and Pump Capacity Increase

Existing hydraulic modelling results indicated that properties to the south of the pond start to experience flooding into the back half of the properties in the 10% AEP event. The intent of this option was to lower the water level of pond pump by 0.5 m and increase the pump capacity to 2 m^3/s to manage the water level in the pond during a flood event. The modelling results showed that the pump capacity was too high as the downstream drainage channel did not have capacity for the increased flow rate and therefore properties on northern side of pond were shown to be impacted.

An adjustment was then made where a second option was assessed utilising the existing pump capacity and lowering the starting water level in the pond by 0.5m, however this only provided a flood level reduction of approximately 100 mm at the pond. This option did not provide protection to houses located at 26 and 28 Hebden Street in the 1% AEP event and was therefore also considered ineffective.

The flood impact for the 1% AEP is shown in Figure 3-12.

N
W
E
S

Pump to 2000 L/s plus reduction in pond starting level

Flood Impact (m)
- <0.50
- -0.50 to -0.30
- -0.30 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- 0.30 to 0.50
- > 0.50

Legend
- Cadastre
- Pump upgrade

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Leeton Shire Floodplain Risk Management Plan

Figure 3.12

Yanco
Mitigation Option 3 - Flood Impacts

Job Number: M9500_003
Revision: 0
Drawn: KJM
Date: 22 MAY 2018

3.7.5 Hydraulic Assessment of Yanco Mitigation Option 4: Pond Water Level Reduction and Additional Pond Storage

Hydraulic modelling of the lowered pond water level and additional storage showed a reduction in maximum pond level of approximately 175 mm in the 50 % AEP event and approximately 140 mm in the 10% and 1% AEP events. The property west of Binya Street was observed to experience a 140 mm flood depth reduction in the 1% AEP event and the drainage channel on the northern side of Hebden Street experienced a reduction of approximately 70 mm in the 1% AEP event. No change to depths were observed in the channels downstream of McCaughey Park to Jackson Road for all events. As shown in Table 3-9, this option was predicted to provide at least 1% AEP protection to houses located at 26 and 28 Hebden Street and is therefore the preferred option for the Yanco area.

Houses considered to have the greatest risk of above floor flooding were surveyed, however floor level survey was not captured for all houses within this specific area or throughout Leeton Shire. As such, therefore there may be additional houses that experience above floor inundation that have not been identified. It should also be noted that the reported results are based on flood model results and supplied floor level survey.

Table 3-9 House Flood Impact Summary – McCaughey Park

Property Address	Floor Level (mAHD)	Existing 1% AEP Flood Level (mAHD)(Flood Immunity)	Existing 1% AEP Depth of Inundation above Floor (mm)	Mitigation Result
28 Hebden Street	137.489	137.51	23 mm	House Protected
26 Hebden Street	137.509	137.51	3 mm	House Protected

Depending on LSC's intended future use of the land considered to provide additional storage, alternative options could be considered should recreational use of the land be preferred over additional pond area. For example, the land could function as a dry storage area which would normally function as an overland flow path and only become inundated once the pond reached maximum capacity, however the duration of inundation following a large flood event should also be considered.

The flood impact for the 1% AEP is shown in Figure 3-13.

N
W
E
S

Increase pond storage volume

Flood Impact (m)
- <0.50
- -0.50 to -0.30
- -0.30 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- 0.30 to 0.50
- > 0.50

Legend
- Cadastre
- Pond Excavation

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Leeton Shire Floodplain Risk Management Plan

Figure 3.13

Yanco
Mitigation Option 4 - Flood Impacts

Job Number: M9500_003
Revision: 0
Drawn: KJM
Date: 22 MAY 2018

3.8 Evaluation of Flood Behaviour Modification Measures

In order to fully evaluate the flood risk mitigation measures identified for Leeton and Yanco, hydraulic modelling and a simplified cost-benefit analysis has been undertaken. The following sections outline these assessments and the evaluation summary of the measures.

3.8.1 Preliminary Cost Estimate

Preliminary construction cost estimates have been undertaken for works associated with the preferred mitigation options. The estimates are for the supply and installation of infrastructure and exclude costs associated with acquiring land or easements. The operational costs for the pump are also excluded.

The construction cost estimates represent indicative budget cost allocations based upon conceptual infrastructure sizing and should be updated as part of the future detailed design of the infrastructure works. Costing assumptions for each mitigation options and infrastructure type are provided in the following sections.

Table 3-10 Landsdowne Estate Mitifation Option: Pump Upgrade, Channel Regrade and Widening, & Culvert Upgrade

Infrastructure Type/Works	Approximate Cost ($)	Assumptions
900 mm RCP	$174,000	Rocla 2017 pricing; 19 m culvert length; total 6 barrels; includes road resurfacing, headwalls, 50% contingency.
Channel Upgrade	$126,000	2 km length; no surface treatment; 9 m top width; 1 m base width; 0.2 m additional depth; 50% contingency.
Pump	$265,000	Flood mitigation pump (2000 L/s) and diesel power pack; Based on supply quote provided by Fluid Engineering Pty Ltd on 29/06/2018. Includes construction and electrical control panel costs.
TOTAL	$585,000	High level indicative costs only.

Table 3-11 Pond Water Level Reduction and Additional Pond Storage

Infrastructure Type/Works	Approximate Cost ($)	Assumptions
Excavation for Pond Storage	$360,000	Excavation Rate: $30/m^3; Excavation volume: 8,000 m^3; 50% contingency.
TOTAL	$360,000	High level indicative costs only, excludes dumping costs.

3.8.2 Simplified Cost Benefit Analysis

Benefits of the mitigation option have been based upon the subsequent protection of buildings, namely residential dwellings, in comparison to the cost of constructing the solution. The evaluation has been represented by the following formula:

$$\frac{Cost\ of\ Construction\ of\ Option\ (\$)}{Number\ of\ Dwellings\ Potentially\ Protected} = \$/Dwelling$$

Table 3-12 Cost benefit Analysis Summary

Mitigation Measure	Estimated Cost	Number of Dwellings Potentially Protected	Evaluation Outcome ($/Dwelling)
Landsdowne Estate Mitigation Option	$585,000	3	$195,000
Pond Water Level Reduction and Additional Pond Storage	$360,000	2	$180,000

3.9 Flood Damage Assessment

The flood damage assessment has been based on a recent floodplain risk management study in regional Queensland (i.e. Toowoomba) where a review of flood damage curves across Queensland and New South Wales was undertaken to determine the most suitable curves for use. The adopted flood damage curves are described in the following sections.

3.9.1 Input Data

The key data input for the flood damage assessment were:

- Building polygons
  - Building polygons and floor survey were key GIS inputs utilised in the flood damage estimate. Polygons covering buildings within the extent of impact due to the proposed mitigation measure were delineated manually.
- Floor levels
  - Where floor survey was available as provided by LSC, these levels were adopted in the assessment. In the absence of floor level survey, the floor level was assumed to be 150 mm above the average ground level in the building location.
- Structure type and footings
  - Structure type (i.e. single storey, multi-storey) and footings (slab versus stumps) were inspected utilising aerial photography and Google Street View.

3.9.2 Residential Flood Damage Curves

The residential flood damages were calculated based upon modified stage-damage curves developed by O2 Engineering for Ipswich City Council in 2011 (O2 Engineering, 2011), hereafter referred to as the Ipswich curves. These curves were developed as it was considered that the commonly used stage damage curves, such as ANUFLOOD, RAM and the NSW OEH Curves (OEH, 2007), tended to significantly under-predict flood damages, particularly at higher depths (Markar and Mirfenderesk, 2010). These existing curves are typically around 20 years old and building materials, costs and methodology has changed significantly over this time.

