ATTACHMENTS PROVIDED UNDER SEPARATE COVER

FLOODPLAIN RISK MANAGEMENT ADVISORY COMMITTEE

15 February 2024

City of Wagga Wagga

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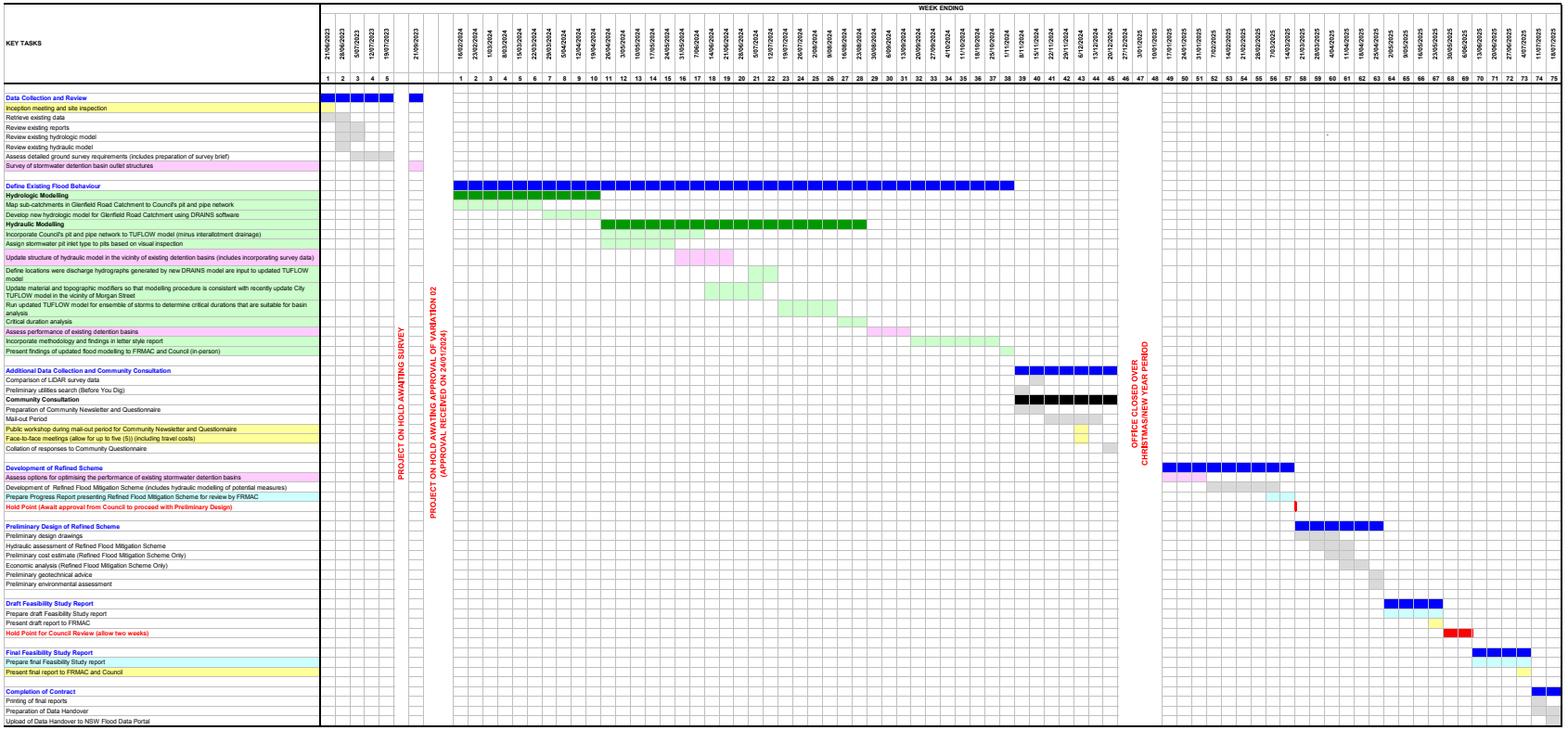


FIGURE 1
PROPOSED TIMETABLE
GLENFIELD ROAD DRAIN FLOODING INVESTIGATION


Stantec
City of Wagga Wagga
Levee Pump Augmentation Project
Presented to FRMAC
Presenters:
Manoj Shrestha and Andy Sheehan - Stantec
Andrew Mason – Wagga Wagga City Council
15th February 2024

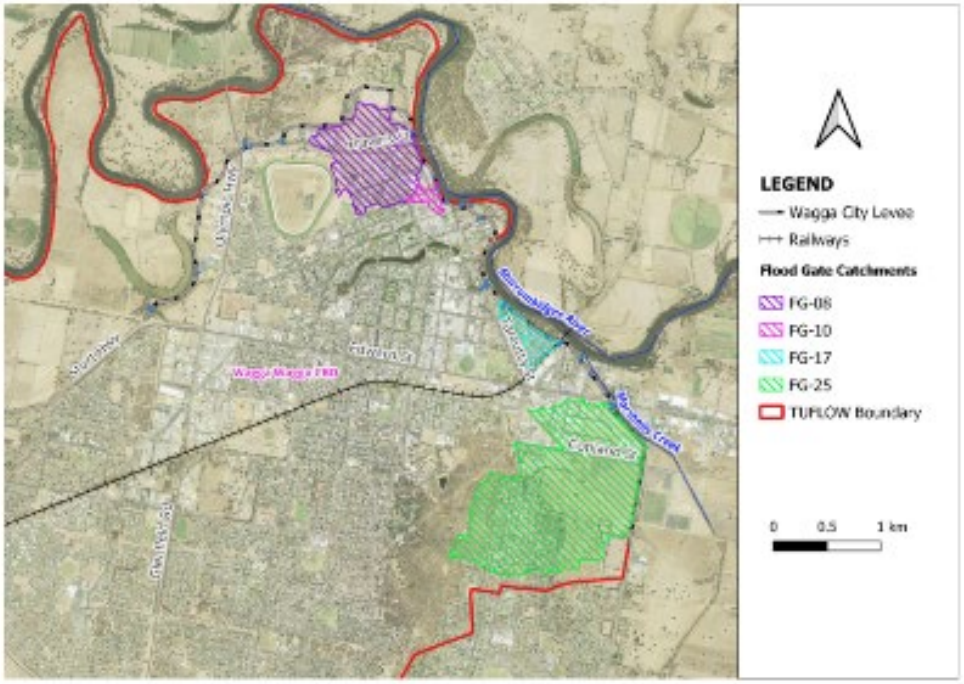
Key Project Aim and Outcome – Flood modelling, catchment analysis and volume determination

Key Project Aim:

- determine recommended pump station duty flow rates to maintain acceptable flood conditions behind the flood levee in Wagga Wagga.

Key Project Outcome:

- Agree on design duty flows at each pump station site for development in the concept design stages.



Methodology

Step 1: Model updated based on review undertaken by Stantec

- Model updated with latest Light Detection and Ranging (LiDAR) data.
- Manning's values updated in the model based on latest aerial imagery.
- Model resolution increased to 2m for the catchments of floodgates- 8, 10, 17 and 25.
- Amendments to the pipe networks to resolve the major issues observed such as snapping the pipes, fixing the inverts of the pipes, removing adverse gradients etc.
- Updates to the missing pits and pipes, bridge structure and culverts based on available as-constructed drawings and information from site visits.

Step 2: Assess the requirements for the renewal and upgrade of four existing pump stations

- Agreed with Council model scenarios to be run
- Run the range of model scenarios required for the 1% AEP event
- Analyse and report on the model results for each scenario and recommendations to inform Council decision making on pumping requirements

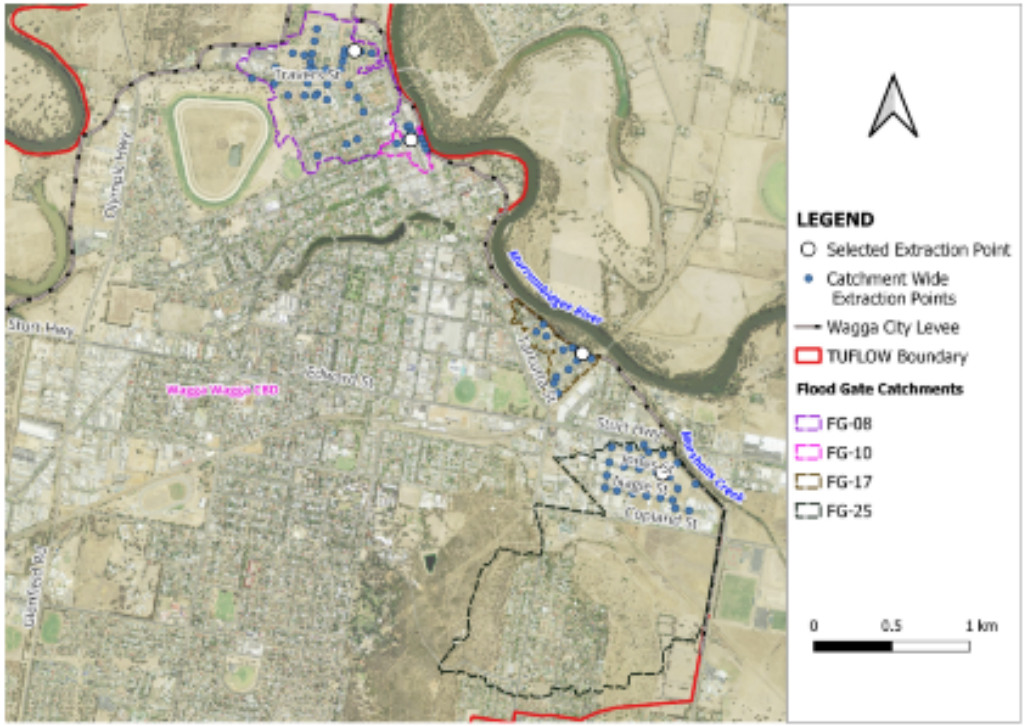
Methodology

- 5 Scenarios run in TUFLOW

Scenarios	Description
Scenario 1 – Baseline condition	All flood gates open
Scenario 2	Flood gates shut
Scenario 3	Flood gates shut with 300 L/s
Scenario 4	Flood gates shut with 600 L/s
Scenario 5	Flood gates shut with 900 L/s

Methodology

- Updated TUFLOW model used to assess 3 pumping scenarios relative to Scenario 1 and Scenario 2
- Peak duration of inundation assessed over several points for four catchments
- A plot of flood level versus time has been provided at four selected location.



Flood Gate Catchment	Selected Locations
Flood Gate 8	Location 1- Road centreline near 29 Incarnie Crescent
Flood Gate 10	Location 2 - Road intersection Kincaid and Fitzmaurice St,
Flood Gate 17	Location 3 - Road centreline intersection Higgins Ave and Reddoch St
Flood Gate 25	Location 4 -Road centreline near 11 Jones St

City of Wagga Wagga

Stantec

Results

Flood Gate Catchment 8

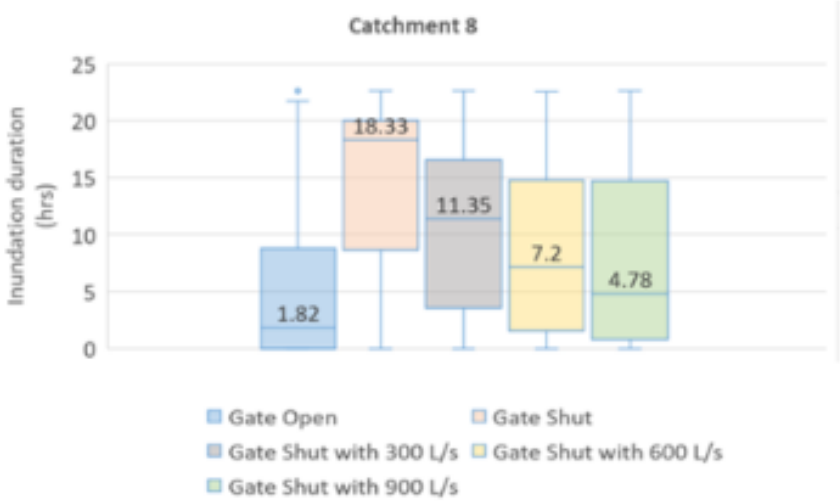


Figure : Box plot diagram for overall duration of inundation for different scenarios

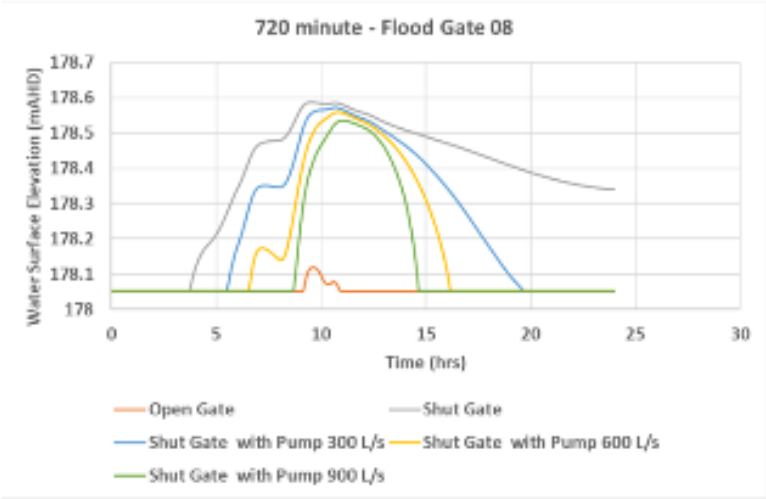


Figure: Flood level vs time plot at Location 1

Results

Flood Gate Catchment 10

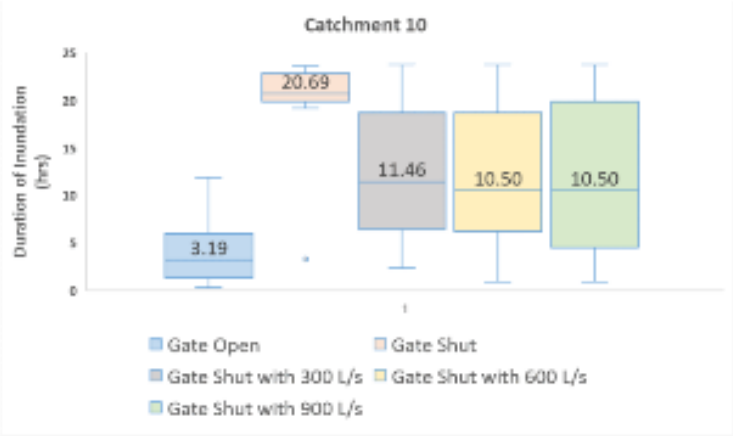


Figure : Box plot diagram for overall duration of inundation for different scenarios

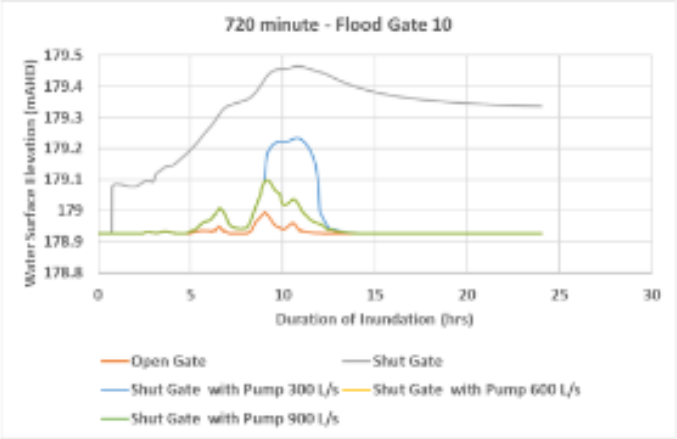


Figure: Flood level vs time plot at Location 2

Results

Flood Gate Catchment 17

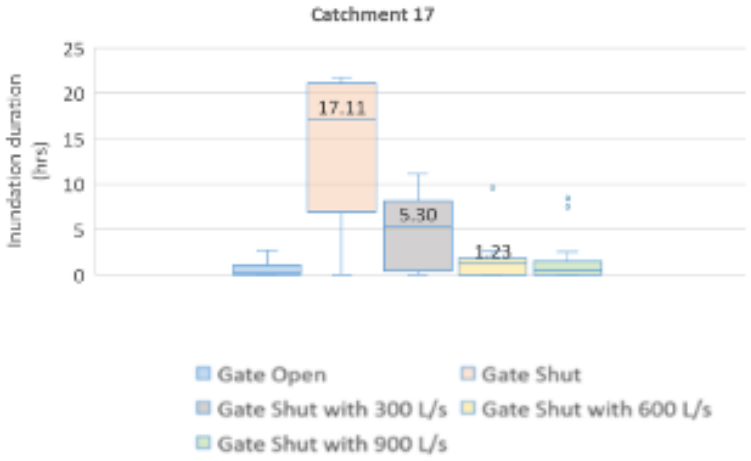


Figure : Box plot diagram for overall duration of inundation for different scenarios

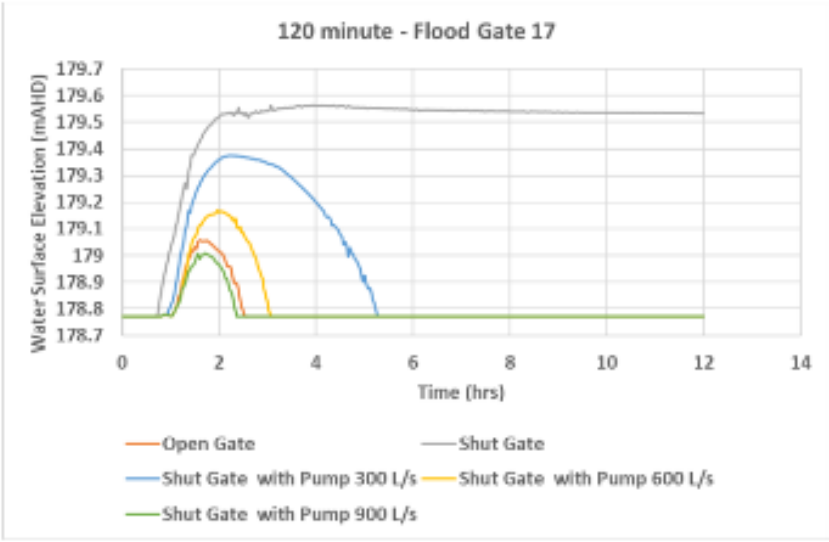


Figure: Flood level vs time plot at Location 3

Results

Flood Gate Catchment 25

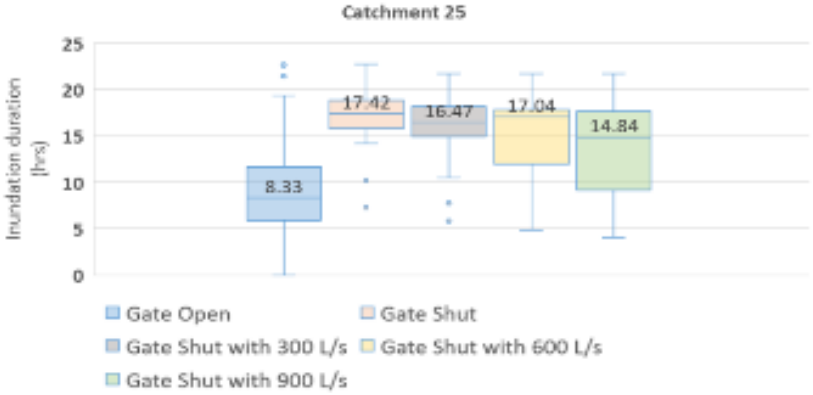


Figure : Box plot diagram for overall duration of inundation for different scenarios

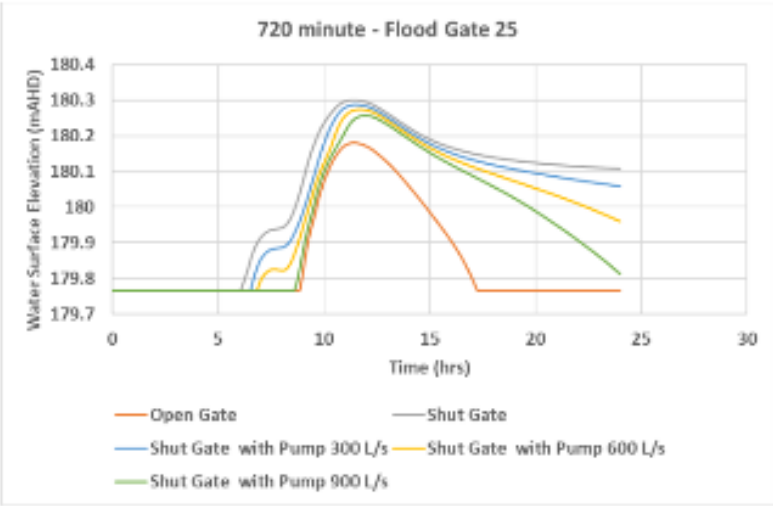


Figure: Flood level vs time plot at Location 4

Results

- Peak duration of flood inundation at four locations for 5 Scenarios

Scenarios	Duration of Inundation in hrs (Storm event)			
	Flood gate 8 – Location 1	Flood gate 10 – Location 2	Flood gate 17 – Location 3	Flood gate 25 – Location 4
Open Gate	2.3 (120 min)	1.2 (120 min)	1.3 (120 min)	8.5 (360 min)
Shut Gate	>20 (720 min)	> 23 (720 min)	> 21.6 (720 min)	> 18 (720 min)
Shut Gate with Pump 300 L/s	13.3 (720 min)	4.6 (720 min)	8.3 (720 min)	> 17 (720 hrs)
Shut Gate with Pump 600 L/s	9.6 (720 min)	3.8 (720 min)	1.8 (120 min)	> 17 (720 hrs)
Shut Gate with Pump 900 L/s	7 (360 min)	3.8 (720 min)	1.1 (120 min)	> 16 (360 min)

Results

- Scenario 1- Peak Flows

Location	Peak flow (m3/s)	Critical duration
Flood gate 8	2.1	90 min
Flood gate 10	0.64	90 min
Flood gate 17	0.88	90 min
Flood gate 25	3.3	720 min

Conclusions

- In general, the higher pump duty flow rates resulted in improvement in duration of flood inundation compared to the scenario where all the flood gates are closed (as expected)
- Scenario 5 (900 L/s pump rate) reduces the duration of inundation comparable to Scenario 1 for Catchment 10 and 17.
- For catchment 8 and 25, a higher pump rate capacity in the order of > 2000 L/s may be required to reduce the duration of inundation comparable to Scenario 1.

Questions

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Stantec

LAKE ALBERT FEASIBILITY STUDY

Part 2 - Data Review and Hydraulic Model Review

30 January 2024

Prepared for:
Wagga Wagga City Council

Prepared by:
Stantec

Project Number:
300203943

Lake Albert Feasibility Study

Revision	Description	Author	Date	Quality Check	Date	Independent Review	Date
R01	Draft for Client Review	VJ	30/1/2024	MG	30/1/2024	MG	30/1/2024

Project Number: 300203943

Lake Albert Feasibility Study

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Project Number: 300203943

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1 Introduction

Lake Albert is situated in the southern parts of Wagga Wagga and is one of the most popular recreational facilities in the city. It caters for boating, fishing, swimming and other aquatic activities, and is encircled by a 5.5 km walking and cycling track, with parks and community facilities along the way.

Stantec has been engaged by Wagga Wagga City Council to assess feasibility of using Lake Albert to provide additional flood mitigation to the broader area.

Figure 1 shows locality of Lake Albert and surrounding areas.

Figure 1 Locality of Lake Albert

1.1 Background

Wagga Wagga City Council completed the Wagga Wagga Major Overland Flow Floodplain Risk Management Study and Plan (MOFFRMS&P) in 2021. The main objective of the study was to develop flood risk mitigation strategies that address existing, future and continuing flood problems due to local catchment (not riverine) flooding in Wagga Wagga.

The study provided an opportunity to test a variety of methods to enhance the role that Lake Albert plays in Wagga Wagga's flood mitigation. (MOFFRMS&P, 2021).

The "Lake Albert Enhanced Flow Scheme" was proposed to reduce flood damages to properties along Crooked Creek, Stringybark Creek, and downstream of Lake Albert Road. The three key elements of the scheme as described in MOFFRMS&P (2021) are provided below:

- Stage 1 (LA01): Raising Lake Albert Road
- Stage 2 (LA02): Augmentation of Crooked Creek Diversion into Lake Albert.
- Stage 3 (LA03): Augmentation of Stringybark Creek Diversion into Lake Albert

Within the MOFFRMS&P these three components were modelled as individual risk management options, however a consolidated Lake Albert Enhanced Flow Scheme adopting all three options was the preferred outcome for the area. The Lake Albert Feasibility Study will investigate and determine the feasibility and effectiveness of the Lake Albert Enhanced Flow Scheme. This includes detailed hydraulic and economic assessments, preliminary utilities, detailed survey and Geotech analysis, environmental and cultural assessments, an understanding of the social cost and subsequent Cost/Benefit analysis.

1.2 Project Objectives

The tasks involved within the study will include:

Part 1 – Data Collation & Validation:

- Data Collation and Review: a comprehensive data collation and review process will be undertaken. All critical data gaps will be communicated to Wagga Wagga City Council along with any recommendations.
- Inception Meeting and Site Tour: A site tour will be undertaken to identify key flood control features, key opportunities, key constraints, any critical needs for the project and key local stakeholders and members of the community with an interest in the project. We will ensure that sufficient notice will be given to enable other stakeholders to attend if required.
- Community Consultation: Community consultation will be guided by the revised City of Wagga Wagga Community Engagement Strategy and the International Association for Public Participation (IAP2) Public Participation Spectrum.

- Targeted consultation with key stakeholders via phone, email and committee meetings to inform them of the study and obtain necessary material to supplement the data review.

Part 2 – Investigative Works & Environmental Assessment:

- Investigative works; including lidar and topographic survey data review, preliminary utilities assessment and Preliminary Geotechnical Advice & Investigation will be undertaken.
- Preliminary Environmental Assessments (Environmental Constraints Analysis): A review of planning pathway for each of the options would be undertaken to inform the environmental constraints within each of the study areas. The review would be undertaken through desktop assessment and spatial analysis to ascertain the key environmental constraints and limitations associated with the proposed options for Lake Albert.
- Cultural Heritage Assessment (Due Diligence Assessment): Stantec will engage ACHM to undertake Cultural Heritage Assessment.
- **Hydraulic Assessment:** The existing hydrological and hydraulic models and reports will be reviewed by Stantec to interrogate the previous work undertaken.

Part 3 –Mitigation Options Assessment:

The Mitigation Options Assessment will be undertaken in two distinct phases including:

- Phase 1: Confirm and Assess mitigation options including preliminary costings and cost benefit analysis;
- Phase 2: Preliminary Design of preferred option.

This report summarises the outcomes of **Hydraulic Assessment (Part 2)**.

2 Previous Studies

2.1 Wagga Wagga Major Overland Flow Study (WMAwater, 2011)

In 2011 WMAwater undertook Wagga Wagga Major Overland Flow Flood Study (MOFFS) on behalf of Wagga Wagga City Council. The study focused on overland flow flooding only (and not Riverine flooding).

Due to the large size of the study area the flood behavior was presented through four as below:

- East Wagga– Marshalls and Crooked Creeks;
- Wagga North – Duke's Creek;
- City – Glenfield Drain, Silvalite Reserve, various CBD bound flow paths; and
- Lake Albert – Stringybark Creek, Crooked Creek.

2.2 Wagga Wagga Major Overland Flow Floodplain Risk Management Scoping Study Flood Study (WMAwater, 2012)

This study followed the Wagga Wagga Major Overland Flow Flood Study and provided the below recommendations prior to the Major Overland Flow Floodplain Risk Management Study (MOFFRMS&P) being undertaken:

- Model revision to include detailed structure survey;
- Tailwater sensitivity assessment was required to be examined for the City model domain;
- A critical duration assessment is required to be undertaken as part of the MOFFRMS&P.

2.3 Wagga Wagga Major Overland Flow Model Update (WMAwater, 2015)

Following the recommendations from Wagga Wagga Major Overland Flow Floodplain Risk Management Scoping Study Flood Study (2012) the flood models were updated. According to WMAwater (2015) the Key updates included the following:

- New survey was carried out and updated structure details fed into the model;
- Initial water levels for various storages (Lake Albert, Wollundry Lagoon, Flowerdale Storage Area etc.) were revised;
- Revised Areal Reduction Factors (ARFs) were applied from the 2013 ARR Revision;

- A more recent version of TUFLOW was applied (2012 versus 2009 previously used);
- 1% AEP local rainfall runs were combined with a 2Y ARI River level; and
- A variety of durations were assessed via hydrologic and hydraulic modelling to produce a suite of design results based on a peak envelope approach. The resulting flood models were used in the MOFFRMS investigation.

2.4 Wagga Wagga Major Overland Flow Floodplain Risk Management Study and Plan (WMAwater, 2021)

The main objective of the Major Overland Flow Floodplain Risk Management Study and Plan (MOFFRMS&P) was to develop flood risk mitigation strategies that address existing, future and continuing flood problems due to local catchment (not riverine) flooding in Wagga Wagga. Riverine flooding from the Murrumbidgee River was not assessed in this Study (WMAwater, 2021).

In line with other mitigation options, the study investigated the opportunity to utilise Lake Albert for improving flooding conditions under “Lake Albert Enhanced Flow Scheme”. Details of this scheme are discussed in **Section 4**.

3 Existing Flooding Conditions

The below flooding issues have been identified by MOFFRMS&P (WMAwater, 2021):

- Properties upstream (south) of Craft Street and southeast of Lake Albert, including areas around Bell Gum Place, Poplar Road, and Gregadoo Road between Olearia Place and Redbank Road are affected by flooding from Crooked Creek, and downstream reaches of Boiling Down Creek. Out of bank flow occurs in events greater than and including the 20% AEP event. Properties on the eastern side of Bell Gum Place flooded above floor in 20% AEP and 10% AEP events. Access may be restricted across Craft Street, Gregadoo Road and further south where Crooked Creek crosses Boiling Down Road;
- Residences north of Brunskill Road (downstream of Rawlings Park), including Sycamore Road, Vincent Road and adjoining streets are affected by flooding from Crooked Creek (Sycamore Drain). In the 10% AEP event and greater, Sycamore Drain overtops Brunskill Road, restricting access. Properties along Sycamore Road are inundated above floor in the 10% AEP event. In the 5% AEP event, Sycamore Road is overtopped;
- Residences along Stringybark Creek from Springvale Road to Lake Albert Road/Kooringal Road are affected by flooding from Stringybark Creek and overland flow along Plumpton Road. Over-floor inundation occurs at properties on Hakea Place adjacent to the Lake Albert diversion channel in events as frequent as the 20% AEP event. Springvale Drive is also overtopped in this event between Mallee Road and Featherwood Road.

Plots showing the existing flood behaviour around the Lake Albert study area (extracted from the 2021 MOFFRMS&P report) are provided in **Appendix A**.

4 Lake Albert Enhanced Flow Scheme

Key elements of this scheme include below (WMAwater, 2021):

- **Stage 1 (LA01):** Raise Lake Albert Road and reduce the capacity of the existing outlet structure beneath Lake Albert Road and Lakeside Drive to:

  a) Increase available airspace in Lake Albert for temporary flood storage capacity above the current water level; and

  b) Reduce the rate at which flow drains out of Lake Albert, thereby reducing peak flood levels downstream.

- **Stage 2 (LA02):** Upgrade the Crooked Creek Diversion Channel to improve conveyance of flow from Crooked Creek into Lake Albert and reduce peak flows in Crooked Creek downstream of Craft Street.

- **Stage 3 (LA03):** Upgrade the Stringybark Creek Diversion Channel to improve conveyance of flow from Stringybark Creek into Lake Albert, thereby reducing peak flows in Stringybark Creek downstream of Nelson Drive.

Figure 2 shows the current utilisation of Lake Albert for Flood Mitigation.

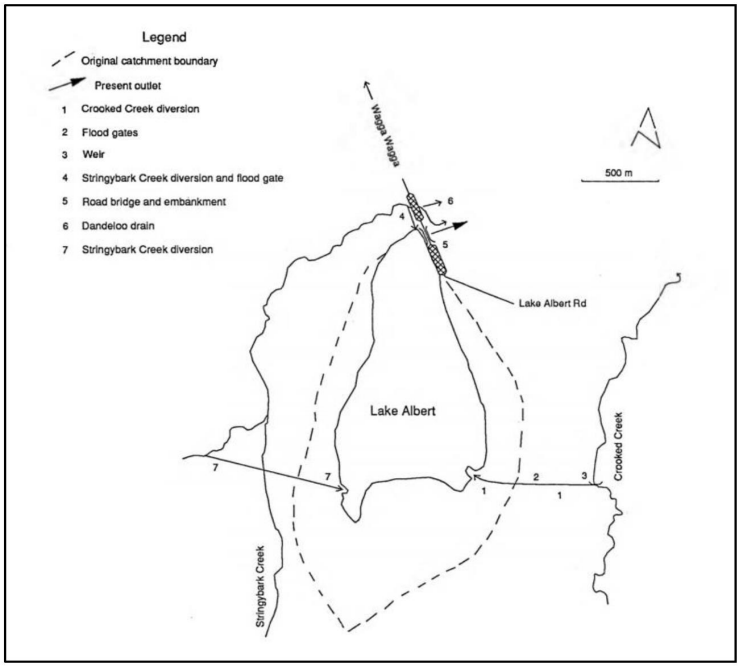


Figure 2 Utilisation of Lake Albert for Flood Mitigation (source: WMAwater 2021)

Lake Albert Feasibility Study
4 Lake Albert Enhanced Flow Scheme

The below concerns were raised by WMAWater (2021) regarding the proposed options:

LA01:

- Minor increase in surface area of Lake Albert;
- Increases flood levels by up to 0.45 m in the 1% AEP event in Lake Albert;
- Potential adverse impacts to properties at southern end of the Lake and boating infrastructure surrounding the lake;
- Lake Albert Road will require closure while works are underway.

LA02:

- Environmental factors including retention of 'low flow' through the original creek channel;
- Erosion, scouring and sedimentation concerns will need to be considered in the design of widened channels;
- Potential loss of habitat;
- Acquisition of privately owned land adjacent to the creek may be necessary depending on preferred channel width.

LA03:

- Environmental factors including retention of 'low flow' through the original creek channel;
- Erosion, scouring and sedimentation concerns will need to be considered in design of widened channels;
- Acquisition of privately owned land adjacent to the creek may be necessary depending on preferred channel width.

5 TUFLOW Model Review

Lake Albert is located within the extents of Lake Albert TUFLOW model. However, the afflux of the proposed Lake Albert Enhanced Flow Scheme extends further downstream to the extents of East TUFLOW model. Therefore, in this section both Lake Albert and East TUFLOW models have been reviewed. Both Lake Albert TUFLOW model and East TUFLOW model were reviewed as a part of this assessment.

Figure 3 shows the extents of the East and Lake Albert TUFLOW models.

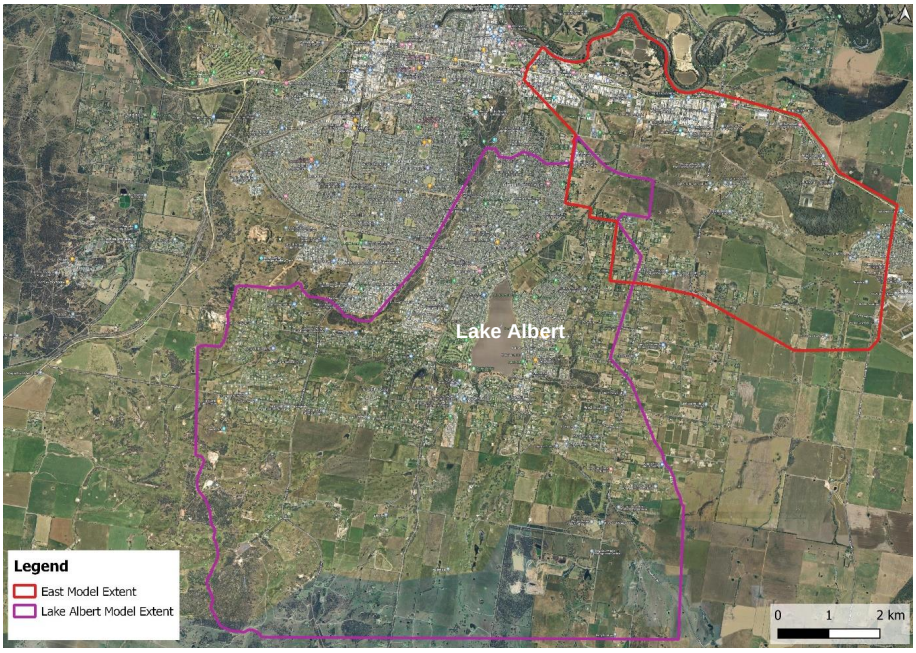


Figure 3 Extents of the "East" and "Lake Albert" TUFLOW Models

5.1 Lake Albert Model

5.1.1 MODEL RERUN

A copy of the Lake Albert TUFLOW model was provided to Stantec by Council. The model was re-run for the following scenarios and events:

- Present Day - 1% Annual Exceedance Probability (AEP) – 2hr Event

- Option LA01 - 1% AEP – 2hr Event
- Option LA02 - 1% AEP – 2hr Event
- Option LA03 - 1% AEP – 2hr Event
- Option Ultimate (LA01 + LA02 + LA03) - 1% AEP – 2hr Event

All five re-run models noted above were able to be simulated completely and were generally stable with no negative depth warning.

The results from the Present Day scenario were compared with the results provided by Council and it was confirmed to be matching. Results from other scenarios were not provided to Stantec so couldn't be compared.

5.1.2 GEOMETRY

5.1.2.1 Model Extents

The model extent covers an area of approximately 69 km^2 and includes the areas of interest including Lake Albert, downstream and upstream areas.

The model extends about 2.7 km downstream of Lake Albert and this provides certainty that the flood model results within the areas of interest are not affected by the boundary conditions.

5.1.2.2 Model Topography

5.1.2.2.1 Source of Topography Data

Lake Albert model adopts the topography data from the Aerial Laser Survey (ALS) also known as LIDAR for the wider Murrumbidgee River floodplain in obtained in 2009. This data is now considered outdated and it is recommended to be updated with the latest available ALS data. It is not clear if the topography of the Lake itself has been sourced from Lidar data or bathymetry survey data. If the source of the Lake topography data is Lidar data, it is recommended that the Lake Bathymetry data being obtained and adopted in the model.

Stantec obtained Lidar 2022 from the Elevation and Depth - Foundation Spatial Data (ELVIS) website (Elvis (fsdf.org.au)). A difference plot comparing the latest LIDAR (2022) with the 2009 Lidar is presented in **Appendix B**. An extract for the area around Lake Albert and the two creeks is shown in **Figure 4**.

Typically across most of the study area differences are within the expected accuracy of LiDAR to one standard deviation, + / - 0.15 meters.

The 2022 data shows lower levels (blue areas) in the two diversion channels suggesting either erosion has occurred over time in those channel resulting in their widening or lowering, or the accuracy and detail of the definition of the channels has improved. To the north-east a development site, shown by the large blue area) has been developed since 2009 resulting in significant changes in terrain levels for that site. For Lake Albert there are lower levels in the 2022 data, with varying

differences across the waterbody. Overall, there are sufficient changes in terrain in some key locations to consider updating the base LiDAR used in the model.

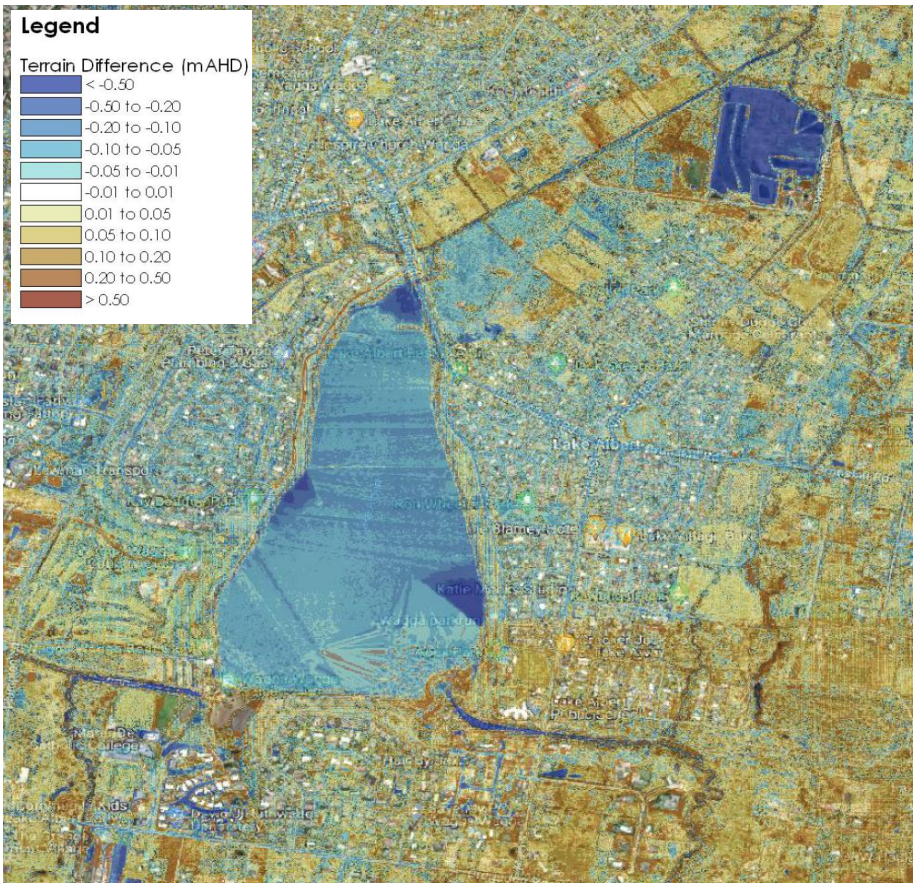


Figure 4 LiDAR Terrain Differences – 2022 Data Less 2009 Data Adopted in the TUFLOW Model

5.1.2.2.2 Cell Size

Lake Albert TUFLOW model adopts a 5m x 5m cell size, resulting in calculation points spaced every 2.5 metres (as TUFLOW calculates at mid-points and corners of the cells). It is recommended to update the model to a finer cell size (3m x 3m or 2m x 2m) to provide a more accurate presentation of the flood behaviour.

5.1.2.3 Presentation of Buildings

Buildings have been modelled as blockages to the flow by nulling the related cells out of the model. High level review of the blocked buildings layer from the model compared to aerial photography suggests the buildings layer is not generally appropriate. There are missing buildings within the 1% AEP and PMF flood extents around the Lake. It is recommended that these missing buildings being added to the model.

5.1.2.4 Presentation of Waterways

The main waterways within the model extents including Stringybark Creek and Crooked Creek are modelled as 2D elements. However, the diversion channels from both Stringybark Creek and Crooked Creek to Lake Albert are modelled as 1D elements.

1D channel elements in TUFLOW often create instabilities and other potential model issues at the 1D / 2D boundary, though in this case it does not appear that these 1D channels have caused any significant model issues. Therefore modelling the diversion channels as 1D elements was evidently considered suitable for the purpose of the FRMSP. However, since Lake Albert Enhanced Flow Scheme includes improving the conveyance of the diversion channels, it is recommended to model these channels as 2D elements for the feasibility assessment to provide a more accurate presentation of the proposed channel upgrades in the model.

It is also recommended that presenting the diversion channels as 2D elements being undertaken along with changing the model cell size from 5m x 5m to a finer cell size (3m x 3m or 2m x 2m) to assure the existing and enhanced conveyance of the channels are estimated with appropriate accuracy.

5.1.3 ROUGHNESS

Figure 5 shows the land use types adopted for the Lake Albert model extents. The roughness values adopted for each of the land use types are presented in **Table 1.**

The majority of study area is modelled as Pasture with roughness value of 0.045. This includes some areas of dense or semi-dense vegetation and rural lots, which need to be modelled with a higher roughness value. Stantec recommends updating the roughness values at least within the PMF extents (if not for the whole study area).