The Ipswich curves were developed using a range of information, including curves derived by Kellogg Brown and Root (KBR, 2011), rebuilding costs from the 2011 flooding and structural damage estimates. The Ipswich curves break residential damages into three separate categories; External Damage, Contents Damage and Structural Damage. Therefore, damages were calculated separately for each of these three categories.

The Ipswich Curves have been updated for use in the study, with modifications as summarised below:

- Inflate all damage curves using the Consumer Price Index (CPI). This has been done using the ratio of CPI in June 2011 to June 2018 using information provided by the ABS (ABS, 2017).

- Assume that 80% of External Damage occurs at 0.5 m depth of above ground flooding; and assume that 80% of first storey Contents Damage occurs at 1 m depth of above floor flooding, and 80% of second storey Contents Damage to occur at 2.75 m depth of above floor flooding.

- Use of a Post Flood Inflation Factor to account for the cost of material and labour increasing due to higher demand for structural repairs. This is applied as a multiplier to structural damages. A value of 1.0 has been applied based on the values recommended in the NSW OEH (OEH, 2007) residential damage calculator.

- Use of a Regional Cost Variation Factor to account for the different construction costs in different areas. This is applied as a multiplier to structural damages. No specific Leeton value could be found and the closest location (Griffith) has a value of 1.08, which has been adopted in the curve.

Maximum Water Surface Elevation (WSE) rasters for each modelled event were sampled using the building polygons as discussed above. The resulting attribute table was then extracted into an Excel spreadsheet and the WSE within each building polygon was then assigned. These values were then used to calculate the above ground depth and above floor depth. The flooding depths along with the stage damage curves were used to calculate the flood damage for each building for each event.

The flood damages were then amalgamated and the Annual Average Damage (AAD) and Net Present Value (NPV) calculated. The AAD represents the average cost per year of flood

damages over a long time period while the NPV was calculated by projecting the AAD forward 50 years with a discount rate (4%, 7% and 11% per annum were used) to calculate the current value of flood damages.

3.9.2.1. Actual vs Potential Damages

The Ipswich curves are potential damage curves and do not take into account the behaviour of the occupants during a flood. Therefore, the *Stage-damage Curves for Current Flood Risk Management Studies* Memo (O2 Engineering, 2011) recommends using an Actual vs. Potential Damage multiplier. The values for this multiplier have been derived from the RAM calculations and are based on the assumptions that:

- A more experienced community will take more action to limit their external and contents damage (e.g. lifting contents on to tables, moving cars out of the floodplain)
- The more flood warning time that is available, the more action can be undertaken.

Given that there were significant floods in 2012, it was assumed that the community is somewhat experienced. Therefore, an Actual v. Potential Damage multiplier of 0.64, assuming a warning time of at least 6 hours (based on Table 17 in Section 2.4 of the *Stage-damage Curves for Current Flood Risk Management Studies* Memo (O2 Engineering, 2011).

3.9.3 Indirect Damages

O2 Engineering (2011) reported that there has been no recent work to estimate indirect flood damages and recommended the application of 15% of the estimated direct damage. This figure has been adopted in these estimates. Indirect damages allow for additional costs associated with disruptions to any physical or economic activities, including things such as disruption to business and costs associated with alternative transport or accommodation.

3.9.4 Residential Flood Damage Estimate

The total tangible direct and indirect flood damage per AEP associated with residential buildings is summarised in Table 1 and graphically in Figure 3-14 and Figure 3-15. This estimate includes damages associated with external, contents and structural damage. The estimate is dependent on building footprint, residential structure type and depth of flooding. The event damages provided below also include an additional 15% to account for indirect damages. Average Annual Damage (AAD) is used to account for the probabilistic nature of flood damages. It represents the theoretical tangible damage incurred on average each year if a very long period of flood records is considered. It takes into account the value of the damage in each flood and the probability of the flood. The contribution of each event to the AAD is also summarised in Table 1.

Table 3-13 Residential Damage per Annual Exceedance Probability

AEP (1:x)	Leeton – AEP Event Damage ($)	Leeton – Contribution to Average Annual Damage ($)	Yanco – AEP Event Damage ($)	Yanco – Contribution to Average Annual Damage ($)
PMF	$13,342,590	$14,747	$7,840,320	$8,473
500	$1,344,301	$3,285	$596,200	$1,378
200	$845,771	$3,783	$322,565	$1,252
100	$667,307	$5,642	$178,225	$1,248
50	$461,179	$12,320	$71,364	$1,746
20	$360,149	$16,737	$45,037	$2,123
10	$309,340	$15,467	$39,896	$1,995

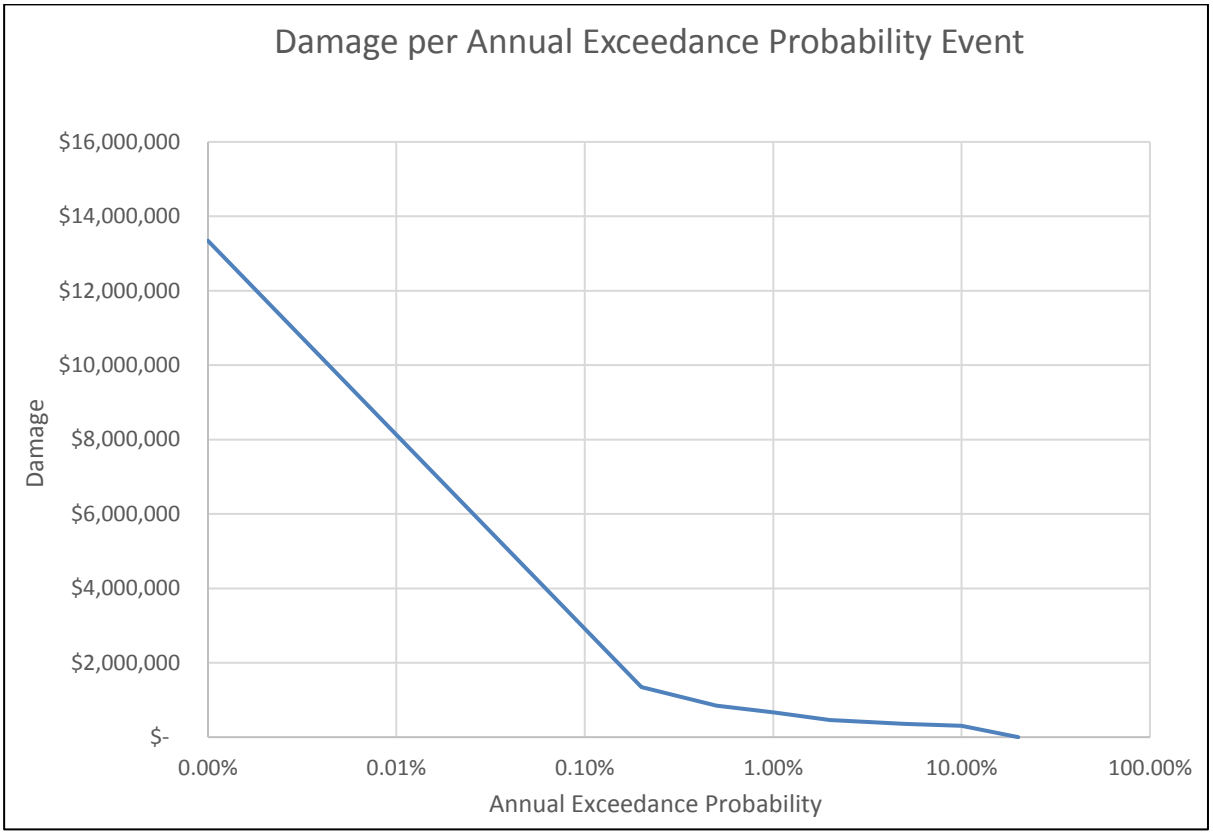

Figure 3-14 Damage vs Annual Exceedance Probability Event - Leeton

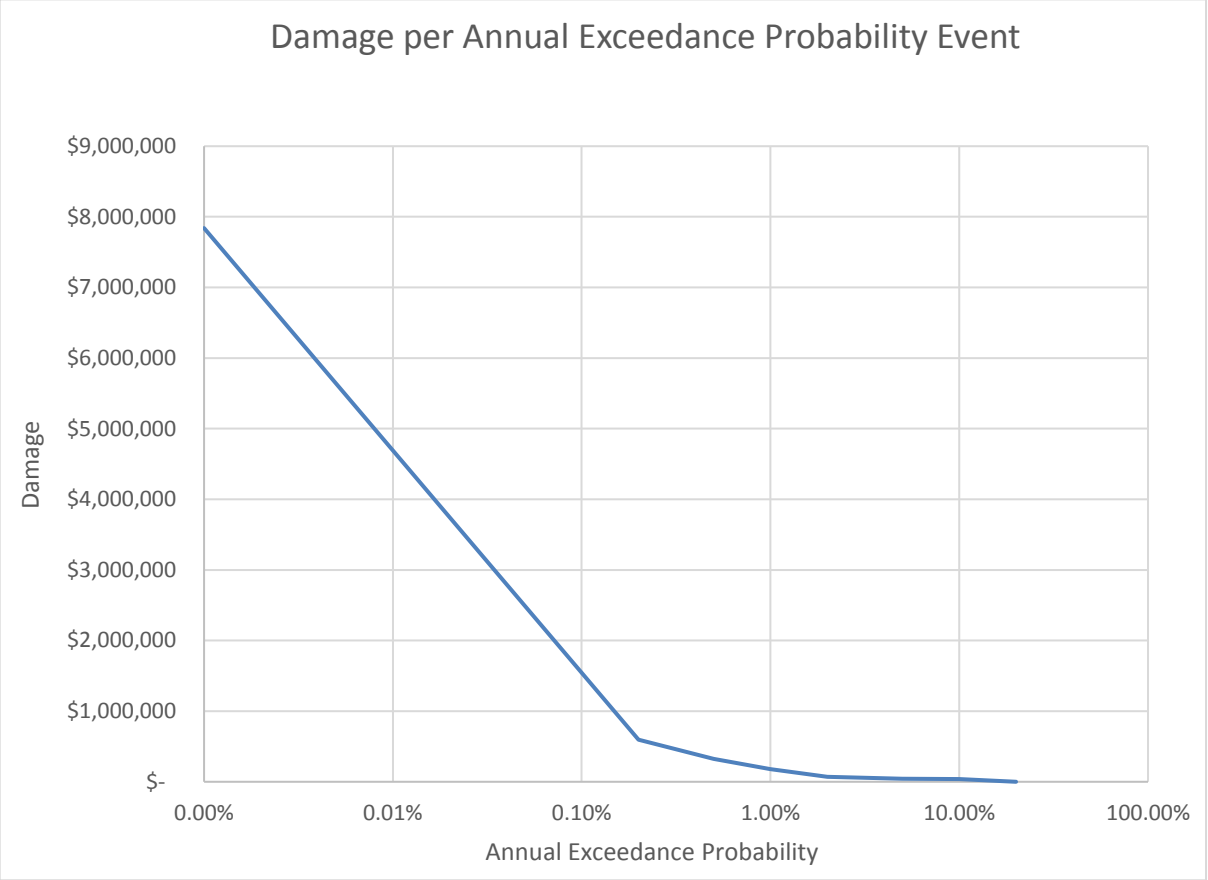

Figure 3-15 Damage vs Annual Exceedance Probability Event - Yanco

3.9.5 Cost-Benefit Analysis of Flood Mitigation Measures

A comparison of the average annual damages for the two identified mitigation measures (Landsdowne Estate Mitigation Option and McCaughey Park Pond Water Level Reduction and Additional Pond Storage) in comparison to the base case is provided in Figure 3-16. A summary of the analysis is provided in Table 3-14, which outlines the cost to implement the measure, the benefit in terms of reduction of Average Annual Damage and the resultant Cost-Benefit Ratio (CBR).

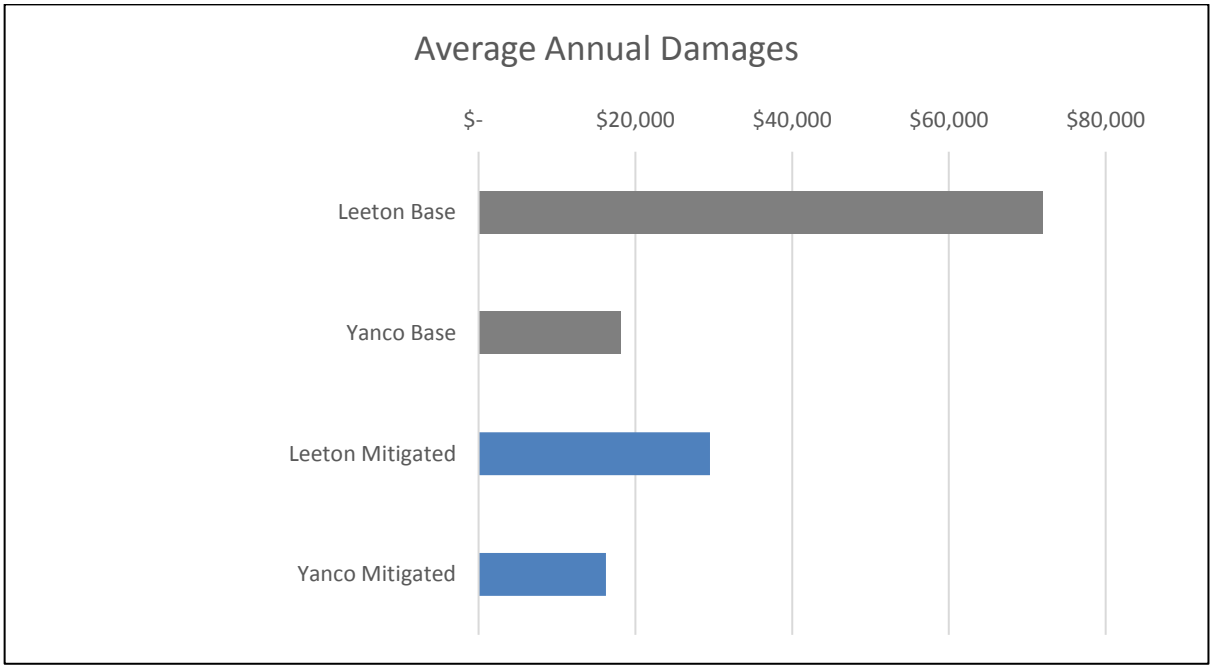

Figure 3-16 Average Annual Damages

Table 3-14 Cost Benefit Analysis

Scenario	Averaged Annual Damages	Net Present Value of Damages	Cost of Option	Option Benefit	Benefit/ Cost Ratio
Leeton - Base Case	$71,981	$1,602,933	n/a	n/a	n/a
Leeton - Landsdowne Estate Mitigation Option	$29,529	$436,052	$585,000	$626,881	1.07
Yanco – Base Case	$18,215	$268,980	n/a	n/a	n/a
Yanco - McCaughey Park Pond Water Level Reduction and Additional Pond Storage	$16,254	$240,020	$360,000	$28.960	0.08

4. RECOMMENDED FLOOD RISK MANAGEMENT MEASURES

Based on the above mitigation options identification and assessment, the following flood risk management measures are recommended.