Table 1 Lake Albert Model Roughness values

Land Use Type	Roughness Value
Pasture	0.045
Lots	0.060
Water Bodies	0.030
Roads	0.022
Creek Permanent Water	0.040
Vegetation	0.100

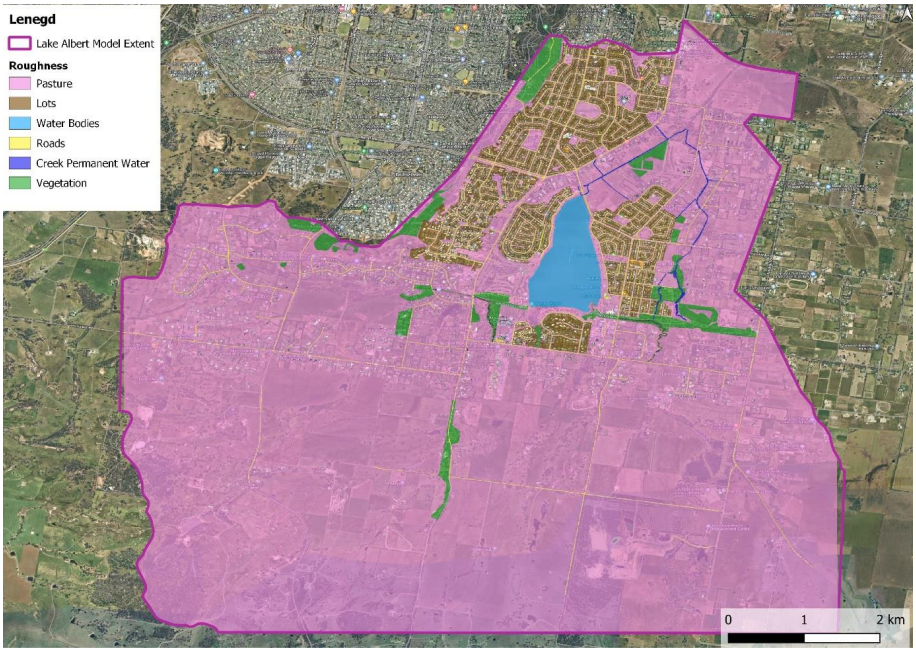


Figure 5 Adopted Land Use Types for Lake Albert Model

5.1.4 INFLOWS

Inflow hydrographs have been adopted from the WBNM hydrology model outputs and are applied into the TUFLOW model using 2d_sa polygons.

Stantec has not reviewed the WBNM model set up or parameters, and therefore cannot comment on suitability of adopted inflows. The assumption is that the Council adopted hydrology model is suitable.

5.1.5 DOWNSTREAM BOUNDARY CONDITIONS

Review of the model boundary conditions shows that static tailwater level has been adopted in the Lake Albert model.

Wagga Wagga Major Overland Flow Study (WMAwater, 2011) indicates:

"The downstream boundary, for most model domains (Lake Albert excluded) is the Murrumbidgee River and this has been incorporated into the modelling as an adjustable water level which can be sloped as required. For all design runs a 2Y ARI flood level has been used for the Murrumbidgee River."

While the report doesn't mention source of the adopted tailwater level for the Lake Albert model, from a review of the model run batch files it seems Murrumbidgee River 2Y ARI flood levels have been adopted.

Wagga Wagga Major Overland Flow Model Update (WMAwater, 2015) discussed the suitability of the adopted Murrumbidgee River 2Y ARI flood levels and assessed the sensitivity of flood levels to the elevated Murrumbidgee River flood levels. The outcomes generally showed sensitivity to the adopted tailwater levels and concluded further investigation is required. However, the Lake Albert study area was not found sensitive to adopted tailwater levels. Therefore, no further investigations are deemed necessary for the purpose of this study.

5.1.6 1D ELEMENTS

The drainage network is included in the Lake Albert model. Stantec reviewed the drainage network in the model, below is a summary of findings:

- Appropriate number of cells is adopted for connecting 1D elements to the 2D domain;
- Suitable entry and exist losses are adopted for the drainage network;
- Width and height contraction factors for majority of the pipes are acceptable. However, a number of "R" type pipes have height contraction factor equal to "0". It is recommended to update these factors to "0.6". This includes (but not limited to) the outlet culverts of Lake Albert;
- While a detailed review of pipe and pit inverts and snapping was not undertaken, the pipe capacity plots for the 1%AEP events were reviewed which shows the majority of downstream pipes are fully functioning. This indicates that the network's overall setup and functioning is ok. Considering that the drainage network is mostly located downstream of Lake Albert it is not expected that details of the drainage network will affect the outcomes of the feasibility assessment.

As previously noted, the two diversion channels on the upstream side of Lake Albert have both been modelled as 1D channel elements, while on the downstream end of Lake Albert, the two outlets have also both been modelled as 1D elements with the following dimensions:

- 2 x 1500mm Circular Culvert
- 5 x 2960mm x 920mm Box Culverts.

5.1.7 BRIDGES

There are a number of bridges in the model including the structures within Lake Albert are modelled as 2D layered Flow Constriction.

Stantec did not have access to the drawings or survey data for the bridges and therefore cannot comment on the accuracy of the adopted loss and blockage factors for the bridges.

It is recommended that the accuracy of the modelling assumptions for the Lake Albert structures being assessed based on available data and drawings (including survey data).

5.1.8 OPTION MODEL REVIEW

5.1.8.1 Stage 1 (LA01)

This option is modelled through:

- Raising the lake weir outlet by 1m-2m by using "2d_zsh" elements, or line geometry files that alter the two-dimensional terrain of the model (**Figure 6**). The adopted method is considered acceptable for the option development stage. It is recommended that in the detailed design stage, the proposed weir upgrade being modelled through including the weir surface Triangulated Irregular Network (TIN) rather than using "2d_zsh" elements;
- Reduce the capacity of the existing outlet structure beneath Lake Albert Road and Lakeside Drive through halving the number of structures (**Figure 6**). The outlets will be reduced as below for the east and west outlets:
  - 2 x 1500mm Circular Culvert reduced to 1 x 1500mm Circular Culvert
  - 5 x 2960mm x 920mm Box Culverts reduced to 3 x 2960mm x 920mm Box Culverts.

5.1.8.2 Stage 2 (LA02)

This option is modelled through:

- Stage 1 (LA01) elements;
- Creating a 1m height levee adjacent to the Crooked Creek Diversion Channel using "2d_zsh" elements. The adopted method is considered acceptable for the option development stage. It is recommended that in the detailed design stage, the proposed levee being modelled through including the design TIN surface rather than using "2d_zsh" elements;
- Upgrade some parts of the Crooked Creek Diversion Channel through widening the channel (approximately 50% increase in the channel width) (**Figure 6**).

5.1.8.3 Stage 3 (LA03)

This option is modelled through:

- Stage 1 (LA01) elements;
- Creating a 1m height levee along Nelson Drive using "2d_zsh" elements. The adopted method is considered acceptable for the option development stage. It is recommended that in the detailed design stage, the proposed levee being modelled through including the design TIN surface rather than using "2d_zsh" elements;
- Upgrade some parts of the Stringybark Creek Diversion Channel through widening the channel (approximately 50% increase in the channel width) (**Figure 6**).

Figure 6 Options Details

5.1.8.4 Ultimate Scenario

This scenario had been modelled through combining the Stage 1 to Stage 3 option elements in one model run to show the ultimate outcome of the Lake Albert Enhanced Flow Scheme.

5.2 East Model

5.2.1 MODEL RERUN

The East TUFLOW model provided to Stantec was re-run for the following scenarios and events and the results generated by WMAwater (2021) were successfully replicated:

- Present Day - 1% Annual Exceedance Probability (AEP) – 2hr Event
- Option LA01 - 1% AEP – 2hr Event
- Option LA02 - 1% AEP – 2hr Event
- Option LA03 - 1% AEP – 2hr Event

All four re-run models noted above were able to be simulated completely and were generally stable with no negative depth warning.

The results from LA01, LA02 and la03 scenarios were compared with the results provided by Council (generated by WMAwater (2021)) and were confirmed to be matching. Results from the Present Day scenario were not provided to Stantec so couldn't be compared.

5.2.2 GEOMETRY

5.2.2.1 Model Extents

The model extent covers an area of approximately 26 km^2 and covers East wagga Wagga and Gumly Gumly areas.

The model extends about 4.9 km downstream of are of interest and this provides certainty that the flood model results within the areas of interest are not affected by the boundary conditions.

5.2.2.2 Model Topography

5.2.2.2.1 Source of Topography Data

East model adopts the topography data from the LIDAR for the wider Murrumbidgee River floodplain in obtained in 2009. This data is now considered outdated and it is recommended to be updated with the latest available ALS data.

Stantec obtained Lidar 2022 from the Elevation and Depth - Foundation Spatial Data (ELVIS) website (Elvis_(fsdf.org.au)). The difference plot comparing the latest LIDAR (2022) with the 2009 Lidar is presented in **Appendix B**.

5.2.2.2.2 Cell Size

The East TUFLOW model adopts a 5m x 5m cell size. It is recommended to update the model to a finer cell size (3m x 3m or 2m x 2m) to provide a more accurate presentation of the flood behaviour.

5.2.2.3 Presentation of Buildings

Buildings have been modelled as blockages to the flow by nulling the related cells out of the model. High level review of the blocked buildings layer from the model compared to aerial photography suggests the buildings layer is not generally appropriate. There are missing buildings within the 1% AEP and PMF flood extents downstream of the Lake. It is recommended that these missing buildings being added to the model.

5.2.2.4 Presentation of Waterways

The waterways within the model extents including Marshalls Creek and overland flowpaths are modelled as 2D elements. Considering the width of the creek this assumption seems reasonable. However, upgrading the model to a finer cell size can provide a better presentation of Marshalls Creek's flood behaviour.

5.2.3 ROUGHNESS

Figure 7 shows the land use types adopted for the East model extents. The roughness values adopted for each of the land use types are presented in **Table 2**.

The majority of study area is modelled as Pasture with roughness value of 0.045. This includes some areas of semi-dense vegetation and rural lots, which need to be modelled with a higher roughness value. Stantec recommends updating the roughness values at least within the PMF extents (if not for the whole study area).

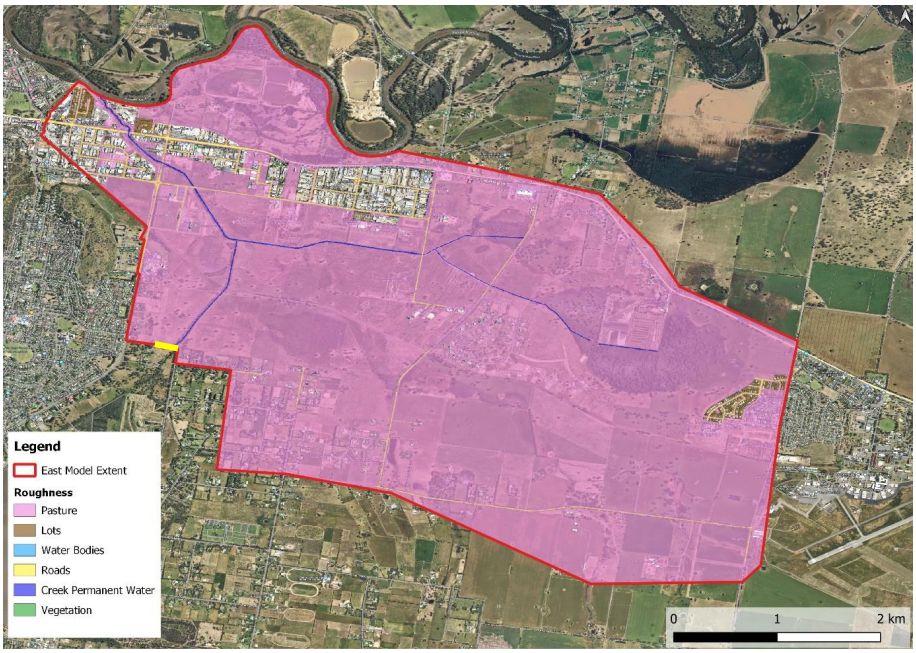


Figure 7 Adopted Land Use Types for East Model

Table 2 East Model Roughness values

Land Use Type	Roughness Value
Pasture	0.045
Lots	0.060
Water Bodies	0.030
Roads	0.022

5.2.4 INFLOWS

Inflow hydrographs have generally been adopted from the WBNM hydrology model outputs and are applied into the TUFLOW model using 2d_sa polygons. Inflows from Lake Albert model have been applied as QT boundaries. The approximate location of the inflow boundary from the Lake Albert model has been shown in yellow in **Figure 7**. The modelling approach is to extract from PO hydrograph results from the Lake Albert TUFLOW model and insert them as inflows into the East model at this location.

Stantec has not reviewed the WBNM model set up or parameters, and therefore cannot comment on suitability of adopted hydrology.

5.2.5 DOWNSTREAM BOUNDARY CONDITIONS

Review of the model boundary conditions shows that Static tailwater level has been adopted in the Lake Albert model. Wagga Wagga Major Overland Flow Study (WMAwater, 2011) indicates:

"The downstream boundary, for most model domains (Lake Albert excluded) is the Murrumbidgee River and this has been incorporated into the modelling as an adjustable water level which can be sloped as required. For all design runs a 2Y ARI flood level has been used for the Murrumbidgee River."

Wagga Wagga Major Overland Flow Model Update (WMAwater, 2015) discussed the suitability of the adopted Murrumbidgee River 2Y ARI flood levels and assessed the sensitivity of flood levels to the elevated Murrumbidgee River flood levels. The outcomes generally showed sensitivity to the adopted tailwater levels and concluded further investigation is required. However, the East model study area was not found sensitive to adopted tailwater levels. Therefore, no further investigations are deemed necessary for the purpose of this study.

5.2.6 1D ELEMENTS

The drainage network is included in the Lake Albert model. Stantec reviewed the drainage network in the model, below is a summary of findings:

- Appropriate number of cells is adopted for connecting 1D elements to the 2D domain;
- Suitable entry and exist losses are adopted for the drainage network;

- Width and height contraction factors for the pipes are acceptable

5.2.7 BRIDGES

There are a number of bridges in the model which are modelled as 2D layered Flow Constriction.

Stantec did not have access to the drawings or survey data for the bridges and therefore cannot comment on the accuracy of the adopted loss and blockage factors for the bridges.

5.2.8 OPTION MODEL REVIEW

The proposed Options including Stage 1 (LA01), Stage 2 (LA02) and Stage 3 (LA03) are not within the East model extents. Therefore, the impacts of these options have been presented in the East model through applying the resultant upstream flows into the model (as QT boundaries).

This approach is considered acceptable, however extra care needs to be taken to ensure the inflows are updated in case any changes are applied to the Lake Albert model.

5.3 Lake Albert and East Model review Summary and Recommendations

Stantec reviewed the suitability of the current Lake Albert and East TUFLOW models from Wagga Wagga Major Overland Flow Floodplain Risk Management Study and Plan (WMAwater, 2021) for the purpose of Lake Albert feasibility assessment.

In general, the modelling parameters and assumptions were found suitable for the purpose of the feasibility assessment, however Stantec would like to recommend a few considerations for Council's review. These recommendations are listed in **Table 3**.

Lake Albert Feasibility Study
5 TUFLOW Model Review

Table 3 Traffic Light Review of Lake Albert and East Models

Description of Issue	Model	Potential Significance	Recommended Action
Tuflow Engine	Lake Albert / East	Moderate	The models are being run with the 2018 Tuflow engine. It bis recommended to test running the models with a recent Tuflow engine and if the difference in results are negligible, the recent Tuflow engine being adopted for future runs.
Outdated Lidar Data	Lake Albert / East	Major	Updating model with latest Lidar Data
Model Cell Size (5m) is slightly coarse	Lake Albert / East	Major	Updating the model with a finer cell size
Presentation of Buildings in the model	Lake Albert / East	Moderate	There are missing buildings around and downstream of the lake, it is recommended that the buildings within the PMF extents being added to the model.
Lake Albert Topography	Lake Albert	Major	It is not clear what the source of Lake Alert topography data is. This needs to be confirmed with Council. If the source is Lidar data, it is recommended that bathymetry data being obtained and adopted in the model.
Stringybark Creek and Crooked Creek diversion channels are currently modelled as 1D elements.	Lake Albert	Major	Modelling Stringybark Creek and Crooked Creek diversion channels as 2D elements to assure the existing and enhanced conveyance of the channels are estimated with appropriate accuracy. The change needs to be undertaken along with changing the model cell size from 5m x 5m to a finer cell size.
The majority of study area is modelled as Pasture with roughness value of 0.045. This includes some areas of dense or semi-dense vegetation and rural lots	Lake Albert / East	Moderate	Updating the roughness values at least within the PMF extents (if not for the whole study area).

Lake Albert Feasibility Study
5 TUFLOW Model Review

Description of Issue	Model	Potential Significance	Recommended Action
A number of R type pipes have height contraction factor equal to “0”.	Lake Albert	Moderate	It is recommended to update these factors to “0.6”. This includes (but not limited to) the outlet culverts of Lake Albert
Accuracy of Modelling assumptions for Lake Albert Outlet Structures	Lake Albert	Moderate	It is recommended that the accuracy of the modelling assumptions for the Lake Albert structures being assessed based on available data and drawings (including survey data).
Presentation of proposed weir and levees in the model	Lake Albert	Major	In the current model setup the proposed weir and levees are modelled by using “2d_zsh” elements. It is recommended that in the design stage, the proposed weir upgrade and levees being modelled through including the proposed TIN surface rather than using “2d_zsh” elements.

6 Outcomes of the Enhanced Flow Scheme

MOFFRMS&P (WMAwater, 2021) indicates that the proposed scheme has been tested for a range of events including 20% AEP, 10% AEP, 5% AEP, 2% AEP, 1% AEP, 0.5% AEP, 0.2% AEP and PMF events and the results showed the number of flood affected properties will be reduced in all events, as a result of the proposed scheme (See **Table 4**).

Table 4 Ultimate Property Affectation (Source: WMAwater (2021))

Event	Properties Affected (externally)			Properties Flooded Over Floor		
	Current	Option (Ultimate)	Change	Current	Option (Ultimate)	Change
20% AEP	1707	1703	-4	45	46	1
10% AEP	1956	1914	-42	76	68	-8
5% AEP	2171	2061	-110	111	96	-15
2% AEP	2470	2350	-120	275	206	-69
1% AEP	2640	2505	-135	348	287	-61
0.5% AEP	2768	2662	-106	395	344	-51
0.2% AEP	2887	2781	-106	448	410	-38
PMF	3944	3924	-20	744	733	-11

Figures showing the Difference from the Ultimate Scenario flood levels for the 5% AEP and 1% AEP events compared to Present day flood levels are shown in **Appendix C** (Source: WMAwater (2021)).

7 Data Gap

Stantec could not find any indication (in the reports or flood model) that the survey data is included in the TUFLOW model. This needs to be confirmed by Council.

Stantec recommends the below survey data to be obtained and included in the model (if not already):

- Survey of Lake Albert Road;
- Lake Albert Bathymetry data;
- Survey of Crooked Creek Diversion Channel and surrounding areas;
- Survey of Stringybark Creek Diversion Channel, Nelson Drive and surrounding areas.

8 Conclusion and Recommendations

Stantec undertook a detailed review of the existing hydraulic (TUFLOW) models and associating data and provided a number of recommendations for the models upgrade:

- Testing the possibility of adopting a recent Tuflow engine rather than the 2018 enf=gine currently being used by the models (Moderate issue);
- Updating model with latest Lidar data (Major issue);
- Updating the model with a finer cell size (Major issue);
- Missing buildings within the PMF flood extents (around and downstream of the Lake) to be added to the model (Moderate issue);
- Modelling Stringybark Creek and Crooked Creek diversion channels as 2D elements to assure the existing and enhanced conveyance of the channels are estimated with appropriate accuracy. The change needs to be undertaken along with changing the model cell size from 5m x 5m to a finer cell size (Major issue);
- Updating the roughness values at least within the PMF extents (if not for the whole study area) (Moderate issue);
- A number of R type pipes have height contraction factor equal to “0”. It is recommended to update these factors to “0.6”. This includes (but not limited to) the outlet culverts of Lake Albert (Moderate issue);
- It is recommended that the accuracy of the modelling assumptions for the Lake Albert structures being assessed based on available data and drawings (including survey data) (Moderate issue);
- In the current model setup the proposed weir and levees are modelled by using “2d_zsh” elements. It is recommended that in the design stage, the proposed weir upgrade and levees being modelled through including the proposed TIN surface rather than using “2d_zsh” elements(Major issue).

Stantec also recommends the below survey data to be obtained and included in the model (if not already):

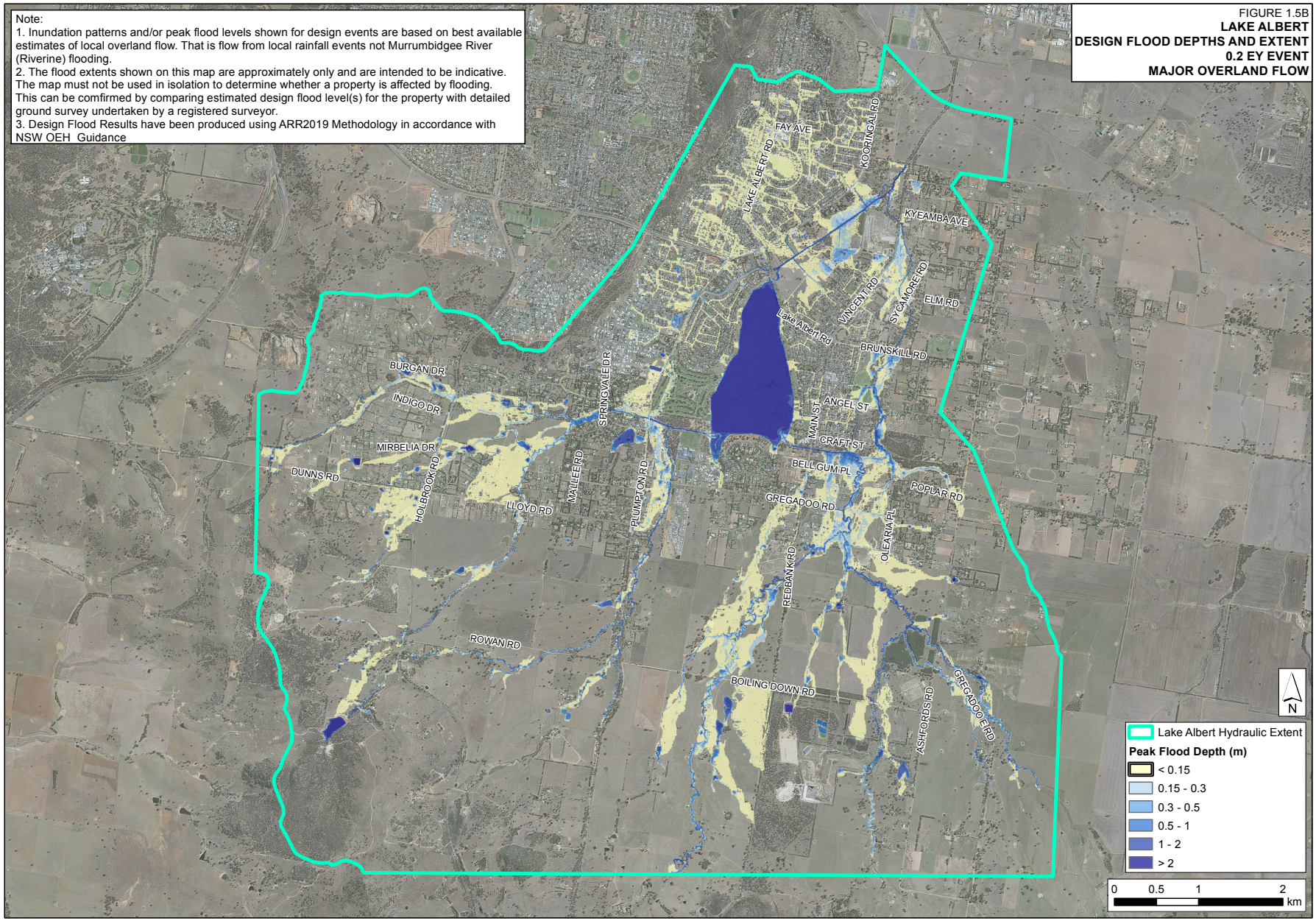
- Survey of Lake Albert Road;
- Lake Albert Bathymetry data;
- Survey of Crooked Creek Diversion Channel and surrounding areas;
- Survey of Stringybark Creek Diversion Channel, Nelson Drive and surrounding areas.

Lake Albert Feasibility Study

APPENDICES

Project Number: 300203943

Appendix A - Existing Flood Behaviour


Note:
1. Inundation patterns and/or peak flood levels shown for design events are based on best available estimates of local overland flow. That is flow from local rainfall events not Murrumbidgee River (Riverine) flooding.
2. The flood extents shown on this map are approximately only and are intended to be indicative. The map must not be used in isolation to determine whether a property is affected by flooding. This can be comfirmed by comparing estimated design flood level(s) for the property with detailed ground survey undertaken by a registered surveyor.
3. Design Flood Results have been produced using ARR2019 Methodology in accordance with NSW OEH Guidance
FIGURE 1.5B
LAKE ALBERT
DESIGN FLOOD DEPTHS AND EXTENT
0.2 EY EVENT
MAJOR OVERLAND FLOW
FAY AVE
KOORINGAL RD
LAKE ALBERT RD
KYEAMBA AVE
SYCAMORE RD
VINCENT RD
ELM RD
Lake Albert Rd
BRUNSKILL RD
BURGAN DR
INDIGO DR
SPRINGVALE DR
MAIN ST
ANGEL ST
CRAFT ST
MIRBELIA DR
DUNNS RD
HOLBROOK RD
MALLEE RD
PLUMPTON RD
BELL GUM PL
POPLAR RD
GREGADOO RD
LLOYD RD
OLEARIA PL
REDBANK RD
ROWAN RD
BOILING DOWN RD
ASHFORDS RD
GREGADOO E RD
N
Lake Albert Hydraulic Extent
Peak Flood Depth (m)
< 0.15
0.15 - 0.3
0.3 - 0.5
0.5 - 1
1 - 2
> 2
0 0.5 1 2
km

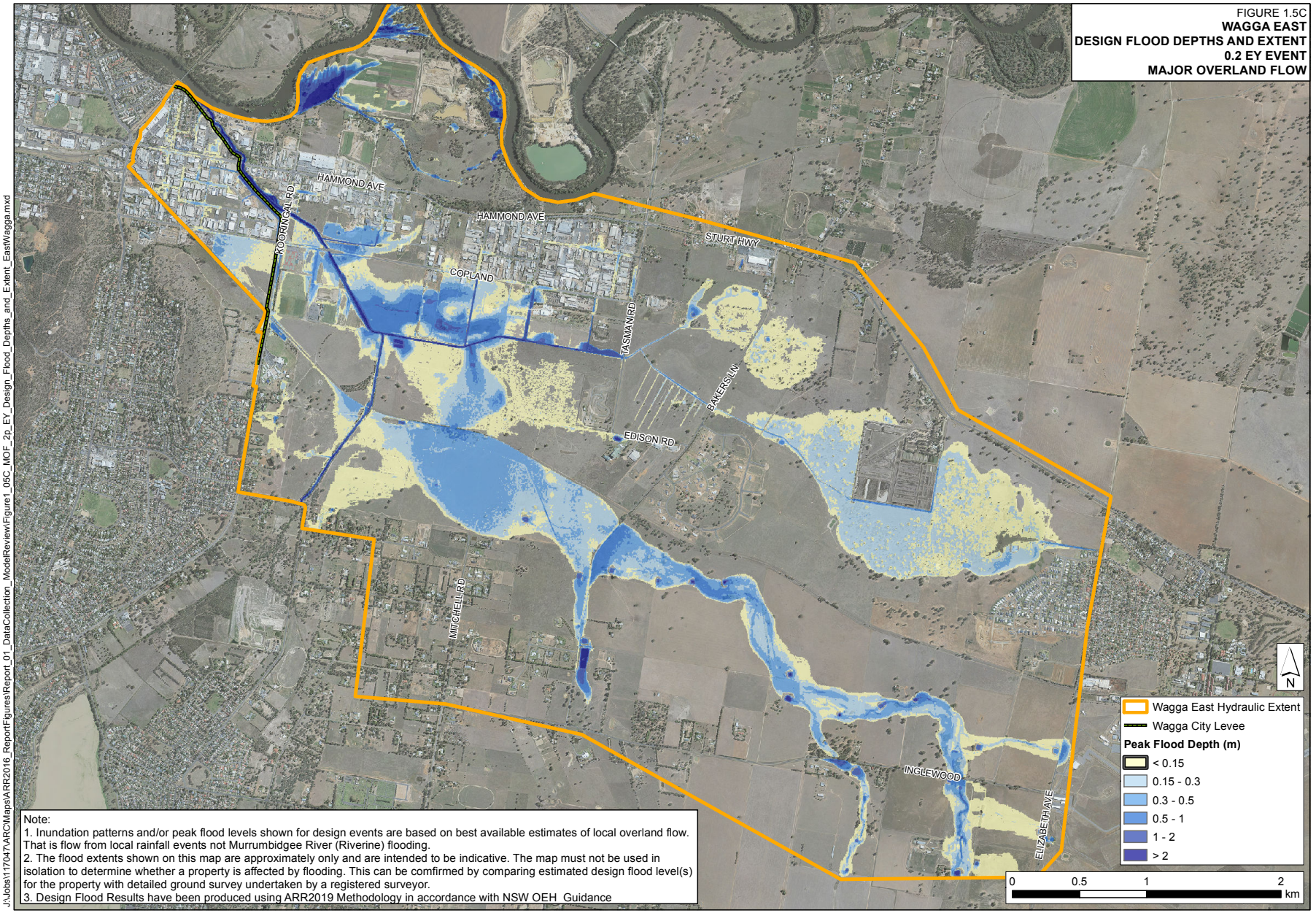
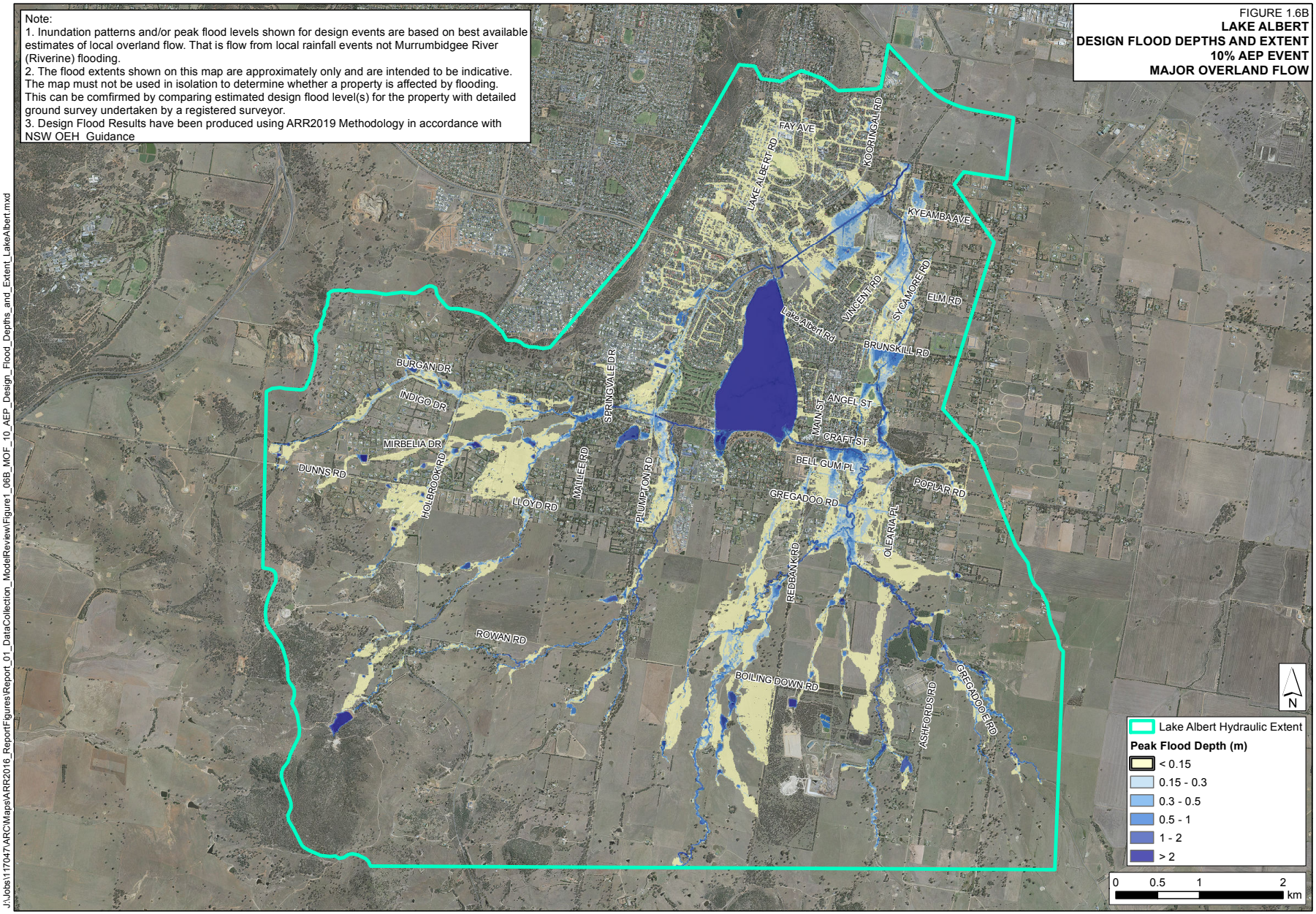


FIGURE 1.5C
WAGGA EAST
DESIGN FLOOD DEPTHS AND EXTENT
0.2 EY EVENT
MAJOR OVERLAND FLOW
HAMMOND AVE
HAMMOND AVE
KOORINGAL RD
COPLAND
STURT HWY
TASMAN RD
BAKERS LN
EDISON RD
MITCHELL RD
INGLEWOOD
ELIZABETH AVE
N
Wagga East Hydraulic Extent
Wagga City Levee
Peak Flood Depth (m)
< 0.15
0.15 - 0.3
0.3 - 0.5
0.5 - 1
1 - 2
> 2
0
0.5
1
2
km
Note:
1. Inundation patterns and/or peak flood levels shown for design events are based on best available estimates of local overland flow. That is flow from local rainfall events not Murrumbidgee River (Riverine) flooding.
2. The flood extents shown on this map are approximately only and are intended to be indicative. The map must not be used in isolation to determine whether a property is affected by flooding. This can be comfirmed by comparing estimated design flood level(s) for the property with detailed ground survey undertaken by a registered surveyor.
3. Design Flood Results have been produced using ARR2019 Methodology in accordance with NSW OEH Guidance
J:\Jobs\117047\ARC\Maps\ARR2016_ReportFigures\Report_01_DataCollection_ModelReview\Figure1_05C_MOF_2p_EY_Design_Flood_Depths_and_Extent_EastWagga.mxd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1. Inundation patterns and/or peak flood levels shown for design events are based on best available estimates of local overland flow. That is flow from local rainfall events not Murrumbidgee River (Riverine) flooding.
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FIGURE 1.6B
LAKE ALBERT
DESIGN FLOOD DEPTHS AND EXTENT
10% AEP EVENT
MAJOR OVERLAND FLOW
FAY AVE
KOORINGAL RD
LAKE ALBERT RD
KYEAMBA AVE
SYCAMORE RD
VINCENT RD
ELM RD
Lake Albert Rd
BRUNSKILL RD
BURGAN DR
INDIGO DR
SPRINGVALE DR
MAIN ST
ANGEL ST
CRAFT ST
MIRBELIA DR
DUNNS RD
HOLBROOK RD
MALLEE RD
PLUMPTON RD
BELL GUM PL
POPLAR RD
LLOYD RD
GREGADOO RD
OLEARIA PL
REDBANK RD
ROWAN RD
BOILING DOWN RD
ASHFORDS RD
GREGADOO E RD
N
Lake Albert Hydraulic Extent
Peak Flood Depth (m)
< 0.15
0.15 - 0.3
0.3 - 0.5
0.5 - 1
1 - 2
> 2
0 0.5 1 2
km
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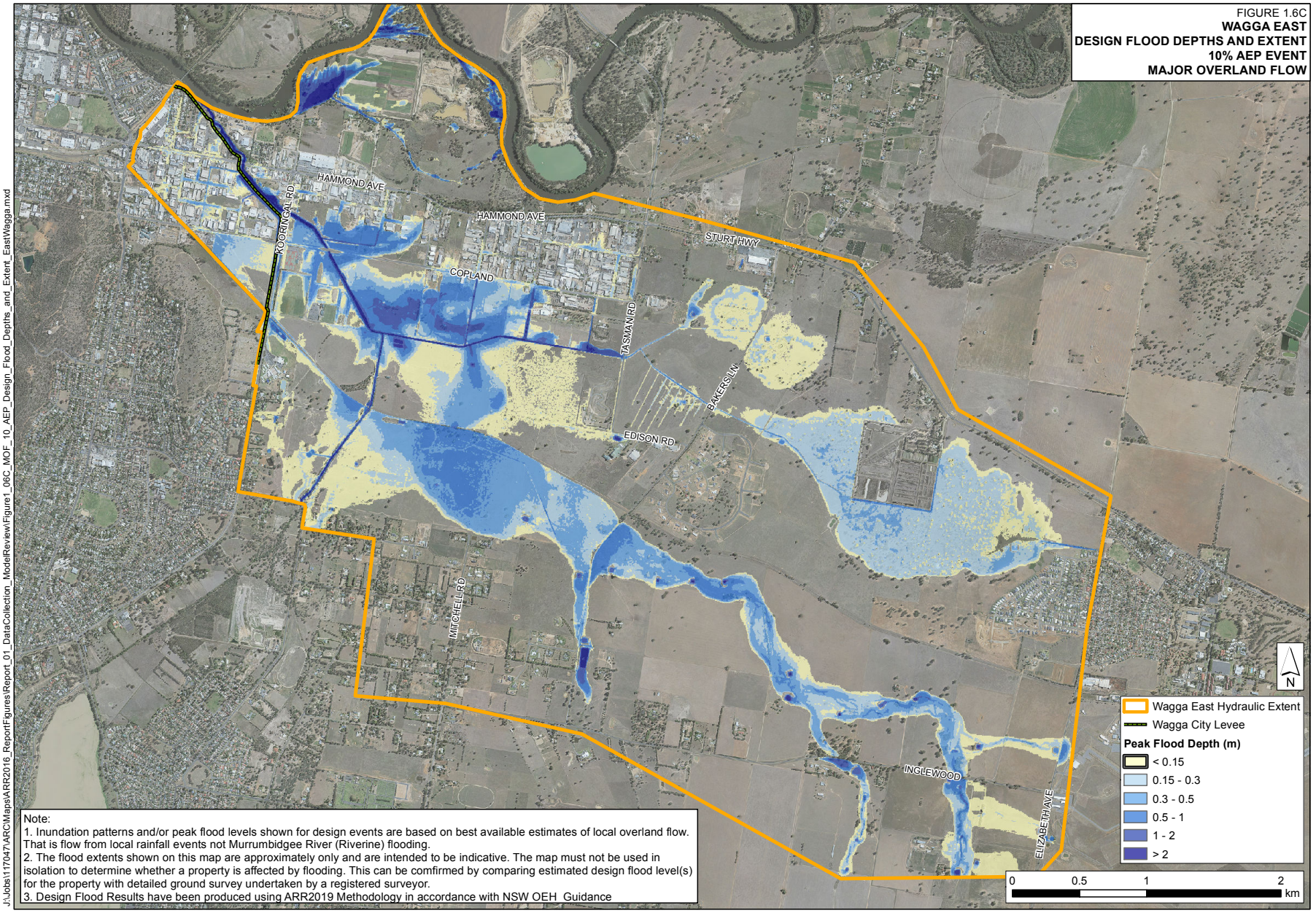
FIGURE 1.6C
WAGGA EAST
DESIGN FLOOD DEPTHS AND EXTENT
10% AEP EVENT
MAJOR OVERLAND FLOW
HAMMOND AVE
HAMMOND AVE
KOORINGAL RD
COPLAND
STURT HWY
TASMAN RD
BAKERS LN
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MITCHELL RD
INGLEWOOD
ELIZABETH AVE
N
Wagga East Hydraulic Extent
Wagga City Levee
Peak Flood Depth (m)
< 0.15
0.15 - 0.3
0.3 - 0.5
0.5 - 1
1 - 2
> 2
0
0.5
1
2
km
Note:
1. Inundation patterns and/or peak flood levels shown for design events are based on best available estimates of local overland flow. That is flow from local rainfall events not Murrumbidgee River (Riverine) flooding.
2. The flood extents shown on this map are approximately only and are intended to be indicative. The map must not be used in isolation to determine whether a property is affected by flooding. This can be comfirmed by comparing estimated design flood level(s) for the property with detailed ground survey undertaken by a registered surveyor.
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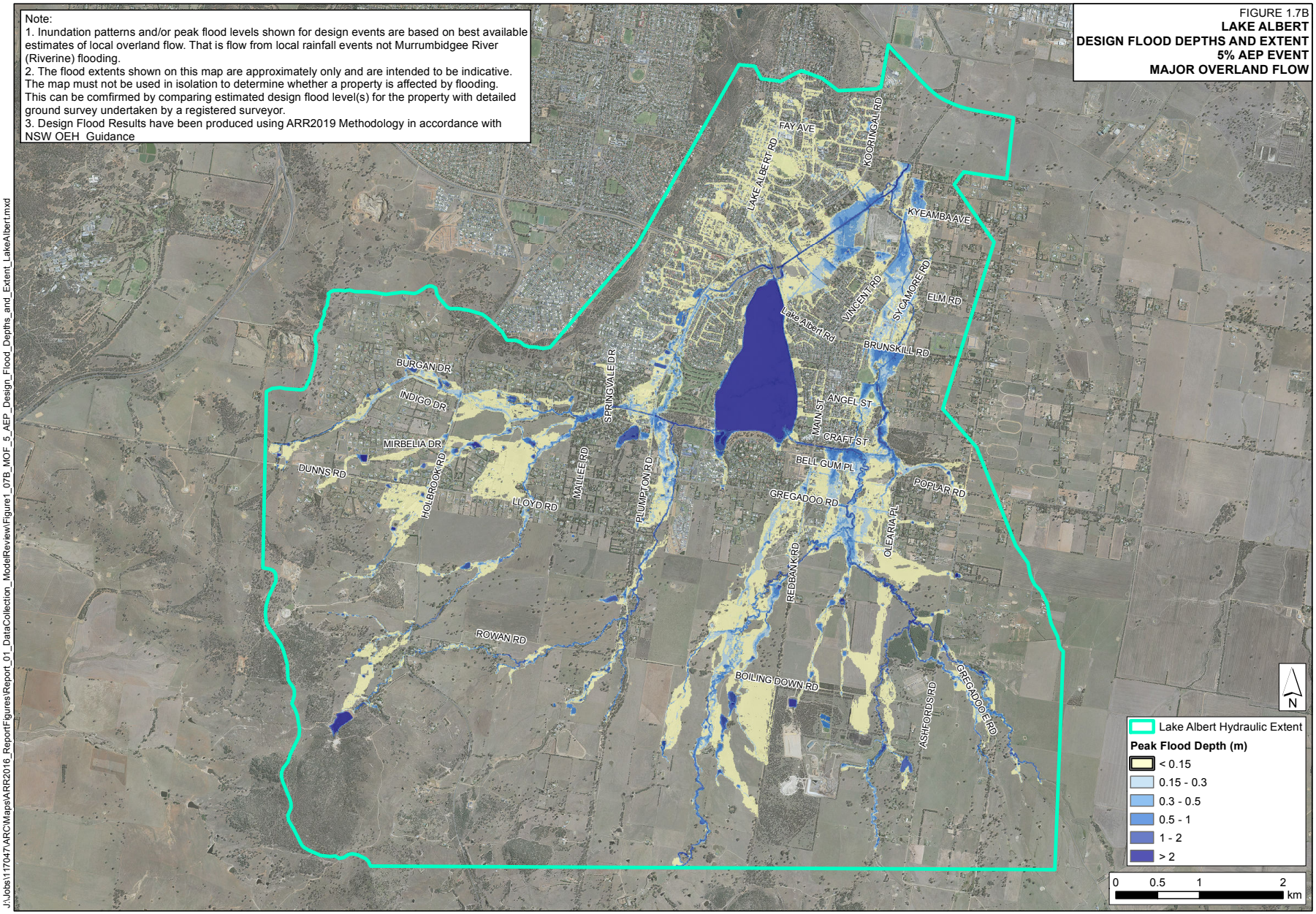
J:\Jobs\117047\ARC\Maps\ARR2016_ReportFigures\Report_01_DataCollection_ModelReview\Figure1_06C_MOF_10_AEP_Design_Flood_Depths_and_Extent_EastWagga.mxd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1. Inundation patterns and/or peak flood levels shown for design events are based on best available estimates of local overland flow. That is flow from local rainfall events not Murrumbidgee River (Riverine) flooding.
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3. Design Flood Results have been produced using ARR2019 Methodology in accordance with NSW OEH Guidance
FIGURE 1.7B
LAKE ALBERT
DESIGN FLOOD DEPTHS AND EXTENT
5% AEP EVENT
MAJOR OVERLAND FLOW
FAY AVE
KOORINGAL RD
LAKE ALBERT RD
KYEAMBA AVE
SYCAMORE RD
ELM RD
VINCENT RD
Lake Albert Rd
BRUNSKILL RD
BURGAN DR
INDIGO DR
SPRINGVALE DR
MAIN ST
ANGEL ST
CRAFT ST
MIRBELIA DR
DUNNS RD
HOLBROOK RD
MALLEE RD
PLUMPTON RD
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POPLAR RD
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REDBANK RD
ROWAN RD
BOILING DOWN RD
ASHFORDS RD
GREGADOO E RD
N
Lake Albert Hydraulic Extent
Peak Flood Depth (m)
< 0.15
0.15 - 0.3
0.3 - 0.5
0.5 - 1
1 - 2
> 2
0 0.5 1 2
km
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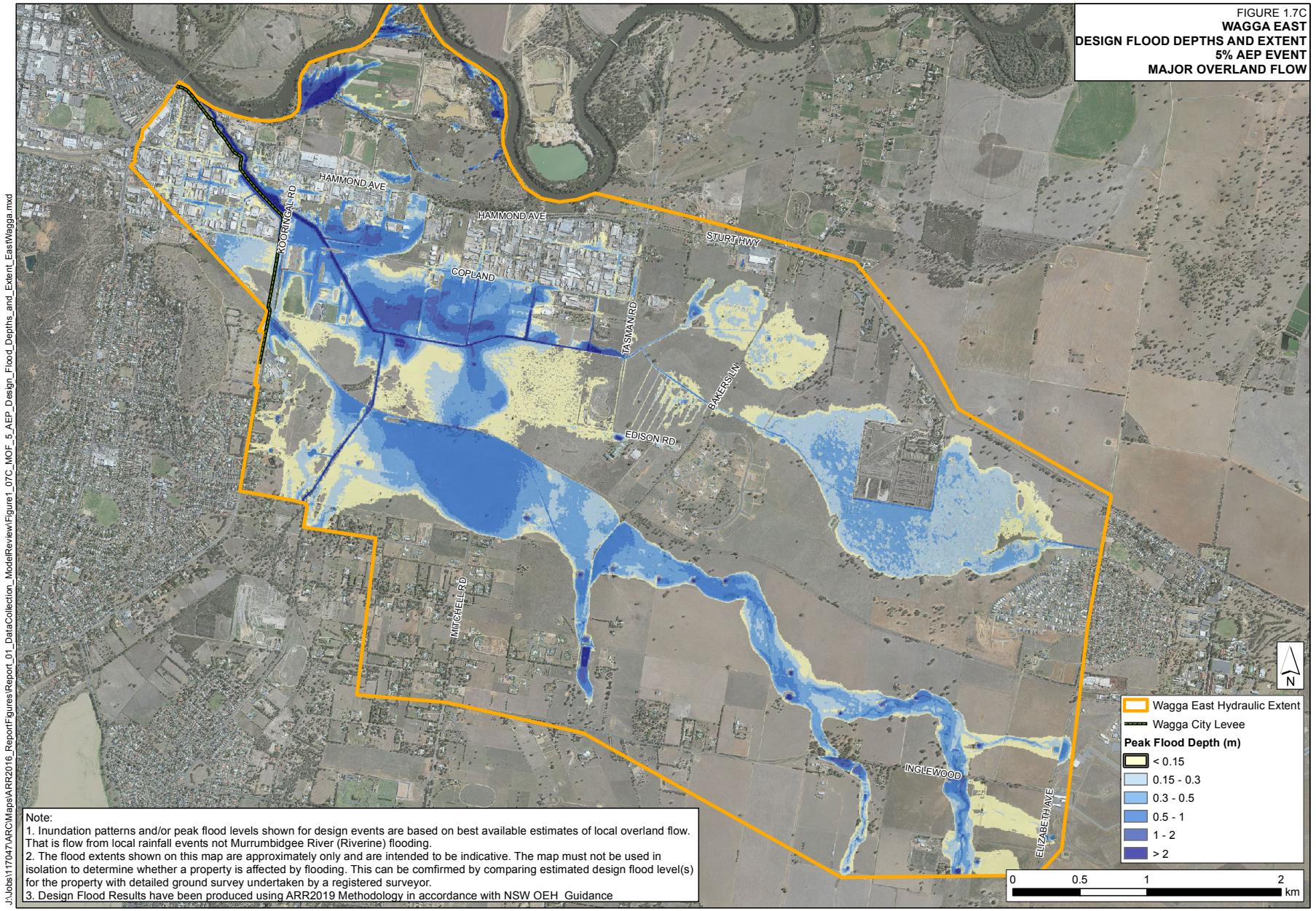
FIGURE 1.7C
WAGGA EAST
DESIGN FLOOD DEPTHS AND EXTENT
5% AEP EVENT
MAJOR OVERLAND FLOW
HAMMOND AVE
HAMMOND AVE
KOORINGAL RD
COPLAND
STURT HWY
TASMAN RD
BAKERS LN
EDISON RD
MITCHELL RD
INGLEWOOD
ELIZABETH AVE
N
Wagga East Hydraulic Extent
Wagga City Levee
Peak Flood Depth (m)
< 0.15
0.15 - 0.3
0.3 - 0.5
0.5 - 1
1 - 2
> 2
0
0.5
1
2
km
Note:
1. Inundation patterns and/or peak flood levels shown for design events are based on best available estimates of local overland flow. That is flow from local rainfall events not Murrumbidgee River (Riverine) flooding.
2. The flood extents shown on this map are approximately only and are intended to be indicative. The map must not be used in isolation to determine whether a property is affected by flooding. This can be comfirmed by comparing estimated design flood level(s) for the property with detailed ground survey undertaken by a registered surveyor.
3. Design Flood Results have been produced using ARR2019 Methodology in accordance with NSW OEH Guidance
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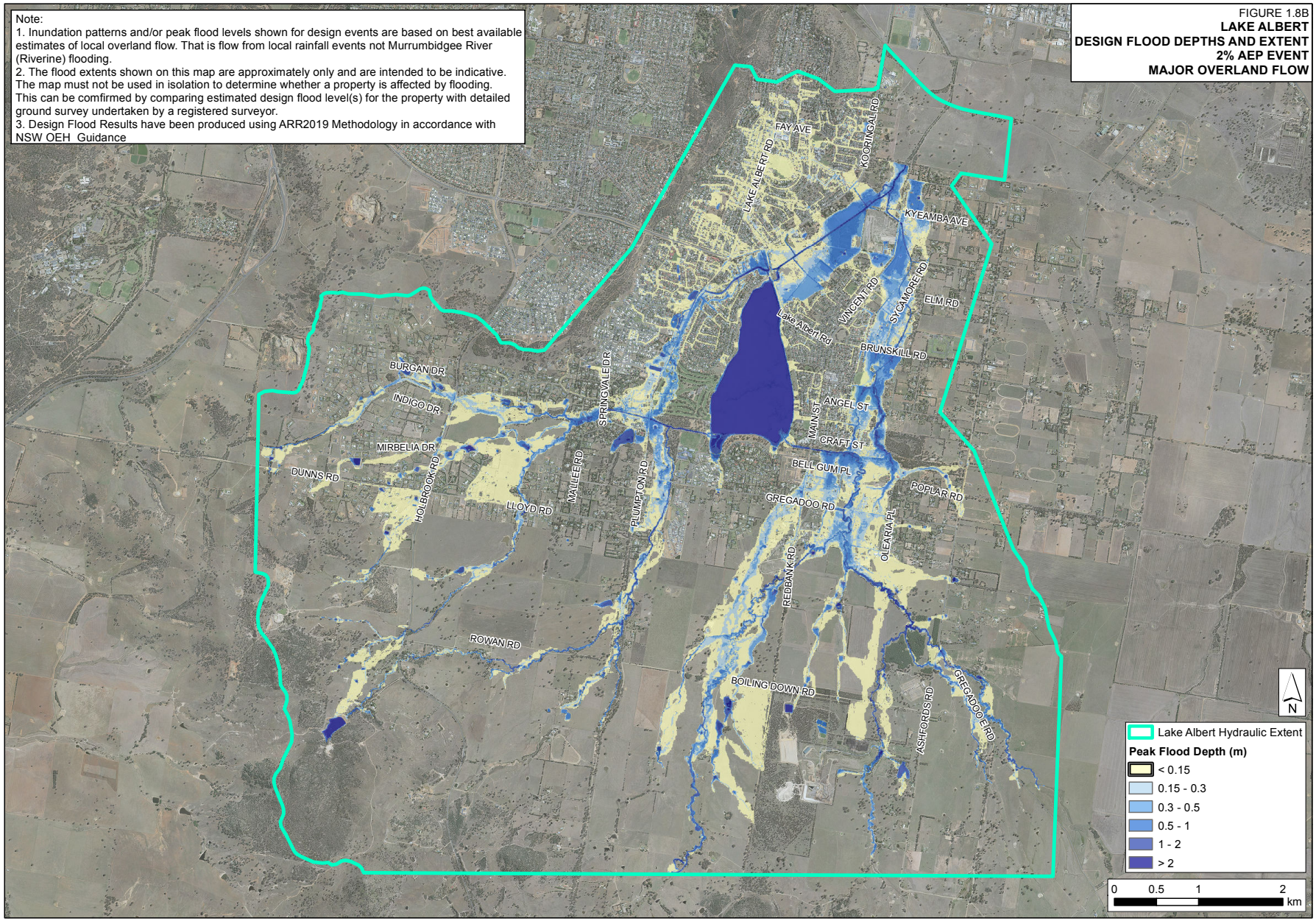