4.1 Property Modification Measures

4.1.1 Zoning and Development Control

An area along Petersham Road (north of Fivebough Road) may have the potential to be developed as this is outside of the flood storage zone. However, potential developments are to ensure free draining of stormwater runoff and ensure drainage connectivity to a downstream channel.

Should development within the flood storage zone be proposed, land development controls should be implemented to ensure no impacts external to the site. As such, it is recommended that land development controls be considered by LSC for incorporation into the Leeton LEP which may include:

- Development is to ensure free draining of stormwater runoff and ensure drainage connectivity to a downstream drainage channel.
- Development is to ensure no adverse impacts external to the development site including impacts to the safety, value or use (current and potential) of any land in the vicinity.
- No imported fill to ensure no loss of flood storage or alternatively flood modelling is required to adequately demonstrate no worsening of existing flood conditions for a range of design events with consideration of cumulative impacts. Houses on stumps could be considered to provide a suitable development outcome.
- Driveways of properties located within the Flood Planning Area should be constructed at existing/natural ground level (i.e. no filling of driveway access). Where this is not possible, adequate cross drainage is to be provided and it is to be demonstrated that the proposed works will not cause adverse flood impacts to surrounding properties.
- Finished floor levels for any proposed building or extension within the Flood Planning Area are to be set above the Flood Planning Level (i.e. 1% AEP flood level plus 300 mm freeboard).
- Rezoning to restrict development within high risk areas (including vulnerable land uses) in the Flood Planning Area.
- Flood free access – demonstrate within acceptable trafficability limits that the development will not be isolated in the event of a major flood (1% AEP flood).
- Development does not impede the flow of floodwaters/stormwater runoff causing worsening of flood depths or levels on neighbouring properties. This includes any significant flow obstructions within the development.

- Development does not increase the flood level or flow of stormwater runoff to surrounding properties.

- Openings in structures such as fences or the like should be provided below the Flood Planning Level to allow free flow of stormwater.

- Critical infrastructure is to be located above the Flood Planning Level to not impact the social and economic wellbeing of the community during and after a flood event. Critical infrastructure includes physical facilities, supply chains, systems, assets, information technologies and communication networks.

- Land use control to ensure that vulnerable land uses (child care, hospital, kindergarten, school, aged care, aged retirement living, etc.) are not located in Flood Prone Areas where there may be risk to life.

The proposed development controls and objectives are outlined in Appendix D.

With regards to the adoption of an appropriate freeboard to define flood planning levels, a letter of advice was prepared for LSC and is provided in Appendix C. The advice specified the industry standard freeboard of 0.5 m which is widely adopted by local government authorities, however other factors were also outlined for LSC's consideration. These included local flooding characteristics, flood risk and development control.

4.2 Response Modification Measures

It is recommended that the following response modification measures be considered for adoption by LSC:

4.2.1 Community Flood Awareness and Readiness

- Incorporate the key outcomes from this study into LSC media.

- Develop a Community Flood Awareness and Readiness Program in conjunction with the NSW SES which not only provides general flood risk management information to the wider community but focuses on providing information to assist protect properties considered vulnerable to flood impacts. The program should also specifically focus on increasing awareness of the flood impacts associated with land filling.

4.2.2 Flood Predictions and Warnings

- In conjunction with the NSW SES and BOM, communicate the forecasted and recorded rainfall and associated warnings to the community through local media to increase the community's awareness and preparedness. Recorded rainfall triggers based on rainfall intensity and total rainfall should be further investigated in order to consider suitable triggers for flood warning.

- LSC to consider the installation of flood depth indicators at key locations (including road crossings along major roads such as Irrigation Way) to increase awareness of flood

risks. This could improve road safety as well as inform residents of at risk buildings or infrastructure to prepare for flood protection (i.e. sand bagging, lifting furniture, etc.). This would allow the NSW SES to capture and record flood intelligence for future flood planning and flood response operations.

4.2.3 Flood Emergency Response Planning

- Develop a Flood Emergency Response Plan in conjunction with the NSW SES which may include a list of flood prone properties that need to be protected (i.e. sand bagging) and or evacuated in a flood event. Vulnerable residents (due to age, disability, etc.) at risk of flooding should also be identified and included in the plan so that assistance can be provided. The plan should be developed in consultation with the community, particularly those at greatest risk.

4.3 Flood Behaviour Modification Measures

It is recommended that the following flood behaviour modification measures be considered by LSC to provide flood relief to critical hotspot areas in Leeton and Yanco:

4.3.1 Landsdowne Estate Drainage Improvement

The recommended flood mitigation option for Landsdowne Estate is Option 2 as outlined in Section 3.6.1. The key components of this option include increasing the pump capacity to 2,000 L/s within the detention basin, increase the downstream drainage channel grade (approximate average) from 0.03% to 0.08% as shown in Table 3-10 and upgrade Almond Road and Grevillea Road culverts to 4/900 mm RCPs (3 additional pipes) to increase discharge from Landsdowne Estate.

A hydraulic assessment of this option indicates that a 1% AEP flood immunity for all houses surveyed in Landsdowne Estate is achieved and an additional 250 mm reduction in flood depth to properties immediately downstream of Almond Road is observed. This option is estimated to cost approximately $585,000 to implement.

4.3.2 McCaughey Park Additional Flood Storage

The recommended flood mitigation option for McGaughey Park is Option 4 as outlined in Section 3.6.2. The key components of this option include increasing the pond storage volume and 0.5 m lowered pond starting water level (135.6 m AHD) with the existing pump capacity. The additional storage will be gained from approximately 1 hectare of open space land immediately south of the pond between the drainage channel and properties on Binya Street. The additional storage was based on excavating up to 1.6 m (136.4 m AHD base level) to determine whether additional storage would provide a tangible benefit.

This option was predicted to provide at least 1% AEP protection to houses located at 26 and 28 Hebden Street. This option is estimated to cost approximately $360,000 to implement.

4.4 Measures for Further Consideration/Investigation

- Flood Behaviour Modification - Mitigation Option 4: In order to limit the runoff volume at Landsdowne Estate, this option would involve removal of the sub drain under main canal near Corbie Hill Road and regrade the drainage channel to redirect flow in a northerly direction to the sub drain near Grevillia Road. Given the approvals that would be required from Murrumbidgee Irrigation and affected property owners, it is advised that discussions between relevant stakeholders (i.e. LSC, MI and affected property owners) be held to determine whether this option could be achieved and whether further investigated is warranted. As such, a hydraulic assessment has not been undertaken however it is recommended that this is undertaken depending on the outcome from stakeholder discussions.

5. FLOODPLAIN RISK MANAGEMENT PLAN

5.1 Introduction

The Leeton Shire Floodplain Risk Management Plan (the Plan) was developed to mitigate major flood risks in Leeton and Yanco. The Plan was developed based on the flood risks and potential management measures identified and evaluated in the floodplain risk management study.

The Plan was developed based on a fit for purpose approach and should be revised as additional planning and design is undertaken.

The Plan outlines a list of prioritised actions which are recommended based on environmental, economic, social and engineering considerations.

5.2 Objectives

Building further upon the Leeton Shire Flood Study, the Leeton Shire Floodplain Risk Management Study has identified major flood risks relevant to the Leeton Shire. These major risks generally relate to above floor inundation of buildings due to inadequate drainage which is restricted by flat grades. The Leeton Shire Floodplain Risk Management Plan has been developed based on the risks identified in the Leeton Shire Floodplain Risk Management Study and a holistic approach to flood risk management. As such, the objectives were to consider and identify suitable flood risk mitigation measures which include engineered solutions, land use planning and development control, and flood emergency management.