Note:
1. Inundation patterns and/or peak flood levels shown for design events are based on best available estimates of local overland flow. That is flow from local rainfall events not Murrumbidgee River (Riverine) flooding.
2. The flood extents shown on this map are approximately only and are intended to be indicative. The map must not be used in isolation to determine whether a property is affected by flooding. This can be comfirmed by comparing estimated design flood level(s) for the property with detailed ground survey undertaken by a registered surveyor.
3. Design Flood Results have been produced using ARR2019 Methodology in accordance with NSW OEH Guidance
FIGURE 1.8B
LAKE ALBERT
DESIGN FLOOD DEPTHS AND EXTENT
2% AEP EVENT
MAJOR OVERLAND FLOW
FAY AVE
KOORINGAL RD
LAKE ALBERT RD
KYEAMBA AVE
SYCAMORE RD
VINCENT RD
ELM RD
Lake Albert Rd
BRUNSKILL RD
BURGAN DR
INDIGO DR
SPRINGVALE DR
MAIN ST
ANGEL ST
CRAFT ST
MIRBELIA DR
DUNNS RD
HOLBROOK RD
MALLEE RD
PLUMPTON RD
BELL GUM PL
POPLAR RD
GREGADOO RD
LLOYD RD
OLEARIA PL
REDBANK RD
ROWAN RD
BOILING DOWN RD
ASHFORDS RD
GREGADOO E RD
N
Lake Albert Hydraulic Extent
Peak Flood Depth (m)
< 0.15
0.15 - 0.3
0.3 - 0.5
0.5 - 1
1 - 2
> 2
0 0.5 1 2
km

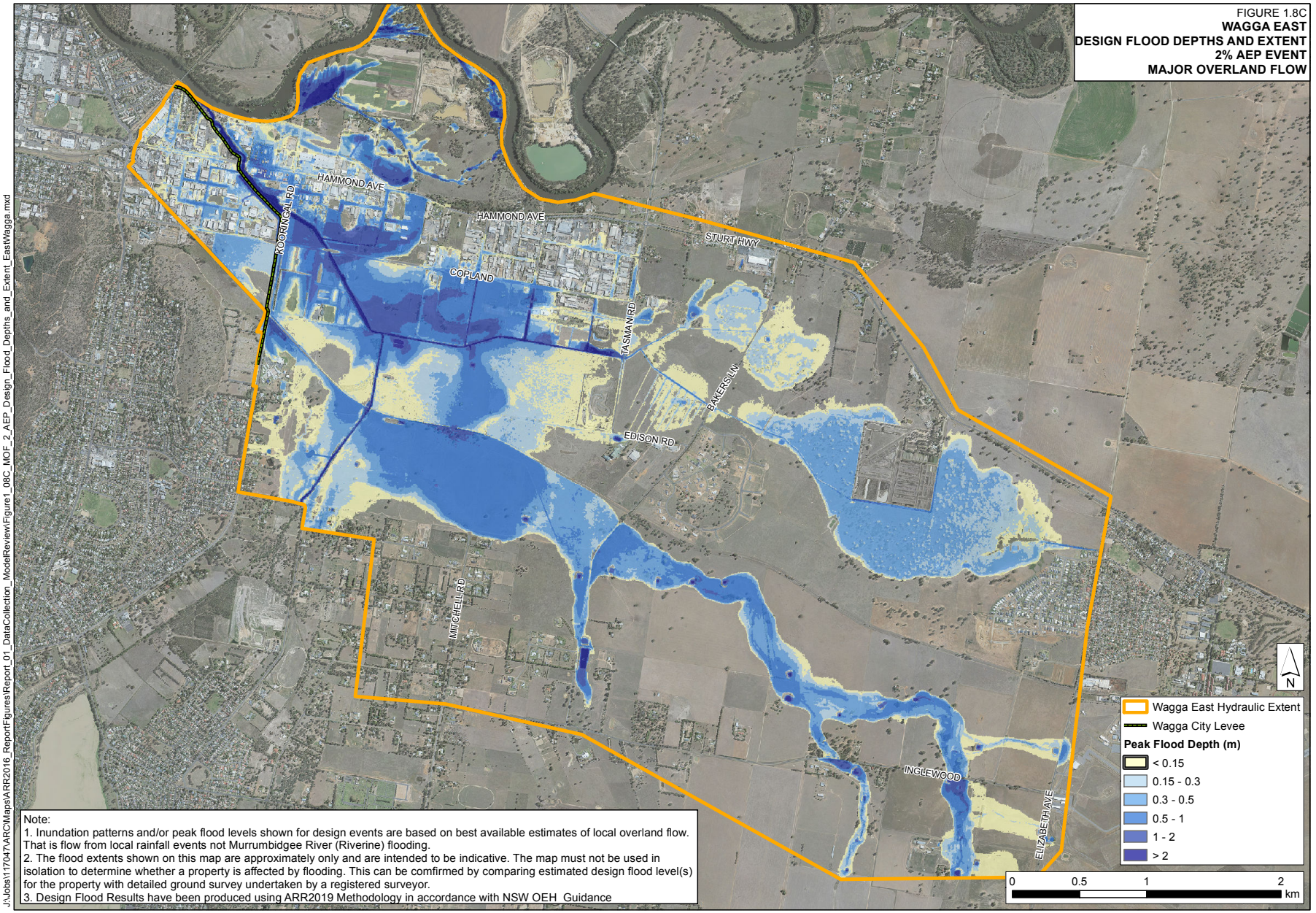
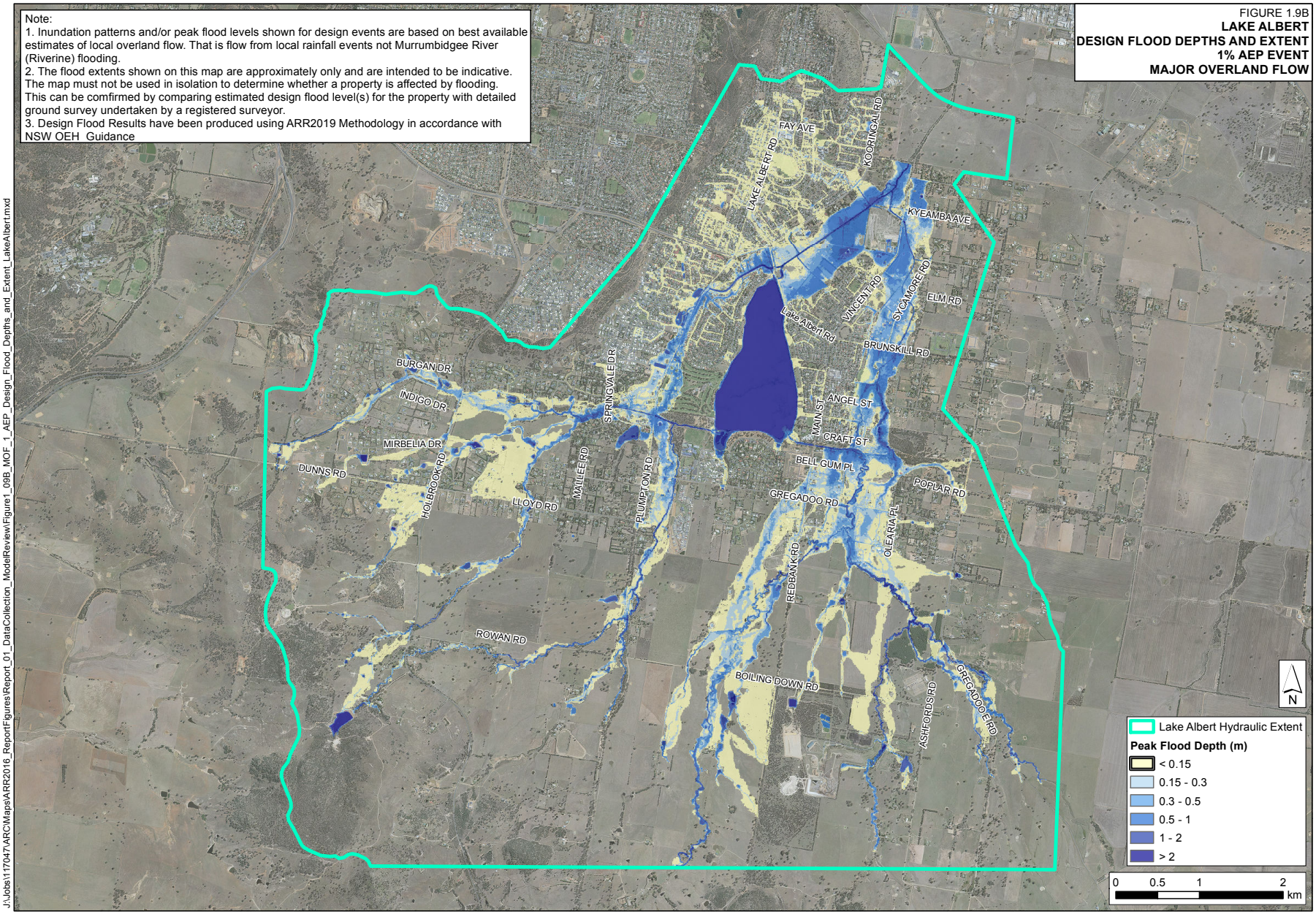


FIGURE 1.8C
WAGGA EAST
DESIGN FLOOD DEPTHS AND EXTENT
2% AEP EVENT
MAJOR OVERLAND FLOW
HAMMOND AVE
KOORINGAL RD
HAMMOND AVE
STURT HWY
COPLAND
TASMAN RD
BAKERS LN
EDISON RD
MITCHELL RD
INGLEWOOD
ELIZABETH AVE
N
Wagga East Hydraulic Extent
Wagga City Levee
Peak Flood Depth (m)
< 0.15
0.15 - 0.3
0.3 - 0.5
0.5 - 1
1 - 2
> 2
0
0.5
1
2
km
Note:
1. Inundation patterns and/or peak flood levels shown for design events are based on best available estimates of local overland flow. That is flow from local rainfall events not Murrumbidgee River (Riverine) flooding.
2. The flood extents shown on this map are approximately only and are intended to be indicative. The map must not be used in isolation to determine whether a property is affected by flooding. This can be comfirmed by comparing estimated design flood level(s) for the property with detailed ground survey undertaken by a registered surveyor.
3. Design Flood Results have been produced using ARR2019 Methodology in accordance with NSW OEH Guidance
J:\Jobs\117047\ARC\Maps\ARR2016_ReportFigures\Report_01_DataCollection_ModelReview\Figure1_08C_MOF_2_AEP_Design_Flood_Depths_and_Extent_EastWagga.mxd


Note:
1. Inundation patterns and/or peak flood levels shown for design events are based on best available estimates of local overland flow. That is flow from local rainfall events not Murrumbidgee River (Riverine) flooding.
2. The flood extents shown on this map are approximately only and are intended to be indicative. The map must not be used in isolation to determine whether a property is affected by flooding. This can be comfirmed by comparing estimated design flood level(s) for the property with detailed ground survey undertaken by a registered surveyor.
3. Design Flood Results have been produced using ARR2019 Methodology in accordance with NSW OEH Guidance
FIGURE 1.9B
LAKE ALBERT
DESIGN FLOOD DEPTHS AND EXTENT
1% AEP EVENT
MAJOR OVERLAND FLOW
FAY AVE
KOORINGAL RD
LAKE ALBERT RD
KYEAMBA AVE
SYCAMORE RD
VINCENT RD
ELM RD
Lake Albert Rd
BRUNSKILL RD
BURGAN DR
INDIGO DR
SPRINGVALE DR
MAIN ST
ANGEL ST
CRAFT ST
MIRBELIA DR
DUNNS RD
HOLBROOK RD
MALLEE RD
PLUMPTON RD
BELL GUM PL
POPLAR RD
LLOYD RD
GREGADOO RD
OLEARIA PL
REDBANK RD
ROWAN RD
BOILING DOWN RD
ASHFORDS RD
GREGADOO E RD
N
Lake Albert Hydraulic Extent
Peak Flood Depth (m)
< 0.15
0.15 - 0.3
0.3 - 0.5
0.5 - 1
1 - 2
> 2
0 0.5 1 2
km
J:\Jobs\117047\ARC\Maps\ARR2016_ReportFigures\Report_01_DataCollection_ModelReview\Figure1_09B_MOF_1_AEP_Design_Flood_Depths_and_Extent_LakeAlbert.mxd

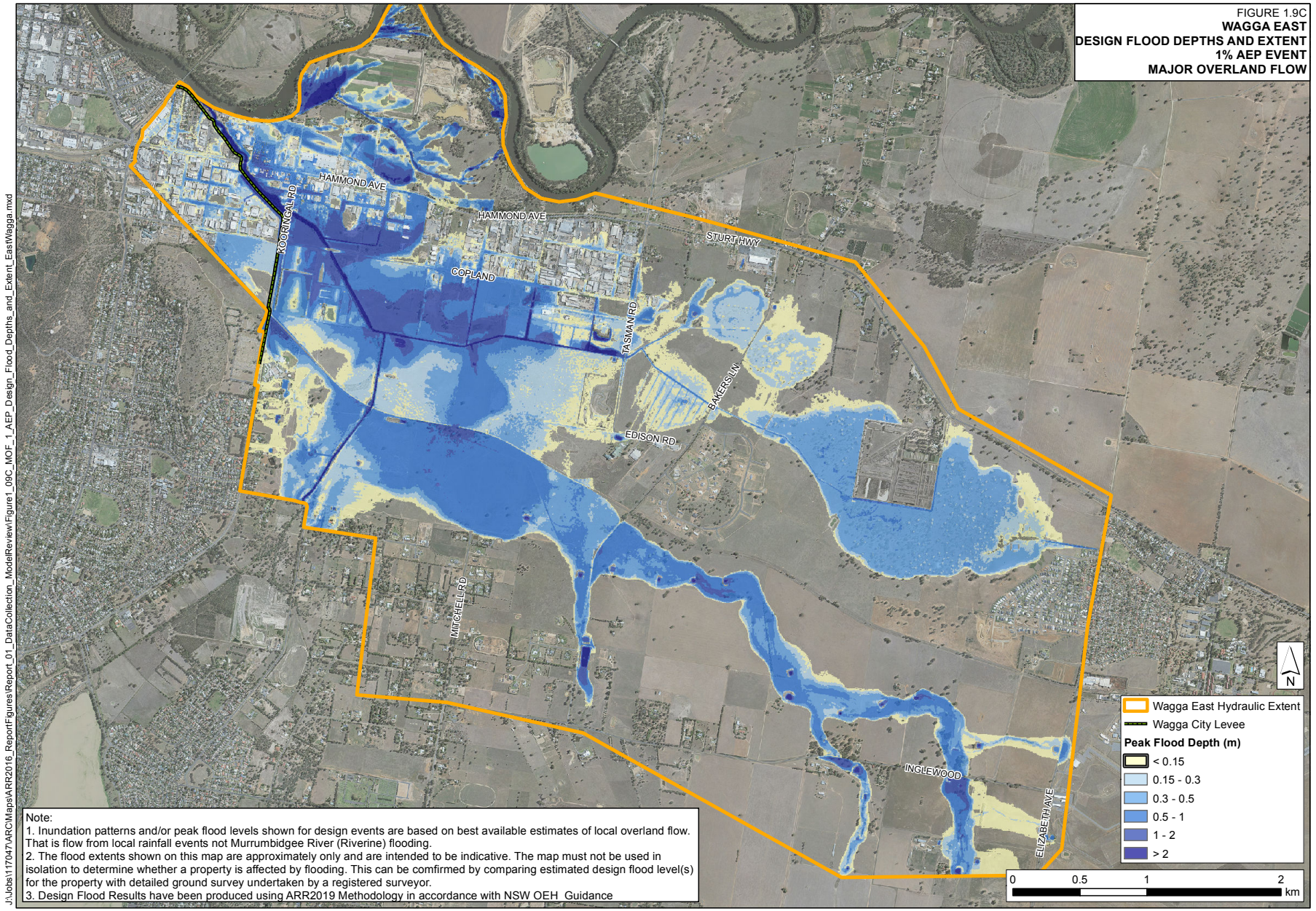
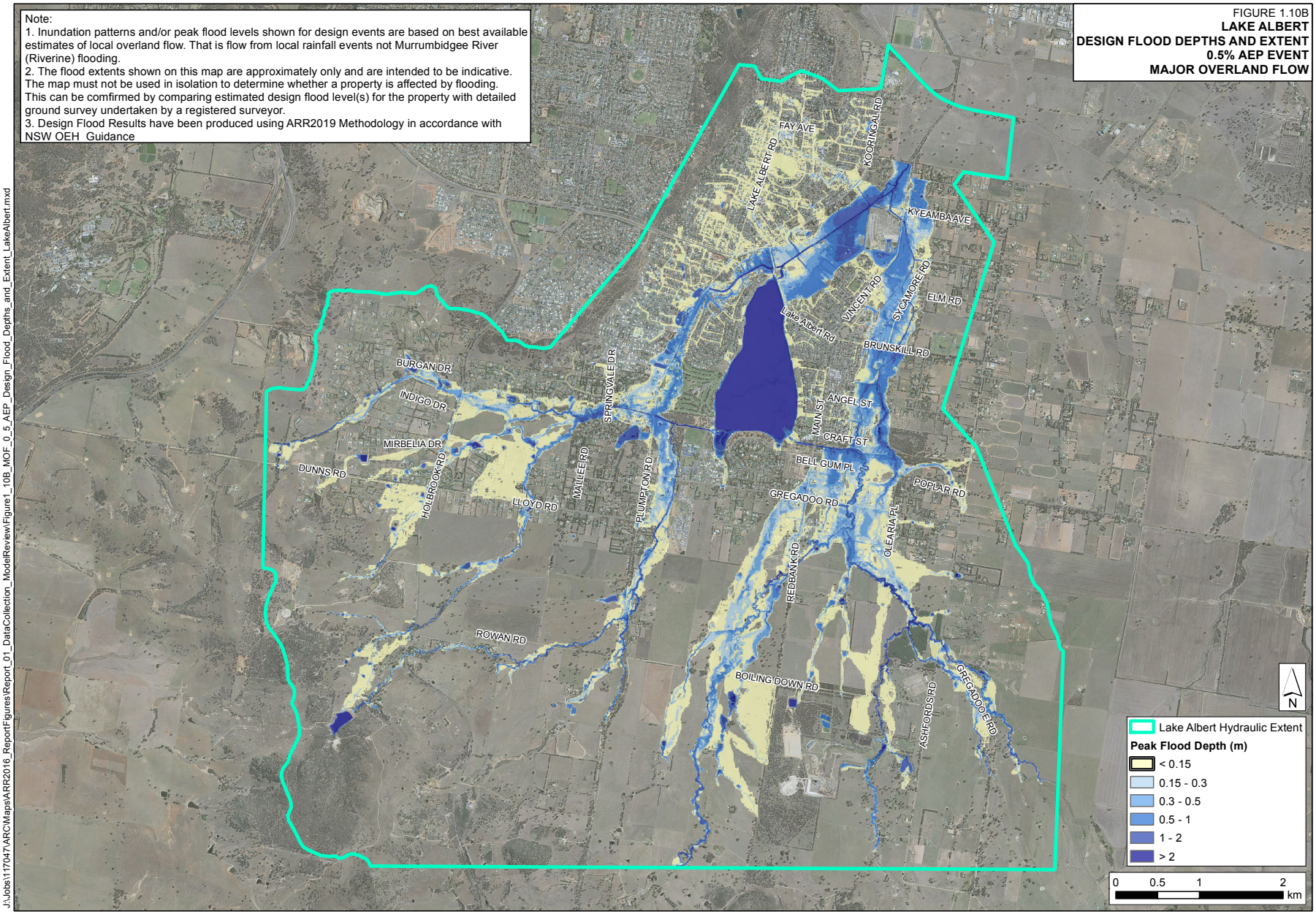


FIGURE 1.9C
WAGGA EAST
DESIGN FLOOD DEPTHS AND EXTENT
1% AEP EVENT
MAJOR OVERLAND FLOW
HAMMOND AVE
HAMMOND AVE
KOORINGAL RD
COPLAND
STURT HWY
TASMAN RD
BAKERS LN
EDISON RD
MITCHELL RD
INGLEWOOD
ELIZABETH AVE
N
Wagga East Hydraulic Extent
Wagga City Levee
Peak Flood Depth (m)
< 0.15
0.15 - 0.3
0.3 - 0.5
0.5 - 1
1 - 2
> 2
0
0.5
1
2
km
Note:
1. Inundation patterns and/or peak flood levels shown for design events are based on best available estimates of local overland flow. That is flow from local rainfall events not Murrumbidgee River (Riverine) flooding.
2. The flood extents shown on this map are approximately only and are intended to be indicative. The map must not be used in isolation to determine whether a property is affected by flooding. This can be comfirmed by comparing estimated design flood level(s) for the property with detailed ground survey undertaken by a registered surveyor.
3. Design Flood Results have been produced using ARR2019 Methodology in accordance with NSW OEH Guidance
J:\Jobs\117047\ARC\Maps\ARR2016_ReportFigures\Report_01_DataCollection_ModelReview\Figure1_09C_MOF_1_AEP_Design_Flood_Depths_and_Extent_EastWagga.mxd


Note:
1. Inundation patterns and/or peak flood levels shown for design events are based on best available estimates of local overland flow. That is flow from local rainfall events not Murrumbidgee River (Riverine) flooding.
2. The flood extents shown on this map are approximately only and are intended to be indicative. The map must not be used in isolation to determine whether a property is affected by flooding. This can be comfirmed by comparing estimated design flood level(s) for the property with detailed ground survey undertaken by a registered surveyor.
3. Design Flood Results have been produced using ARR2019 Methodology in accordance with NSW OEH Guidance
FIGURE 1.10B
LAKE ALBERT
DESIGN FLOOD DEPTHS AND EXTENT
0.5% AEP EVENT
MAJOR OVERLAND FLOW
FAY AVE
LAKE ALBERT RD
KOORINGAL RD
KYEAMBA AVE
VINCENT RD
SYCAMORE RD
ELM RD
Lake Albert Rd
BRUNSKILL RD
BURGAN DR
INDIGO DR
SPRINGVALE DR
MAIN ST
ANGEL ST
CRAFT ST
MIRBELIA DR
DUNNS RD
HOLBROOK RD
MALLEE RD
PLUMPTON RD
BELL GUM PL
GREGADOO RD
POPLAR RD
LLOYD RD
OLEARIA PL
REDBANK RD
ROWAN RD
BOILING DOWN RD
ASHFORDS RD
GREGADOO E RD
N
Lake Albert Hydraulic Extent
Peak Flood Depth (m)
< 0.15
0.15 - 0.3
0.3 - 0.5
0.5 - 1
1 - 2
> 2
0 0.5 1 2
km
J:\Jobs\117047\ARC\Maps\ARR2016_ReportFigures\Report_01_DataCollection_ModelReview\Figure1_10B_MOF_0_5_AEP_Design_Flood_Depths_and_Extent_LakeAlbert.mxd

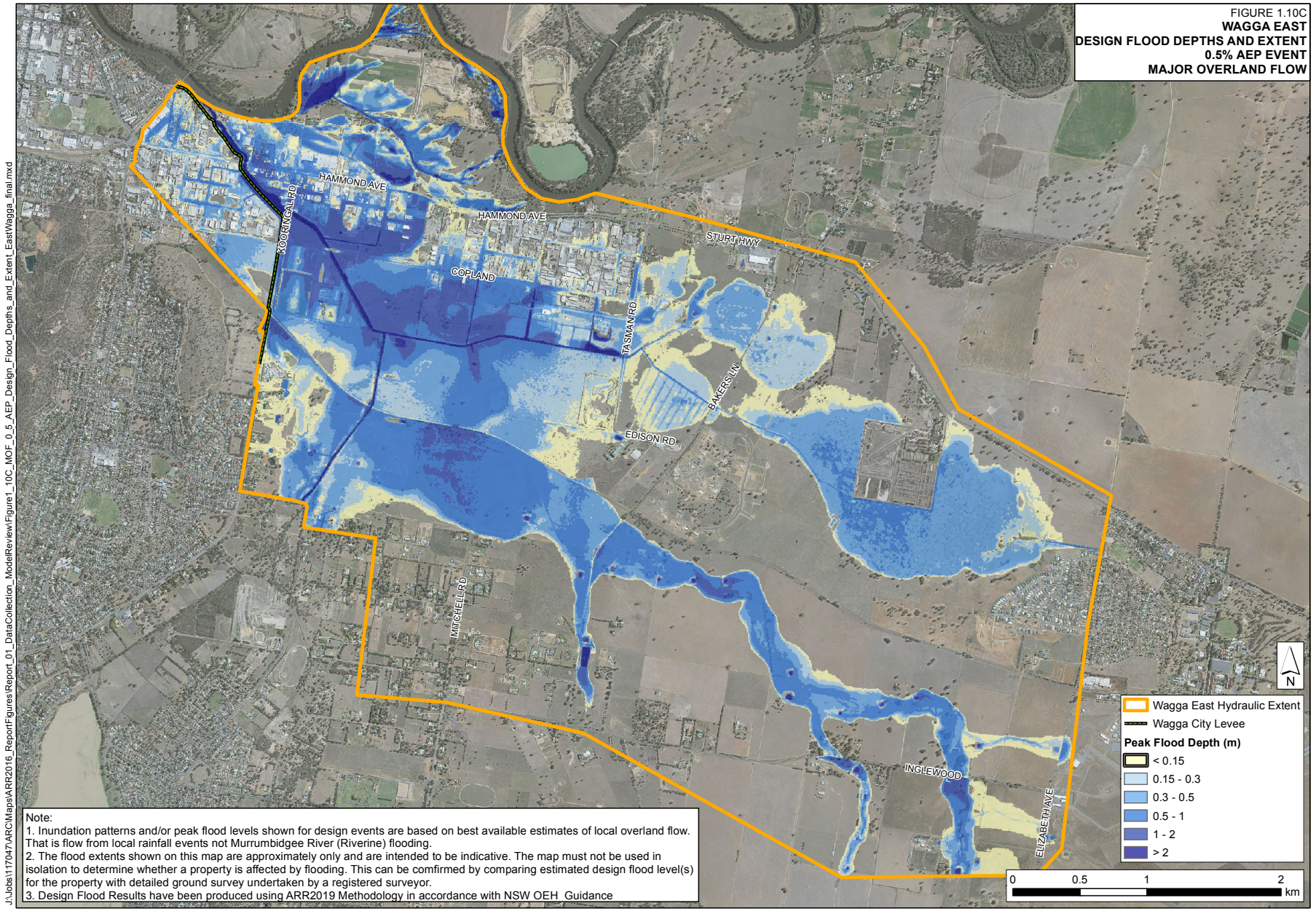


FIGURE 1.10C
WAGGA EAST
DESIGN FLOOD DEPTHS AND EXTENT
0.5% AEP EVENT
MAJOR OVERLAND FLOW
HAMMOND AVE
HAMMOND AVE
KOORINGAL RD
COPLAND
STURT HWY
TASMAN RD
BAKERS LN
EDISON RD
MITCHELL RD
INGLEWOOD
ELIZABETH AVE
N
Wagga East Hydraulic Extent
Wagga City Levee
Peak Flood Depth (m)
< 0.15
0.15 - 0.3
0.3 - 0.5
0.5 - 1
1 - 2
> 2
0
0.5
1
2
km
Note:
1. Inundation patterns and/or peak flood levels shown for design events are based on best available estimates of local overland flow. That is flow from local rainfall events not Murrumbidgee River (Riverine) flooding.
2. The flood extents shown on this map are approximately only and are intended to be indicative. The map must not be used in isolation to determine whether a property is affected by flooding. This can be comfirmed by comparing estimated design flood level(s) for the property with detailed ground survey undertaken by a registered surveyor.
3. Design Flood Results have been produced using ARR2019 Methodology in accordance with NSW OEH Guidance
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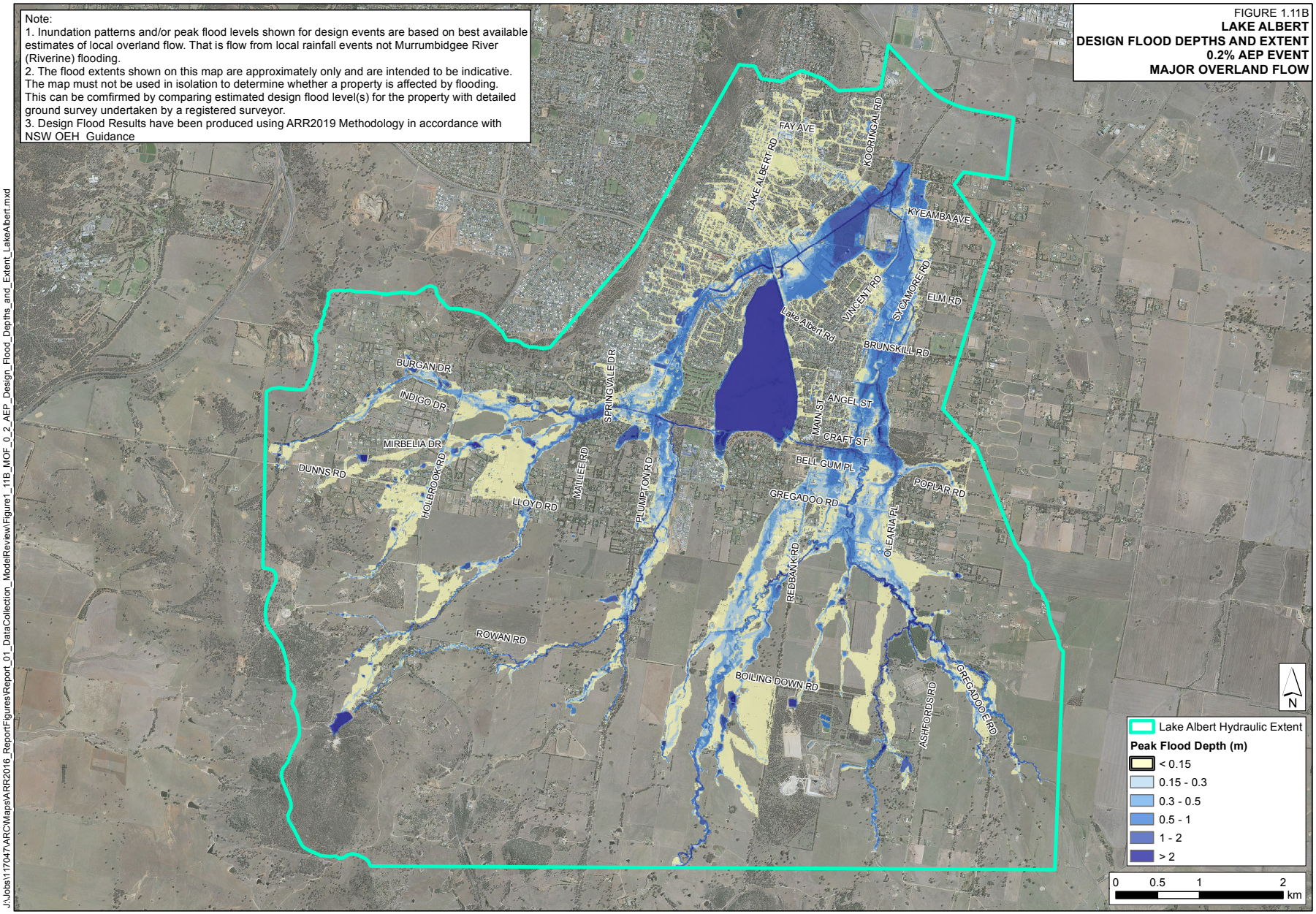
Note:
1. Inundation patterns and/or peak flood levels shown for design events are based on best available estimates of local overland flow. That is flow from local rainfall events not Murrumbidgee River (Riverine) flooding.
2. The flood extents shown on this map are approximately only and are intended to be indicative. The map must not be used in isolation to determine whether a property is affected by flooding. This can be comfirmed by comparing estimated design flood level(s) for the property with detailed ground survey undertaken by a registered surveyor.
3. Design Flood Results have been produced using ARR2019 Methodology in accordance with NSW OEH Guidance
FIGURE 1.11B
LAKE ALBERT
DESIGN FLOOD DEPTHS AND EXTENT
0.2% AEP EVENT
MAJOR OVERLAND FLOW
J:\Jobs\117047\ARC\Maps\ARR2016_ReportFigures\Report_01_DataCollection_ModelReview\Figure1_11B_MOF_0_2_AEP_Design_Flood_Depths_and_Extent_LakeAlbert.mxd
FAY AVE
LAKE ALBERT RD
KOORINGAL RD
KYEAMBA AVE
VINCENT RD
SYCAMORE RD
ELM RD
Lake Albert Rd
BRUNSKILL RD
BURGAN DR
INDIGO DR
SPRINGVALE DR
MAIN ST
ANGEL ST
CRAFT ST
MIRBELIA DR
DUNNS RD
HOLBROOK RD
MALLEE RD
PLUMPTON RD
BELL GUM PL
POPLAR RD
GREGADOO RD
LLOYD RD
OLEARIA PL
REDBANK RD
ROWAN RD
BOILING DOWN RD
ASHFORDS RD
GREGADOO E RD
N
Lake Albert Hydraulic Extent
Peak Flood Depth (m)
< 0.15
0.15 - 0.3
0.3 - 0.5
0.5 - 1
1 - 2
> 2
0 0.5 1 2
km

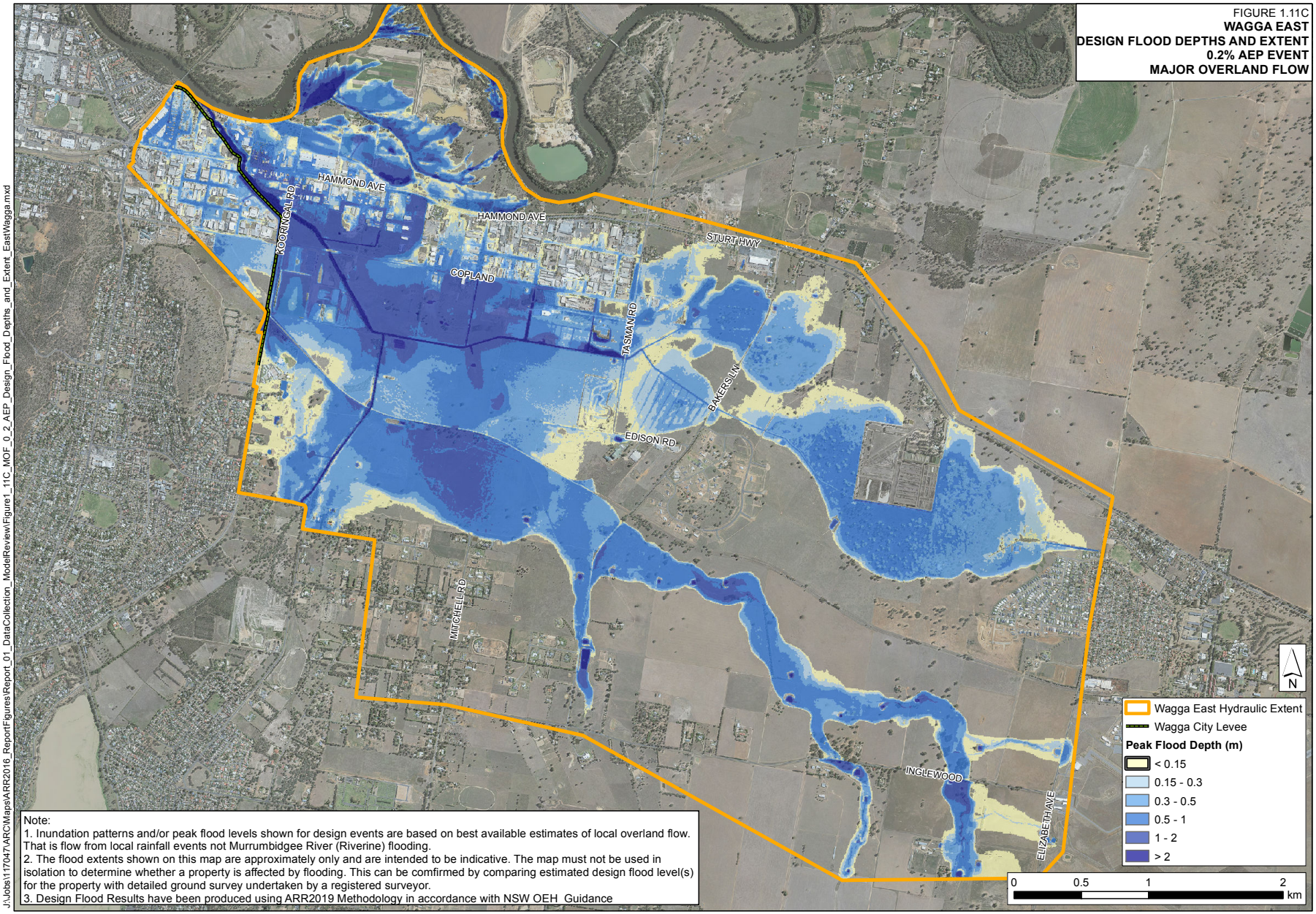
FIGURE 1.11C
WAGGA EAST
DESIGN FLOOD DEPTHS AND EXTENT
0.2% AEP EVENT
MAJOR OVERLAND FLOW
HAMMOND AVE
HAMMOND AVE
KOORINGAL RD
COPLAND
STURT HWY
TASMAN RD
BAKERS LN
EDISON RD
MITCHELL RD
INGLEWOOD
ELIZABETH AVE
N
Wagga East Hydraulic Extent
Wagga City Levee
Peak Flood Depth (m)
< 0.15
0.15 - 0.3
0.3 - 0.5
0.5 - 1
1 - 2
> 2
0
0.5
1
2
km
Note:
1. Inundation patterns and/or peak flood levels shown for design events are based on best available estimates of local overland flow. That is flow from local rainfall events not Murrumbidgee River (Riverine) flooding.
2. The flood extents shown on this map are approximately only and are intended to be indicative. The map must not be used in isolation to determine whether a property is affected by flooding. This can be comfirmed by comparing estimated design flood level(s) for the property with detailed ground survey undertaken by a registered surveyor.
3. Design Flood Results have been produced using ARR2019 Methodology in accordance with NSW OEH Guidance
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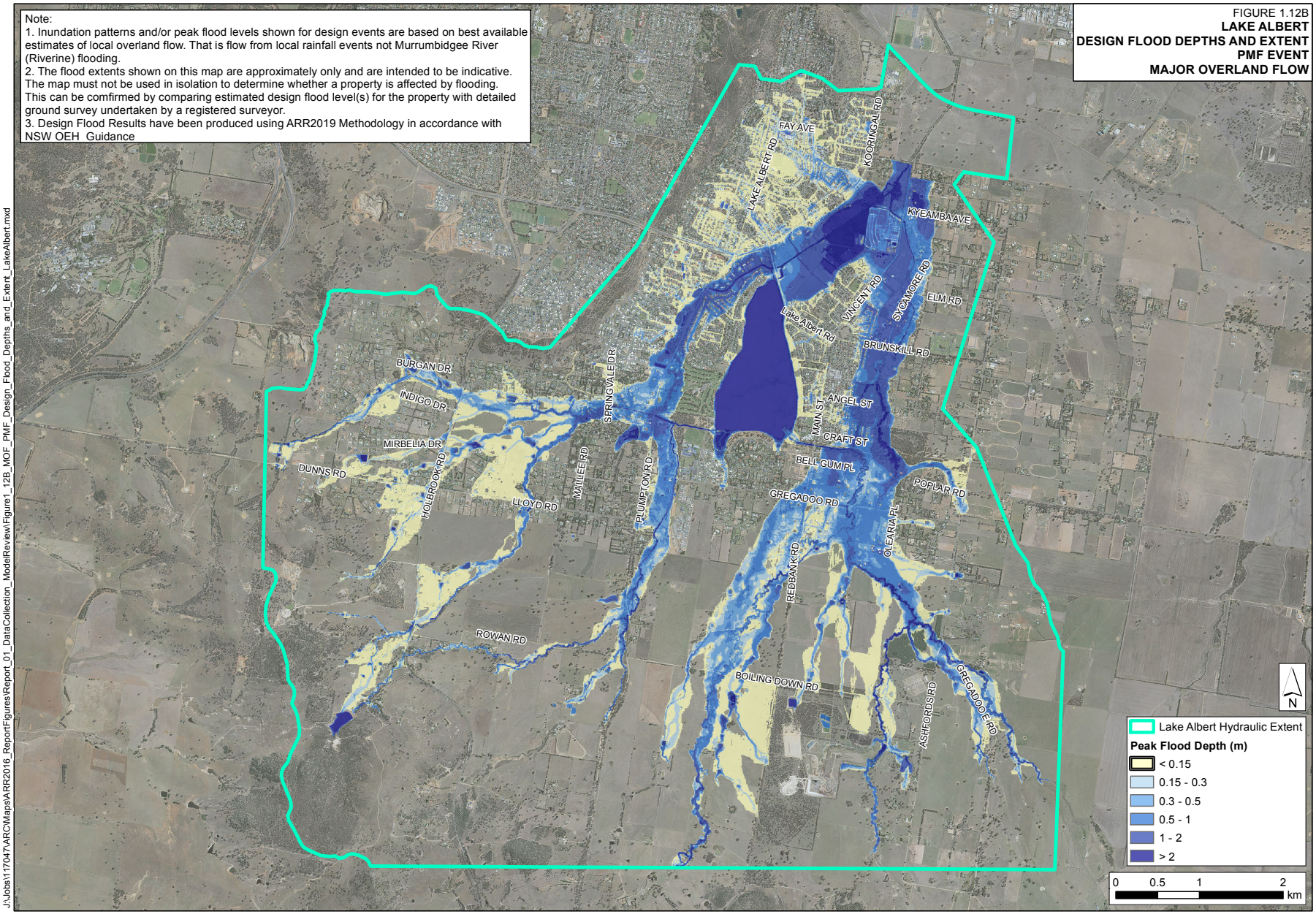

Note:
1. Inundation patterns and/or peak flood levels shown for design events are based on best available estimates of local overland flow. That is flow from local rainfall events not Murrumbidgee River (Riverine) flooding.
2. The flood extents shown on this map are approximately only and are intended to be indicative. The map must not be used in isolation to determine whether a property is affected by flooding. This can be comfirmed by comparing estimated design flood level(s) for the property with detailed ground survey undertaken by a registered surveyor.
3. Design Flood Results have been produced using ARR2019 Methodology in accordance with NSW OEH Guidance
FIGURE 1.12B
LAKE ALBERT
DESIGN FLOOD DEPTHS AND EXTENT
PMF EVENT
MAJOR OVERLAND FLOW
FAY AVE
LAKE ALBERT RD
KOORINGAL RD
KYEAMBA AVE
SYCAMORE RD
VINCENT RD
ELM RD
Lake Albert Rd
BRUNSKILL RD
BURGAN DR
INDIGO DR
MIRBELIA DR
DUNNS RD
HOLBROOK RD
SPRINGVALE DR
MAILLEE RD
PLUMPTON RD
LLOYD RD
MAIN ST
ANGEL ST
CRAFT ST
BELL GUM PL
GREGADOO RD
POPLAR RD
OLEARIA PL
REDBANK RD
ROWAN RD
BOILING DOWN RD
ASHFORDS RD
GREGADOO RD
N
Lake Albert Hydraulic Extent
Peak Flood Depth (m)
< 0.15
0.15 - 0.3
0.3 - 0.5
0.5 - 1
1 - 2
> 2
0 0.5 1 2
km
J:\Jobs\117047\ARC\Maps\ARR2016_ReportFigures\Report_01_DataCollection_ModelReview\Figure1_12B_MOF_PMF_Design_Flood_Depths_and_Extent_LakeAlbert.mxd

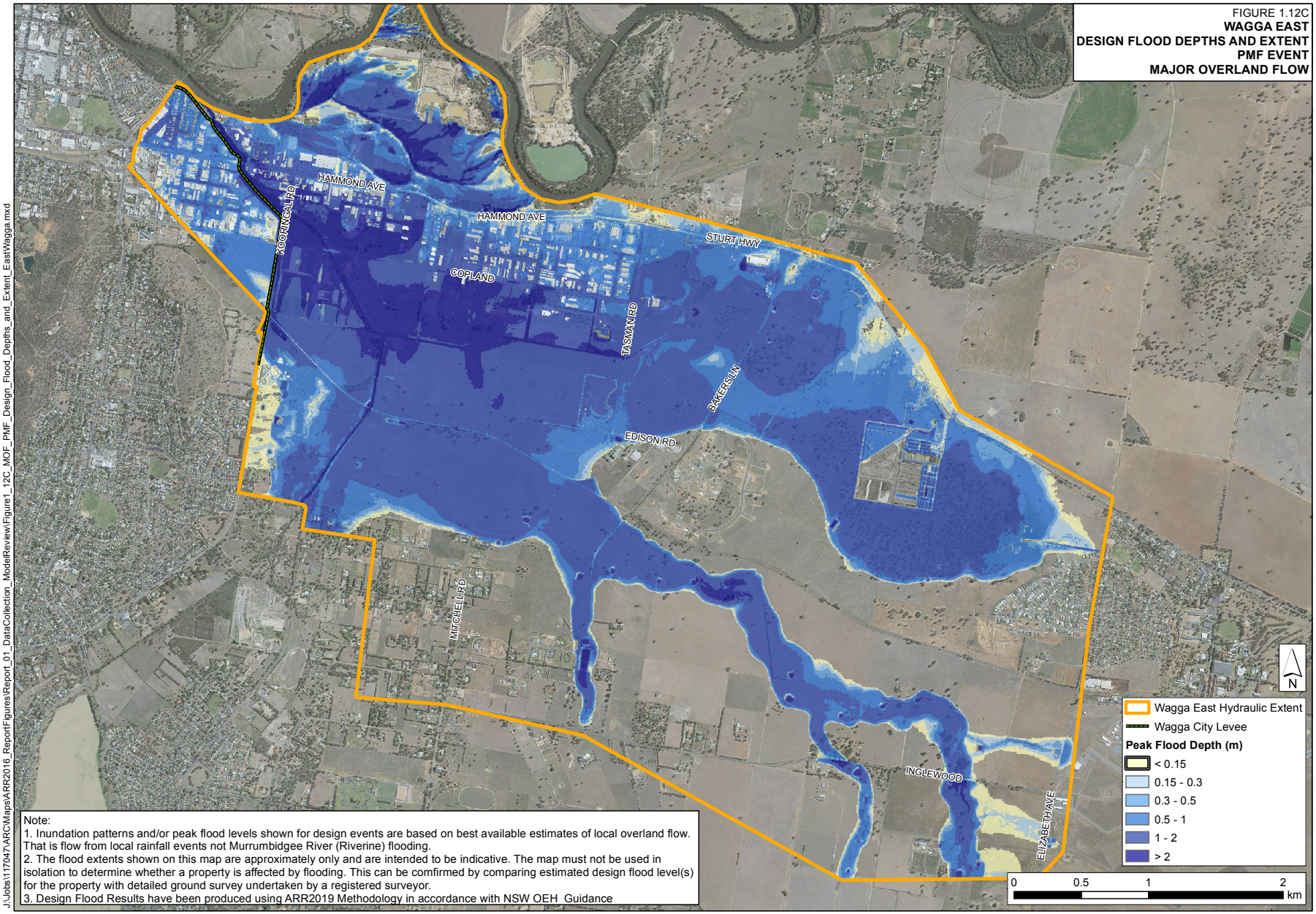
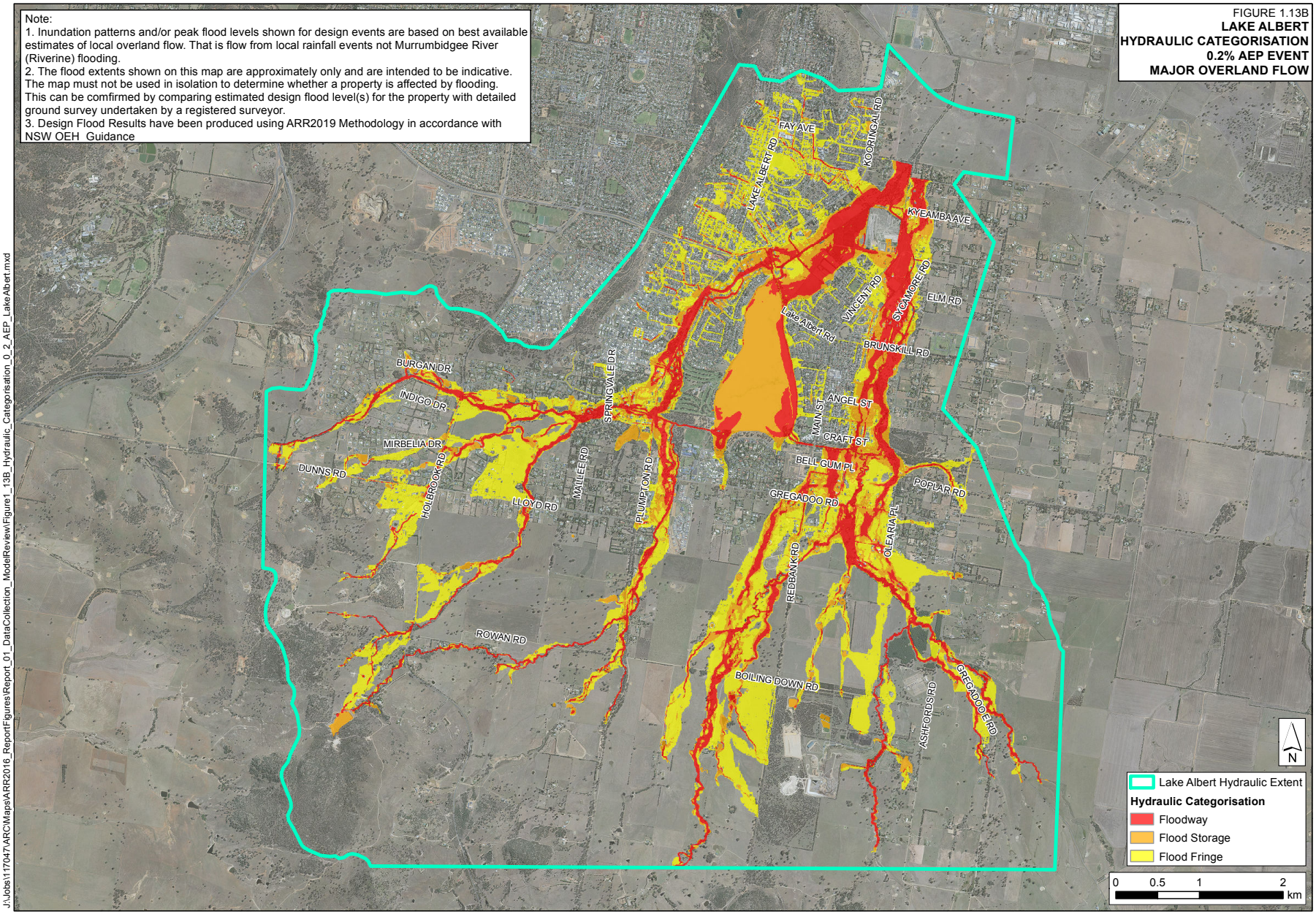


FIGURE 1.12C
WAGGA EAST
DESIGN FLOOD DEPTHS AND EXTENT
PMF EVENT
MAJOR OVERLAND FLOW
HAMMOND AVE
HAMMOND AVE
KOORINGAL RD
COPLAND
STURT HWY
TASMAN RD
BAKERS LN
EDISON RD
MITCHELL RD
INGLEWOOD
ELIZABETH AVE
N
Wagga East Hydraulic Extent
Wagga City Levee
Peak Flood Depth (m)
< 0.15
0.15 - 0.3
0.3 - 0.5
0.5 - 1
1 - 2
> 2
0
0.5
1
2
km
Note:
1. Inundation patterns and/or peak flood levels shown for design events are based on best available estimates of local overland flow. That is flow from local rainfall events not Murrumbidgee River (Riverine) flooding.
2. The flood extents shown on this map are approximately only and are intended to be indicative. The map must not be used in isolation to determine whether a property is affected by flooding. This can be comfirmed by comparing estimated design flood level(s) for the property with detailed ground survey undertaken by a registered surveyor.
3. Design Flood Results have been produced using ARR2019 Methodology in accordance with NSW OEH Guidance
J:\Jobs\117047\ARC\Maps\ARR2016_ReportFigures\Report_01_DataCollection_ModelReview\Figure1_12C_MOF_PMF_Design_Flood_Depths_and_Extent_EastWagga.mxd


Note:
1. Inundation patterns and/or peak flood levels shown for design events are based on best available estimates of local overland flow. That is flow from local rainfall events not Murrumbidgee River (Riverine) flooding.
2. The flood extents shown on this map are approximately only and are intended to be indicative. The map must not be used in isolation to determine whether a property is affected by flooding. This can be comfirmed by comparing estimated design flood level(s) for the property with detailed ground survey undertaken by a registered surveyor.
3. Design Flood Results have been produced using ARR2019 Methodology in accordance with NSW OEH Guidance
FIGURE 1.13B
LAKE ALBERT
HYDRAULIC CATEGORISATION
0.2% AEP EVENT
MAJOR OVERLAND FLOW
FAY AVE
KOORINGAL RD
LAKE ALBERT RD
KYEAMBA AVE
SYCAMORE RD
VINCENT RD
ELM RD
Lake Albert Rd
BRUNSKILL RD
BURGAN DR
INDIGO DR
SPRINGVALE DR
MAIN ST
ANGEL ST
CRAFT ST
MIRBELIA DR
DUNNS RD
HOLBROOK RD
MALLEE RD
PLUMPTON RD
LLOYD RD
BELL GUM PL
POPLAR RD
GREGADOO RD
OLEARIA PL
REDBANK RD
ROWAN RD
BOILING DOWN RD
ASHFORDS RD
GREGADOO E RD
N
Lake Albert Hydraulic Extent
Hydraulic Categorisation
Floodway
Flood Storage
Flood Fringe
0 0.5 1 2
km
J:\Jobs\117047\ARC\Maps\ARR2016_ReportFigures\Report_01_DataCollection_ModelReview\Figure1_13B_Hydraulic_Categorisation_0_2_AEP_LakeAlbert.mxd

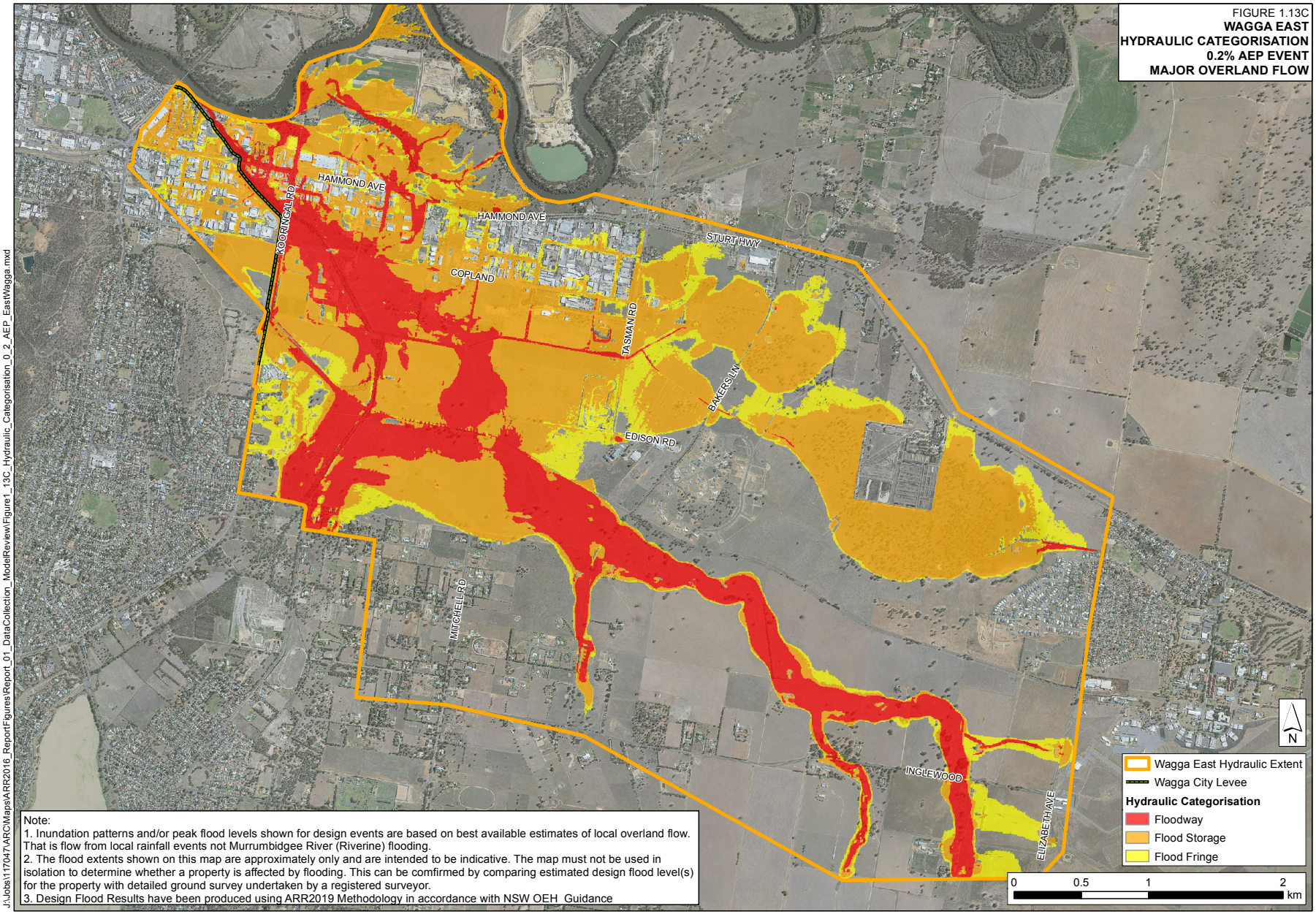
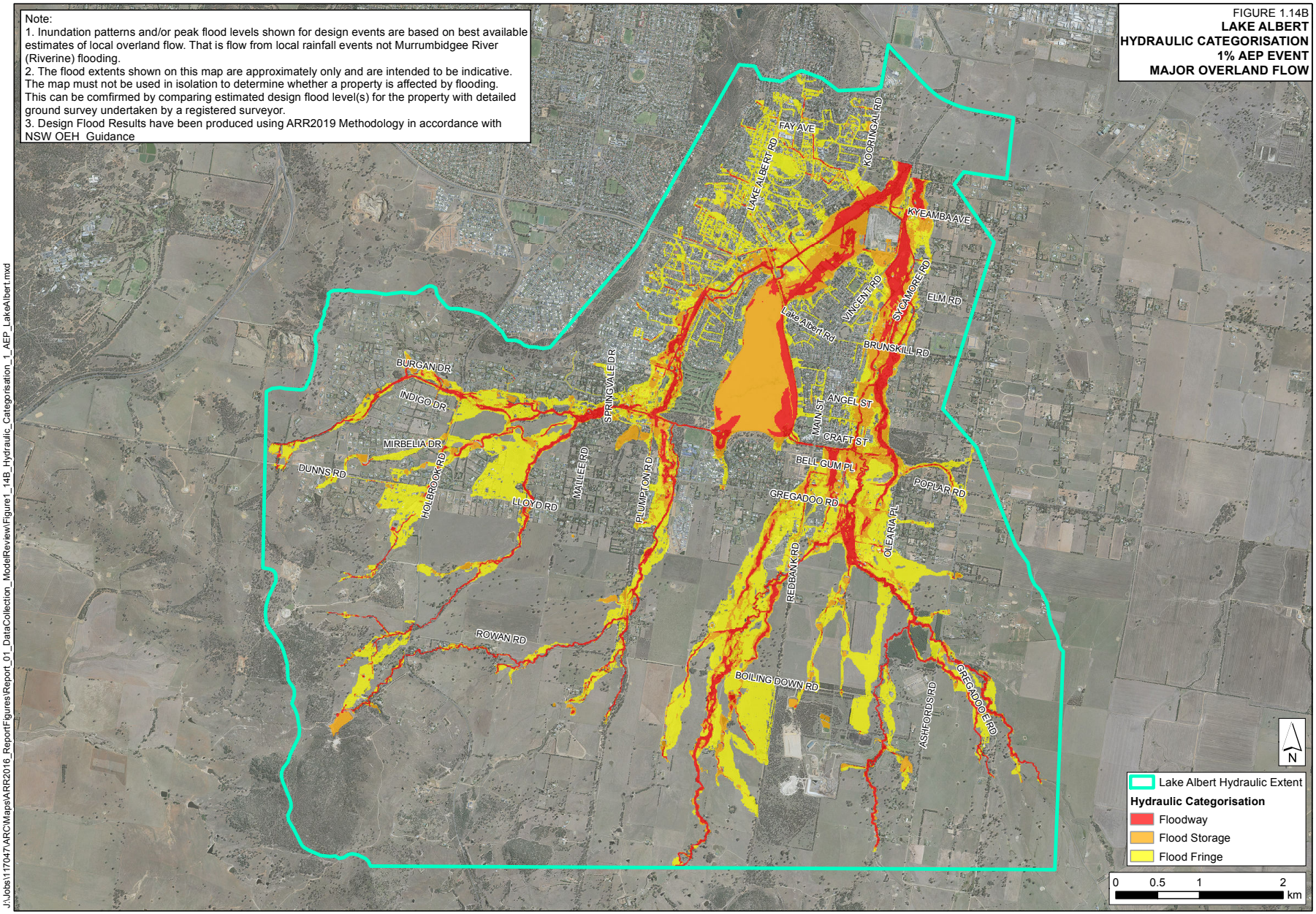


FIGURE 1.13C
WAGGA EAST
HYDRAULIC CATEGORISATION
0.2% AEP EVENT
MAJOR OVERLAND FLOW
HAMMOND AVE
KOORINGAL RD
HAMMOND AVE
COPLAND
STURT HWY
TASMAN RD
BAKERS LN
EDISON RD
MITCHELL RD
INGLEWOOD
ELIZABETH AVE
N
Wagga East Hydraulic Extent
Wagga City Levee
Hydraulic Categorisation
Floodway
Flood Storage
Flood Fringe
0
0.5
1
2
km
Note:
1. Inundation patterns and/or peak flood levels shown for design events are based on best available estimates of local overland flow. That is flow from local rainfall events not Murrumbidgee River (Riverine) flooding.
2. The flood extents shown on this map are approximately only and are intended to be indicative. The map must not be used in isolation to determine whether a property is affected by flooding. This can be comfirmed by comparing estimated design flood level(s) for the property with detailed ground survey undertaken by a registered surveyor.
3. Design Flood Results have been produced using ARR2019 Methodology in accordance with NSW OEH Guidance
J:\Jobs\117047\ARC\Maps\ARR2016_ReportFigures\Report_01_DataCollection_ModelReview\Figure1_13C_Hydraulic_Categorisation_0_2_AEP_EastWagga.mxd


Note:
1. Inundation patterns and/or peak flood levels shown for design events are based on best available estimates of local overland flow. That is flow from local rainfall events not Murrumbidgee River (Riverine) flooding.
2. The flood extents shown on this map are approximately only and are intended to be indicative. The map must not be used in isolation to determine whether a property is affected by flooding. This can be comfirmed by comparing estimated design flood level(s) for the property with detailed ground survey undertaken by a registered surveyor.
3. Design Flood Results have been produced using ARR2019 Methodology in accordance with NSW OEH Guidance
FIGURE 1.14B
LAKE ALBERT
HYDRAULIC CATEGORISATION
1% AEP EVENT
MAJOR OVERLAND FLOW
FAY AVE
KOORINGAL RD
LAKE ALBERT RD
KYEAMBA AVE
SYCAMORE RD
VINCENT RD
ELM RD
Lake Albert Rd
BRUNSKILL RD
BURGAN DR
INDIGO DR
SPRINGVALE DR
MAIN ST
ANGEL ST
CRAFT ST
MIRBELIA DR
DUNNS RD
HOLBROOK RD
MALLEE RD
PLUMPTON RD
LLOYD RD
BELL GUM PL
POPLAR RD
GREGADOO RD
OLEARIA PL
REDBANK RD
ROWAN RD
BOILING DOWN RD
ASHFORDS RD
GREGADOO E RD
N
Lake Albert Hydraulic Extent
Hydraulic Categorisation
Floodway
Flood Storage
Flood Fringe
0 0.5 1 2
km
J:\Jobs\117047\ARC\Maps\ARR2016_ReportFigures\Report_01_DataCollection_ModelReview\Figure1_14B_Hydraulic_Categorisation_1_AEP_LakeAlbert.mxd