5.3 Recommended Measures

The recommended measures to achieve the aforementioned objectives are outlined in Table 5-1.

Table 5-1 Recommended Measures

Measure	Description
Landsdowne Estate Drainage Upgrade	Consider feasibility of the proposed works and undertake further investigation and design if deemed potentially viable.
McCaughey Park Pond Expansion	Consider feasibility of the proposed works and undertake further investigation and design if deemed potentially viable.
Zoning and Development Control	Consider recommended measures and incorporate into LEP.
Community Flood Awareness & Preparedness	Develop a tailored community Flood Awareness & Preparedness Program in consultation with the communities and risk and the NSW SES.

Measure	Description
Flood Predictions and Warnings	Develop a Flood Warning System for the Leeton Shire in conjunction with the Australian Bureau of Meteorology (BOM) and the NSW SES. Consider the installation of flood depth indicators at key locations.
Flood Emergency Response	Develop a Flood Emergency Response Plan for the Leeton Shire in consultation with the community, NSW SES and all relevant stakeholders including Murrumbidgee Irrigation (MI).

5.4 Plan Implementation

An implementation plan has been developed, summarising the required actions, responsibilities, and priorities for each of the recommended measures and is provided in Table 5-2.

Table 5-2 Implementation Plan

Priority	Measure	Implementation	Responsibility
1	Zoning and Development Control	Incorporate proposed development controls into the LEP.	Planning, Building and Health (TBC)
2	Landsdowne Estate Drainage Upgrade	Consider feasibility of the proposed works and undertake further investigation and design if deemed potentially viable.	Engineering Technical Services (TBC)
3	McCaughey Park Pond Expansion	Consider feasibility of the proposed works and undertake further investigation and design if deemed potentially viable.	Engineering Technical Services (TBC)
4	Flood Predictions and Warnings	Develop a fit for purpose Flood Warning System for the Leeton Shire in conjunction with the Australian Bureau of Meteorology (BOM) and the NSW SES. Consider the installation of flood depth indicators at key locations.	Engineering Technical Services, Community Services, BOM and the NSW SES.

Priority	Measure	Implementation	Responsibility
5	Flood Emergency Response	Develop a Flood Emergency Response Plan for the Leeton Shire in consultation with the community, NSW SES and all relevant stakeholders including MI.	Engineering Technical Services, Community Services and the NSW SES.
6	Community Flood Awareness and Preparedness	Develop a tailored community Flood Education and Awareness Program in consultation with the communities at-risk and the NSW SES.	Community Services and NSW SES.

It is advised that the Leeton Shire Floodplain Risk Management Plan be progressed as follows:

1. LSC allocates priorities and an associated timeframe to components of the Plan, based on available sources of funding and budgetary constraints;

2. LSC negotiates other sources of funding; and

3. As funds become available, implementation of the Plan proceeds in accordance with established priorities.

The Plan should be regarded as an organic tool requiring review and modification over time. The Plan should also be reviewed every 5 years in order to remain relevant in terms of understanding local flood risks and advances in floodplain management.

6. QUALIFICATIONS

a. In preparing this document, including all relevant calculation and modelling, Engeny Water Management (Engeny) has exercised the degree of skill, care and diligence normally exercised by members of the engineering profession and has acted in accordance with accepted practices of engineering principles.

b. Engeny has used reasonable endeavours to inform itself of the parameters and requirements of the project and has taken reasonable steps to ensure that the works and document is as accurate and comprehensive as possible given the information upon which it has been based including information that may have been provided or obtained by any third party or external sources which has not been independently verified.

c. Engeny reserves the right to review and amend any aspect of the works performed including any opinions and recommendations from the works included or referred to in the works if:

   (i) Additional sources of information not presently available (for whatever reason) are provided or become known to Engeny; or

   (ii) Engeny considers it prudent to revise any aspect of the works in light of any information which becomes known to it after the date of submission.

d. Engeny does not give any warranty nor accept any liability in relation to the completeness or accuracy of the works, which may be inherently reliant upon the completeness and accuracy of the input data and the agreed scope of works. All limitations of liability shall apply for the benefit of the employees, agents and representatives of Engeny to the same extent that they apply for the benefit of Engeny.

e. This document is for the use of the party to whom it is addressed and for no other persons. No responsibility is accepted to any third party for the whole or part of the contents of this report.

f. If any claim or demand is made by any person against Engeny on the basis of detriment sustained or alleged to have been sustained as a result of reliance upon the report or information therein, Engeny will rely upon this provision as a defence to any such claim or demand.

g. This report does not provide legal advice.

7. REFERENCES

BMT WBM (2010) *TUFLOW User Manual*.

Bureau of Meteorology (BoM 2003a). The Estimation of Probable Maximum Precipitation in Australia: Generalised Short-Duration Method, June 2003.

Department of Infrastructure Planning and Natural Resources (2005), Floodplain Development Manual.

Engineers Australian (1987) Australian Rainfall and Runoff – Volume 1 and 2.

IEAUST (1999). Australian Rainfall and Runoff – Volume 1: A Guide to Flood Estimation The Institution of Engineers, Australia, Barton, ACT.

APPENDIX A

Hotspot Identification and Mitigation Options Summary

LEETON SHIRE FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN: MITIGATION OPTION NOTES					
Hot Spot Location	**Flood Event Impacted (Year ARI)**	**Source/Issue of Flooding**	**Potential Mitigation/Investigation**	**Potential Benefit/Results Discussion**	**Other**
Landsdowne Estate	2	Water ponds behind bund on adjecent lot to west before entering site at estate entrance (Almond Rd).	Bund (levee) at Lot 21 on DP/SP 1107447 to prevent water entering Landsdowne Estate, therefore drainage via underground pipes only.	Would likely impact adjacent property therefore not included in options. Drainage solution likely to be required. No hydraulic assessment undertaken.	
		Basin is lower than downstream channel, pump capacity (15L/s) is limited, low capacity of downstream channel and two downstream road crossing culverts restrict drainage capacity and cause significant ponding behind road embankments.	Improve downstream channel conveyance (increase grade only) and increase culvert capacity under Almond Rd and Grevillea Rd. Increased channel grade (not width) and upgraded culverts to 3/900mmx900mm RCBC, combined with upgrading the pump capacity in basin to 2m³/s (flood relief pump).	Provided reduction in flood levels at Landsdowne Estate and within downstream properties/farms. Increase in flood levels downstream of Grevillea Rd (~400mm in 5yr & ~500mm in 100yr ARI) as expected with increased conveyance of culverts and channel. Now predicted to have immunity of house pads at Landsdowne in 2-5yr ARI (dependant on pad levels). Reasonable flood extent reductions of properties/farms between Landsdowne Estate and Grevillea Rd in 2 & 5 year ARI events.	Increasing the width of the drainage channels downstream of Landsdowne Estate could potentially provide further flood relief to residents in the area. The flood irrigation bunds/contours would need to be moved into the property boundaries and out of drainage reserve. Further investigation warranted.
		Low pump rates combined with downstream hydraulic controls causes ponding and backwater up pipes and within Landsdowne Road and into properties within the Estate.	Increase pump rate.		
	50	Water ponds behind bund on adjacent lot to south before overtopping in 50 year event.	Increase bund height.	Would likely increase water levels on property to south therefore not included in options. No hydraulic assessment undertaken.	
McCaughey Park	10	Existing modelling results suggest properties to south of pond start to experience flooding into back half of properties in 10 year ARI event.	Operate pond at lower starting level to increase available storage and increase pump capacity.	Lowered water level of pond pump (0.5m) and increased pump capacity to 2m^3/s, pump capacity too high as downstream channel cannot convey flows and floods properties on northern side of pond. Second option assessed with existing pump capacity and lowered starting water level by 0.5m, however this only provided approx. 100 mm reductions in levels at the pond so option considered ineffective.	Look to create significant additional storage in open space to the south of Pond (between properties and existing drain) with existing pump capacity and lowered start pump level.
Petersham Road (Gruie St)	50	Water ponds behind road crests.	Increase underground pipe capacity.	No mitigation options modelled. Capacity of existing pipes in Petersham Rd are < 2yr ARI therefore option to include additional pipe unlikely to provide any benefit. Expensive upgrade to underground infrastructure is likely to be required to alleviate an isolated local flooding issue.	
Petersham Road (Between Grevillia Rd and Fivebough Rd)	5 to 10	Water ponds in properties along Petersham Rd (west side) and along Fivebough Rd (southern side) due to limited pipe capacity and ponding behind road crests.	Increase underground pipe capacity.		
		Ponding on Lot 656 on DP/SP 720231 as land is lower than roadside swale and pit inlet (by approx. 200-300 mm).	Install field inlet within Lot 656 with connection to existing pit (dependant on existing pipe invert levels) - may need to increase pipe capacity downstream of proposed field inlet.		
Petersham/Fivebough Rd Intersection	10 to 20	Water ponds behind Fivebough Rd crossing and backs up into Lot 139 on DP/SP 751742.	Increase capacity under Fivebough Rd.	Nuisance flooding/local flooding issues.	