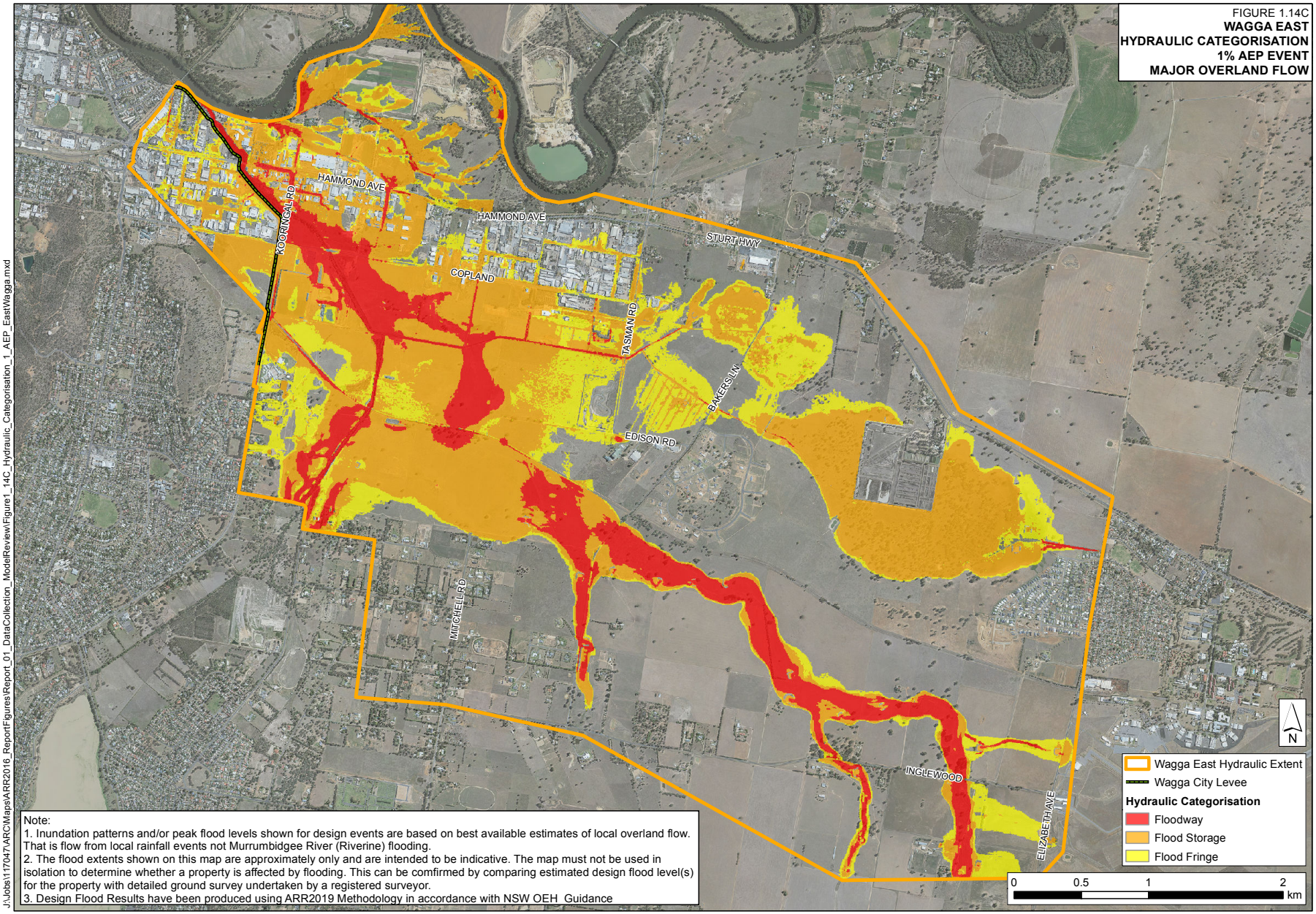


FIGURE 1.14C
WAGGA EAST
HYDRAULIC CATEGORISATION
1% AEP EVENT
MAJOR OVERLAND FLOW
HAMMOND AVE
HAMMOND AVE
KOORINGAL RD
COPLAND
STURT HWY
TASMAN RD
BAKERS LN
EDISON RD
MITCHELL RD
INGLEWOOD
ELIZABETH AVE
N
Wagga East Hydraulic Extent
Wagga City Levee
Hydraulic Categorisation
Floodway
Flood Storage
Flood Fringe
0
0.5
1
2
km
Note:
1. Inundation patterns and/or peak flood levels shown for design events are based on best available estimates of local overland flow. That is flow from local rainfall events not Murrumbidgee River (Riverine) flooding.
2. The flood extents shown on this map are approximately only and are intended to be indicative. The map must not be used in isolation to determine whether a property is affected by flooding. This can be comfirmed by comparing estimated design flood level(s) for the property with detailed ground survey undertaken by a registered surveyor.
3. Design Flood Results have been produced using ARR2019 Methodology in accordance with NSW OEH Guidance
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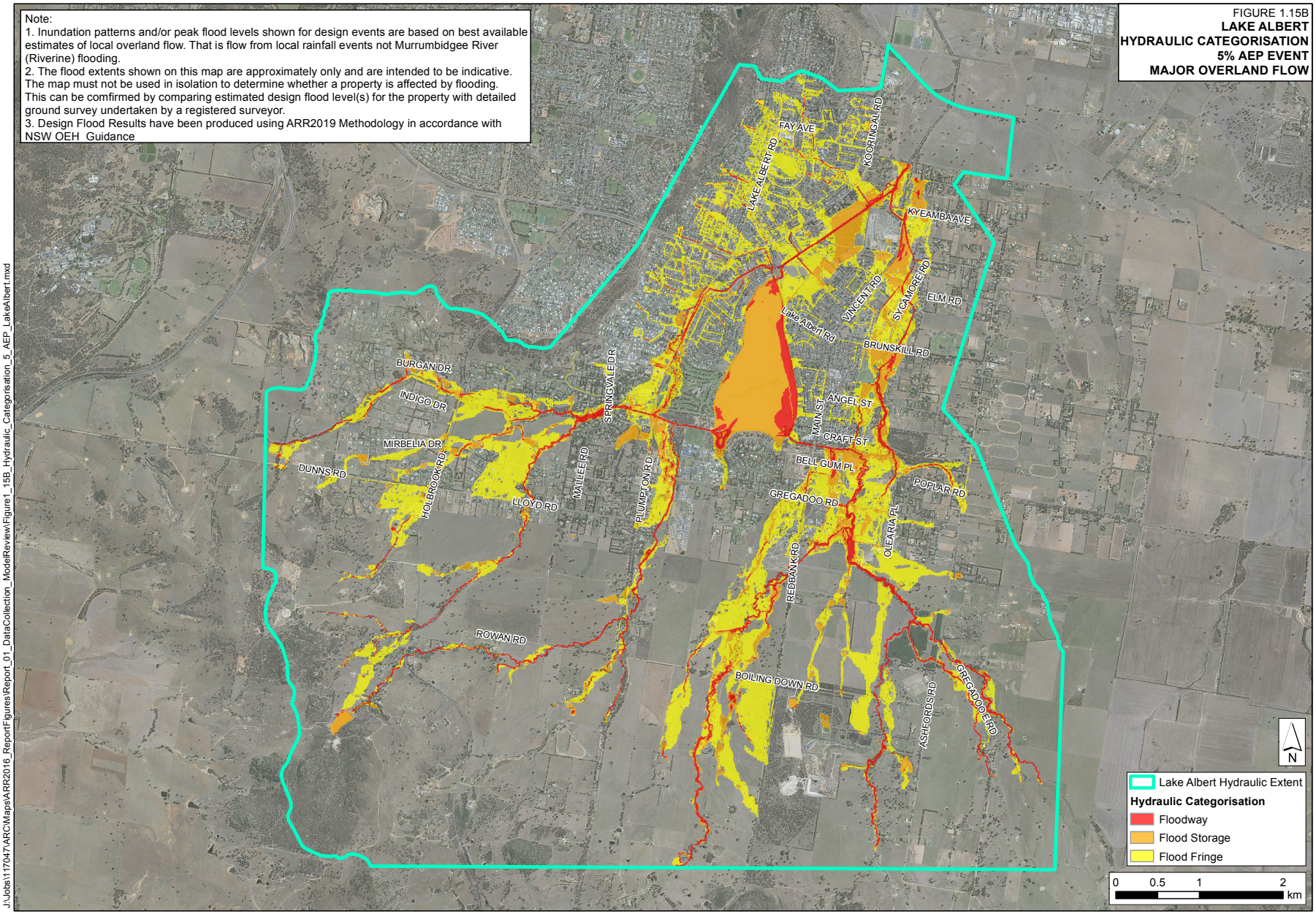
Note:
1. Inundation patterns and/or peak flood levels shown for design events are based on best available estimates of local overland flow. That is flow from local rainfall events not Murrumbidgee River (Riverine) flooding.
2. The flood extents shown on this map are approximately only and are intended to be indicative. The map must not be used in isolation to determine whether a property is affected by flooding. This can be comfirmed by comparing estimated design flood level(s) for the property with detailed ground survey undertaken by a registered surveyor.
3. Design Flood Results have been produced using ARR2019 Methodology in accordance with NSW OEH Guidance
FIGURE 1.15B
LAKE ALBERT
HYDRAULIC CATEGORISATION
5% AEP EVENT
MAJOR OVERLAND FLOW
FAY AVE
KOORINGAL RD
LAKE ALBERT RD
KYEAMBA AVE
SYCAMORE RD
VINCENT RD
ELM RD
Lake Albert Rd
BRUNSKILL RD
BURGAN DR
INDIGO DR
SPRINGVALE DR
MAIN ST
ANGEL ST
CRAFT ST
MIRBELIA DR
DUNNS RD
HOLBROOK RD
MALLEE RD
PLUMPTON RD
BELL GUM PL
POPLAR RD
GREGADOO RD
LLOYD RD
OLEARIA PL
REDBANK RD
ROWAN RD
BOILING DOWN RD
ASHFORDS RD
GREGADOO E RD
N
Lake Albert Hydraulic Extent
Hydraulic Categorisation
Floodway
Flood Storage
Flood Fringe
0 0.5 1 2
km
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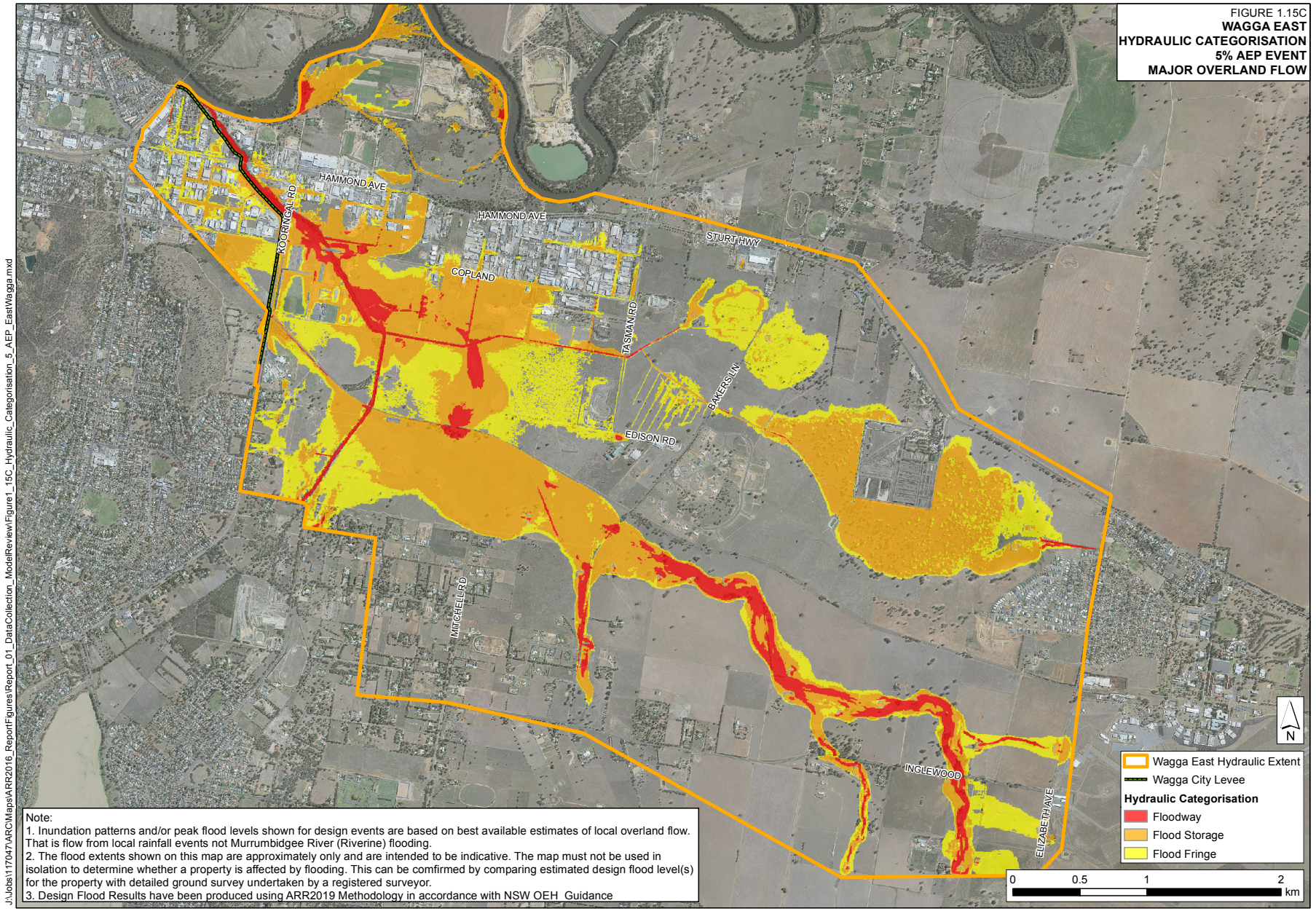
FIGURE 1.15C
WAGGA EAST
HYDRAULIC CATEGORISATION
5% AEP EVENT
MAJOR OVERLAND FLOW
HAMMOND AVE
KOORINGAL RD
HAMMOND AVE
COPLAND
STURT HWY
TASMAN RD
BAKERS LN
EDISON RD
MITCHELL RD
INGLEWOOD
ELIZABETH AVE
N
Wagga East Hydraulic Extent
Wagga City Levee
Hydraulic Categorisation
Floodway
Flood Storage
Flood Fringe
0
0.5
1
2
km
Note:
1. Inundation patterns and/or peak flood levels shown for design events are based on best available estimates of local overland flow. That is flow from local rainfall events not Murrumbidgee River (Riverine) flooding.
2. The flood extents shown on this map are approximately only and are intended to be indicative. The map must not be used in isolation to determine whether a property is affected by flooding. This can be comfirmed by comparing estimated design flood level(s) for the property with detailed ground survey undertaken by a registered surveyor.
3. Design Flood Results have been produced using ARR2019 Methodology in accordance with NSW OEH Guidance
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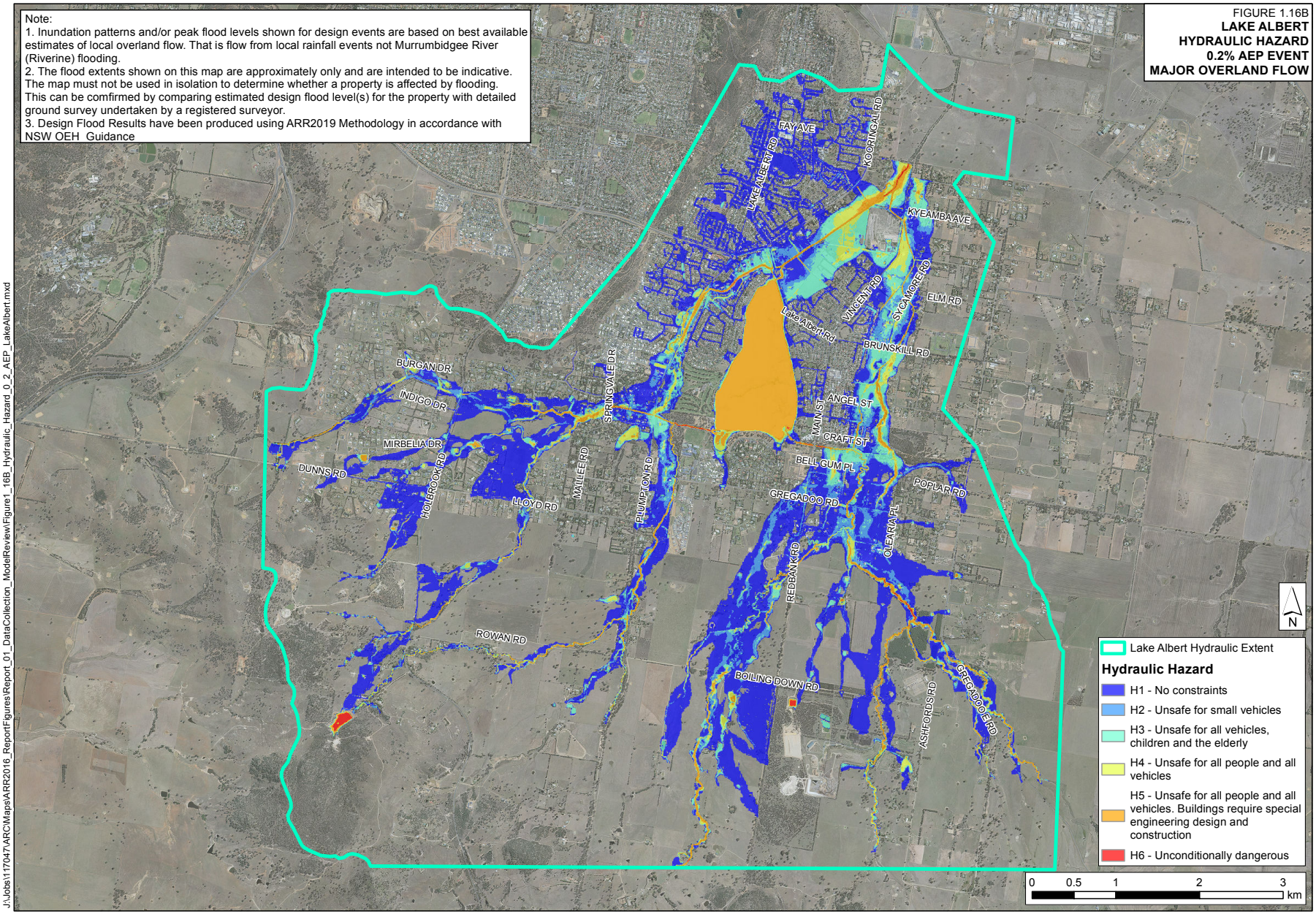
Note:
1. Inundation patterns and/or peak flood levels shown for design events are based on best available estimates of local overland flow. That is flow from local rainfall events not Murrumbidgee River (Riverine) flooding.
2. The flood extents shown on this map are approximately only and are intended to be indicative. The map must not be used in isolation to determine whether a property is affected by flooding. This can be comfirmed by comparing estimated design flood level(s) for the property with detailed ground survey undertaken by a registered surveyor.
3. Design Flood Results have been produced using ARR2019 Methodology in accordance with NSW OEH Guidance
FIGURE 1.16B
LAKE ALBERT
HYDRAULIC HAZARD
0.2% AEP EVENT
MAJOR OVERLAND FLOW
FAY AVE
KOORINGAL RD
LAKE ALBERT RD
KYEAMBA AVE
SYCAMORE RD
VINCENT RD
ELM RD
Lake Albert Rd
BRUNSKILL RD
BURGAN DR
INDIGO DR
SPRINGVALE DR
MAIN ST
ANGEL ST
CRAFT ST
MIRBELIA DR
DUNNS RD
HOLBROOK RD
MALLEE RD
PLUMPTON RD
BELL GUM PL
POPLAR RD
LLOYD RD
GREGADOO RD
OLEARIA PL
REDBANK RD
ROWAN RD
BOILING DOWN RD
ASHFORDS RD
GREGADOO E RD
N
Lake Albert Hydraulic Extent
Hydraulic Hazard
H1 - No constraints
H2 - Unsafe for small vehicles
H3 - Unsafe for all vehicles, children and the elderly
H4 - Unsafe for all people and all vehicles
H5 - Unsafe for all people and all vehicles. Buildings require special engineering design and construction
H6 - Unconditionally dangerous
0 0.5 1 2 3
km
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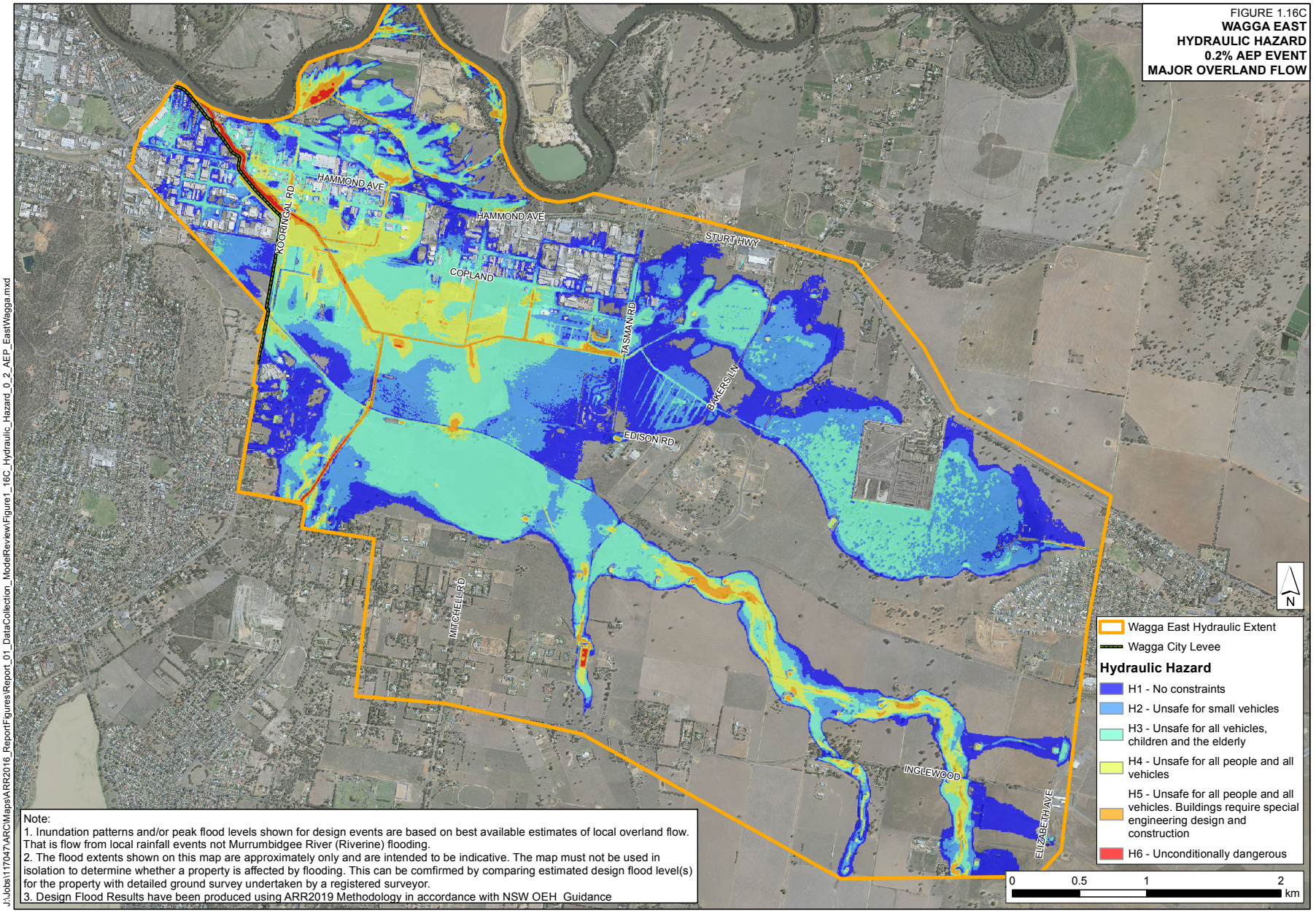
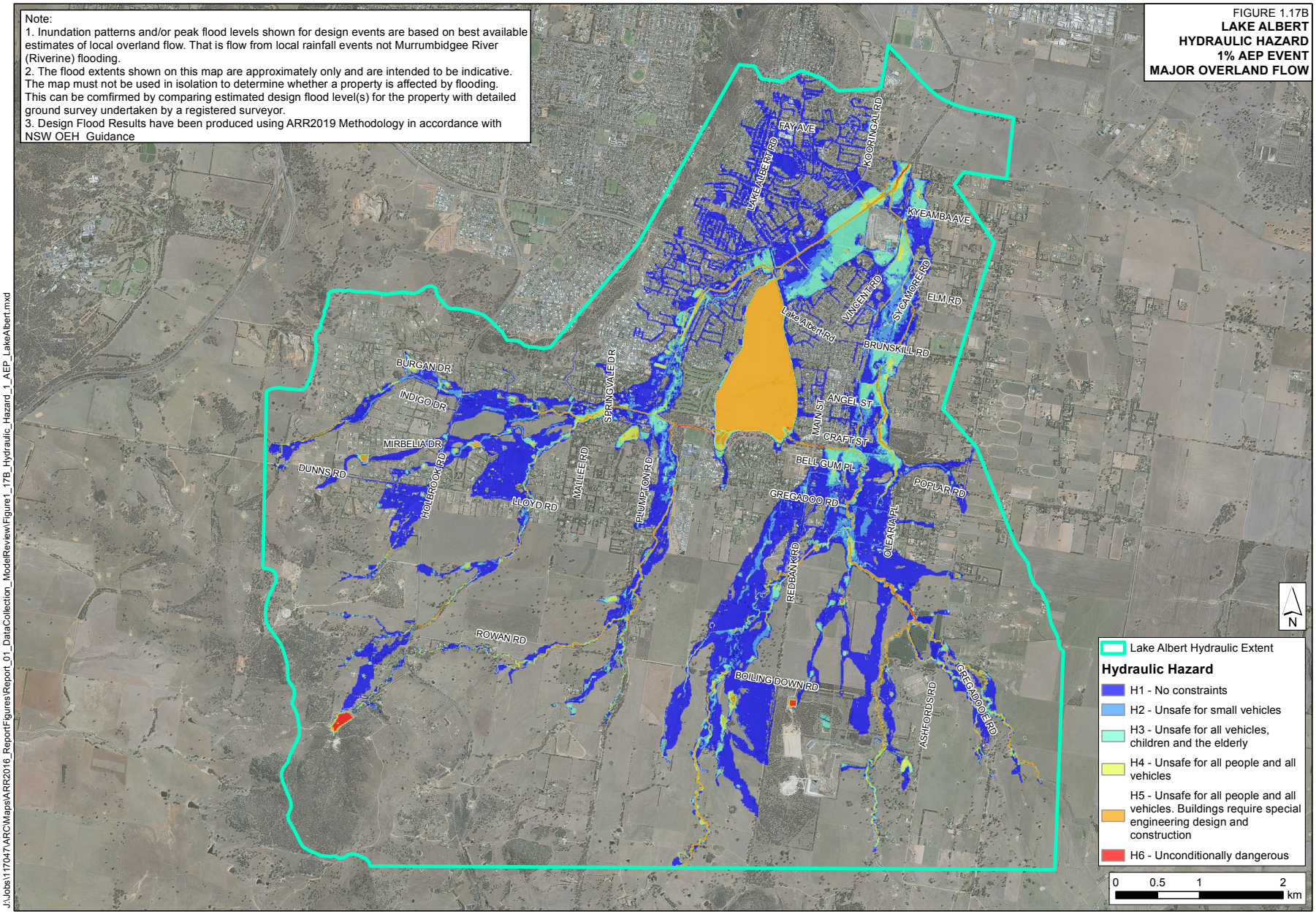


FIGURE 1.16C
WAGGA EAST
HYDRAULIC HAZARD
0.2% AEP EVENT
MAJOR OVERLAND FLOW
HAMMOND AVE
HAMMOND AVE
KOORINGAL RD
COPLAND
STURT HWY
TASMAN RD
BAKERS LN
EDISON RD
MITCHELL RD
INGLEWOOD
ELIZABETH AVE
N
Wagga East Hydraulic Extent
Wagga City Levee
Hydraulic Hazard
H1 - No constraints
H2 - Unsafe for small vehicles
H3 - Unsafe for all vehicles, children and the elderly
H4 - Unsafe for all people and all vehicles
H5 - Unsafe for all people and all vehicles. Buildings require special engineering design and construction
H6 - Unconditionally dangerous
0 0.5 1 2
km
Note:
1. Inundation patterns and/or peak flood levels shown for design events are based on best available estimates of local overland flow. That is flow from local rainfall events not Murrumbidgee River (Riverine) flooding.
2. The flood extents shown on this map are approximately only and are intended to be indicative. The map must not be used in isolation to determine whether a property is affected by flooding. This can be comfirmed by comparing estimated design flood level(s) for the property with detailed ground survey undertaken by a registered surveyor.
3. Design Flood Results have been produced using ARR2019 Methodology in accordance with NSW OEH Guidance
J:\Jobs\117047\ARC\Maps\ARR2016_ReportFigures\Report_01_DataCollection_ModelReview\Figure1_16C_Hydraulic_Hazard_0_2_AEP_EastWagga.mxd


Note:
1. Inundation patterns and/or peak flood levels shown for design events are based on best available estimates of local overland flow. That is flow from local rainfall events not Murrumbidgee River (Riverine) flooding.
2. The flood extents shown on this map are approximately only and are intended to be indicative. The map must not be used in isolation to determine whether a property is affected by flooding. This can be comfirmed by comparing estimated design flood level(s) for the property with detailed ground survey undertaken by a registered surveyor.
3. Design Flood Results have been produced using ARR2019 Methodology in accordance with NSW OEH Guidance
FIGURE 1.17B
LAKE ALBERT
HYDRAULIC HAZARD
1% AEP EVENT
MAJOR OVERLAND FLOW
FAY AVE
KOORINGAL RD
LAKE ALBERT RD
KYEAMBA AVE
SYCAMORE RD
VINCENT RD
ELM RD
Lake Albert Rd
BRUNSKILL RD
BURGAN DR
INDIGO DR
SPRINGVALE DR
MAIN ST
ANGEL ST
CRAFT ST
MIRBELIA DR
DUNNS RD
HOLBROOK RD
MALLEE RD
PUMPTON RD
BELL GUM PL
POPLAR RD
LLOYD RD
GREGADOO RD
OLEARIA PL
REDBANK RD
ROWAN RD
BOILING DOWN RD
ASHFORDS RD
GREGADOO E RD
N
Lake Albert Hydraulic Extent
Hydraulic Hazard
H1 - No constraints
H2 - Unsafe for small vehicles
H3 - Unsafe for all vehicles, children and the elderly
H4 - Unsafe for all people and all vehicles
H5 - Unsafe for all people and all vehicles. Buildings require special engineering design and construction
H6 - Unconditionally dangerous
0 0.5 1 2
km
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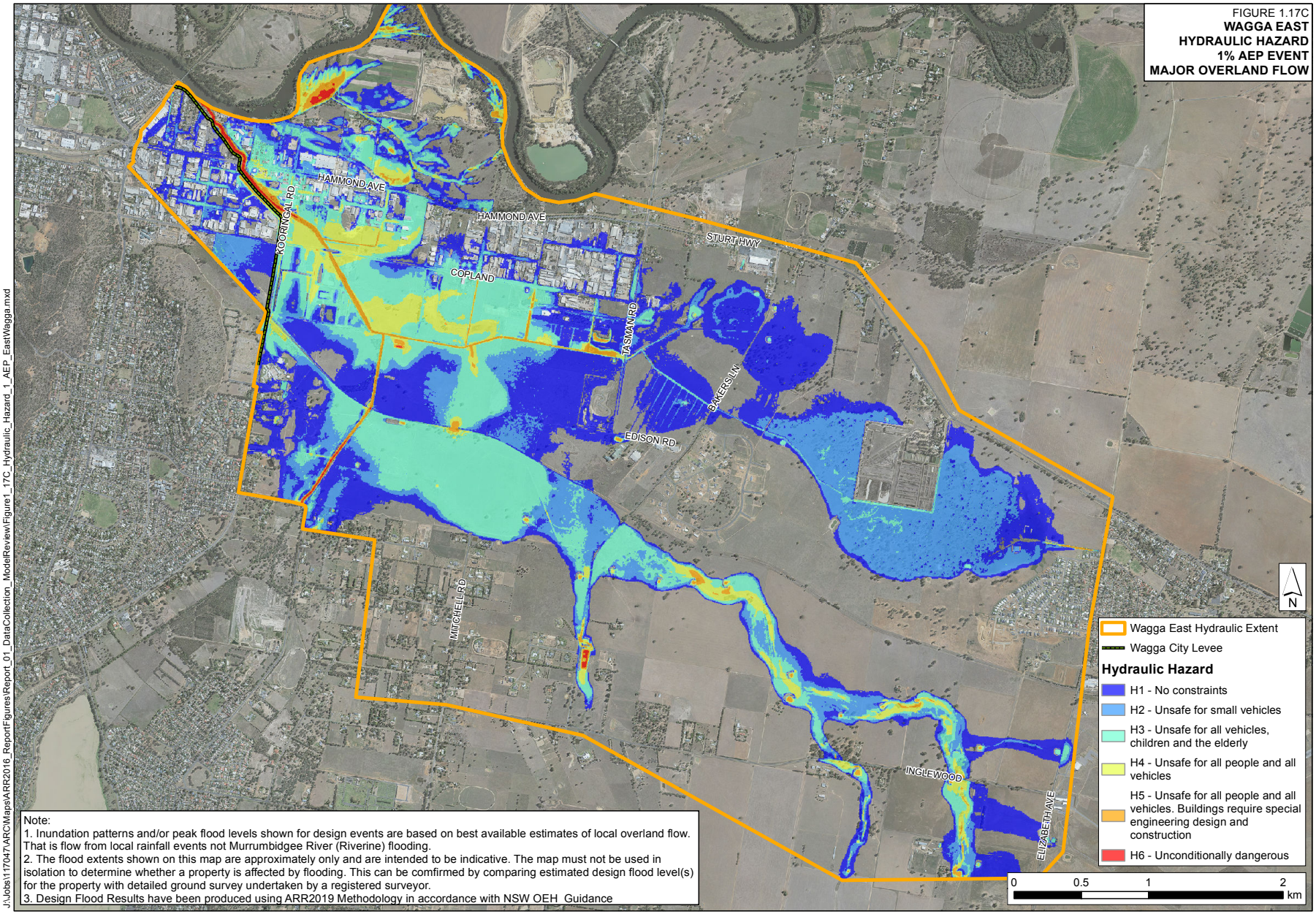
FIGURE 1.17C
WAGGA EAST
HYDRAULIC HAZARD
1% AEP EVENT
MAJOR OVERLAND FLOW
HAMMOND AVE
HAMMOND AVE
KOORINGAL RD
COPLAND
STURT HWY
TASMAN RD
BAKERS LN
EDISON RD
MITCHELL RD
INGLEWOOD
ELIZABETH AVE
N
Wagga East Hydraulic Extent
Wagga City Levee
Hydraulic Hazard
H1 - No constraints
H2 - Unsafe for small vehicles
H3 - Unsafe for all vehicles, children and the elderly
H4 - Unsafe for all people and all vehicles
H5 - Unsafe for all people and all vehicles. Buildings require special engineering design and construction
H6 - Unconditionally dangerous
0 0.5 1 2
km
Note:
1. Inundation patterns and/or peak flood levels shown for design events are based on best available estimates of local overland flow. That is flow from local rainfall events not Murrumbidgee River (Riverine) flooding.
2. The flood extents shown on this map are approximately only and are intended to be indicative. The map must not be used in isolation to determine whether a property is affected by flooding. This can be comfirmed by comparing estimated design flood level(s) for the property with detailed ground survey undertaken by a registered surveyor.
3. Design Flood Results have been produced using ARR2019 Methodology in accordance with NSW OEH Guidance
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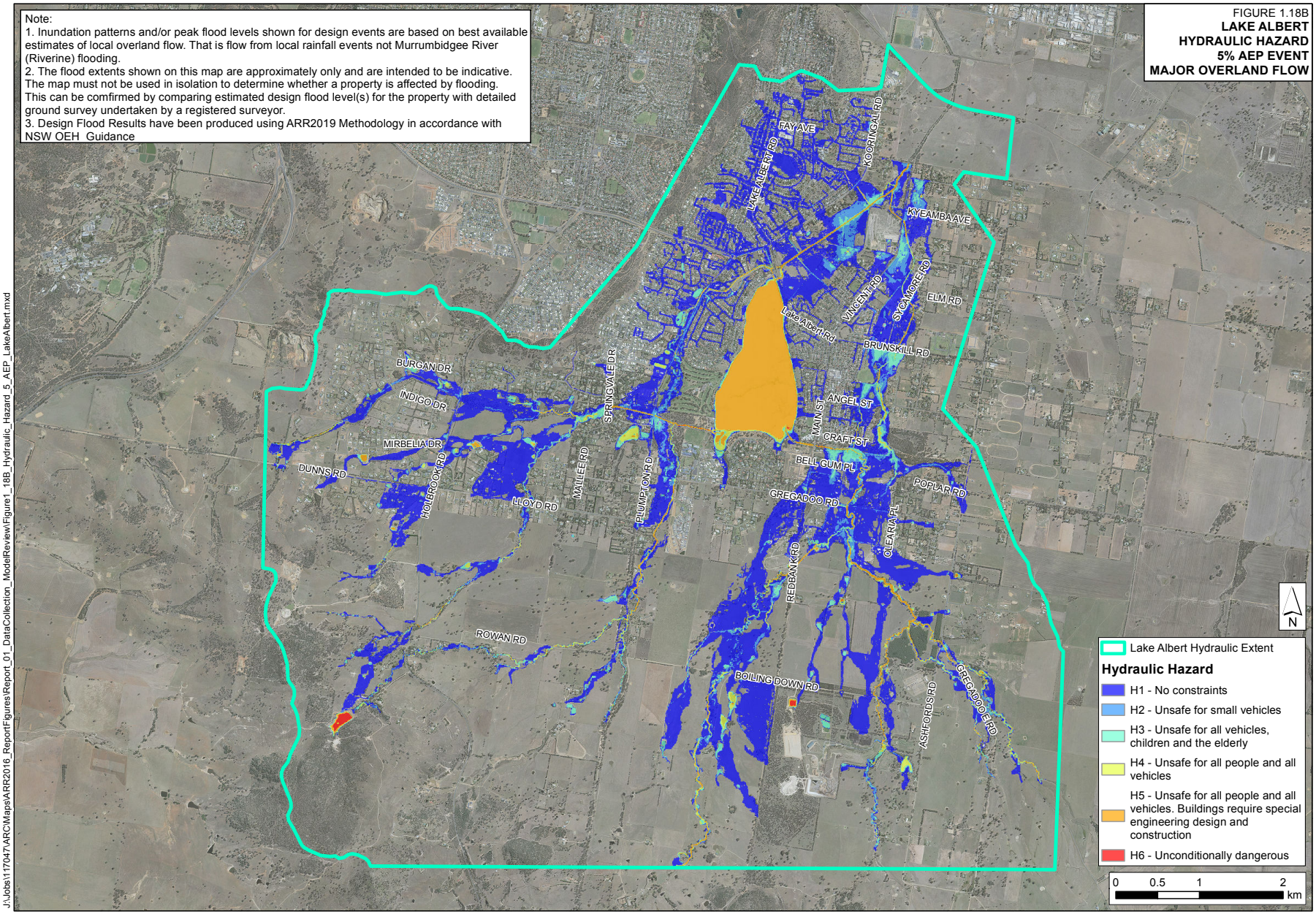

Note:
1. Inundation patterns and/or peak flood levels shown for design events are based on best available estimates of local overland flow. That is flow from local rainfall events not Murrumbidgee River (Riverine) flooding.
2. The flood extents shown on this map are approximately only and are intended to be indicative. The map must not be used in isolation to determine whether a property is affected by flooding. This can be comfirmed by comparing estimated design flood level(s) for the property with detailed ground survey undertaken by a registered surveyor.
3. Design Flood Results have been produced using ARR2019 Methodology in accordance with NSW OEH Guidance
FIGURE 1.18B
LAKE ALBERT
HYDRAULIC HAZARD
5% AEP EVENT
MAJOR OVERLAND FLOW
J:\Jobs\117047\ARC\Maps\ARR2016_ReportFigures\Report_01_DataCollection_ModelReview\Figure1_18B_Hydraulic_Hazard_5_AEP_LakeAlbert.mxd
FAY AVE
KOORINGAL RD
LAKE ALBERT RD
KYEAMBA AVE
VINCENT RD
SYCAMORE RD
ELM RD
Lake Albert Rd
BRUNSKILL RD
BURGAN DR
INDIGO DR
SPRINGVALE DR
MAIN ST
ANGEL ST
CRAFT ST
MIRBELIA DR
DUNNS RD
HOLBROOK RD
MALLEE RD
PLUMPTON RD
BELL GUM PL
POPLAR RD
LLOYD RD
GREGADOO RD
OLEARIA PL
REDBANK RD
ROWAN RD
BOILING DOWN RD
ASHFORDS RD
GREGADOO E RD
N
Lake Albert Hydraulic Extent
Hydraulic Hazard
H1 - No constraints
H2 - Unsafe for small vehicles
H3 - Unsafe for all vehicles, children and the elderly
H4 - Unsafe for all people and all vehicles
H5 - Unsafe for all people and all vehicles. Buildings require special engineering design and construction
H6 - Unconditionally dangerous
0 0.5 1 2
km

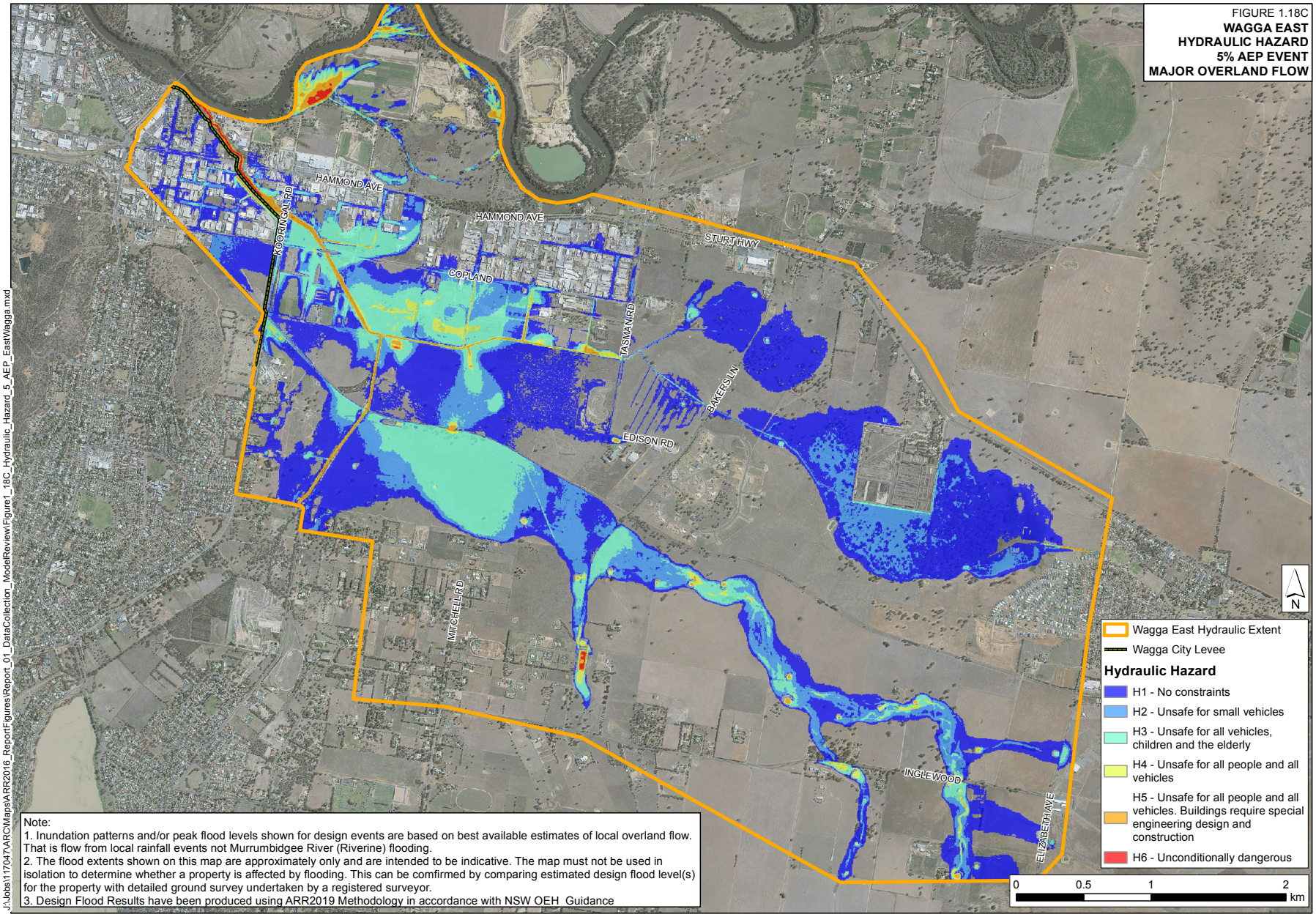
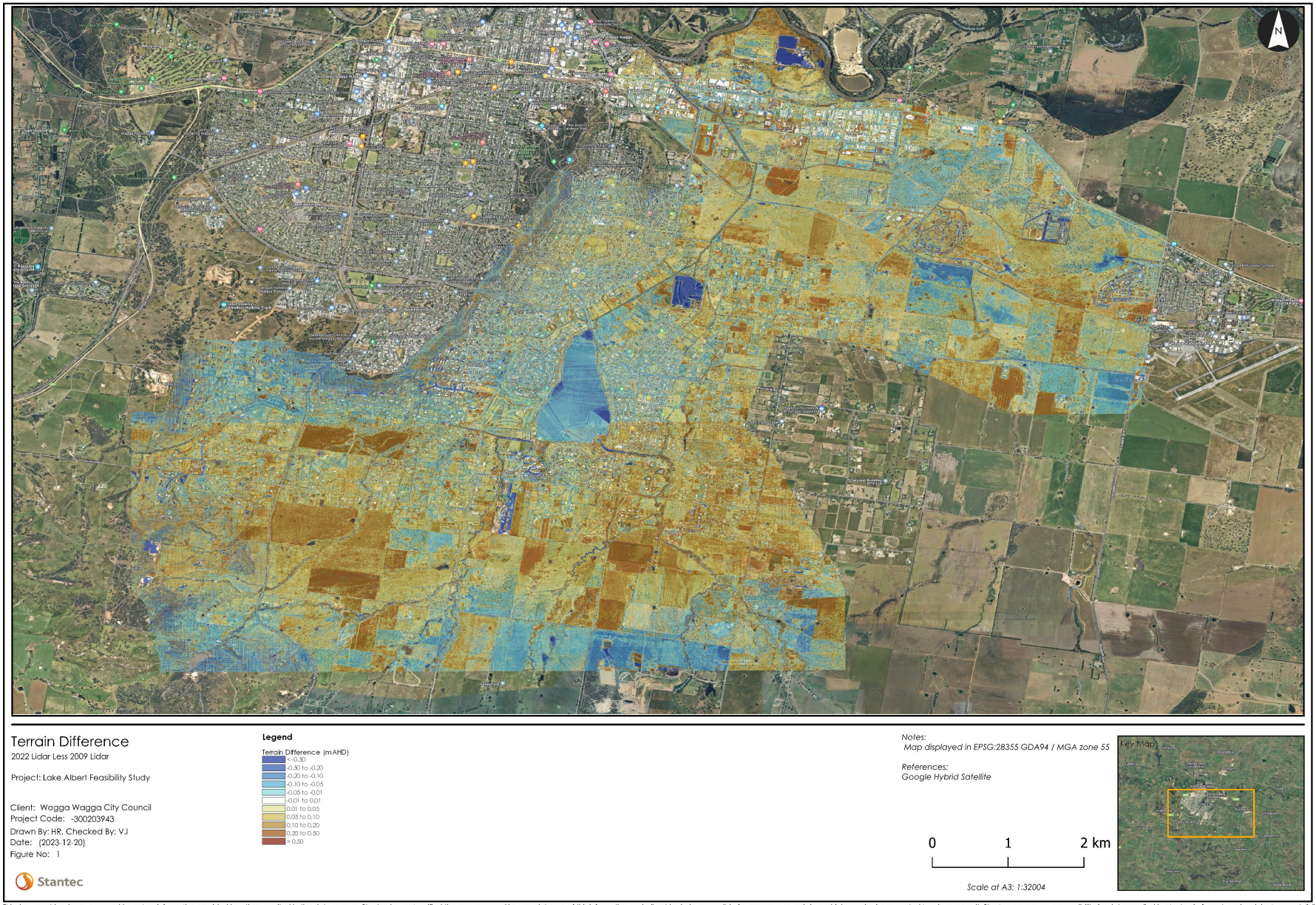


FIGURE 1.18C
WAGGA EAST
HYDRAULIC HAZARD
5% AEP EVENT
MAJOR OVERLAND FLOW
HAMMOND AVE
KOORINGAL RD
HAMMOND AVE
COPLAND
STURT HWY
TASMAN RD
BAKERS LN
EDISON RD
MITCHELL RD
INGLEWOOD
ELIZABETH AVE
N
Wagga East Hydraulic Extent
Wagga City Levee
Hydraulic Hazard
H1 - No constraints
H2 - Unsafe for small vehicles
H3 - Unsafe for all vehicles, children and the elderly
H4 - Unsafe for all people and all vehicles
H5 - Unsafe for all people and all vehicles. Buildings require special engineering design and construction
H6 - Unconditionally dangerous
0 0.5 1 2
km
J:\Jobs\117047\ARC\Maps\ARR2016_ReportFigures\Report_01_DataCollection_ModelReview\Figure1_18C_Hydraulic_Hazard_5_AEP_EastWagga.mxd
Note:
1. Inundation patterns and/or peak flood levels shown for design events are based on best available estimates of local overland flow. That is flow from local rainfall events not Murrumbidgee River (Riverine) flooding.
2. The flood extents shown on this map are approximately only and are intended to be indicative. The map must not be used in isolation to determine whether a property is affected by flooding. This can be comfirmed by comparing estimated design flood level(s) for the property with detailed ground survey undertaken by a registered surveyor.
3. Design Flood Results have been produced using ARR2019 Methodology in accordance with NSW OEH Guidance

Appendix B - Lidar Difference (2022 vs 2009)



Appendix C - Ultimate Lake Albert Scheme Afflux

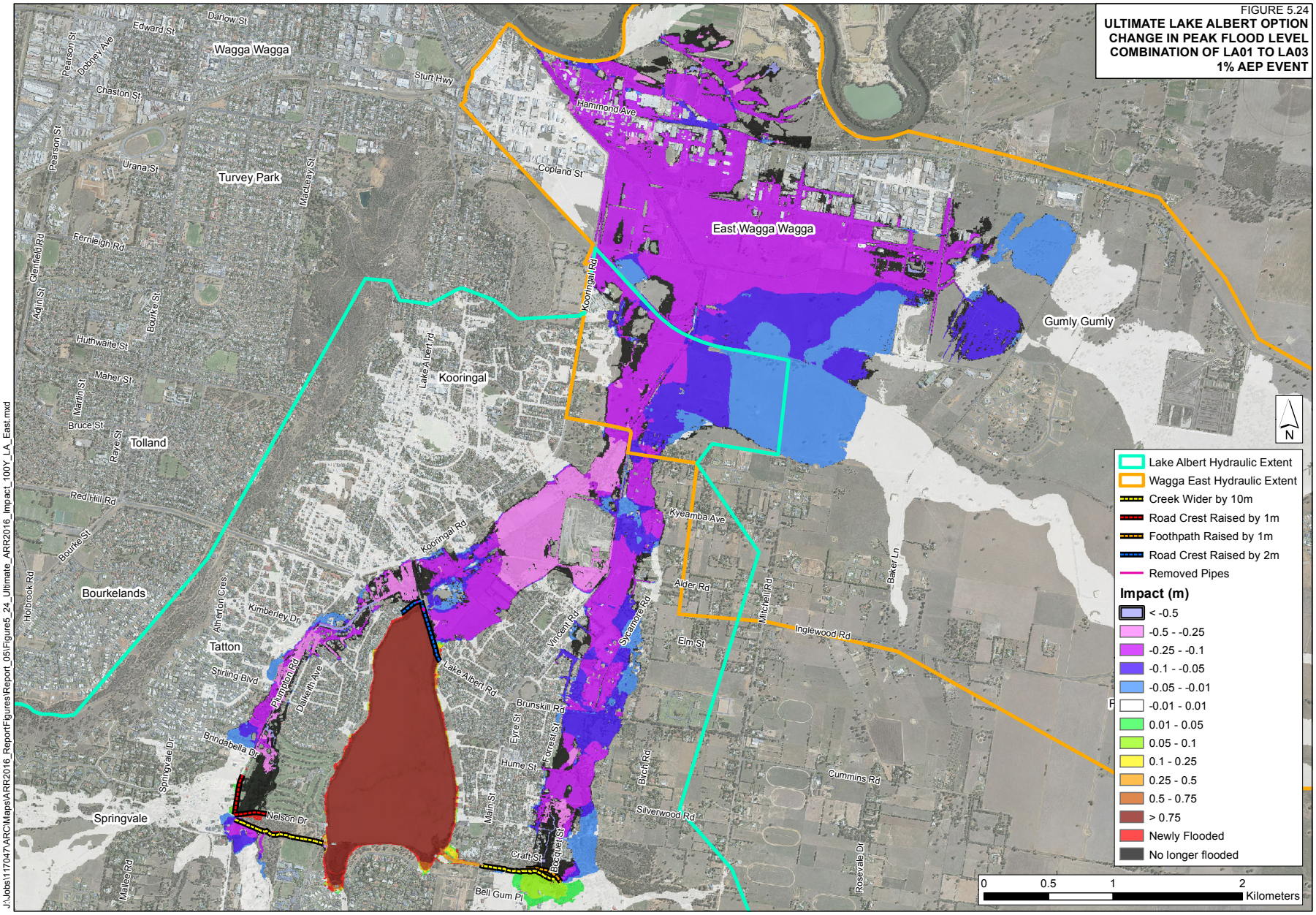


FIGURE 5.24
ULTIMATE LAKE ALBERT OPTION
CHANGE IN PEAK FLOOD LEVEL
COMBINATION OF LA01 TO LA03
1% AEP EVENT
Wagga Wagga
Turvey Park
East Wagga Wagga
Gumly Gumly
Kooringal
Tolland
Bourkelands
Tatton
Springvale
Lake Albert Hydraulic Extent
Wagga East Hydraulic Extent
Creek Wider by 10m
Road Crest Raised by 1m
Foothpath Raised by 1m
Road Crest Raised by 2m
Removed Pipes
Impact (m)
< -0.5
-0.5 - -0.25
-0.25 - -0.1
-0.1 - -0.05
-0.05 - -0.01
-0.01 - 0.01
0.01 - 0.05
0.05 - 0.1
0.1 - 0.25
0.25 - 0.5
0.5 - 0.75
> 0.75
Newly Flooded
No longer flooded
0 0.5 1 2
Kilometers
N
J:\Jobs\117047\ARC\Maps\ARR2016_ReportFigures\Report_05\Figures5_24_Ultimate_ARR2016_Impact_100Y_LA_East.mxd

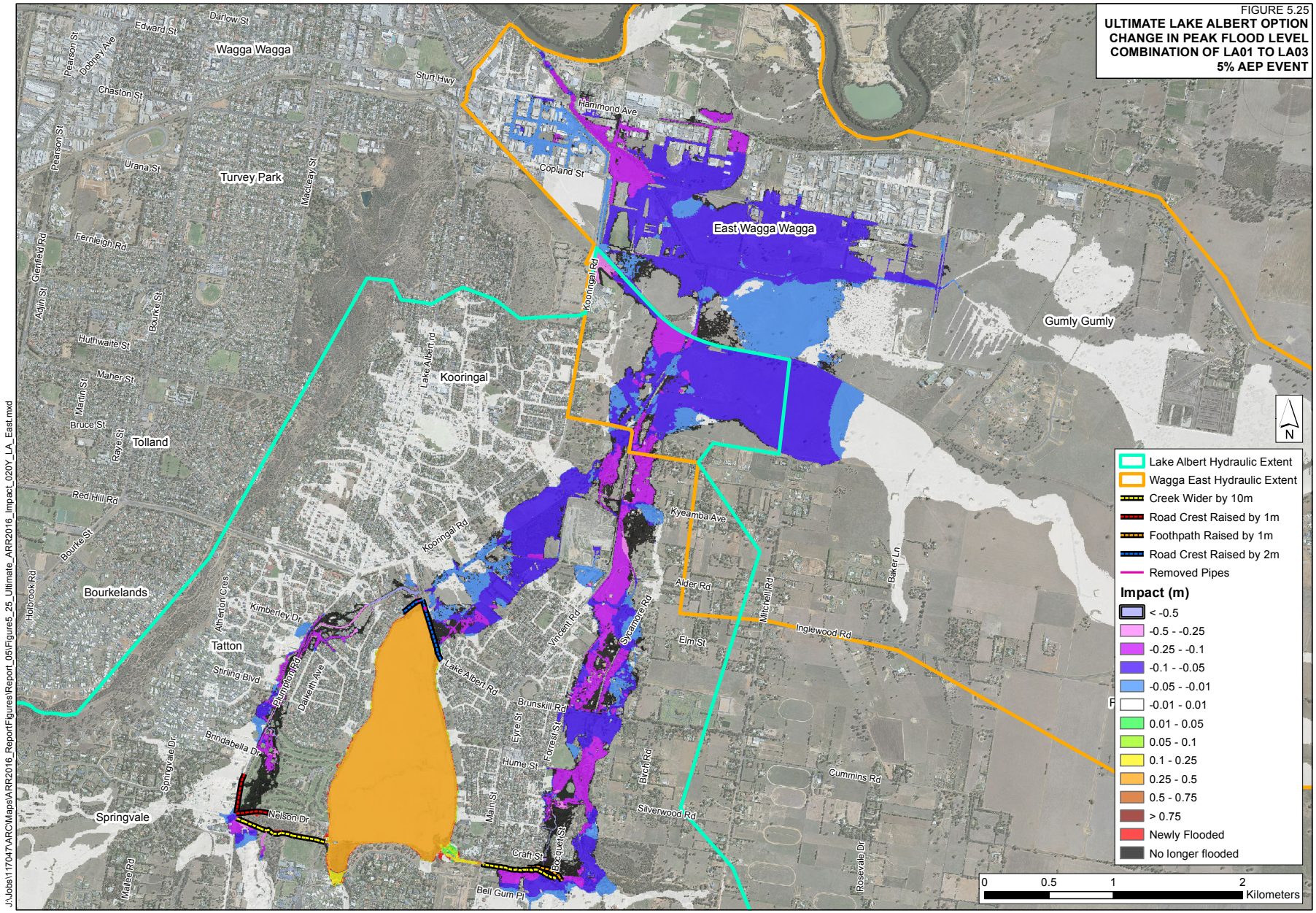


FIGURE 5.25
ULTIMATE LAKE ALBERT OPTION
CHANGE IN PEAK FLOOD LEVEL
COMBINATION OF LA01 TO LA03
5% AEP EVENT
Wagga Wagga
Turvey Park
East Wagga Wagga
Gumly Gumly
Kooringal
Tolland
Bourkelands
Tatton
Springvale
Lake Albert Hydraulic Extent
Wagga East Hydraulic Extent
Creek Wider by 10m
Road Crest Raised by 1m
Foothpath Raised by 1m
Road Crest Raised by 2m
Removed Pipes
Impact (m)
< -0.5
-0.5 - -0.25
-0.25 - -0.1
-0.1 - -0.05
-0.05 - -0.01
-0.01 - 0.01
0.01 - 0.05
0.05 - 0.1
0.1 - 0.25
0.25 - 0.5
0.5 - 0.75
> 0.75
Newly Flooded
No longer flooded
0 0.5 1 2
Kilometers
N
J:\Jobs\117047\ARC\Maps\ARR2016_ReportFigures\Report_05\Figures5_25_Ultimate_ARR2016_Impact_020Y_LA_East.mxd

ACHM
AUSTRALIAN CULTURAL HERITAGE MANAGEMENT

Due Diligence Report

LAKE ALBERT FEASIBILITY STUDY - Part 2

Aboriginal Cultural Heritage Due Diligence Assessment

By: Molly Quinn

Date: 23 January 2024

Client Name: Stantec Australia Pty Ltd
Client Contact: Venus Jofreh
Address: 207 Kent Street Sydney
New South Wales 2000

Phone: +61 2 8448 1862
Email: venus.jofreh@stantec.com

ADELAIDE
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LAKE ALBERT FEASIBILITY STUDY - Part 2

Aboriginal Cultural Heritage Due Diligence Assessment

By: Molly Quinn

Date: 23 January 2024

Client Name: Stantec Australia Pty Ltd
Client Contact: Venus Jofreh
Address: 207 Kent Street Sydney
New South Wales 2000

Phone: +61 2 8448 1862
Email: venus.jofreh@stantec.com

Aboriginal Cultural Heritage Present within the Activity Area: No

Document Control Information

Document information
Client: Stantec Australia Pty Ltd Client Contact: Venus Jofreh Title: LAKE ALBERT FEASIBILITY STUDY - Part 2 Subtitle: Aboriginal Cultural Heritage Due Diligence Assessment Our Ref: P23-0198 Date: 23 January 2024

Version	Date	Details
1	23/01/2024	Draft report

Recipient Name	Organisation	Hardcopy	Electronic	Transmission Method	Purpose	Date

Author, Reviewer and Approver details				
Prepared by:	Molly Quinn	Date: 23/01/2024	Signature:	
Reviewed by:		Date:	Signature:	
Approved by:		Date:	Signature:	

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The professional advice and opinions contained in this document are those of the consultants, Australian Cultural Heritage Management (Victoria) Pty Ltd, and do not represent the opinions and policies of any third party.

The professional advice and opinions contained in this document do not constitute legal advice.

Spatial Data

Spatial data captured by Australian Cultural Heritage Management (Victoria) Pty Ltd in this document for any newly recorded sites has been obtained by using hand held or differential GPS units using the GDA94 co-ordinate system.

Abbreviations

Term	Meaning
ACHM	Australian Cultural Heritage Management Pty Ltd
ACHA	Aboriginal Cultural Heritage Assessment
AHIMS	Aboriginal Heritage Information Management System
AHIP	Aboriginal Heritage Impact Permit
Km	Kilometers
LA01	Lake Albert Enhanced Flow Scheme Stage 1
LA02	Lake Albert Enhanced Flow Scheme Stage 2
LA03	Lake Albert Enhanced Flow Scheme Stage 3
LALC	Local Aboriginal Land Council
LGA	Local Government Area
NSW	New South Wales
Project areas	Location of works footprint of LA01, LA02, and LA03

Table of contents

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1 Introduction

Australian Cultural Heritage Management (ACHM) was engaged by Stantec, on behalf of Wagga Wagga City Council, to undertake an Aboriginal cultural heritage due diligence assessment for the proposed three-stage Lake Albert Enhanced Flow Scheme (LA01, LA02, LA03).

The assessment area covered by this desktop covers approximately 0.0143 km^2 (LA01, 1,300m^2; LA02, 5,800 m^2: LA03, 7,200 m^2) of land in three areas adjacent to Lake Albert, within the City of Wagga Wagga Local Government Area (LGA) in NSW.

This assessment involves identifying any factors that suggest the presence of Aboriginal cultural heritage within the project area footprint. This will be achieved through background research of the landscape as well as identification of previously recorded sites and surveys of the area. ACHM are also required to determine if any statutory heritage requirements are triggered by the proposed activity.

This report is based on the information presented to ACHM by the client and a review of the Aboriginal cultural heritage available for the project area. A pedestrian archaeological field inspection was not completed as part of this assessment.

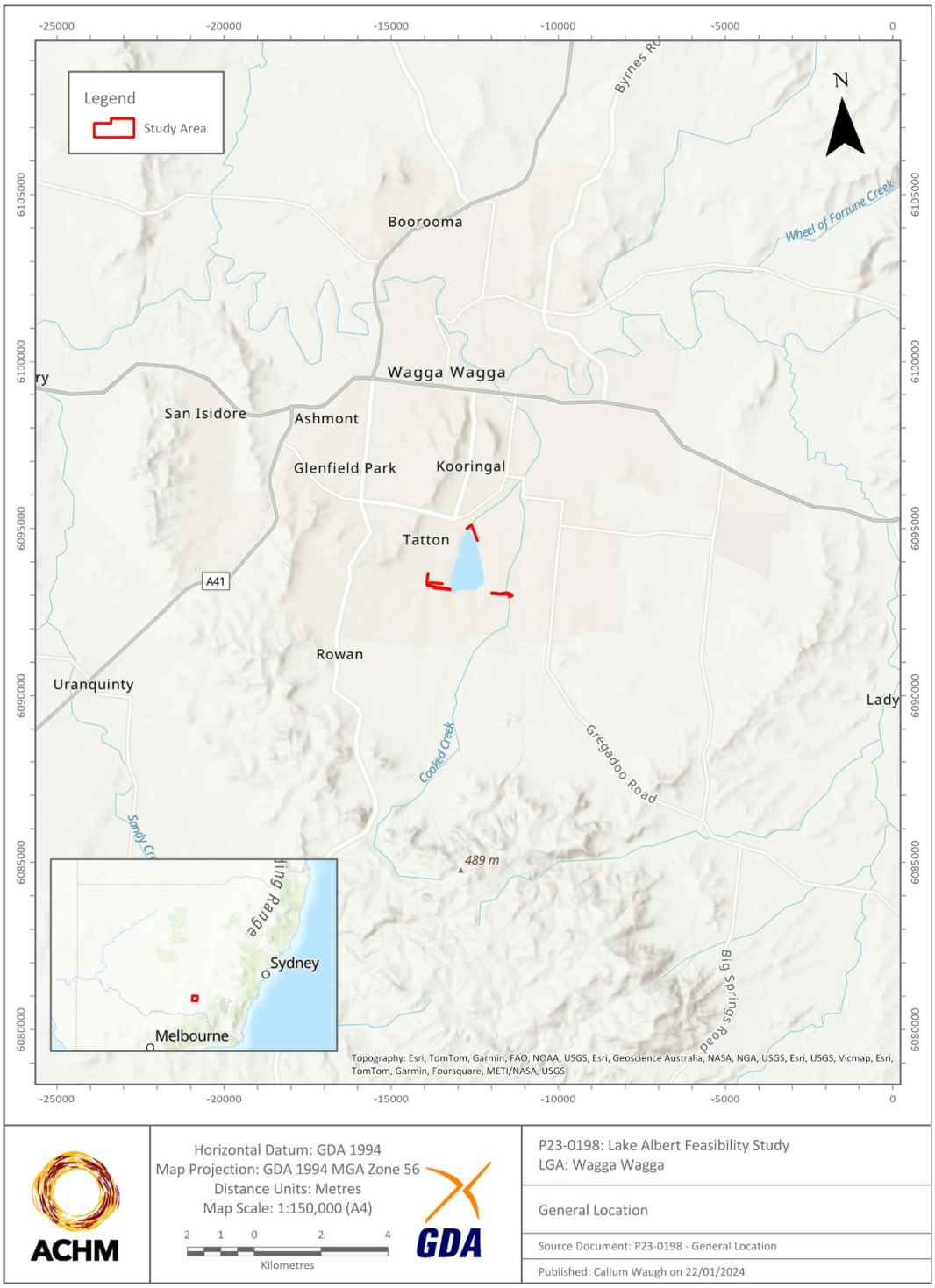
1.1 Limitations

This report covers a desktop assessment only. No detailed pedestrian survey, archaeological subsurface testing or excavation was undertaken prior to the preparation of this report.

1.2 Proposed Activity and Potential Impacts on Cultural Heritage Values

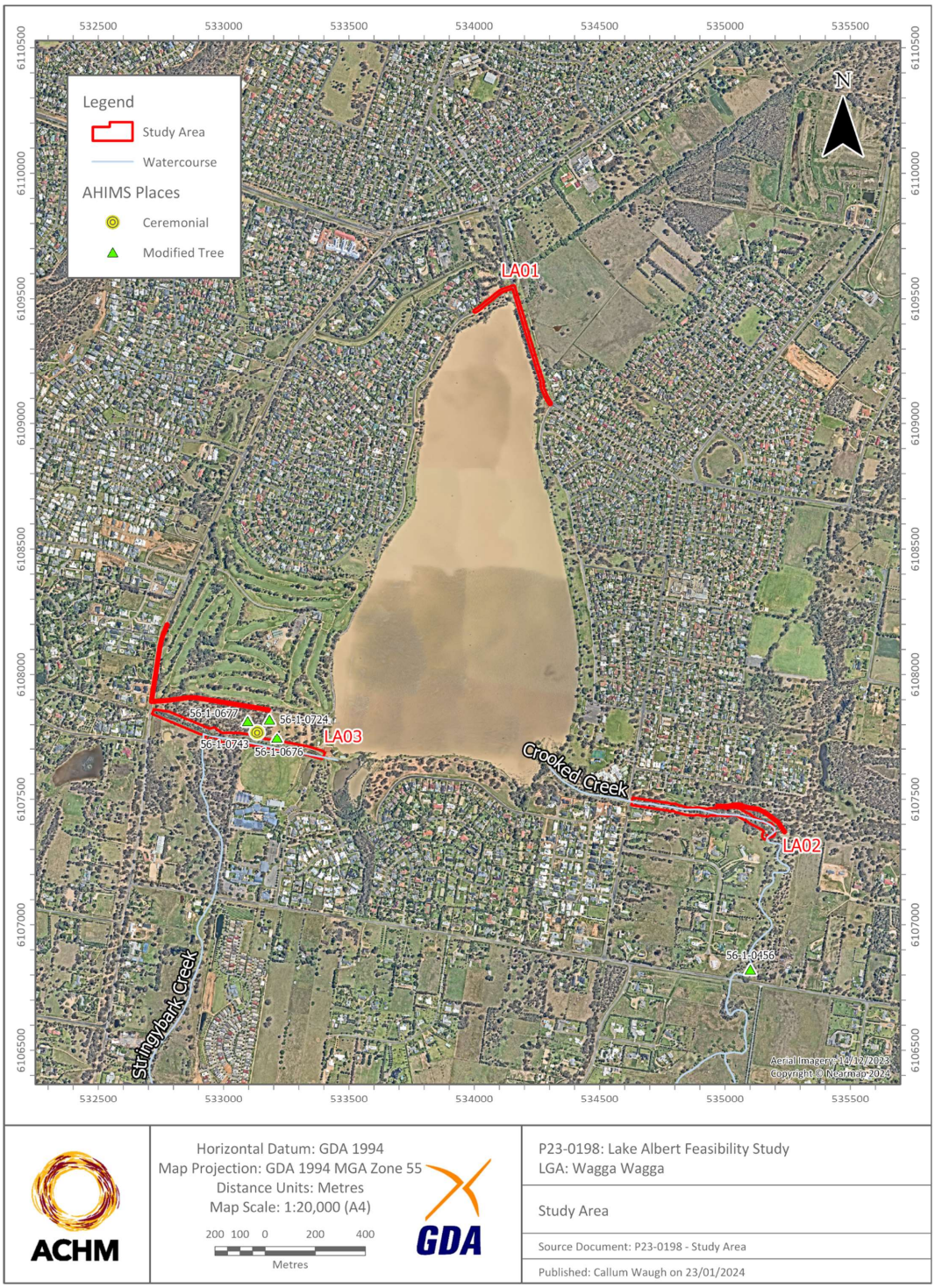
The proposed works for the Lake Albert Enhanced Flow Scheme include three stages (LA01, LA02, LA03) taking place across three project areas (Map 1-1 through 1-4).

LAKE ALBERT FEASIBILITY STUDY - Part 2



Map 1–1: General location of Lake Albert.

LAKE ALBERT FEASIBILITY STUDY - Part 2



Map 1–2: Location of three project areas around Lake Albert.

1.2.1 LA01: Raising Lake Albert Road

The first stage of the scheme will raise Lake Albert Road at the northeast corner of Lake Albert by approximately 2 m over a length of 450 m, and Lakeside Drive by approximately 2 m for 200 m from its intersection with Lake Albert Road. Additional works will include the modification of the existing outlet structures between both Lake Albert Road and Lakeside Drive. Outcomes will include the reduction of peak flood levels downstream of Lake Albert, preparing Lake Albert to be able to store a greater capacity of water during a flood event.

Land use around LA01 works is mainly residential, with some farmland to the north.

1.2.2 LA02: Augmentation of Crooked Creek Diversion into Lake Albert

Stage two will involve the expansion of the Crooked Creek diversion, and construction of a 1 m high diversion embankment along Craft Street to assist in the function of the Crooked Creek diversion channel and provide protection to residences north of Craft Street. The existing diversion will be augmented by 10 m. Over a length of 580 m, the augmented diversion channel would require the excavation of approximately 6,800 m^3 of earth from the existing creek bank.

Land use around the proposed LA02 works is predominantly Lake Albert public recreation land, with private buildings to the north and south (Lake Albert Public School, residential). The Crooked Creek diversion was originally cut in 1900 from the natural (south to north, parallel to Lake Albert on the eastern shore) path of Crooked Creek. As such, the diversion itself is not a natural waterway. However, the project area still falls within 200 m of natural watercourses (Lake Albert swamp). If any elevated flat land associated with these creek lines remains undisturbed within the project area, there is potential that unidentified Aboriginal cultural heritage may be impacted.

1.2.3 LA03: Augmentation of Stringybark Creek Diversion into Lake Albert

Stage three proposes raising the road heights on Plumpton Road and Nelson Drive adjacent to the intersection by 1 m to reduce flood risk along Plumpton Road and minimise the overtopping of the road. Works will widen the Stringybark Creek diversion channel by 10 m from the creek intersection with Plumpton Road to Lake Albert. Over the channel length of 720 m, this stage requires the removal of approximately 27,200 m^3 of earth from the creek banks.

Current land use around Stringybark Creek is predominantly part of the wider Lake Albert public recreation area. Buildings and development are present in the east, where the diversion connects to Lake Albert. Evidence of disturbance is present around the diversion in the form of utilised fields associated with Mater Dei Catholic College and Wagga Wagga Sailing Club. The original course of Stringybark Creek ran south to north parallel to the current Lake Albert; the portion of the 'creek' on which works are proposed is a diversion and not part of the natural course. Despite this, the assessment area still falls within 200 m of natural watercourses (the original south to north trajectory of Stringybark Creek, Lake Albert Swamp). If any elevated flat land associated with these creek lines remains undisturbed within the project area, there is potential that unidentified Aboriginal cultural heritage may be impacted.

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Map 1–3: LA01 work project area.

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Map 1–4: LA02 work project area.

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Map 1–5: LA03 work project area, including sites within proximity.

1.2.4 Proposed Activity

The three stages of the Lake Albert Enhanced Flow Scheme involve varying levels of associated ground disturbance. This assessment will provide Stantec with the opportunity to avoid any potential areas of Aboriginal cultural heritage, including previously recorded sites and potential sub-surface deposits that would require additional investigation. If these areas cannot be avoided, additional cultural heritage investigation will be required.

Future assessments may include an Aboriginal Cultural Heritage Assessment (ACHA) of the project area. This may also include sub-surface investigation and salvage of areas of cultural heritage that will be impacted by the proposed works.

1.2.5 Potential Impacts on Cultural Heritage

Construction of the Lake Albert infrastructure includes the following activities that have the potential to cause harm to cultural heritage places through ground disturbance:

- Excavation of potentially undisturbed areas adjacent to the diversions at Stringybark and Crooked Creeks;
- Levelling of ground for concrete foundations and pads;
- Civil works that include grading, compaction, drainage, and sediment control.
- Vehicle movement across the project area.

Impacts to cultural heritage may occur wherever ground disturbance works are undertaken, or vegetation is removed.

If landforms of archaeological sensitivity for the presence of potential Aboriginal cultural heritage are identified in the project area, further archaeological investigation in the form of an Aboriginal Cultural Heritage Assessment (ACHA) and potential sub-surface investigation will be recommended, prior to the commencement of future stages of the project. Further discussion on the archaeological sensitivity of the project area is provided in Section 3.2 below.

1.3 Traditional Owners

The Lake Albert project area covers the traditional lands of the Wiradjuri peoples. The contemporary boundaries of the Wagga Wagga Local Aboriginal Land Council (LALC) are depicted in Map 1-6.

1.4 Native Title

There are no current native title claims for the project area.

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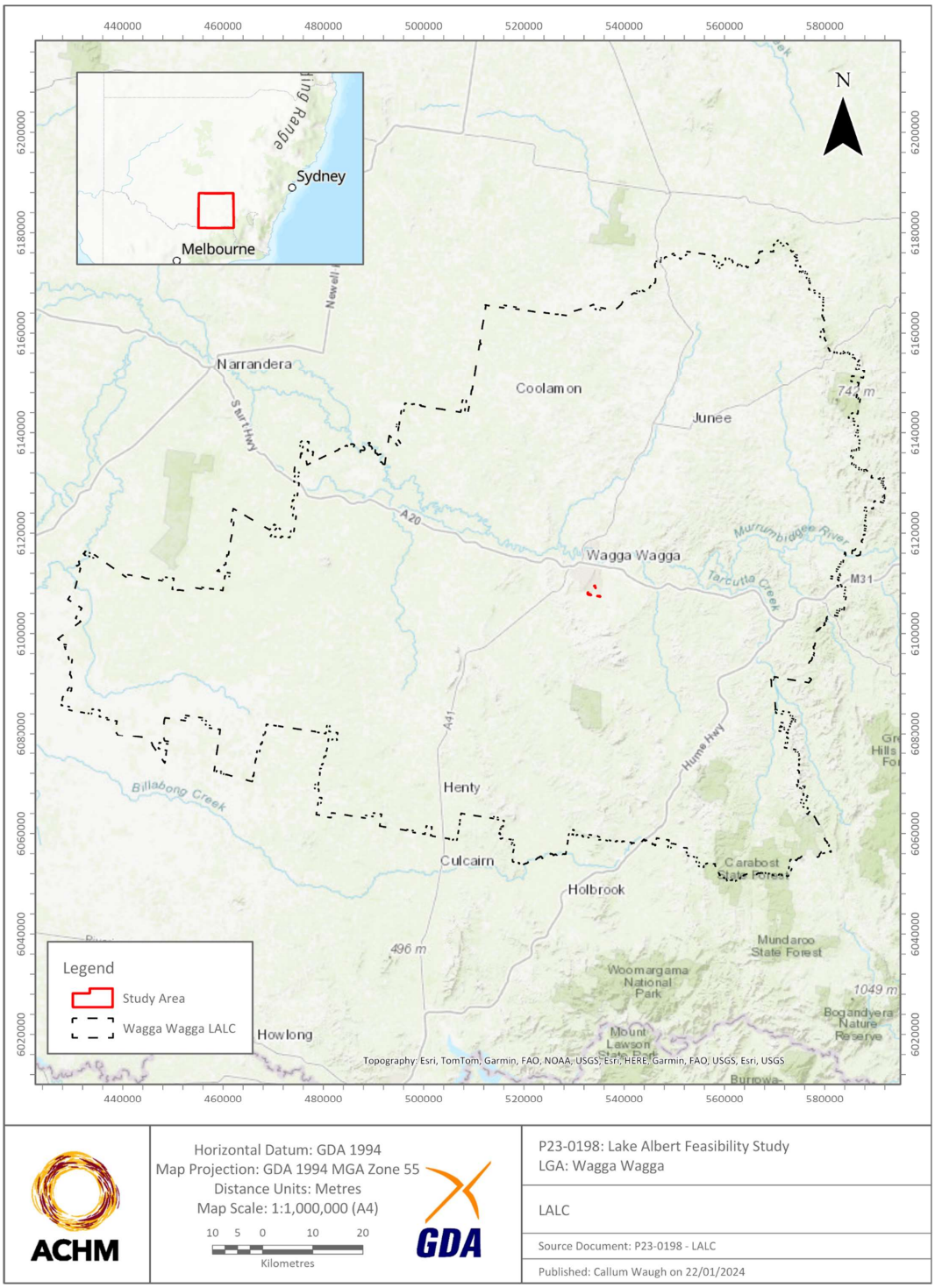

Map 1–6: Map showing the Wagga Wagga LALC boundaries that cover the Project Area.

2 Heritage Protection Legislation

This section outlines information on all the relevant state and Commonwealth legislation designed for the protection of Aboriginal and non-Aboriginal heritage to be considered during this project.

2.1 Aboriginal Heritage Legislation

2.1.1 National Parks and Wildlife Act 1974 (NSW)

The National Parks and Wildlife Act 1974 is the New South Wales legislation covering the management and protection of Aboriginal Cultural Heritage. The Act provides for the proper care, protection and preservation of Aboriginal Objects and declared Aboriginal Places by establishing offences of harm. The NPW Act defines Aboriginal Objects and Aboriginal places:

> *"Aboriginal object means any deposit, object or material evidence (not being a handicraft made for sale) relating to the Aboriginal habitation of the area that comprises New South Wales, being habitation before or concurrent with (or both) the occupation of that area by persons of non-Aboriginal extraction and includes Aboriginal remains."*

Section 87 of the NPW Act establishes defences against prosecution under s.86 (1), (2) or (4) - harming or desecrating Aboriginal objects and Aboriginal places. The defences are as follows:

1. An Aboriginal Heritage Impact Permit (AHIP) authorising the harm (s.87(1))
2. Exercising due diligence to establish Aboriginal Objects will not be harmed (s.87(2)). Due diligence may be achieved by compliance with requirements set out in the National Parks and Wildlife Regulation 2009 (the NPW Regulation) or a code of practice adopted or prescribed by the NPW Regulation (s.87(3)).

For State Significant Developments (SSD) AHIPS are not required, as impact to any sites is assessed through the EIS process.

The Greater Blue Mountains Area, which is listed on the World Heritage List as a Declared Place (ID:917) is also subject to the National Parks and Wildlife Act 1974 for its significant historic and natural value to the State.

2.1.2 The National Parks and Wildlife Regulation 2009 (NSW)

The NPW Regulation 2009 (cl.80A) assigns the Due Diligence Code of Practice for the Protection of Aboriginal Objects in NSW as one of the codes of practice that can be complied with pursuant to s.87 of the NPW Act. Disturbed land is defined by cl.80B (4) as;

> *"…disturbed if it has been the subject of a human activity that has changed the land's surface, being changes that remain clear and observable". Examples given in the notes to cl.80B (4) include "construction or installation of utilities and other similar services (such as above or below ground electrical infrastructure, water or sewerage pipelines, stormwater drainage and other similar infrastructure)".*

The presence and extent of ground disturbance is a key determinant in establishing the cultural heritage potential of an area under the Due Diligence Code of Practice for the Protection of Aboriginal Objects in NSW (Appendix 7-2).

3 Heritage Databases Searches

The following databases / registers were searched for heritage sites / values in proximity to the Activity Area. These searches provide an indication of the current cultural heritage sites in the proposed Activity Area, as well as an indication of what sites are likely to be present and yet unidentified.

- Aboriginal Heritage Information Management System (AHIMS)
- National Native Title Register (see Section 1.4)
- ACHM Archives and Register

3.1 Discussion

3.1.1 AHIMS Search

The Aboriginal Heritage Information Management System (AHIMS) is maintained by Heritage NSW and provides a database of previously recorded Aboriginal heritage sites. A search provides basic information about any sites previously identified within a defined area. However, a register search is not conclusive evidence of the presence or absence of Aboriginal heritage sites, as it requires that an area has been inspected and details of any sites located have been provided to Heritage NSW to add to the register. As a starting point, the search will indicate whether any sites are known within or adjacent to the investigation area.

A basic search of the AHIMS database was conducted around the proposed works area extent on 17 January 2024. The AHIMS Client Service Number was 855304. The search area included the proposed three-stage areas covered by this assessment and a 2 km buffer zone. There were 73 Aboriginal sites and no declared Aboriginal Places recorded in the search area.

No known sites are within 100 m of LA01 and LA02 project areas. The closest to LA02 is a scar tree approximately 750 metres to the south (56-1-0456).

Four sites are within 100 m of the location of works planned for stage 3 (LA03), near the Stringybark Creek diversion (56-1-0677, 56-1-0676, 56-1-0724, and 56-1-0743). All sites are located north of the current path of Stringybark Creek, south of Nelson Drive. All four sites are classified as Modified Trees. Site cards were requested for three of the sites (56-1-0677, 56-1-0676, 56-1-0724) while one site card was not available on AHIMS (56-1-0743). One site is listed as a ring tree (56-1-0676), with details “Wiradjuri ring tree, needs to be protected at all costs. These boundary marker trees are very few remaining in NSW“, and the other two (56-1-0677, 56-1-0724) are trees with large scars. All were recorded by Wiradjuri man Mark Saddler.

Map 3-1 and Map 3-2 show the locations of the AHIMS sites in relation to the project area and Table 3-1 shows a breakdown of the of the site types.

The lack of known sites near project areas LA01 and LA02 does not necessarily reflect a lack of Aboriginal cultural material but could also indicate a lack of previous targeted archaeological investigation. If areas of archaeological sensitivity are present in the proposed areas that have not been previously disturbed by infrastructure or landscape modification, there is some likelihood that potential unidentified Aboriginal heritage may be present.

Table 3–1: AHIMS Search results: Sites within 2 Km of project areas

Site ID	Site Name	Site Type
56-1-0645	L-AFT-2	Artefact Scatter / Isolated Artefact
56-1-0501	ROWANS TSR 2	Modified Tree (Carved or Scarred)
56-1-0097	L-IF-2	Artefact Scatter / Isolated Artefact
56-1-0561	Plumpton Rd 2236	Modified Tree (Carved or Scarred)
56-1-0549	Lloyd 530368	Modified Tree (Carved or Scarred)
56-1-0690	Wisteria Place 1	Modified Tree (Carved or Scarred)
56-1-0096	L-IF-1	Artefact Scatter / Isolated Artefact
56-1-0050	LN 4	Artefact Scatter / Isolated Artefact
56-1-0049	LN 3	Artefact Scatter / Isolated Artefact
56-1-0623	Gregadoo SF IF4	Artefact Scatter / Isolated Artefact
56-1-0667	Lloyd Scar Underpass	Modified Tree (Carved or Scarred)
56-1-0572	Lloyd 529306 L-ST-6 (duplicate copy 56-1-0102)	Modified Tree (Carved or Scarred)
56-1-0743	Budhu Madhan (Star Tree)	Modified Tree (Carved or Scarred)
56-1-0548	Llyod 530361	Modified Tree (Carved or Scarred)
56-1-0520	Springvale 957	Modified Tree (Carved or Scarred)

56-1-0714	Lloyd Road Artefact Scatter 1	Artefact Scatter / Isolated Artefact
56-1-0721	Birrimul 001	Modified Tree (Carved or Scarred)
56-1-0580	L-AFT-1	Artefact Scatter / Isolated Artefact
56-1-0738	Springvale PAD 04	Potential Archaeological Deposit (PAD)
56-1-0099	L-ST-2	Modified Tree (Carved or Scarred)
56-1-0047	LN 1	Artefact Scatter / Isolated Artefact
56-1-0573	Lloyd 529096	Modified Tree (Carved or Scarred)
56-1-0632	L-AFT-4	Artefact Scatter / Isolated Artefact
56-1-0579	L-IF-3	Artefact Scatter / Isolated Artefact
56-1-0631	L-IF-4	Artefact Scatter / Isolated Artefact
56-1-0674	Lloyd Artefact Repatriation 1	Artefact Scatter / Isolated Artefact
56-1-0575	Lloyd 529359 L-ST-6 (duplicate copy 56-1-0103)	Modified Tree (Carved or Scarred)
56-1-0503	ROWANS TSR 4	Modified Tree (Carved or Scarred)
56-1-0712	Holbrook Road Artefact Scatter 2	Artefact Scatter / Isolated Artefact
56-1-0559	Plumpton Rd 2370	Modified Tree (Carved or Scarred)
56-1-0724	Boat Club 001	Modified Tree (Carved or Scarred)
56-1-0571	Lloyd 529137	Artefact Scatter / Isolated Artefact
56-1-0500	ROWANS TSR 1	Artefact Scatter / Isolated Artefact
56-1-0100	L-ST-3	Modified Tree (Carved or Scarred)
56-1-0102	L-ST-5 (duplicate copy 56-1-0572)	Modified Tree (Carved or Scarred)
56-1-0576	Lloyd 529314	Modified Tree (Carved or Scarred)
56-1-0747	Tarcutta Reserve Mt Comatawa Track	Modified Tree (Carved or Scarred)
56-1-0311	Flowerdale1	Modified Tree (Carved or Scarred)
56-1-0052	Lloyd Neighbourhood 1	Artefact Scatter / Isolated Artefact
56-1-0634	L-AFT-6	Artefact Scatter / Isolated Artefact
56-1-0692	Tasman Rd Ercildone Rd	Modified Tree (Carved or Scarred)
56-1-0676	Ring Tree Boat Club Wagga	Modified Tree (Carved or Scarred)
56-1-0527	Gregadoo SF 463	Artefact Scatter / Isolated Artefact
56-1-0723	Biirimul 004	Modified Tree (Carved or Scarred)
56-1-0716	Springvale AS01	Artefact Scatter / Isolated Artefact
56-1-0737	Springvale PAD 03	Potential Archaeological Deposit (PAD)
56-1-0101	L-ST-4	Modified Tree (Carved or Scarred)
56-1-0633	L-AFT-5	Artefact Scatter / Isolated Artefact
56-1-0691	Tasman/Ercildoune Rd	Modified Tree (Carved or Scarred)
56-1-0541	Gregadoo SF IF2	Artefact Scatter / Isolated Artefact
56-1-0125	LLOYD SITE 1	Modified Tree (Carved or Scarred)
56-1-0502	ROWANS TSR 3	Modified Tree (Carved or Scarred)
56-1-0585	Stringybark Creek 529852	Modified Tree (Carved or Scarred)
56-1-0574	Lloyd 530222	Modified Tree (Carved or Scarred)
56-1-0080	WW105	Modified Tree (Carved or Scarred)
56-1-0425	Red Hill Rd West 1	Modified Tree (Carved or Scarred)
56-1-0570	Lloyd 528729 (Not an Aboriginal Object)	Modified Tree (Carved or Scarred)
56-1-0569	Lloyd 528899	Artefact Scatter / Isolated Artefact
56-1-0483	Mitchell Rd 240 Canoe Tree	Modified Tree (Carved or Scarred)
56-1-0528	Gregadoo SF 619	Artefact Scatter / Isolated Artefact
56-1-0531	Gregadoo SF 645	Modified Tree (Carved or Scarred)
56-1-0560	Plumpton Rd 2381	Modified Tree (Carved or Scarred)
56-1-0713	Holbrook Road Artefact Scatter 1	Artefact Scatter / Isolated Artefact
56-1-0715	Lloyd Road Isolated Find 1	Artefact Scatter / Isolated Artefact
56-1-0098	L-ST-1	Modified Tree (Carved or Scarred)
56-1-0048	LN 2	Artefact Scatter / Isolated Artefact
56-1-0456	Crooked Creek Ring Tree 1	Modified Tree (Carved or Scarred)
56-1-0646	L-AFT-3	Artefact Scatter / Isolated Artefact
56-1-0578	Lloyd 529316	Modified Tree (Carved or Scarred)
56-1-0103	L-ST-6 (duplicate copy 56-1-0575)	Modified Tree (Carved or Scarred)
56-1-0677	Wagga Boat Club Crown Land Scar Tree	Modified Tree (Carved or Scarred)

56-1-0577	Springvale 530749	Modified Tree (Carved or Scarred)
56-1-0722	Birrimul 002	Artefact Scatter / Isolated Artefact

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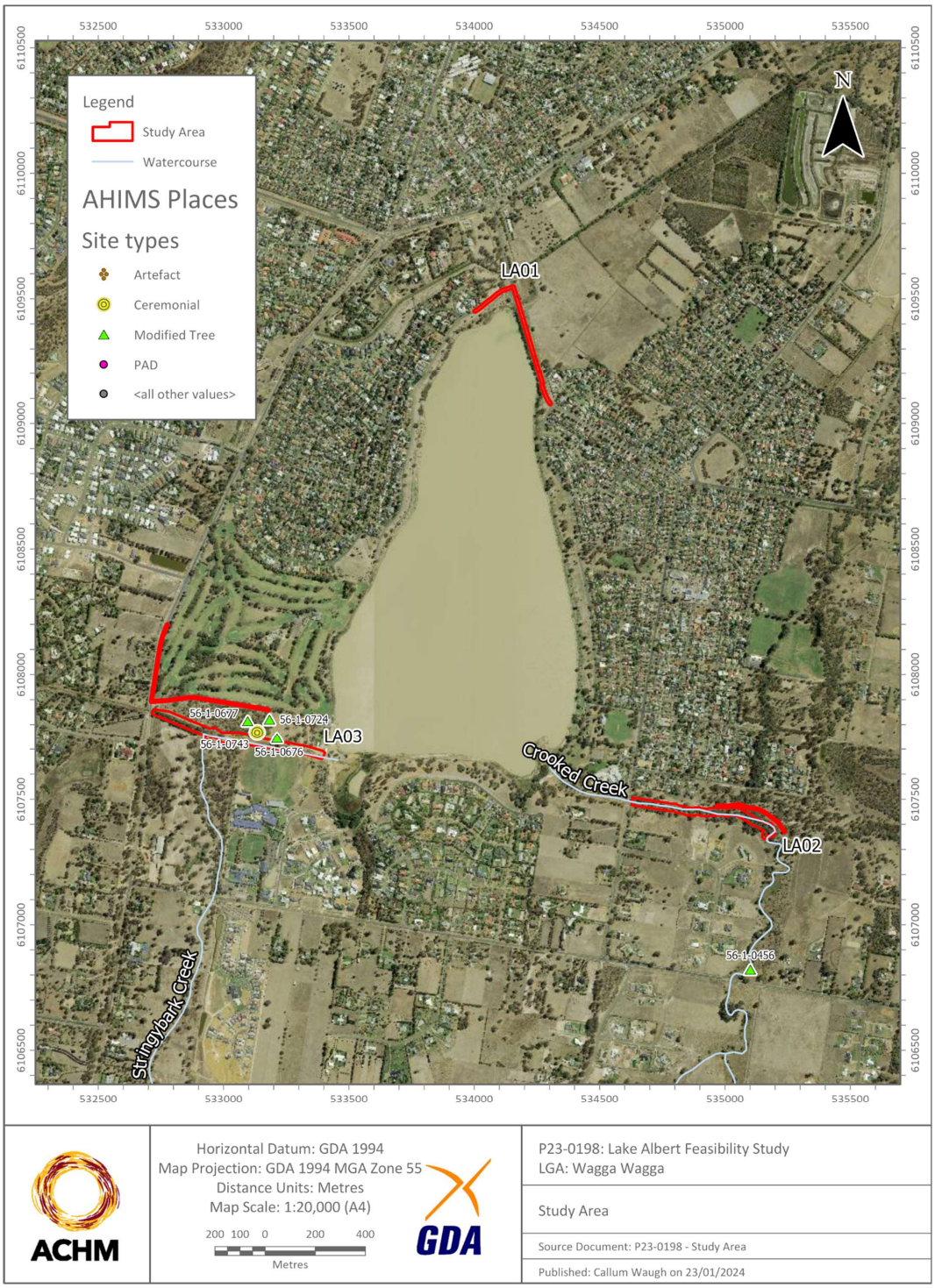

Map 3–1: AHIMS Sites within 400 metres of the project areas.

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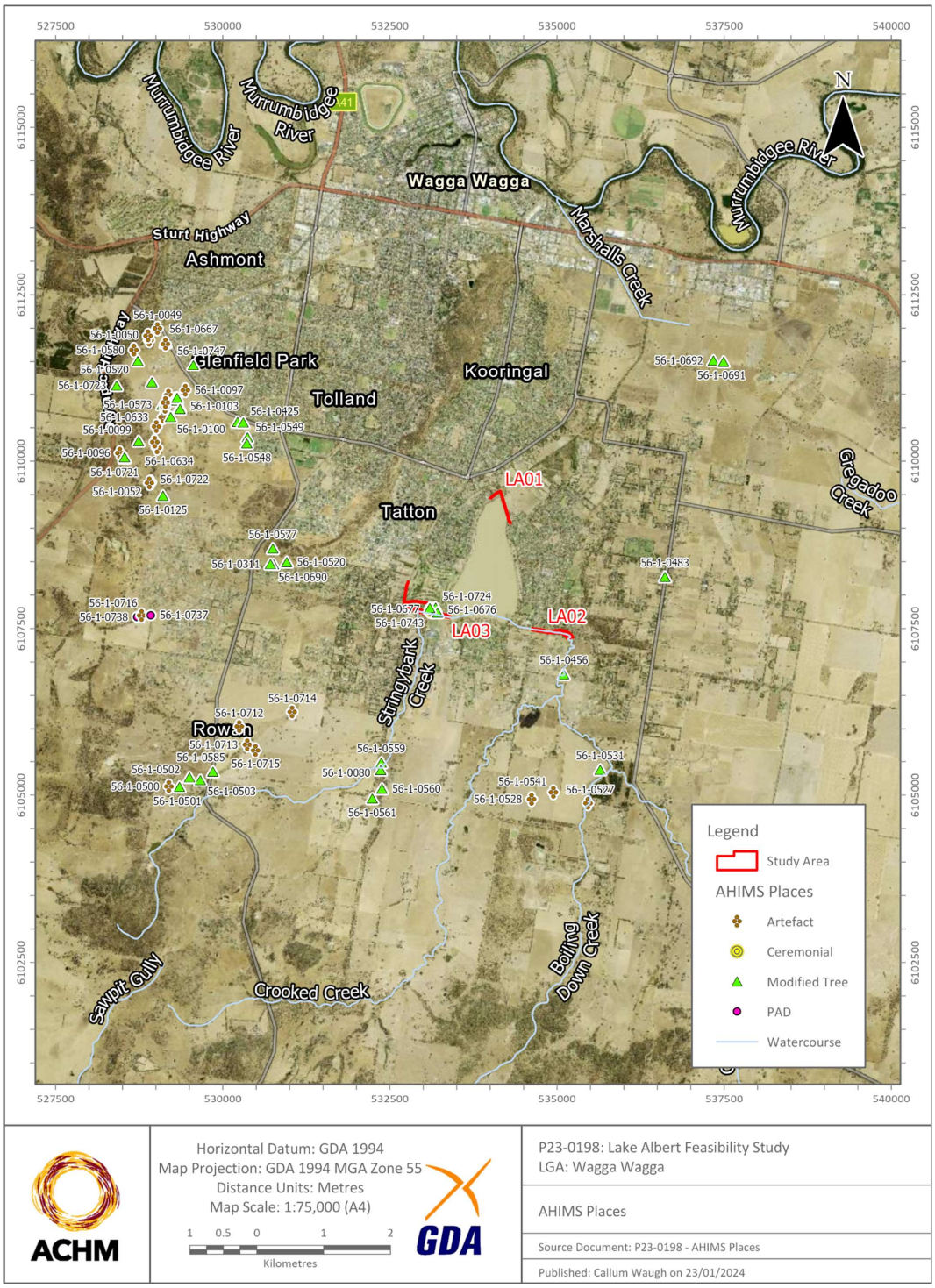

Map 3–2: AHIMS Sites within 2 Km of the project areas.

3.1.2 Previous Archaeological Investigation in the Activity Area

Many previous archaeological investigations have been completed near the Activity Area and wider surrounding Wagga Wagga region. A summary of these has been provided below as an indication of the types of Aboriginal sites that have and may be identified in the project areas.

Hiscock, P., 1983. An Archaeological Survey of the Proposed 330 kV Transmission Line, Wagga Wagga-Darlington Point

Hiscock undertook a survey running from Wagga Wagga to Darlington Point in 198e3, dividing the study area into multiple corridors. Within the first corridor, 12 scarred trees and 13 artefact scatters were located.

Green, D., 2002. Wiradjuri Heritage Study for the Wagga Wagga Local Government Area of New South Wales

In 2002, Green authored research reviewing previous archaeological assessments within the Wagga Wagga LGA for the Wiradjuri Heritage Study. Results informed a predictive model for the region, summarised as follows:

Through this research, a number of predictive model statements for the region were developed:

- Quartz is the most common material found within lithic assemblages, followed by chert, silcrete and quartzite;
- Artefact scatters are most likely found in well drained areas near reliable water sources;
- Hearths and cultural material are likely to be found at the base of sand dunes;
- Shell middens are often associated with charcoal and burnt deposits;
- Burials are most commonly found within sand dunes or alluvial sites following disturbance or erosion;
- Modified trees are likely to occur near water .

Kelleher and Nightingale, 2008. Wagga Wagga Local Environmental Study: Aboriginal Cultural Heritage Assessment.

The aim of this study was to identify the Aboriginal cultural heritage values of the eight study areas for inclusion in the Local Environmental Study for Wagga Wagga City Council. The research consisted of a preliminary investigation of Aboriginal site distribution and landscape features based on desktop and field-sourced information followed by the development of a predictive model of site distribution and areas of archaeological sensitivity based on desktop and field-sourced information. While not directly pertaining to Lake Albert, certain conclusions about the wider area are applicable.