Cudgel St & Binya St Intersection	2	Water ponds behind Binya Street (opposite pond) as pipe capacity is very low (450 mm dia and completely blocked).	Increase capacity under Binya St & decrease flood extent on private property adjacent pond.	Upgrade to pipe not hydraulically assessed as pond tailwater controls flood extent in property.	
Yanco private property flooding (Edon St to Research Rd)	2	Water ponds in private property as topography has small lip (bund) before properties enter open drains. Supply channels also cause ponding in properties.	Remove sections of bunds to ensure free draining. Likely considered as nuisance flooding as properties adopt flood irrigation practices.	No mitigation proposed as isolated local drainage issue.	Could be further investigated and considered by LSC as part of localised drainage works.
Railway (Yanco)	2	No underground infrastructure identified/provided hence large amount of ponding behind railway embankment in two locations	Install culverts to allow water to pass through railway embankment. Likely to cause impact to downstream property so will need to be a combined solution with downstream works (i.e. drainage channel to Binya St and into pond/open drain).	No mitigation proposed as would increase flood risk to downstream property (private).	
Progress St (Yanco)	100	Water overtops western side of Progress St and enters private property towards open drain to pond.	Increase pit and pipe capacity .	No mitigation proposed as isolated local drainage issue.	
Eastern Yanco	2	Existing model results indicated flooding of existing houses in larger events (>10yr ARI). Water also ponds in private property as topography has small lip (bund) before properties enter open drains. Supply channels also cause ponding into properties.	Increase culvert sizes under Davis Rd to Irrigation Way from various 450-750mm dia's to 3/600mm x 600mm RCBC.	Mitigation modelling results for 2yr ARI showed a reduction to flood levels in drainage reserves between Davis Rd and Irrigation Way of approx. 40-80mm. Increased flood levels predicted downstream Irrigation Way (as expected) by approx. 40-50mm.	Increasing the width of the drainage channel downstream of Davis Rd unlikely to reduce flooding due to limited availability to increase channel grade prior to supply channel parallel to Irrigation Way. Drainage channel increases grade downstream of Irrigation Way so if channel invert can be lowered and piped under subdrain then potential to reduce some flooding to properties in east Yanco.
Golf Club Estate	> 100	No issue with flooding in 100 year ARI event. Both basins overtop in 50 year ARI event into large depression adjacent the estate.	No drainage improvements required.	No issues in 100 year ARI event.	
McCaughey Park & East Yanco	2 to 10	Existing hydraulic results indicated flooding of existing houses in larger events (>10yr ARI). Water also ponds in private property as topography has small lip (bund) before properties enter open drains. Lots of supply channels also cause ponding into properties. Pooling in property as channel bund is higher than ground levels. Water predicted to overtop into channel from 26 hebden St above 10yr ARI. Small sub drain not included in 26 Hebden St. Hebden St has 100y immunity from the pond and the channel. 100yr ARI breaks out of channel first into 26 Hebden St and fills block of houses.	Lower start pump level in pond by 0.5m and increase pond storage volume to the south (approx 1 ha). Upgraded culverts (east Yanco) from approx Short St to Irrigation Way. (3/600mmx600mm RCBC).	~175mm reductions in levels in pond in 2yr ARI, with ~140mm reductions in 10yr & 100yr ARI. No change to levels in property west of Binya St in 2y, ~140mm reductions in 10y & 100y. ~70mm reductions in drain on northern side of Hebden St (2y, 10y, 100y). No change to depths in drains downstream of pond to Jackson Rd (2yr, 10yr, 100yr ARI). Minor reductions in drains (less than 100mm) upstream of Irrigation Way in 2yr ARI. up to 30mm reductions to properties either side of Davis Rd in 10yr & 100yr ARI. Minor increase (less than 30mm) in drain downstream of Irrigation Way in 2yr ARI. Typically 30-60mm increases in drains and properties downstream of Irrigation Way to McQuillan Rd (10yr & 100yr ARI). 10-30mm increases in 10yr & 100yr ARI to large basin downstream of Golf Links development due to minor increased flows/levels in drain at Racecourse Rd (water will overtop drain and head east to the basin).	Flood level changes appear to be localised. Upgrades to pond showed reduced levels immediately at the pond and areas affected by pond backwater (i.e. open drain on northern side of pond and property to west on Binya St). No tangible changes to flood extents and depths in eastern Yanco with the proposed culvert upgrades. As expected there are slight reductions in the drain and properties along the drain, with increased levels predicted downstream of Irrigation Way by increasing conveyance through the culverts.