Findings concluded that Aboriginal material culture is more likely to occur in locations with access to lithic raw material, diverse and consistently available subsistence resources, and landforms associated with these features.

Of particular note, the research indicated that open camp sites would be more likely to occur around as follows:

> *"major valleys in the region, especially the Murrumbidgee River floodplain, would have been an important source of water and subsistence resources even through drier periods. Elevated, well drained areas associated with these floodplains will potentially demonstrate longer term and more frequent occupation; archaeological material along smaller tributaries is likely to represent smaller, more focussed occupation events;" (Page 7: Kelleher and Nightingale, A., 2008)*

Ultimately, the developed predictive model agreed with Green (2002), where areas with the highest archaeological sensitivity are likely to occur on low rises within undulating terrain adjacent to drainage features.

Navin Officer, 2022. EnergyConnect (NSW – Eastern Section) Buronga to Wagga Wagga, NSW Revised Aboriginal Cultural Heritage Assessment Report.

Report on archaeological findings of a survey and excavation conducted from Buronga to Wagga Wagga. Survey transect was within 4 kilometres south of the Project Area. The survey and subsequent excavation recorded 105 new sites, and 45 new PADs.

3.1.3 Discussion

Based on the presence of 73 Aboriginal sites within a 2-kilometre buffer and 4 Aboriginal sites within close proximity (200 m) to project area LA03, as well as the results of previous archaeological studies within the area, the following conclusions may be drawn:

- Generally, there has been a moderate to high number of artefact and modified tree sites identified in the area, even in areas of previous disturbance. This suggests that sites will be identified in association with ephemeral and permanent water sources in the area.

- Although Lake Albert is artificial, it is located on a natural swamp lying between two natural creek lines, and as such, the areas surrounding Lake Albert do have archaeological potential (as demonstrated by the sites adjacent to LA02).

4 Environmental Background

4.1 Geology, Topography, and Vegetation

The landscape context assessment is based on several classifications that have been made at national and regional level for Australia. The national Interim Biogeographic Regionalisation for Australia (IBRA) system identifies the proposal area as located within the NSW Southwestern Slopes bioregion of southeastern Australia (DECCW 2019).

The Southwestern Slopes bioregion extends from north of Cowra through southern NSW and into Victoria, containing foothills and isolated ranges which are the lower slopes of the Great Dividing Range. The climate is sub-humid with hot summers and no dry season; the Murray, Murrumbidgee, Lachlan, and Macquarie River Catchments are all a part of the Southwestern Slopes bioregion.

A wide range of rock types is present within the bioregion, each of which affect the soil types present. Geology, soils and vegetation are complex, but typically contain granites and eucalypt woodlands. Geologically, the bioregion is entirely contained within the Lachlan Fold Belt, which consists of Cambrian to Early Carboniferous sedimentary and volcanic rocks.

The project area is comprised of one Mitchell soil landscape (Table 4-1; Mitchell 2002, SEED), and three soil landscapes as defined by the Soil Landscape Series (Table 4-2; DPIE, eSpade). The Mitchell soil landscape "Mtl - Murrumbidgee - Tarcutta Lakes, Swamps and Lunettes" is present within Lake Albert itself, project areas contain Mitchell soil landscape "Mtc - Murrumbidgee - Tarcutta Channels and Floodplains". The DPIE soil landscape series present within the project area include Roping Pole Swamp 8327rp (LA01, LA02, LA03), Redbank Transferral (LA02), and O'Brien's Creek Alluvial (LA02, LA03).

Table 4–1: Mitchell Landscape Types within project areas (Mitchell 2002, SEED)

Mitchell Landscape Type	Environmental Description	Soils	Vegetation
Mtc - Murrumbidgee - Tarcutta Channels and Floodplains	Channels, floodplain and terraces of Murrumbidgee tributaries on Quaternary alluvium, general elevation 200 to 400m, local relief 25m.	Undifferentiated organic sand and loam on the floodplain, brown gradational loam and yellow texture-contrast soils on higher terraces.	River red gum (*Eucalyptus camaldulensis*) gallery woodland on banks, yellow box (*Eucalyptus melliodora*) and grey box (*Eucalyptus microcarpa*) open woodland on floodplain and terraces.
Mtl - Murrumbidgee - Tarcutta Lakes, Swamps and Lunettes	Back plain swamps with Quaternary fluvial and lacustrine sediments filled by high river flows. General elevation 150m, local relief <5m	Heavy self-mulching and cracking grey or brown clay, loamy sand lunette with red-brown gradational profile.	Swamp floor with lignum (*Muehlenbeckia cunninghamii*) and cane grass (*Eragrostis australasica*), margins with black box (*Eucalyptus largiflorens*) and river cooba (*Acacia stenophylla*), inlet/outlet channels lined Page 93 with river red gum (*Eucalyptus camaldulensis*). Lunettes with black box and white cypress pine (*Callitris glaucophylla*).

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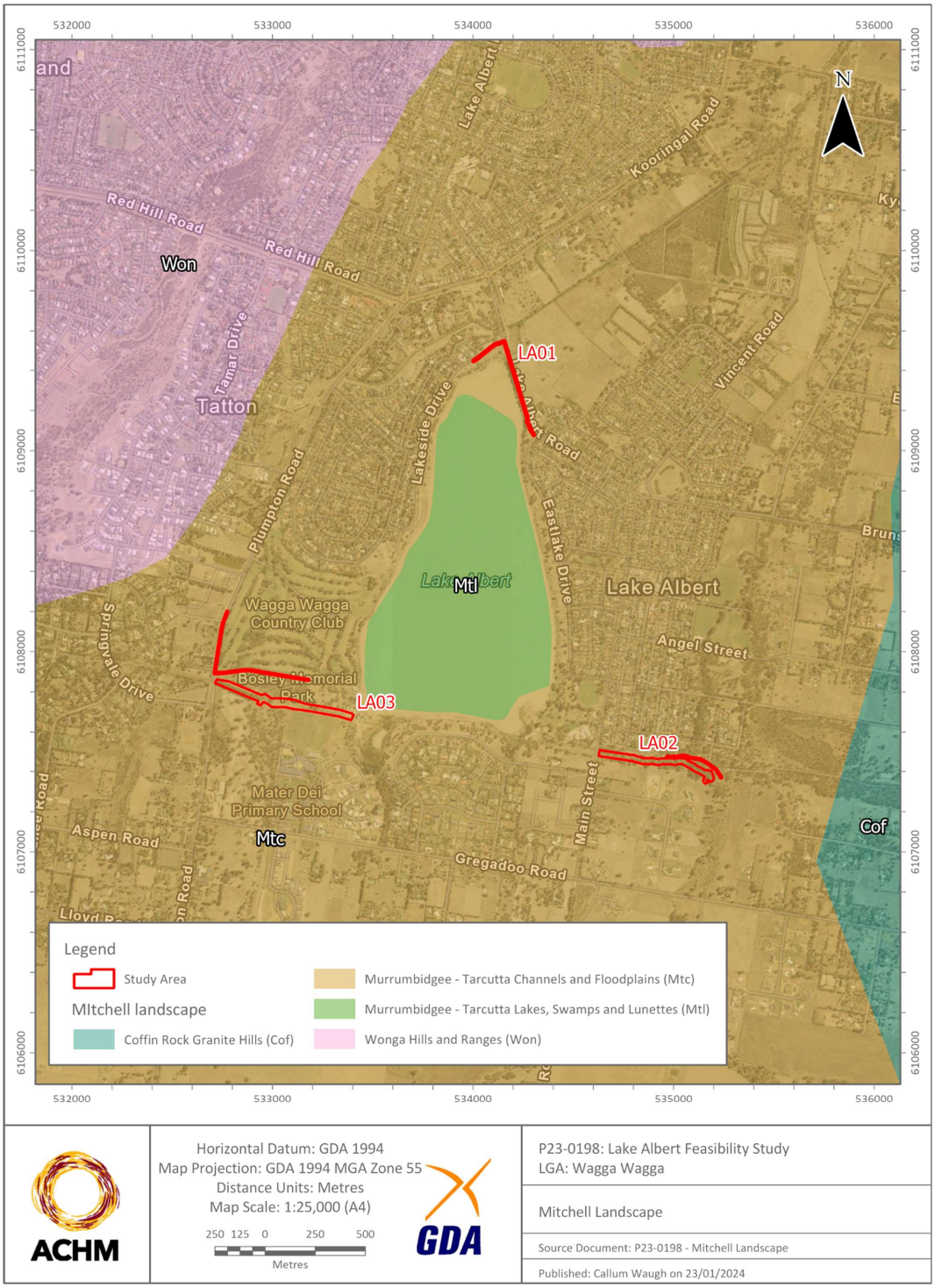

Map 4–1: Mitchell Landscapes near the project areas.

Table 4–2: Soil Landscapes within project areas.

Soil Landscape	Geology	Topography	Soils	Vegetation	Land Use
Roping pole (LA01, LA02, LA03)	Thick (>20 m) Cainozoic alluvial clay (with minor sands in depth) sequences.	Shallow and various sized (up to 1.5 km across) depressions in extensive undulating plains. Slope gradients <1% within the depressions and up to 5% along the narrow marginal zone. Local relief within the depression is <1 m and the depression floor up to 10 m lower than the surrounding plains. The elevation ranges from 165 m near the western margins to 250 m at a swamp near Mangoplah.	Moderately deep (90 – 120 cm). Silty clay topsoil (A horizon), greyish medium clay (B horizon), brown sandy clay (subsoil- BC or C horizon).	Partially to extensively cleared. Vegetation type varies from open tall woodland with swampy grasses to swampy grasses dominant. Most common tree species include river red gum, yellow box and grey box. Understorey species include clustered dock, curled dock, rushes, brome grass, fescues and barley grass.	Unused or natural pasture for cattle grazing. Evident salinisation occurs near the marginal zones.
O'Brien's Creek Alluvial (LA02, LA03)	Thick (>2 m) Cainozoic to present alluvial and slope-washed sediments derived from granite and metasedimentary rock hilly areas.	Gently undulating plains and valley flats along many creeks and drainage lines. Slope gradients mostly <3%. Local relief mostly <10 m. Most creeks have incised from 1 – 10 m from the plain surfaces. There are three landform sub-zones: 1) extensive (up to 3 km wide) undulating plains; 2) unidirectional sloping plains adjacent to hill footslopes with rare drainage lines; and 3) a belt near creek channels, slightly lower and more subject to flooding.	Moderately deep (80 - 150 cm) Mottled Subnatric Red Sodosols and Mottled Mesonatric Brown Sodosols on plains; Mottled Subnatric Brown Sodosols near some channel zones. Brown clay loam (topsoil - A horizon), bleached silty clay loam (A2 horizon), mottled brown clay (subsoil - B2 horizon), mottled brown heavy clay (subsoil- BC horizon), mottled brown light medium clay (subsoil - B3 horizon).	Mostly cleared. Isolated very small areas of partially cleared tall open-woodland exist along creek channels, some roads and in Crown reserves. Most common tree species include grey box, yellow box, white box, red stringybark, white cypress pine and river red gum in the channel zones. Understorey species include wallaby grass, spear grass, brome grass, fescue, barley grass, burr medic, and clovers. In waterlogged areas common species include clustered dock and curled dock.	The extensive plains are mainly used for cropping (wheat with minor barley and cereal rye) and improved pasture (dryland lucerne). In relatively narrow drainage flats, especially towards the south-eastern part of the mapping area, the most common land use is natural pasture for sheep and cattle grazing.
Redbank Transferral	Thick (>3 m) Cainozoic alluvial and slope-washed sediments derived mostly from Mount Flakney Adamellite and less from Ordovician metasedimentary rocks (probably with minor windblown clay addition).	Very gently inclined, long (>2 km) piedmont adjacent to granite hills. Slope gradients are predominantly <3%. Local relief is mostly <10 m within an elevation range of 210 - 270 m. Narrow (<l00 m) drainage depressions incised <10 m from the piedmont surface.	Moderately deep (80 - 120 cm) Eutrophic Brown Chromosols on slopes, moderately deep (80 - 120 cm) Mottled Subnatric Brown Sodosols in drainage lines.	Almost completely cleared except for trees along some roads and drainage lines. Most common tree species include white box, grey box, yellow box and red stringybark. Understorey species include kangaroo grass, tussock grass, plains grass, paterson's curse, spear grass and wallaby grass.	Cropping for wheat with barley and cereal rye, and improved pasture of dryland lucerne. Minor natural pasture for sheep and cattle grazing on steeper parts near the hills and along drainage lines. Hobby farms, rural residential and urban development in the areas close to Lake Albert.

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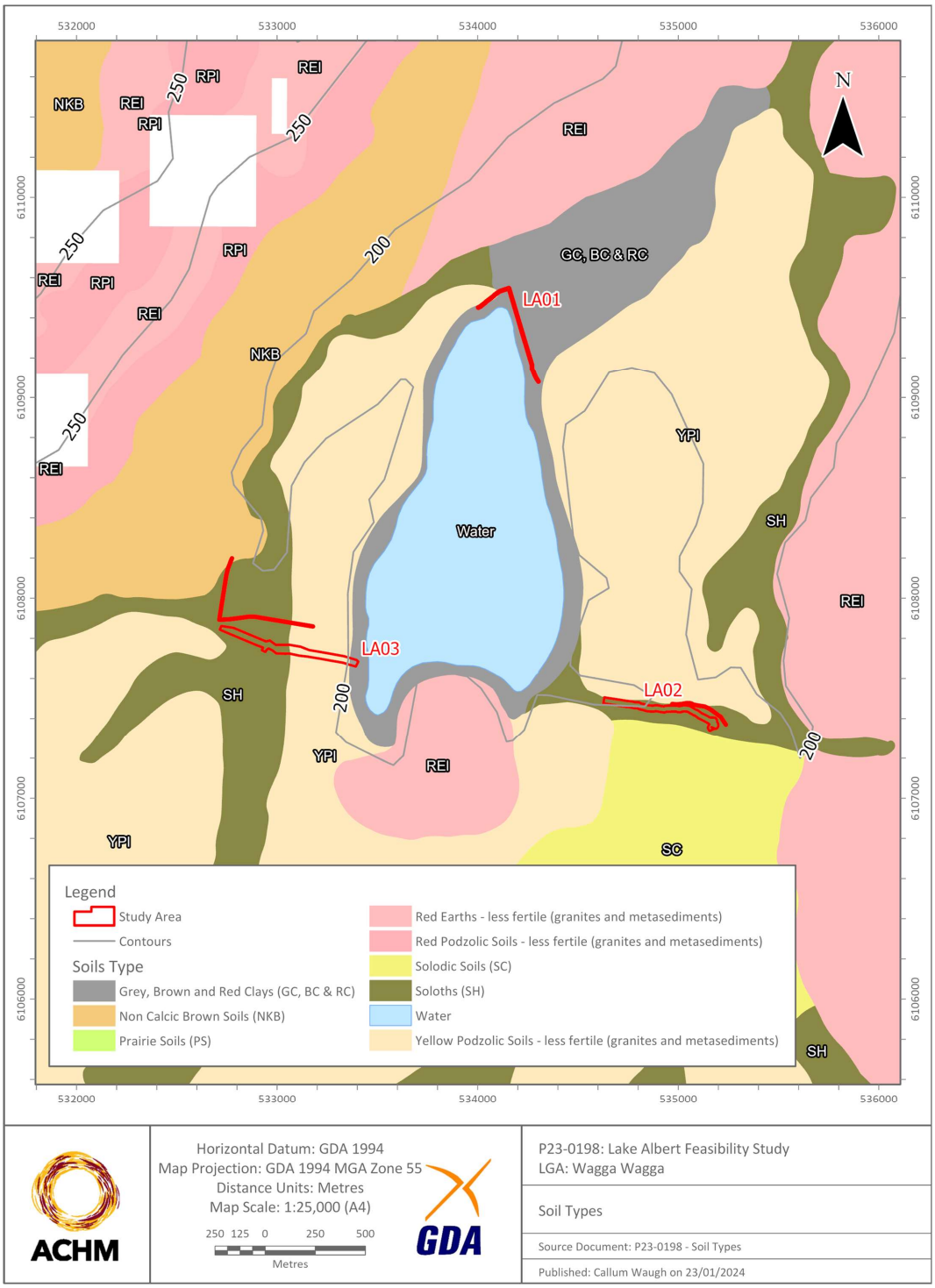

Map 4–2: Dominant soil types within project areas.

4.2 Archaeologically Sensitive Landforms

Previous archaeological and geomorphological research indicates that archaeological evidence of past Aboriginal practices is likely to be associated with certain landforms. Examples of such landscape features are listed below:

- Within 200 m of water,
- Within a sand dune system,
- On a ridge top, ridge line or headland,
- Within 200 m below or above a cliff face,
- Within 20 m of or in a cave, rock shelter, or a cave mouth.

Utilising the predictive models developed in the area surrounding Wagga Wagga, the following landscape features are local landforms which may be associated with Aboriginal practices:

- In proximity to water,
- In well drained areas near water sources,
- At the base of sand dunes,
- Within sand dunes or alluvial sites.

4.2.1 LA01: Raising Lake Albert Road

The proposed impact for raising Lake Albert Road does not involve excavation of material aside from the modification of the existing outlet structures between both Lake Albert Road and Lakeside Drive. The first step on the Due Diligence Code of Practice (Appendix 7.2) asks if the activity will "disturb the ground surface or any culturally modified trees". Though the works planned for LA01 will not disturb the ground surface, there is still potential for disturbance to modified trees, given the large volume of modified trees recorded within the wider area as well as the proximity of LA01 to a water source. It is recommended a pedestrian survey confirm the presence or absence of modified trees within the LA01 project area. If modified trees are not present, as the activity at LA01 will not impact the ground surface, LA01 will not require further archaeological works. If modified trees are present, further consultation will be required.

4.2.2 LA02: Augmentation of Crooked Creek Diversion into Lake Albert and LA03: LA03: Augmentation of Stringybark Creek Diversion into Lake Albert

Stage LA02 and LA03 will involve excavation of embankment to both the Crooked Creek and Stringybark Creek diversions, respectively. Their activity area is located in land that which has been subject to historical development, i.e., the construction of respective drainage channels and creation of parkland and associated infrastructure. Despite this, there may be areas of previously undisturbed land associated with the current embankment of the two drainage lines which have potential to contain surface or sub-surface cultural material.

The project is also within an area of watercourses, which are known to support Aboriginal cultural sites and objects. This is reinforced by the 73 previously recorded sites that have been identified within 2 km of the project area. Additionally, the presence of multiple sites within close proximity to LA03 demonstrates a high potential for scar trees in both locations.

The above factors significantly increase the likelihood of identifying additional sites and objects of Aboriginal cultural heritage, in particular modified trees, artefact scatters, isolated artefacts, or additional cultural material.

Closer inspection of the proposed activity area is required to determine the nature and extent of potential archaeological features which may intersect with the area covered by the desktop portion of this assessment. Additionally, closer inspection of the project area boundary and the identified scar trees near LA03 must occur to determine the extent of the root system of the trees. Damage to the root system constitutes impact to an archaeological site.

The proximity to available water sources (original swampland, original course of both Crooked and Stringybark Creek) constitutes archaeologically sensitive landforms, and previously recorded sites renders the activity area as containing moderate to high archaeological sensitivity to the presence of Aboriginal sites and requiring further investigation.

4.3 Predictive Model

4.3.1 Aboriginal Heritage

One part of the activity area may contain previously recorded sites (LA03); any root system of an existing scar tree is part of the site and cannot be impacted without further consultation.

The additional portions of the project areas which do not contain any previously recorded Aboriginal sites may be due to a lack of previous targeted archaeological investigation, rather than a lack of potential for sites to be present. The surrounding cultural landscape is rich in volume, containing a range of artefact scatters, scarred trees, and potential archaeological deposits (PADs).

Sites are often located along watercourses, terraces, ridgelines; however, they can potentially occur anywhere in the landscape. Given the length of time Aboriginal people have lived in the region they would have traversed the project areas regularly. Our ability to identify the remains of this behaviour depends on the visibility of the archaeological record, ground surface conditions, the extent and nature of disturbance that has occurred to the landscape through historical land use (e.g., land clearing) and the nature of past Aboriginal land use.

The following Aboriginal objects and sites may potentially occur within the project areas:

- Artefact Scatters (or isolated finds),
- Culturally Modified Trees (Scarred Trees),
- Potential Archaeological Deposits (PAD) (sub-surface archaeological sites).

The project areas are generally moderate to high archaeological sensitivity, due to their proximity to water sources. The level of previous disturbance reduces the sensitivity and is likely to affect the integrity of any potential Aboriginal cultural heritage that may be present.

This disturbance cannot be assessed through a desktop assessment alone, and it is therefore recommended that a field inspection be completed by a qualified archaeologist to ensure that no unidentified heritage or potential subsurface deposits will be impacted by the proposed works.

4.4 Summary of Desktop Results

To summarise the known data:

- A long history of Aboriginal settlement exists within the activity area and the wider surrounding landscape. 73 known sites have been recorded within a 2 km buffer zone to the project areas.
- Previous disturbances exist throughout the project areas in the form of existing infrastructure for the park and construction of diversions.
- LA01 and LA02 do not contain previously recorded sites, nor are there previously recorded sites adjacent to these project areas.
- The LA03 project area is within close proximity to four modified trees recorded on AHIMS. They may lie within the LA03 project area, as their roots constitute parts of the site. Their location to the works requires further investigation.
- The activity area contains archaeologically sensitive landforms, namely, land in close proximity to water sources, that may contain unidentified Aboriginal sites and objects.
- Levels of previous disturbance can only be predicted through desktop assessment.
- All three areas of activity (LA01, LA02, and LA03) will require field inspection to confirm the likelihood that Aboriginal cultural heritage may be present. In the case of LA03, field inspection will also need to confirm the project area will not impact the root systems of the four adjacent previously recorded modified tree sites.
- The Unanticipated Finds Protocol for Aboriginal and historic heritage Items (Appendix 7.2) should be followed throughout the project in that event that previously unidentified heritage is encountered.

5 Recommendations

Based on the outcomes of this cultural heritage due diligence assessment, the following recommendations are made by ACHM:

Based on the project areas proximity to watercourses and known sites, a pedestrian field survey is suggested for the project areas, along with an ACHA. This would include the following:

- Meaningful opportunities for engagement and consultation with the Wagga Wagga Local Aboriginal Land Councils (LALC) for the project be provided,
- Full compliance with the National Parks and Wildlife Act 1974 (NSW) and the following guidelines:

(a) Guide to Investigating, Assessing and Reporting on Aboriginal Cultural Heritage in NSW (OEH 2011);

(b) Code of Practice for the Archaeological Investigation of Aboriginal Objects in New South Wales (OEH 2010a),

(c) Aboriginal cultural heritage consultation requirements for proponents 2010 (ACHCRP) (OEH 2010b).

- Investigation of the proximity of known sites to the project area within LA03; and
- Identification of any additional heritage within project areas LA01, LA02, and LA03; and
- If evidence of Aboriginal cultural heritage or potential sub-surface deposits are identified during a survey of the activity areas, additional consultation would be required.

To comply with the relevant Heritage NSW requirements, the objectives of the ACHA are to:

- Present the project's consultation methodologies and processes as agreed with the Wagga Wagga LALC, and
- Ensure that Aboriginal people from the Wagga Wagga LALC have the opportunity to participate in and improve the outcomes of the assessment by:

(d) Providing relevant information about the cultural significance and values of the Aboriginal object(s) and/or place(s) within the project areas,

(e) Influencing the design of the method to assess cultural and scientific significance of Aboriginal object(s) and/or place(s) within the project areas,

(f) Actively contributing to the development of cultural heritage management options and recommendations for any Aboriginal object(s) and/or place(s) within the project areas and the wider project area; and

(g) Commenting on draft assessment reports before they are submitted by the proponent to Heritage NSW.

6 Bibliography

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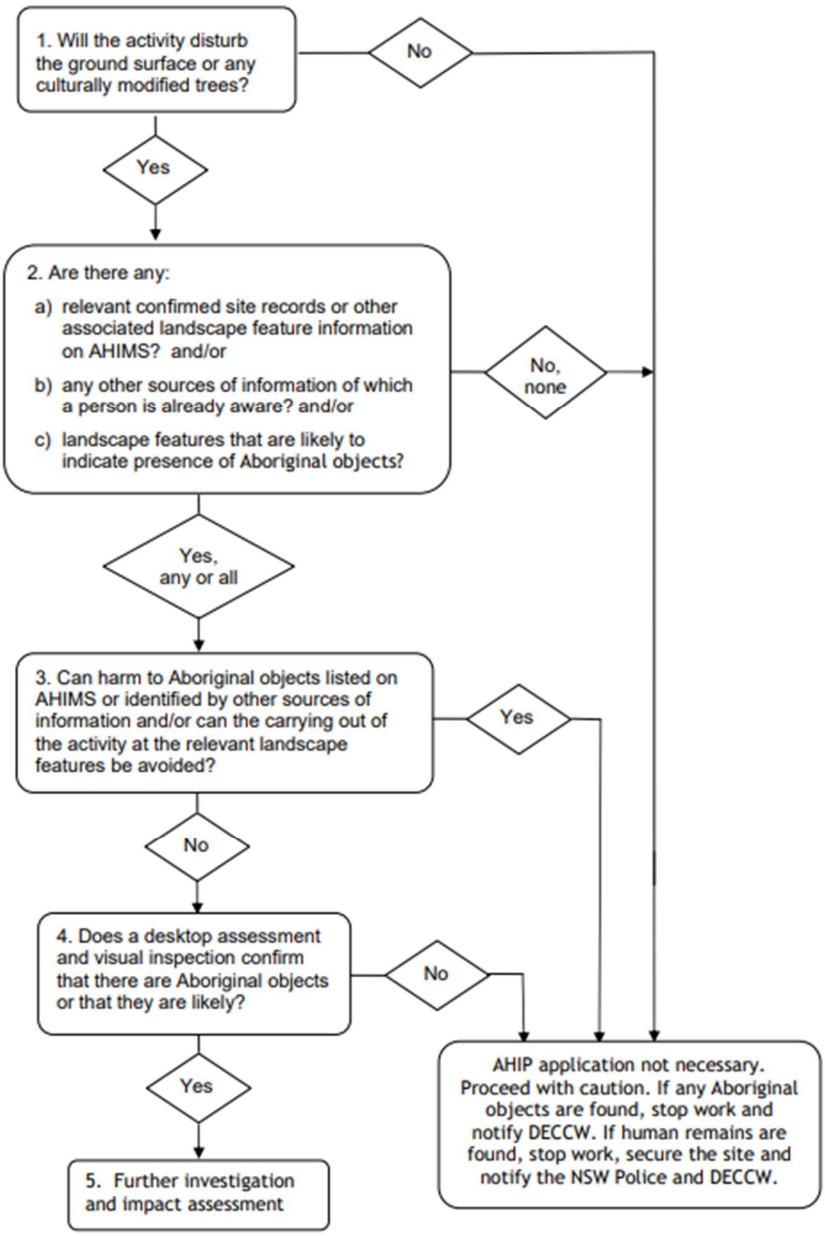
7 Appendices

7.1 Due Diligence Code of Practice



7.2 Unanticipated Finds Protocol

7.2.1 Purpose

This unanticipated find protocol has been developed to provide a method for managing unexpected non-Aboriginal and Aboriginal heritage items identified during the construction and maintenance of the Project. The unanticipated finds protocol has been developed to ensure the successful delivery of the Project while adhering to the NSW National Parks and Wildlife Act 1974 (NPW Act) and the Heritage Act 1977 (Heritage Act).

Despite undertaking appropriate heritage assessment prior to the commencement of the Project, unexpected heritage items may still be identified during construction, operation, and maintenance works. If this happens the following unanticipated finds protocol plan should be implemented.

What is an Unanticipated Heritage Find?

An unanticipated heritage find is defined as any possible Aboriginal or non-Aboriginal heritage object or place, that was not identified or predicted by the project's heritage assessment and is not covered by appropriate permits or development consent conditions. Such finds have potential to be culturally significant and may need to be assessed prior to development impact.

Unexpected heritage finds may include:

- Aboriginal stone artefacts, shell middens, modified trees, hearths and rock art;
- Human skeletal remains; and
- Remains of historic infrastructure and relics.

Aboriginal Heritage places or objects

All Aboriginal objects are protected under the NSW National Parks and Wildlife Act 1974 (NPW Act). An Aboriginal object is defined as: Any deposit, object or material evidence (not being a handicraft made for sale) relating to the Aboriginal habitation of the area that comprises New South Wales, being habitation before or concurrent with the occupation of that area by persons on non-Aboriginal extraction and includes Aboriginal remains. All Aboriginal objects are protected, and it is an offence to harm or desecrate an Aboriginal object or place.

Historic (Non-Aboriginal) Heritage

The Heritage Act 1977 protects relics which are defined as:

> *"Any deposit, artefact, object or material evidence that relates to the settlement of the area that comprises NSW, not being Aboriginal settlement; and is of State or local heritage significance."*

Unanticipated finds management procedure

In the event that any unanticipated Aboriginal heritage places or objects or any substantial intact historic archaeological relics of State or local significance are unexpectedly discovered during the Project, the following management protocols will be implemented:

- Works at that identified heritage location will cease with an appropriate buffer zone of at least 20 metres to allow for the assessment and management of the find. All site personal will be informed about the buffer zone with no further works to occur within the buffer zone;
- Heritage specialist will be engaged to assess the Aboriginal place or object encountered, Representative from the registered the Aboriginal Stakeholders for the Project may also be engaged to assess the cultural significance of the place or object;
- The Project approvals will be reviewed to assess consistency with the approvals to impact Aboriginal heritage within the Activity Area;
- The discovery of an Aboriginal place or object will be reported to the local office of Heritage NSW;
- If the Aboriginal heritage places or objects are found to be covered under the existing approvals to impact Aboriginal heritage within the Activity Area, works may continue to be conducted in accordance with mitigation measures and approval requirements;
- If the Aboriginal heritage places or objects are found to not be covered under the existing approvals to impact Aboriginal heritage within the Activity Area, works will not recommence at the heritage place or object until advised to do so by Heritage NSW;
- If the heritage place or object can be managed in situ, works at the heritage location will not recommence until appropriate heritage management controls have been implemented, such as protective fencing;

- For historic relics, work must cease in the affected area and the Heritage Council must be notified in writing. This is in accordance with section 146 of the Heritage Act 1977;
- Depending on the nature of the discovery, additional assessment may be required prior to the recommencement of work in the area. At a minimum, any find should be recorded by an archaeologist.

Human Skeletal Remains

Where human skeletal remains are unexpectedly found during works for the Project the following protocol would be adopted:

- Works at that location will cease, and an appropriate buffer zone of at least 50 metres will be established;
- The human remains will not be moved;
- The NSW police will be notified, and if the human remains are deemed a crime scene, the place will be managed by the police;
- Should the human remains be deemed Aboriginal or historical by the police, Heritage NSW must be notified immediately to assess the remains; and
- Should the human remains be deemed Aboriginal in origin all registered Aboriginal parties for the Project are to be notified in writing.
- The above process functions only to appropriately identify the human remains and secure the site, from which time the management of the remains is to be determined through liaison with the NSW police, Heritage NSW, and the relevant Aboriginal stakeholder.

COMMERCIAL IN CONFIDENCE

REPORT TYPE

Flood Mitigation Options for Wagga Wagga

Evaluation of options

Prepared for
Wagga Wagga City Council

30 October 2023

THE CENTRE FOR INTERNATIONAL ECONOMICS
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Contents

BOXES, CHARTS AND TABLES

Glossary

AAD	Annual Average Damage - the expected yearly damage cost arising from all occurrences of a given hazard.
AEP	Annual Exceedance Probability
ARI	Annual Recurrence Interval
CBA	Cost Benefit Analysis
Net Benefit	Present Value of Benefits less Present Value of Costs presented in the Economic Analysis
PMF	Probable Maximum Flood
Risk	Risk refers to a situation where the occurrence of a future event is not known, but its probability of occurring is known or can be estimated
WWCC	Wagga Wagga City Council

Summary

The CIE has been engaged by Wagga Wagga City Council (the Council) to undertake an evaluation of three alternative flood mitigation options to manage flood risks in the region, with a particular focus on North Wagga Wagga. The options include:

- **PR1: Voluntary House Raising** (VHR) and **Voluntary House Purchase** (VHP) in the Wagga Wagga Study Area
- **L4B: North Wagga Levee Upgrade to 5% AEP level** of protection with an equivalent upgrade to Hampden Avenue (as embankment) and conveyance improvements through Wilks Park. This also includes building a bridge to assist in evacuating residents from North Wagga.
- **Combined PR1 and L4B**: a combination of the above measures to ascertain the feasibility of a combined solution to combat flooding issues in/around North Wagga.

This report presents the findings of our analysis of the merits of each option. The analysis utilises the flood modelling conducted by WMA Water for the region, the latest data from the Australian Bureau of Statistics, as well as land value and property sales data captured by the NSW Land Valuer General. The analysis also adopts the August 2023 *Flood Damage and Cost Benefit Assessment Tool* which was developed by the NSW Government to assess flood risk mitigation measures consistent with Flood Risk Management Measures Guide MM01.[1]

The tool accounts for both the flood frequency and severity. The tool provides specific guidance on parameter values to use for the calculation of damages including structural/internal damage to buildings, intangibles (e.g. injury/mortality, mental health costs) and external damage (including to roads and utility services). The tool results in higher damage estimates compared to previous assessment tools available.

This evaluation does not provide guidance on how any chosen option should be funded (by government or the community). It also does not place greater weight on any particular part of the community and, therefore, does not provide a judgement on any equity issues.

Following further feedback, the community has requested a levee only option (L4A) to also form part of the evaluation. This additional flood modelling is currently being undertaken and will form part of the next stage of the evaluation report.

1 https://www.environment.nsw.gov.au/topics/water/floodplains/floodplain-guidelines

Preliminary findings

The analysis will continue to be refined for the final report including additional information such as:

- the potential biodiversity offset costs to compensate for land clearing associated with the levee option (e.g. around Wilks Park).
- the potential impact on agricultural production if the levee option changes the flood extent/duration in different parts of the floodplain. Early modelling indicates that this impact is not expected to be material.

The key findings from our analysis include:

- **The VHR scheme in North Wagga Wagga results in *net benefit*s to the community of around $22.9m in present value terms over a 30 year period. The cost of around $120,000/property is relatively low and significantly reduces the Annual Average Damage for the property. We have assumed that the floor level of the property is raised 3m above ground level which substantially reduces the AAD of properties. Applying this to 250 properties in North Wagga Wagga take-up the scheme this will result in a cost of $3m, delivering benefits (i.e. risk reduction) equivalent to $52.9m in present value over 30 years. This results in a *net benefit* of $22.9m. This assumes that the VHR can apply to all properties that have currently not been raised.**
  - **The VHR scheme, however, may prove challenging for certain members of the community that may find the access to be more challenging. Depending on the additional costs of improving access this could impact on the scheme. If, for example, the cost (including improved access) increases to $200,000/property this reduces the *net benefits* from the scheme to $2.9m.**
- **The VHP scheme in North Wagga Wagga is the worst ranked option, resulting in a *net cost* of $55.4m (in present value terms) to the community. The purchase cost of around $400,000/property significantly outweighs the expected damages for most properties.**
  - **The policy could be refined to only target the highest risk properties where the current risks exceed $400,000.**
  - **Further, rather than pre-emptively purchasing the properties the VHP scheme could be applied after a flood event has damaged a property. This could be in, for example, 10 years' time. This would also require pre-planning and providing a place for residents to move immediately.**
- **Raising the levee option (L4B) does substantially reduce the flood risks in some areas. However, it also diverts water to other parts of the floodplain during certain flood events, so there are some negative impacts to others that are also accounted for in our analysis.**
  - **The overall cost of option L4B is around $76m, excluding any biodiversity offset purchases.**
  - **The reduction in risk can vary, depending on the assumptions adopted. For the central case, we assume that for residential properties the largest building is**

the main residence and incurs the main structural/contents damage. Other buildings on the property (e.g. shed/garages) are subject to a lower "external damages" cost estimate. For commercial/industrial properties we assume that all buildings on the lot will be subject to the (higher) structural damage/contents estimates. Therefore, the *costs exceed the benefits* by around $40.8m (in present value terms).

- Combining the L4B option with VHR and VHP applied to properties outside North Wagga Wagga does result in slightly improved results compared to the L4B option on its own, however, it still results in *net costs* of $35m. This assumes that the VHR and VHP options are only applied to high risk properties.
- Combining just the VHR and VHP, targeting the highest risk properties within and outside North Wagga results in *net benefits* of $29m. This highlights the value of adopting a more strategic approach which targets the highest risk properties where there is greatest benefit from the risk reduction.

Preliminary conclusions

For the draft report, the preliminary conclusions are:

- Of the different options that could be adopted to reduce risks for the residents of North Wagga Wagga.
  - the VHR delivers the best outcome for the community. That is, the reduction in risk from raising the homes outweighs the costs of doing so. Although there may be challenges for some households due to accessibility issues which could result in additional costs above the assumed $120,000/property raising. The VHR policy could be refined further by focusing on a more limited range of the highest risk properties in North Wagga Wagga, as well as, in other parts.
  - The levee raising L4B option ranks second. The cost of the project outweighs the reduction in risk, except under certain circumstances.
  - The VHP is the next lowest ranked option given that the reduction in risk is significantly less than the estimated average purchase price of the properties ($400,000 in North Wagga). The VHP policy would be more economically efficient if it targeted a limited group of the high risk properties and the house was not pre-emptively purchased but could be purchased back (even at a market rate prior to flooding). A pre-emptive policy would immediately "destroy" the value of the property with certainty, compared to the comparatively low probability of this.
  - Combining the L4B and VHR/VHB options would be the lowest ranked. The cost of this policy increases but the incremental risk reduction from the combined options is minimal.
- Adopting a VHR option applied to 'high risk' properties in within and outside North Wagga Wagga is likely to be the most cost effective way to manage flood risks in the community.

2 Project Overview

Wagga Wagga has experienced riverine flooding on numerous occasions requiring large scale evacuations and causing considerable damage, loss of property, loss of revenue, disruption of services, disruption of lifestyle and significant inconvenience.

Understanding the chance of different sized floods occurring is important for managing flood risk. The chance of a flood event can be described using a variety of terms, but a common method is the Annual Exceedance Probability (AEP).[2] A flood with a 1% AEP has a 1 in 100 chance of being exceeded in any year. Other terms that express the same idea, such as a '1 in 100 year flood' can be misinterpreted as only occurring once in every 100 years.[3]

Since early settlement, Wagga Wagga has experienced numerous large floods, with four events (1852, 1853, 1870 and 1891) in the 1800's equalling or exceeding 10.5m at the Hampden bridge gauge. Following significant flooding in the 1950's the CBD Levee was constructed to provide flood protection to the township of Wagga Wagga.

The CBD Levee has recently been upgraded to a 1% AEP level of protection. There are a number other levees on the floodplain, including one encircling North Wagga and providing a level of protection of approximately an 12% AEP event, one at Gumly Gumly protecting for flood breakouts north of Lamprey Avenue (up to a 10% AEP level of protection), and the Riverina Water County Council (RWCC) which protects Wagga Wagga's potable water supply.

Wagga Wagga City Council (the Council) has commissioned a range of studies to understand the existing and future flood risk and identify options to manage this risk. The 2018 Floodplain Risk Management Study and Plan conducted by WMA Water analysed the flood risks and options to manage these risks. Since this report WMA Water has undertaken additional modelling which has informed our economic analysis.

Options considered in this study

A range of typical floodplain risk management measures have been previously assessed as to their appropriateness for providing additional protection for Wagga Wagga (table 2.1).

2 https://arr.ga.gov.au/__data/assets/pdf_file/0006/40398/New-ARR-Probability-Terminology_final.pdf

3 https://www.chiefscientist.qld.gov.au/publications/understanding-floods/chances-of-a-flood

2.1 Flood Risk Management Measures considered

Flood modification	Property modification	Response modification
Levees	Land zoning	Community awareness
Temporary Defences	Voluntary purchase	Flood warning
Channel Construction	Building & development controls	Evacuation planning
Channel Modification	Flood proofing	Evacuation access
Major Structure Modification	House raising	Flood plan/ recovery plan
Drainage Network Modification	Flood access	
Drainage Maintenance		
Retarding Basins		

Source: WMAwater (2018), Wagga Wagga Revised Murrumbidgee River, Floodplain Risk Management Study and Plan, April.

Many of these management measures were deemed to be not appropriate for Wagga Wagga and were not considered further.

2.2 Options considered for this case study

For this study, a number of options have been considered for feasibility assessment:

- **PR1: Voluntary House Raising & Voluntary House Purchase** Scheme in Wagga Wagga Study Area
- **L4B: North Wagga Levee Upgrade to 5% AEP level** of protection with an equivalent upgrade to Hampden Avenue (as embankment) and conveyance improvements through Wilks Park. This also includes building a bridge to assist in evacuating residents from North Wagga.
- **Combined PR1+L4B**: combination of the measures to ascertain the feasibility of a combined solution to combat flooding issues in/around North Wagga.
- **L4A**: **North Wagga Levee Upgrade to 5% AEP level of protection.** This excludes the other components (e.g. the bridge) associated with the L4B option.

Project objective

The central task for this project is to assess feasibility of the options above. The analysis considers the impacts across the whole floodplain but with specific focus on residential and non-residential properties impacted in the LGA. The options are expected to provide protection for some properties but the levee raising option has the potential to negatively impacts on other properties, as flood waters are diverted to other parts of the floodplain. The negative impacts could result from increased flooding upstream, environmental and social impacts, and to a lesser degree, a reduced level of flood protection for critical facilities in the broader region. There could also be negative impacts arising for some properties next to a levee bank that could face a loss in 'amenity value' with a higher levee structure.

3 Cost Benefit Analysis Methodology

The feasibility assessment needs to be undertaken in line with the NSW Government's *Guide to Cost-Benefit Analysis* (TPG 23-08).[4] In August 2023, the NSW Government also released specific guidance on conducting a CBA to assess different options that seek to manage flood risks. A specific Excel based tool has also been developed which specifies assumptions for the different parameters required to be modelled.[5]

Overview of a CBA

CBA is a tool designed to place the benefits and costs of particular actions or proposals on a common basis so that they can be compared and understood. It provides a basis on which the NSW Government can assess the net benefits of decisions around flood mitigation and adaptation.[6]

CBA provides a technique that allows a systematic treatment of trade-offs arising from Government decisions and the changes that they entail. It allows for quantification and valuation of the full range of potential impacts that might arise from changes in flood mitigation. It involves aggregation of these impacts across the various types of costs and benefits and through time into a single metric — *the expected present value of net benefits*[7] from a change relative to a 'reference case' (sometimes referred to as 'base case' or 'business as usual'). In the reference case, there may be specific responses that Government will take in the event of a flood (e.g. sandbagging, dredging). Any 'new' actions required will form part of the options to be evaluated.

A CBA framework is focused on the social welfare of the community. The policy option that delivers the highest *net social welfare* (across the community) is considered to be the best for society. The CBA does not place a greater weight on any particular group of residents within the community. As part of the CBA, however, we report on how impacts differ across the floodplain.

CBA is designed to take account of the full range of potential benefits and costs of particular actions. In this sense, it is wholistic and designed to include, for example, the environmental, health and economic impacts of particular actions. A CBA places each of these impacts on a common basis so that they can be compared and understood.

4 https://www.treasury.nsw.gov.au/finance-resource/guidelines-cost-benefit-analysis

5 https://flooddata.ses.nsw.gov.au/flood-projects/nsw-flood-damage-assessment-tool-dt01

6 In this report we use the term 'mitigation' to mean a range of current and future options which help the community to 'adapt' to flood risks.

7 The expected value is the probability weighted value. In this case the options will provide different levels of protection for each flood event. Each flood event has a specific probability of occurrence.

A CBA framework also considers the timing of each of the impacts. Under a CBA approach, future impacts are 'converted' into today's terms so that they can be meaningfully compared. A CBA, for example, will enable an evaluation of policies that deliver different streams of benefits and costs over time.

The key principles of a CBA are presented in box 3.1.