McCaughey Park (26 Hebden Street)	2	Pooling in property as channel bund is higher than ground levels. Water predicted to overtop into channel from 26 Hebden St above 10yr ARI. Small sub drain not included in 26 Hebden St. Hebden St has 100yr ARI immunity from the pond and the channel. 100yr ARI is considered to break out of channel first into 26 Hebden St and fills adjacent properties.	Pumps located in private property and pump to pond (responsibility of residents but no guarantee of benefit).	Individual properties to consider private works to protect houses without causing impacts to other properties.	
Future residential areas (east of Petersham Rd)	2	Water ponds in properties because of small bunds on upstream side of open drains.	Fill proposed residential areas (planning scheme) to assess impacts of filling within floodplain.	Flood level impacts between 100-300 mm (increase) surrounding future res land parcels (i.e. increased flood risk for existing residents) in 100yr ARI.	No filling within floodplain or proposed buildings to be raised on stumps to ensure flood storage is maintained. No filling south of Fivebough Rd. Filling of future development areas north of Fivebough Rd may be possible provided appropriate drainage measures are provided including major open drain and associated culvert upgrades to outlet of drain (i.e. Fivebough Wetlands). This would negate the requirement for detention basins to achieve no worsening of discharge from the sites.
Landsdowne Estate	ALL	Water ponds behind bund on adjacent lot to west before entering estate at road entrance (Almond Rd). Basin is lower than downstream channel and very small pump (15L/s) combined with limited capacity of downstream channel and the two downstream road crossing culverts restrict drainage capacity causing significant ponding behind road embankments. Low pump rates combined with downstream hydraulic controls causes ponding up pipes and within Landsdowne Road and into properties within the Estate. Water ponds behind bund on adjacent lot to south before overtopping in 50 year ARI event.	Increased channel grade and width (to 10m) and upgraded culverts under Almond Rd, Grevillia Rd & Fivebough Rd to 3/900mmx900mm RCBC, combined this with upgrading the pump capacity at Landsdowne to 2m³/s (flood relief pump).	Results in 50-60mm flood depth reductions (5yr ARI) and 150-160mm reductions (100yr ARI) to adjacent property (132 Almond Rd). Significant reduction to flood extent for properties in Landsdowne in 5yr ARI event with only a couple of properties predicted to experience some flooding in 5yr ARI (almost only road and basin flooded), 100yr ARI flood levels reduced by approx. 200mm to properties in Landsdowne Estate. Significant reductions in extent of inundaiton to land downstream of Landsdowne Estate (channel generally has 5yr ARI capacity). No significant change to flood extents in 100yr ARI, however flood depths over road are reduced with improvements to trafficability of Almond Rd predicted. Flood depth reductions in order of 150mm in farms adjacent Landsdowne Estate, Almond Rd is now predicted to be immune (prevents water entering downstream properties). Downstream of Almond Rd (along drain), 300-400mm flood depth reductions in 100yr ARI, properties west of drain predicted to have 250mm reduction in depths (downstream of Almond Rd). Downstream of Grevillia Rd there were no changes to property flooding with increased depths in drains of 250-350mm (5yr and 100yr ARI). By increasing the culvert and channel flow capacity, the depths in the drains at Fivebough Wetlands have increased and therefore increased flows into Fivebough Wetlands. Minor impacts (less than 20mm) to flooding east of Quadling Rd due to higher tailwater levels in drains at Fivebough.	Provided protection to 4 houses inundated above floor level in existing case.

Bypass subdrain that drains to Landsdowne Estate	ALL	Upstream catchment runoff from the ranges to the east pond water behind subdrain that conveys to open drain downstream towards Landsdowne Estate	Remove subdrain and bypass flow to next subdrain to the north (Grevillia Rd) by regrading open drains.	Potential to remove load on the open drain past Landsdowne Estate to alleviate flooding to existing residential areas and convey water through flowpaths predominantly of rural land uses that have no potential for development. This will need to be discussed with Murrumbidgee Irrigation and Leeton Shire Council to confirm viability.	

NON STRUCTURAL MEASURES

Item	Discussion/Option
Evacuation	Results of the flood modelling predict that all flooded road have low flood hazard associated with them due to the nature of flooding (i.e. slow moving water)
Landuse Planning & Development Control	No filling in 100y flood extent AND/OR Only houses raised on stumps above 100y depth plus freeboard with driveway flooded and no imported fill AND/OR Onsite detention policy to ensure free draining solutions (i.e. no pumps)
Drainage Channel Ownership	Agreement between LSC and MI on the ownership of drainage channels and maintenance and develop a memo/doc of agreement/understanding
Formal Warning Service	No formal warning service for local rainfall/flooding events by BOM. Murrumbidgee River has warnings (~2days). Recommend discussions with local SES officers to try determine a trigger rainfall warning system that may cause flooding in Leeton/Yanco in known hotspots (i.e. evacuation, road closures, etc.).
Emergency Response	Develop Local Flood Plan including Flood Emergency Planning
Community Education	Highly recommened to educate the community on flooding in the region and what it means to their safety

Colour Legend:

	Preferred Mitigation Option
	Issue either did not warrant mitigation (nuisance/local stormwater issue) or mitigation option not considered viable.
	Mitigaiton Option Superseded by Preferred Option

APPENDIX B

SES Flood Intelligence Card

FLOOD INTELIGENCE CARD

MURRUMBIDGEE RIVER CRITICAL GAUGE HEIGHTS

LEETON measured at Narrandera Gauge

Location	Gauge Height (m)	
Cudgel Creek starts to flow	4.87	
Euroley Creek starts to flow	6.03	5.46 weir ds Yanco gauge
Flooding overtops bank at Baulches farm –Yanco weir rd.		6.70 ds Yanco weir gauge
Euroley Bridge Road cut	7.39	
Flooding on Murrays farm 1725	7.42	
Flooding Yanco Brickworks	8.03	
Flooding over road near aerodrome	8.07	
Water crosses YAHS school entrance Rd	8.20	
Flooding over road near “Yamba”	8.23	
Consider evacuation of YAHS	8.99	

Any further information required contact Peter Morris

SES Leeton Planner 69559455 or 0429659252

APPENDIX C

Letter: Consideration for Determination of Flood Planning Level

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20 June 2017

Leeton Shire Council
23-25 Chelmsford Place
Leeton, NSW 2705

Attention: Barry Heins

Dear Barry,

RE: CONSIDERATIONS FOR DETERMINATION OF FLOOD PLANNING LEVEL

It is understood that Leeton Shire Council (Council) are in the process of determining an appropriate freeboard allowance to define the flood planning level (FPL). The FPL plays an important role in managing flood risk and is derived from a combination of a flood event (understood to be the 1% AEP for Leeton), and a freeboard. The freeboard acts as a safety factor to account for uncertainties, such as flood modelling uncertainties, rainfall patterns due to climate change, and changes in water level due to development within the floodplain, wave action or any other local factors that are not represented within flood models.

Typically, a freeboard of 0.5m is acceptable and commonly adopted by local government authorities however the freeboard may differ depending on flood risk, local conditions and development control requirements. In determining an appropriate freeboard to be adopted by Council, it is advised that local flooding conditions and associated risks be carefully considered.

Flooding in Leeton does not represent typical floodplain behaviour due to the source of flooding (i.e. typically overland flow), the relatively shallow flood depths and widespread inundation largely due to direct rainfall. For example, applying a freeboard of 0.3m would provide immunity to new buildings for a flood event of a magnitude greater than the 2012 event (return period of approx. 180 years) and in some cases would provide a freeboard depth greater than the actual flood depth given that the 1% AEP flood depth in many locations is below 0.3m.

Flood prone areas are largely characterised by flood storage and therefore due to the significant extent of inundation across the Shire and the associated flood storage, the incremental change in flood depth between flood events is generally minor. For example, sample point 1 (refer to Figure 1) has a flood depth of 0.47m and 0.51m for the 2% and 1% AEP flood events respectively. As such, it is considered that adopting a constant freeboard of 500mm across the local government area may be over conservative and therefore a freeboard of 0.3m may be more appropriate. Table 1 and Figure 1 provide an indication of the flood depth for various events at randomly selected sample points.

Figure 1. Sample Point Locations

Table 1. Flood Depths at Sample Point Locations

ID	PMF Depth (m)	2012 Depth (m)	1:100 AEP Depth (m)	PMF-Q100 Difference (m)	2012-Q100 Difference (m)	1:100 AEP Depth+0.3 Freeboard (m)	1:50 AEP Depth (m)
1	1.42	0.67	0.51	0.91	0.16	0.81	0.47
2	1.25	0.39	0.17	1.08	0.22	0.47	0.06
3	1.35	0.36	0.35	1	0.01	0.65	0.34
4	0.86	0.51	0.39	0.47	0.12	0.69	0.38
5	1.52	0.58	0.38	1.14	0.2	0.68	0.31
6	1.41	0.61	0.28	1.13	0.33	0.58	0.13

ID	PMF Depth (m)	2012 Depth (m)	1:100 AEP Depth (m)	PMF-Q100 Difference (m)	2012-Q100 Difference (m)	1:100 AEP Depth+0.3 Freeboard (m)	1:50 AEP Depth (m)
7	2.13	1.1	0.56	1.57	0.54	0.86	0.46
8	1.52	0.51	0.21	1.31	0.3	0.51	0.2
9	1.07	0.28	0.18	0.89	0.1	0.48	0.16
10	0.37	0.23	0.18	0.19	0.05	0.48	0.18

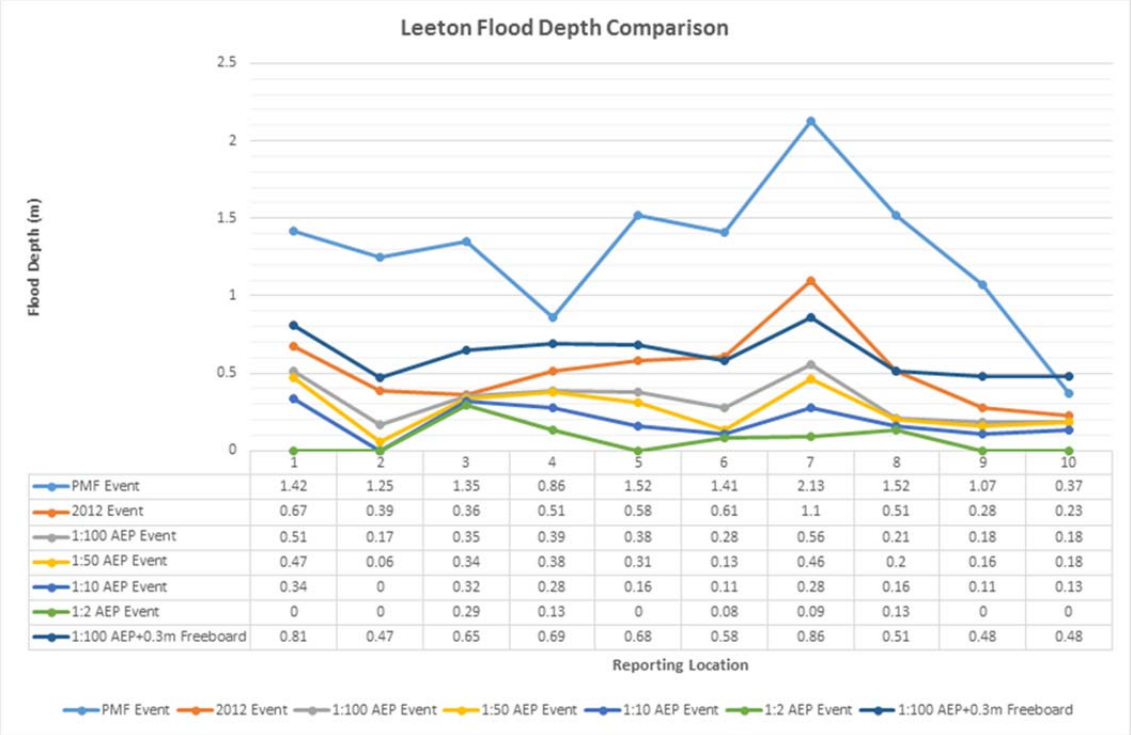

Figure 2. Flood Depth Comparison

I trust that this information assists Council to decide on an appropriate freeboard to define the flood planning level. Please don't hesitate to contact the undersigned for any queries.

Yours faithfully,

Mark Page
Principal Engineer

APPENDIX D

Letter: Leeton Shire Development Controls

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28 March 2019

Leeton Shire Council
23-25 Chelmsford Place
Leeton NSW 4705

Attention: Matthew Vogele

Dear Matthew

RE: LEETON SHIRE DEVELOPMENT CONTROLS

The purpose of this letter is to provide advice to Leeton Shire Council (Council) regarding flood related development controls that could be considered for incorporation into a Development Control Plan. An outline of the objectives and controls is provided as follows.

Development Control Objectives

The development control objectives are outlined as follows:

- Minimise risk to life and damage to property by controlling development on flood prone land.
- Ensure the impacts of the full range of flood sizes up to and including the PMF are considered when assessing development on flood prone land.
- Ensure that development does not have a significant impact on flood behaviour, people's safety, surrounding properties and structures, and the natural environment.
- Ensure that the effects of climate change are considered when assessing development on flood prone land.
- Ensure that development on the floodplain is consistent with the NSW Flood Prone Land Policy and NSW Floodplain Development Manual.
- Ensure that developers and the community are conscious of the potential flood hazard and consequent risk associated with the use and development of land within the floodplain.
- Ensure that all land uses and essential services are appropriately sited and designed in recognition of all potential floods.
- Ensure that development on flood prone land does not place an unacceptable financial burden on landowners or the community.
- Ensure the type, scale and location of development on a site is responsive to the nature and risk of flood hazard present.

Development Controls

The following development control measures should be considered for development within the flood planning area:

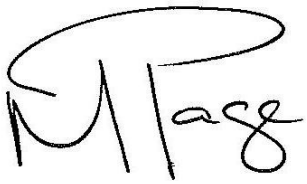
- Development is to ensure free draining of stormwater runoff and ensure drainage connectivity to a downstream drainage channel.
- Development is to ensure no adverse impacts external to the development site including impacts to the safety, value or use (current and potential) of any land in the vicinity.
- No imported fill to ensure no loss of flood storage or alternatively flood modelling is required to adequately demonstrate no worsening of existing flood conditions for a range of design events with consideration of cumulative impacts. Houses on stumps could be considered to provide a suitable development outcome.
- Driveways of properties located within the Flood Planning Area should be constructed at existing/natural ground level (i.e. no filling of driveway access). Where this is not possible, adequate cross drainage is to be provided and it is to be demonstrated that the proposed works will not cause adverse flood impacts to surrounding properties.
- Finished floor levels for any proposed building or extension within the Flood Planning Area are to be set above the Flood Planning Level (i.e. 1% AEP flood level plus 300 mm freeboard).
- Rezoning to restrict development within high risk areas (including vulnerable land uses) in the Flood Planning Area.
- Flood free access – demonstrate within acceptable trafficability limits that the development will not be isolated in the event of a major flood (1% AEP flood).
- Development does not impede the flow of floodwaters/stormwater runoff causing worsening of flood depths or levels on neighbouring properties. This includes any significant flow obstructions within the development.
- Development does not increase the flood level or flow of stormwater runoff to surrounding properties.
- Openings in structures such as fences or the like should be provided below the Flood Planning Level to allow free flow of stormwater.
- Critical infrastructure is to be located above the Flood Planning Level to not impact the social and economic wellbeing of the community during and after a flood event. Critical infrastructure includes physical facilities, supply chains, systems, assets, information technologies and communication networks.
- Land use control to ensure that vulnerable land uses (child care, hospital, kindergarten, school, aged care, aged retirement living, etc.) are not located in Flood Prone Areas where there may be risk to life.

Definition of Terms

- Flood Planning Levels – flood levels derived from the 1% AEP flood event and a freeboard of 300mm selected for floodplain risk management purposes.
- Flood Planning Area – the area of land below the FPL and thus subject to flood related development controls.
- Flood Prone Land – land susceptible to flooding in the PMF event.

We trust that the defined objectives and control measures will assist Leeton Shire Council to appropriately manage development within the Flood Planning Area. Please note that the information contained in this letter is advise provided for further consideration by Council. Should there be any queries, please don't hesitate to contact the undersigned on (07) 3221 7174.

Yours faithfully



Mark Page
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