3.1 Key steps in a CBA

- **Articulating the decision that the CBA is seeking to evaluate.** For example, in relation to flood mitigation, the decision may relate to whether to build a levee and to what height, or whether evacuation routes are improved or both. The way in which the CBA is framed and the information requirements will differ depending on the decision being evaluated.
- **Establishing the reference case** (or 'base case') against which to assess the potential socioeconomic and environmental impacts of changes. In the case of flood mitigation in the case study region, the natural reference case is no change from the policies in place today and no specific new flood mitigation investment. This would mean, for example, that existing Council planning controls such as land use restrictions for flood areas would remain as they currently are.
- **Quantifying the changes** from the base case resulting from the possible scenarios being considered. This will focus on the incremental changes to a range of factors (for example, environmental, economic, social) resulting from the decision. The changes may be certain or could also be defined in probabilistic terms. The quantification should focus on key changes that will be utilised in the valuation stage. For flood mitigation these changes will include changes in the *likelihood* of flood events and changes in the *consequences* of flood events.
- **Placing values on the changes** and aggregating these values in a consistent manner to assess the outcomes.
- **Generating the Net Present Value (NPV)** of the future net benefits cashflow stream, using an appropriate discount rate, and deciding on the **Decision Rule** on which to assess the different options.
- **Undertaking sensitivity analysis** on a key range of variables, particularly given the uncertainties related to specific environmental benefits and costs.
- **Deciding** on which option is better for society. In practice, additional information, aside from the CBA results, may also be utilised when deciding on the preferred option.

It is important to note that a CBA does not consider ***equity issues***. For example, the construction of a raised levee bank may reduce flood impacts in one part of the Wagga Wagga LGA but may increase flood risks for residents upstream. A CBA focuses on

comparing the ***aggregate gains in total versus the total losses***, irrespective of which specific part of the community benefits or loses.

The feasibility analysis will, therefore, need to provide transparent information on the economic, environmental and social impacts of the alternative options. This will enable other information to be presented, in addition to the CBA results, to assist decision makers to assess the options. However, having a robust CBA will provide objective evidence on the quantum of positive and negative impacts on the community, thereby, reducing the need for subjective judgements.

Note that the issue of ***how to fund*** selected options is a separate task to the CBA. The CBA evaluates which options would generate the greatest welfare improvement. Once the options are selected the decision maker then needs to consider how best to fund the options (e.g. via rate increases, a differential flood levy on property owners on different parts of the floodplain, direct grants from state/federal governments).

Application of CBA to responses to mitigate the impacts of flooding

The basic framework for evaluating the costs of flood events and the costs of mitigation options should capture the following.

- The costs of flood events under the base case as well as each mitigation strategy, which comprises:
  - the *probability* of a given flood height/velocity occurring
  - the *consequences* of a given flood height/velocity occurring, such as:
- property damage
- loss of life/injury.
- The costs of each mitigation strategy including:
  - capital costs
  - ongoing operating costs
  - environmental impacts (e.g. biodiversity loss due to associated land clearing).

The costs of flood events under alternative strategies and the costs of the actions that form part of a strategy should be measured over a period of time (e.g. 30 years) and will be discounted back to 2023 dollars. The Treasury Guidelines require the use of a 5 per cent real discount rate, with sensitivity being undertaken at 3 per cent and 7 per cent.[8]

Further all costs should be measured as *economic costs.* Economic costs differ from financial costs because:

- economic costs include costs to those outside of the direct proponent;
- economic costs do not include financial transfers; and
- resources used are valued at their opportunity cost, which may differ from their market price.

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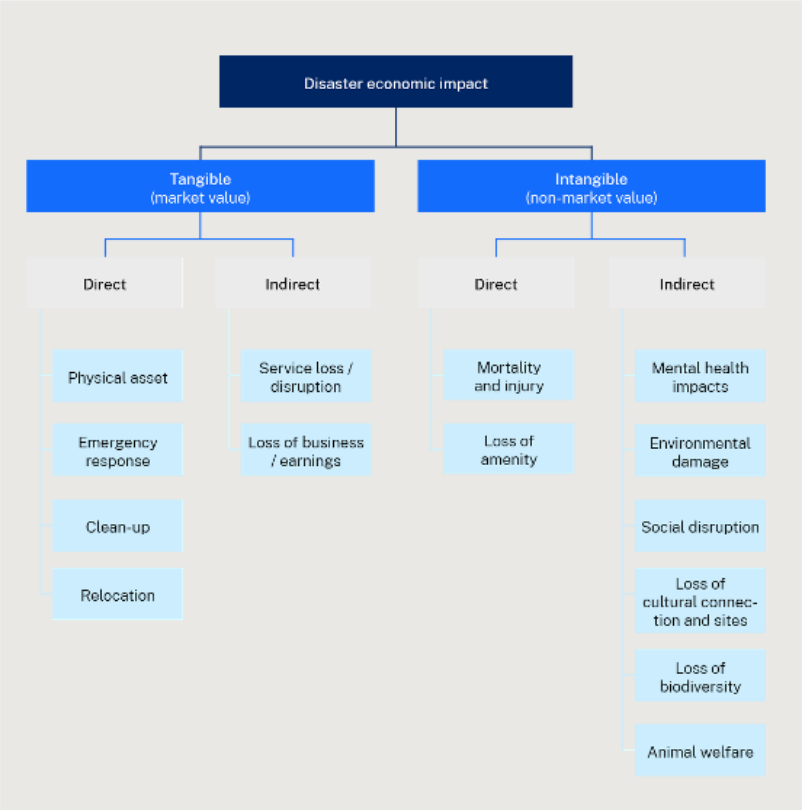
8 See page 94 of Treasury Guidelines https://www.treasury.nsw.gov.au/sites/default/files/2023-04/tpg23-08_nsw-government-guide-to-cost-benefit-analysis_202304.pdf

NSW Government Guidelines

The NSW Government's Disaster CBA Framework (TPG23-17, August 2023) presents different categories of impacts that should be considered in the analysis.

3.2 Categories of disaster impacts



Data source: NSW Treasury (2023), *Disaster Cost-Benefit Framework TPG23-17*, p25

The specific assumptions for the different categories embedded in the Excel based calculator are summarised in Appendix B. Some key assumptions, such as the updated 'stage damage curves', are significantly higher than previously used (e.g. in WMA Water's April 2018 Floodplain Risk Management Study and Plan). Therefore, the results and findings from the previous studies could be substantially different to those reported in the earlier reports.

4 Current risks

This chapter presents information on the flood risks in the absence of any future actions/investments and how the risks change under the options considered. We utilise a number of sources to estimate the risks such as:

- A spatial GIS file of building footprint based on satellite imagery. The information was provided by Council.
- A spatial GIS file of 'properties' in the Wagga Wagga LGA, sourced from the NSW Government.[9]
- A spatial GIS file of 'Meshblocks' in the Wagga Wagga LGA, sourced from the ABS.[10] The MBs identify different categories including Residential, Commercial, Industrial, Education, Hospital/Medical, Primary Production, Parkland and Other.
  - This is combined with datasets of dwelling and population numbers for each Meshblock as reported in 2021 Census.
- A dataset of properties, land values and property sales in NSW sourced from the NSW Land Valuer General.[11]
- There has been some manual reclassification of properties as new information is obtained (e.g. from Google Earth and from Council's visual inspections of properties). This includes two newly built properties currently not reflected in GIS files. Some manual adjustments has also been undertaken to incorporate information on existing house raisings and also the potential for a house to be raised.

The spatial files noted above have been overlaid with spatial GIS flood layers provided by WMA Water, modelled for eight different flood events.[12] WMA Water has undertaken in line with the *Australian Disaster Resilience Handbook 7 Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia* (AIDR 2017). The results in this chapter reflect the case where the existing levees do not "fail" under the flood event.

The results presented in this chapter may differ to WMA Water's April 2018 *Floodplain Risk Management Study and Plan*. This reflects, for example, updated population and dwelling numbers, as well as, updated flood modelling conducted by WMA Water.

9 https://datasets.seed.nsw.gov.au/dataset/nsw-property-web-service

10 https://www.abs.gov.au/statistics/standards/australian-statistical-geography-standard-asgs-edition-3/jul2021-jun2026/access-and-downloads/digital-boundary-files

11 http://www.valuergeneral.nsw.gov.au/land_value_summaries/lv.php

12 This includes AEP events 20%, 10%, 5%, 2%, 1%, 0.5%, 0.2% and PMF. For context, the AEP 1% equates to a 1 in 100 year event and AEP 20% equates to a 1 in 5 year event.

Existing flood risks with no new actions

Based on the 2021 Census the Wagga Wagga LGA has 67,609 persons and 28,151 dwellings, with an area of 4,826 sqkm.[13] The largest flood event, the Probable Maximum (PMF) flood event, floods around 154 sqkm or 3.2% of the LGA.[14]

The *potential* impact differs throughout the floodplain. Table 4.1 presents the suburbs that are impacted (to some extent) by the PMF flood event and the total number of persons, dwellings and land area in each suburb.

4.1 Characteristics of suburbs potentially impacted (to some extent) by PMF event

Suburb	Persons [a]	Dwellings [a]	Total Suburb Area
	no.	no.	sqkm
Gobbagombalin	2,184	767	43.52
Eunanoreenya	165	65	39.29
Alfredtown	80	32	75.48
North Wagga	679	291	16.54
Forest Hill (NSW)	3,081	938	34.81
Oura	246	95	142.35
Yarragundry	72	35	64.98
East Wagga Wagga	213	130	10.61
Gumly Gumly	450	149	12.40
Moorong	175	61	18.92
Wagga Wagga	7,198	3,960	8.90
Euberta	130	55	105.40
Bomen	40	15	27.52
Cartwrights Hill	169	77	2.88
Ashmont	3,747	1,674	2.44
Lake Albert (NSW)	6,291	2,519	24.68
Kooringal (NSW)	7,404	3,304	4.89
Boorooma	1,741	601	1.51
Estella	2,541	1,023	2.00
Brucedale	184	62	49.47
Turvey Park	3,572	1,536	3.77
Downside	124	46	79.82
San Isidore	349	122	4.96
Total	**40,835**	**17,557**	**777.12**

[a] This represents the total number of persons/dwellings in the suburb, not those impacted by each flood event.

Source: ABS 2021 Census QuickStats, https://www.abs.gov.au/census/find-census-data/quickstats/2021/SAL13024

13 https://abs.gov.au/census/find-census-data/quickstats/2021/LGA17750

14 A small proportion of land is within the flood extent but above the flood height. This land does not form part of our estimate of the flooded area in the PMF.

Land area impacted

Table 4.2 calculates the land area impacted (i.e. the flood extent) under the flood events modelled for this study. North Wagga, for example, has a large proportion of area impacted by the three different flood events. In the Wagga Wagga suburb the PMF inundates 8.25sqkm (of the total 8.90sqkm in the suburb), but this falls to 1.92sqkm for the AEP 1% event. For other suburbs, such as Euberta, all flood events only impact on a small proportion of land.

4.2 Land area inundated, by Suburb

Suburb	PMF	AEP 0.2%	AEP 0.5%	AEP 1%	AEP 2%	AEP 5%	AEP 10%	AEP 20%
	sqkm	Sqkm	sqkm	sqkm	sqkm	sqkm	sqkm	sqkm
Alfredtown	16.22	14.39	13.95	13.53	13.03	11.76	9.90	5.97
Ashmont	0.60	0.07	0.00	0.00	0.00	0.00	0.00	0.00
Bomen	2.17	1.84	1.78	1.72	1.66	1.42	1.07	0.00
Boorooma	0.23	0.07	0.00	0.00	0.00	0.00	0.00	0.00
Brucedale	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cartwrights Hill	0.93	0.72	0.68	0.65	0.62	0.59	0.56	0.44
Downside	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
East Wagga Wagga	9.91	8.63	7.41	6.36	5.21	2.85	2.51	2.21
Estella	0.07	0.03	0.00	0.00	0.00	0.00	0.00	0.00
Euberta	5.91	5.49	5.27	4.97	4.63	2.94	2.69	1.54
Eunanoreenya	18.82	17.42	17.26	17.13	16.96	16.03	13.86	7.73
Forest Hill	12.95	10.54	10.29	10.03	9.58	6.76	5.34	2.72
Gobbagombalin	20.55	17.01	16.30	15.98	15.72	15.00	13.91	9.25
Gumly Gumly	9.35	8.72	8.65	8.55	8.10	3.80	3.19	2.09
Kooringal	0.35	0.14	0.01	0.01	0.00	0.00	0.00	0.00
Lake Albert	0.48	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Moorong	9.04	8.58	8.26	8.19	8.12	7.85	7.37	6.07
North Wagga Wagga	15.56	15.35	15.28	15.19	15.10	14.83	13.54	10.17
Oura	11.08	9.88	9.68	9.50	9.26	8.41	7.05	4.83
San Isidore	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Turvey Park	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wagga Wagga	8.20	5.82	2.03	1.91	1.88	1.82	1.69	1.45
Yarragundry	10.28	9.76	9.60	9.39	9.13	7.54	5.54	1.77
Total	**152.85**	**134.45**	**126.43**	**123.08**	**118.99**	**101.60**	**88.21**	**56.25**

Source: CIE summary based on WMA Water flood modelling, assuming no levee failure.

Table 4.3 presents the land area inundated by ABS Meshblock 2021 category.[15] The flood inundation occurs predominately on land classified for Primary Production. This is followed by Residential land. In the PMF event, there is also land used for hospital/medical services. In the AEP 5% to PMF events, there is also inundation of land providing educational services.

15 https://www.abs.gov.au/census/guide-census-data/mesh-block-counts/latest-release

4.3 Land area inundated, by Meshblock

Meshblock	PMF	AEP 0.2%	AEP 0.5%	AEP 1%	AEP 2%	AEP 5%	AEP 10%	AEP 20%
	sqkm	sqkm	sqkm	sqkm	sqkm	sqkm	sqkm	sqkm
Residential	8.49	5.53	3.53	3.41	3.26	2.17	1.49	1.11
Commercial	0.88	0.45	0.15	0.14	0.13	0.07	0.05	0.03
Education	0.21	0.11	0.08	0.04	0.01	0.01	-	-
Hospital/Medical	0.04	-	-	-	-	-	-	-
Industrial	3.61	2.73	1.47	1.33	0.90	0.40	0.27	0.14
Parkland	2.69	2.34	0.90	0.82	0.81	0.78	0.72	0.71
Primary Product	132.29	118.82	116.06	113.14	109.74	94.34	82.26	51.50
Other	4.65	4.46	4.25	4.19	4.15	3.84	3.41	2.75
Total	**152.85**	**134.45**	**126.43**	**123.08**	**118.99**	**101.60**	**88.21**	**56.25**

Source: CIE summary based on WMA Water flood modelling, assuming no levee failure.

Buildings impacted

Building footprint in GIS format based on satellite imagery was provided by Council. This includes small structures such as sheds and garages, as well as, residential dwellings, commercial/industrial and other buildings. A single 'property' (ie block of land) may have multiple buildings on it. Table 4.4 presents the total building footprint impacted in those suburbs with a building. If only a portion of the building is flood exposed we assume that the whole building is defined to be 'impacted'. Therefore, the calculations in the table are likely to be a slight overestimate.

4.4 Area of building footprint impacted, by Suburb

Suburb	PMF	AEP 0.2%	AEP 0.5%	AEP 1%	AEP 2%	AEP 5%	AEP 10%	AEP 20%
	sqm	sqm	sqm	sqm	sqm	sqm	sqm	sqm
Alfredtown	1,769	1,322	1,296	919	919	0	0	0
Ashmont	106,252	3,936	0	0	0	0	0	0
Bomen	4,456	2,809	2,700	2,700	2,323	924	313	0
Boorooma	14,306	1,437	0	0	0	0	0	0
Cartwrights Hill	8,305	4,952	4,539	4,539	4,192	3,946	3,946	3,946
East Wagga Wagga	540,292	490,836	307,825	285,523	166,514	57,178	30,385	16,855
Estella	3,655	2,130	0	0	0	0	0	0
Eunanoreenya	21,123	13,444	11,545	11,166	9,974	6,237	4,015	1,541
Forest Hill	13,289	5,825	5,697	5,641	5,250	4,579	3,834	633
Gobbagombalin	7,385	3,200	3,200	3,200	3,200	2,014	1,328	787
Gumly Gumly	81,908	78,300	75,917	73,997	55,497	13,071	5,064	1,520
Kooringal	27,766	4,454	0	0	0	0	0	0
Lake Albert	4,986	0	0	0	0	0	0	0
Moorong	36,270	25,570	1,578	1,558	534	435	427	396
North Wagga Wagga	119,950	117,970	116,271	110,181	106,985	92,561	26,522	7,156
Oura	36,741	29,770	28,931	28,185	27,725	17,169	1,044	6

Suburb	PMF	AEP 0.2%	AEP 0.5%	AEP 1%	AEP 2%	AEP 5%	AEP 10%	AEP 20%
	sqm	sqm	sqm	sqm	sqm	sqm	sqm	sqm
Turvey Park	2,628	0	0	0	0	0	0	0
Wagga Wagga	1,422,539	912,859	25,708	25,669	25,382	23,767	18,338	13,718
Total	**2,453,621**	**1,698,816**	**585,208**	**553,277**	**408,494**	**221,881**	**95,216**	**46,558**

Source: CIE summary based on WMA Water flood modelling, assuming no levee failure.

Road area impacted

Inundated road area is determined using road corridor information provided in GIS format by Council. Table 4.5 presents the area (sqkm) impacted under each AEP.

4.5 Road area inundated

PMF	AEP 0.2%	AEP 0.5%	AEP 1%	AEP 2%	AEP 5%	AEP 10%	AEP 20%
sqkm	sqkm	sqkm	sqkm	sqkm	sqkm	sqkm	sqkm
8.184	6.815	5.221	4.994	4.698	3.863	3.014	1.787

Source: CIE summary based on WMA Water flood modelling, assuming no levee failure.

Change in risks due to options

Option L4B levee project

Table 4.6 presents the change in area inundated from the levee project. As expected, the levee project significantly reduces the inundation area in North Wagga Wagga for the AEP 20% to the AEP 2% events. There is also a reduction in inundation area in East Wagga Wagga (and a number of other suburbs) for the AEP 20% to AEP 5% events. There is also an increase in inundation area for some flood events in some areas.

4.6 Change in land area inundated due to Option L4B, by Suburb

Suburb	PMF	AEP 0.2%	AEP 0.5%	AEP 1%	AEP 2%	AEP 5%	AEP 10%	AEP 20%
	sqkm	sqkm	Sqkm	sqkm	sqkm	sqkm	sqkm	sqkm
Alfredtown	0.000							
Ashmont								
Bomen	0.001	0.001						
Boorooma		-0.001						
Brucedale	0.000							
Cartwrights Hill				-0.001	-0.002	-0.002		
Downside								
East Wagga Wagga		0.009	0.011	0.019	0.014	-0.047	-0.044	-0.021
Estella								
Euberta			-0.000	-0.001	-0.000	0.003	0.002	0.003

Suburb	PMF	AEP 0.2%	AEP 0.5%	AEP 1%	AEP 2%	AEP 5%	AEP 10%	AEP 20%
	sqkm	sqkm	Sqkm	sqkm	sqkm	sqkm	sqkm	sqkm
Eunanoreenya	0.000		0.001	0.001	0.002	-0.002	-0.003	-0.092
Forest Hill	0.000	0.001	0.001	0.001		-0.004	-0.007	
Gobbagombalin	-0.001	0.001		-0.002	-0.001	0.003	0.006	0.022
Gumly Gumly	0.000	0.002	0.002	0.002	0.003	-0.004	-0.002	-0.022
Kooringal		0.012						
Lake Albert	0.001	0.000						
Moorong		0.000			-0.001	0.003	0.001	0.012
North Wagga Wagga		-0.000	-0.000	0.003	-0.456	-0.754	-0.134	-0.306
Oura	0.000							
San Isidore								
Turvey Park								
Wagga Wagga	0.001	0.043	-0.003	0.001			-0.001	0.007
Yarragundry				-0.001	-0.000	0.010	0.010	0.002
Total	**0.005**	**0.067**	**0.011**	**0.022**	-0.442	-0.794	-0.171	-0.395

Note: A blank indicates that there was no flooding in the suburb for the flood event or there is no impact of the levee project. The data has been rounded to the 3rd decimal place

Source: CIE summary based on WMA Water flood modelling, assuming no levee failure.

Table 4.7 presents the change in area inundated by Meshblock category. The levee project provides additional protection from residential land in the AEP 1% event and smaller. Commercial and Industrial land also gets some protection in the AEP 5% events and smaller. For some Meshblocks there is an increase in flooding, particularly for the larger flood events.

4.7 Change in land area inundated due to Option L4B, by Meshblock

Meshblock	PMF	AEP 0.2%	AEP 0.5%	AEP 1%	AEP 2%	AEP 5%	AEP 10%	AEP 20%
	sqkm	sqkm	sqkm	sqkm	sqkm	sqkm	sqkm	sqkm
Residential	0.000	0.034		-0.003	-0.268	-0.459	-0.022	
Commercial	0.001	0.007	0.000	0.000	0.001	-0.003	-0.002	
Education		0.000	0.000	0.008	-0.004	-0.006		
Hospital/Medical								
Industrial		0.016	0.001	0.002	0.003	-0.015	-0.025	-0.002
Parkland		0.002	-0.003	0.001	-0.018	-0.028	0.004	0.008
Primary Product	0.002	0.007	0.012	0.012	-0.155	-0.282	-0.127	-0.410
Other	0.001	0.001		0.000		-0.002	0.001	0.008
Total	**0.005**	**0.067**	**0.011**	**0.022**	-0.442	-0.794	-0.171	-0.395

Source: CIE summary based on WMA Water flood modelling, assuming no levee failure.

Table 4.8 presents data on the building footprint impacted by the Option L4B. The option results in a substantial reduction in the buildings impacted in North Wagga Wagga for the AEP 1% and smaller events. There is also a substantial reduction in the building footprint impacted in East Wagga Wagga for the AEP 5% and AEP 10% events.

However, there is also an increase in the building footprint impacted in some events, such as the AEP 0.2% (the '1 in 500' year event) in the Wagga Wagga CBD.

4.8 Change in area of building footprint impacted, by Suburb

Suburb	PMF	AEP 0.2%	AEP 0.5%	AEP 1%	AEP 2%	AEP 5%	AEP 10%	AEP 20%
	Sqm	sqm	sqm	sqm	sqm	sqm	sqm	sqm
Alfredtown	0	0	0	0	0	0	0	0
Ashmont	0	0	0	0	0	0	0	0
Bomen	0	0	0	0	0	0	0	0
Boorooma	0	0	0	0	0	0	0	0
Cartwrights Hill	0	0	0	0	0	0	0	0
East Wagga Wagga	0	353	0	182	155	-5,278	-3,230	0
Estella	0	0	0	0	0	0	0	0
Eunanoreenya	0	0	0	0	0	0	0	0
Forest Hill	0	0	0	0	0	0	0	0
Gobbagombalin	0	0	0	0	0	0	0	0
Gumly Gumly	0	0	0	0	0	0	0	0
Kooringal	0	8	0	0	0	0	0	0
Lake Albert	0	0	0	0	0	0	0	0
Moorong	0	0	0	0	0	0	0	0
North Wagga Wagga	0	0	19	-450	-50,282	-68,485	-5,470	-759
Oura	0	0	0	0	0	0	0	0
Turvey Park	0	0	0	0	0	0	0	0
Wagga Wagga	0	12,717	0	0	0	0	0	543
Total	**0**	**13,078**	**19**	**-268**	**-50,127**	**-73,763**	**-8,700**	**-216**

Source: CIE summary based on WMA Water flood modelling, assuming no levee failure.

The protection provided by option L4B is largely related to Residential buildings, with protection also to buildings on primary production land, industrial land and also education facilities. In the AEP 0.2%, option L4B results in increased residential, commercial/industrial building damage in Wagga Wagga and East Wagga Wagga suburbs.

4.9 Change in area of building footprint impacted, by Meshblock

Suburb	PMF	AEP 0.2%	AEP 0.5%	AEP 1%	AEP 2%	AEP 5%	AEP 10%	AEP 20%
	sqm	sqm	sqm	sqm	sqm	sqm	sqm	sqm
Residential	0	10,840	19	-621	-41,190	-56,841	-564	0
Commercial	0	2,177	0	0	64	-770	0	0
Education	0	0	0	0	-2,067	-2,705	0	0
Hospital/Medical	0	0	0	0	0	0	0	0
Industrial	0	61	0	182	0	-1,125	-3,230	0
Parkland	0	0	0	0	0	0	0	45
Primary Product	0	0	0	171	-6,934	-12,324	-4,906	-804

Suburb	PMF	AEP 0.2%	AEP 0.5%	AEP 1%	AEP 2%	AEP 5%	AEP 10%	AEP 20%
	sqm	sqm	sqm	sqm	sqm	sqm	sqm	sqm
Other	0	0	0	0	0	0	0	543
Total	**0**	**13,078**	**19**	**-268**	**-50,127**	**-73,763**	**-8,700**	**-216**

Source: CIE summary based on WMA Water flood modelling, assuming no levee failure.

VHR and VHP options

These options do not change the *frequency* of flood events but change the *consequence* of each event. The next section presents additional information on the reduction in risk (i.e. Annual Average Damage) associated with these options. The precise application of this policy could change. Therefore, we presented a number of scenarios to guide the assessment of this policy.

5 *Economic Benefits*

This chapter presents the economic benefits from the reduction in flood risks associated with each option. The calculations draw on the results from the flood modelling (presented in the previous chapter) and utilise the NSW Government's Flood Damage Assessment Tool. For the central case results we assume that:

- For residential properties, the 'largest building' on the lot is classified as the main residence, with other buildings on the site assumed to be of lesser value (such as sheds/garages). The largest building was based on the building footprint estimated from the building data in GIS format and structural/contents damage was calculated based on the depth of the flood. Dwellings on rural zoned land were treated as residential properties as well.
- For commercial/industrial properties, all buildings on the lot were treated equally and structural/contents damage was calculated based on the depth of the flood.

Benefits from risk reduction

The primary benefit of the L4B option comes through the reduction in expected flood damages over the evaluation period of 50 years. The majority of damage is incurred by residential and commercial properties. These damages are split into four components:

- Structural damage to the building
- Internal damage, primarily damage to contents
- External damage, including damage to roads
- Intangible damage, which includes:
  - Injury and mortality, and
  - Mental health costs to residents and government.

Specific assumptions for the calculation of each of the four main damage types are presented in table 5.1. The assumptions are designed to be in line with he August 2023 *Flood Damage and Cost Benefit Assessment Tool* which was developed by the NSW Government to assess flood risk mitigation measures consistent with Flood Risk Management Measures Guide MM01.[16]

16 https://www.environment.nsw.gov.au/topics/water/floodplains/floodplain-guidelines

5.1 Calculation methodology

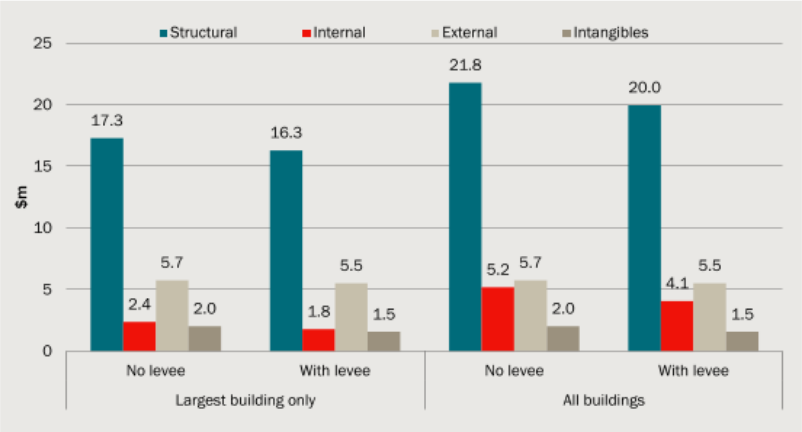
Assumptions	Central Case - Largest building	Sensitivity - All buildings
Which buildings are included	Damages are measured for the largest building on each residential property, based on flood height. For commercial/industrial properties this applies to all buildings on the lot.	Damages are measured for all buildings in the dataset using flood heights.
Structural damage	Where the largest building is under 50 square metres, structural damage is given by the damage from a 'small' building, scaled down linearly according to size.	For buildings under 50 square metres, structural damage is given by the damage from a small building dwelling, scaled down linearly according to size.
Internal damage	Calculated the same way as structural damage.	Calculated the same way as structural damage.
External damage	A single external damage figure applies to each property, irrespective of the number of buildings on the lot.	A single external damage figure applies to each property, irrespective of the number of buildings on the lot.
Intangible damage	Injuries and fatalities are only included for the largest building on each property, using flood depth and velocity. Other intangibles are scaled with size for buildings under 50 square metres. This category does not apply to commercial/industrial properties.	Injuries and fatalities are only included for the largest building on each property, using flood depth and velocity. For buildings under 50 square metres, intangibles are scaled down by size. This category does not apply to commercial/industrial properties.
Other parameters	Drawn from Flood Risk Management Guide MM01 (DPE, 2022) and ABS. For details see Appendix B.	Drawn from Flood Risk Management Guide MM01 (DPE, 2022) and ABS. For details see Appendix B.

Source: The CIE

Risk reduction - Option L4B

Chart 5.2 shows the reduction in AAD achieved by the levee option, split by damage type. On average the levee reduces AAD by $2.3m ever year in the central case, or by $4.3m when using all buildings, resulting in total risk reduction of $36.3m and $64.8m respectively in present value terms over the 30 year period.

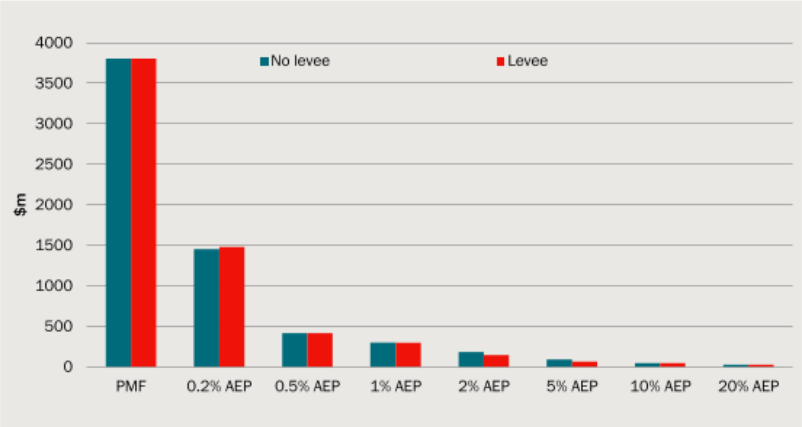
5.2 Impact of the L4B on annual average damage for a single year



Data source: The CIE

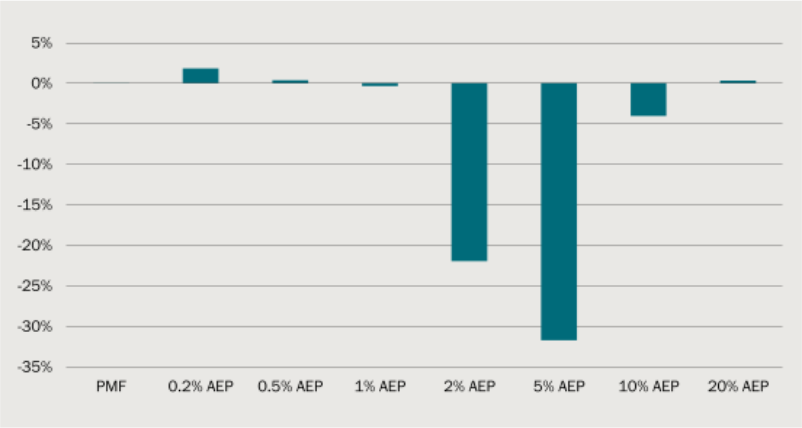
Breaking this damage down into contributions from each flood event, we can see that the benefits of the levee option are achieved in the AEP 2% and the AEP 5% events. Chart 5.3 shows the level of damage in each flood event, and chart 5.4 shows the percentage change.

5.3 Total damage by AEP



Data source: The CIE

5.4 Percentage change in damage from L4B relative to "no levee" option, by AEP



Data source: The CIE

Table 5.5 shows the breakdown of damage in each AEP into damages from residential buildings, commercial buildings, and other damage types.

5.5 Detailed damage breakdown with and without L4B option

	PMF	0.2% AEP	0.5% AEP	1% AEP	2% AEP	5% AEP	10% AEP	20% AEP
	$m	$m	$m	$m	$m	$m	$m	$m
No levee								
Residential	1,568.9	490.1	118.0	95.5	73.1	36.8	7.2	1.0
Commercial	1,988.0	863.0	236.5	147.1	61.0	16.4	11.4	6.9
Public	122.5	33.6	23.9	20.6	16.3	11.5	8.7	5.8
Injuries and fatalities	383.9	34.2	15.8	9.5	4.8	1.0	0.1	0.0
Mental health	57.5	25.3	6.0	5.1	4.0	1.8	0.4	0.1
Road repair	46.2	38.5	29.5	28.2	26.5	21.8	17.0	10.1
Levee								
Residential	1,569.1	501.0	117.6	93.2	36.2	12.4	6.0	1.2
Commercial	1,988.1	877.9	238.4	148.6	62.4	16.0	11.0	6.8
Public	122.5	33.8	23.9	20.5	14.9	11.1	8.7	5.8
Injuries and fatalities	384.0	35.1	15.3	7.9	2.2	0.7	0.2	0.1
Mental health	57.5	25.7	6.0	5.0	1.7	0.6	0.3	0.1
Road repair	46.2	38.6	29.5	28.2	25.7	20.2	16.9	10.1

Note: There is some overlap between these damage categories. Residential damages includes injuries, fatalities and mental health.
Source: The CIE

Risk reduction – VHR in North Wagga Wagga

Voluntary House Raising aims to reduce the damage to property in the flood plain area and reduce the risk to life of residents and potential rescuers. Residents would still have to evacuate as they do now.

There is a range of eligibility criteria for the VHR scheme. This includes, for example:

- Funding is only available for properties with buildings that were approved and constructed prior to 1986.
- Properties which are benefiting substantially from other floodplain mitigation measures –such as houses already protected by a levee or those that will be –will not be funded for VHR.
- VHR should generally return a positive net benefit in damage reduction relative to its cost. Consideration may be given to lower benefit-cost ratios where there are substantial social and community benefits or VHR is compensatory work for the adverse impacts of other mitigation works.
- Some houses may be unsuitable for raising due to construction methods.

For the purposes of the draft report we have modelled the VHR to apply to all targeted residential properties, noting that around 43 homes in North Wagga Wagga have already been raised. We have also assumed that the house will be raised 3m above the ground level for that property.

Raising houses will reduce structural, contents and intangible damages for a flood of the same size. Chart 5.6 shows the distribution of reduction in risk (i.e. AAD) per property in North Wagga Wagga before and after raising dwellings to 3m above ground level.[17]

5.6 Distribution of building AAD in North Wagga Wagga

Data source: The CIE

17 Note that only the largest building on each property was modelled as being raised to 3m off the ground. This does not apply to smaller buildings such as multiple sheds on the property.

In total, there were 250 residential buildings raised in this analysis, with an average reduction in AAD by $13,970 per year for each raised building. However, there is a substantial level of variation across all the buildings of North Wagga Wagga, as indicated in the chart above.

Risk reduction - VHP in North Wagga Wagga

Voluntary Purchase aims to reduce the number of people living in flood area and reduce the risk to life of residents and potential rescuers. The NSW Government has provided some further information about the scheme, particularly in relation to the February/March 2022 flooding in the Northern Rivers region. The factsheet for the Home Buyback Scheme states that,

> Homes being prioritised for a Home Buyback are in areas with more frequent, high and fast floods. There is a severe risk of future flood damage and a high risk to life in these areas. This includes the greatest risk to life to both residents and emergency response agencies sent to rescue them.[18]

Under the Scheme, a selection of the highest risk properties will be identified as potential candidates for further the buyback scheme. The buyback price is the market value of the property immediately prior to any flooding (i.e. pre-damage price).

For the purpose of this draft report, we have assumed that the policy applies to all residential properties in North Wagga Wagga. The purchase is assumed to occur immediately, rather than a delayed or staggered approach. Therefore, this would immediately eliminate the risks in North Wagga Wagga from current levels. The benefits (in terms of risk reduction) are equal to $66.8m in present value terms.

Risk reduction – combined options

For this study we have conducted further analysis of two alternative combined options.

VHR and VHP

For this option we assume that the levee L4B is not constructed. Instead, there is a combination of house raising and purchase which could apply in North Wagga Wagga, as well as, other areas.

- the house purchase option is applied to only those residential properties where the risks (AADs) currently exceed the proposed purchase price (assumed to be $400,000).
- the house raising option is then applied to the next group of properties where the risks are between $120,000 to $400,000.

18 https://www.nsw.gov.au/sites/default/files/2023-05/NRRC-Home-Buyback-Fact-Sheet-and-FAQs-May-2023.pdf

This is likely to be the most economically feasible approach, if Council is seeking to provide a house purchase option for some owners which would eliminate the risks for these properties, including eliminating the risk to life.

5.7 Reduction in risk from combination of raising and purchasing

Discount Rate (p.a.)	Base Case AAD	Houses raised	Houses purchased	Project AAD	Risk reduction
	$m	no.	no.	$m	$m
0.03	385.0	193	81	291.0	94.0
0.05	299.5	193	35	233.5	66.0
0.07	241.2	152	26	193.0	48.2

Note: Base case AADs are drawn across the entire Wagga Wagga region, rather than just North Wagga Wagga.
Source: The CIE

VHR, VHP and the levee option (L4B)

For this option, the levee L4B is constructed. This provides protection for the North Wagga Wagga residents but it may increase the risk to properties outside North Wagga Wagga. The VHR and VHP options would then apply to residents *outside* North Wagga Wagga. We then assess the updated risks for properties outside North Wagga Wagga and apply the same $400,000 and $120,000 threshold rules noted above.

5.8 Reduction in risk from combination of levee, raising and purchasing

Discount Rate (p.a.)	Base Case AAD	Houses raised	Houses purchased	Project Case AAD	Risk reduction
	$m	No.	No.	$m	$m
0.03	385.0	70	9	315.3	69.7
0.05	299.5	48	6	250.2	49.3
0.07	241.2	23	6	204.3	36.9

Note: Base case AADs are drawn across the entire Wagga Wagga region, rather than just North Wagga Wagga.
Source: The CIE

6 Economic Costs

This chapter presents the economic costs associated with the options. The focus in this chapter is on the capital and ongoing operating costs with the options. There are also likely be some costs associated with loss of biodiversity due to clearing needed at Wilks Park for option L4B. These additional biodiversity costs have not been accounted for in the costs below but will be considered further in the final report. Given this the costs below are likely to be an underestimate of the costs for L4B.

Voluntary house raising option – North Wagga Wagga

The cost of the house raising depends on a range of factors such as the types of homes and the height above ground level to which the property is raised. For the purpose of our analysis the Council has advised a construction cost of **$120,000 per property**, based on the recent experience in the Lismore flooding. The cost of $120,000 does not include any costs of improving the accessibility of the property (e.g. ramps). Therefore, the costs would be higher if residents required to improve access. Assuming that 250 homes are raised this equates to **$30m**.

We have assumed that this can raise the existing property by around 3m above ground level, although alternative raising levels are considered in the sensitivity analysis section later in this report.

Voluntary house purchase – North Wagga Wagga

For this option we have assumed that it would apply to all residential properties in North Wagga Wagga. Council has advised that, on average, the cost would be **$400,000/property**. This estimate aligns with the average property price estimate of $401,158/property based on publicly available data from the NSW Land Valuer General which indicates that there have been 19 residential property transactions in North Wagga Wagga in the calendar years 2022 and 2023.[19] Assuming that 290 homes are purchased equates to **$116m**.

There would also be additional costs if these homes are required to be demolished and, for example, turned into public land.

19 https://valuation.property.nsw.gov.au/embed/propertySalesInformation

Option L4B

The option L4B is the high cost option and involves the construction of:

- A raised embankment
- Proposed road to adjoin existing abutment of Wiradjuri Bridge
- Proposed Bridge No.1 of 75m
- Proposed Bridge No.1 of 200m
- A 2.5m pathway adjacent to the proposed road.
- Concrete path to connect to the existing ATP network.

The estimated cost of the project in **$76m (in present value terms)** including both the upfront capital costs and ongoing maintenance costs. These costs do not include the biodiversity offset costs associated with any land clearing required.

The detailed assumptions underpinning the cost estimates are available in a separate document from Council.

Combined options

As noted earlier, there are two separate options:

- The VHR and VHP options combined. This is applied to properties in North Wagga Wagga, as well as, outside the suburb and only applies to high risk properties where the estimated benefit exceeds the costs. The cost of this option is **$37.2m**, assuming that 193 houses are raised and 35 houses purchased.
- The L4B levee option, with the VHR and VHP options combined. The L4B levee provides protection for properties in North Wagga Wagga. The VHR and VHP options would apply to properties outside and only applies to high risk properties where the estimated benefit exceeds the costs. The cost of this option is **$84.0m**, assuming that 48 houses are raised and 6 houses purchased.

Note that the number of properties raised and purchased in these options are also influenced by the discount rate chosen. Under the lower discount rate, this increases the value of the AAD reduction, therefore, there are more homes that exceed the $120,000 and $400,000 thresholds.

7 Cost benefit analysis results

VHR in North Wagga Wagga

A large number of residential properties in North Wagga Wagga are impacted by the floods, meaning that for many of them it is worthwhile to spend the $120,000 to raise the building by 3 metres. Table 7.1 shows the overall results from raising the largest residential building in North Wagga.

Overall, the option to raise every residential building in North Wagga results in benefits which exceed costs by $22.9m, with a benefit-cost ratio of 1.8.

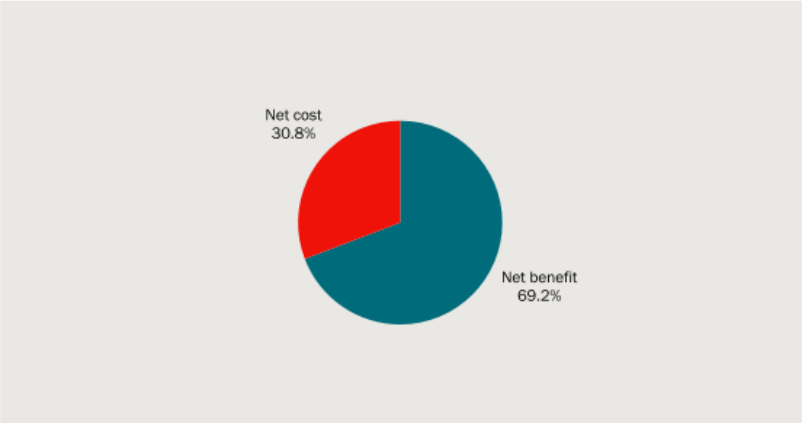
7.1 CBA results for voluntary house raising

Discount Rate (p.a.)	Project Cost	Base Case stream of AAD	Project Case stream of AAD	Total Benefit	Net Benefit	BCR
	$m	$m	$m	$m	$m	
3%	30.0	82.4	15.4	67.0	37.0	2.2
5%	**30.0**	**65.0**	**12.1**	**52.9**	**22.9**	**1.8**
7%	30.0	52.7	9.8	42.9	12.9	1.4

Source: The CIE

However, not every building sustains enough damage on average on floods for the investment to be worthwhile. Chart 7.2 shows the proportion of buildings for which house raising constitutes a net economic benefit. If the program were restricted to only those buildings with expected damage over 30 years greater than $120,000, the net benefit would increase to $27.5m.

7.2 Proportion of buildings which receive net benefits from VHR scheme



Note: This only includes the largest building on each property in North Wagga Wagga
Data source: The CIE

VHP in North Wagga Wagga

Unlike the house raising option, the majority of residential buildings in North Wagga on average do not sustain enough damage over 30 years to make the $400,000 purchase economical. Table 7.3 shows the impact of purchasing every residential property in the suburb.

For each building purchased, the entire stream of AAD is avoided. However, this does not entirely eliminate damage in the area, as there are still non-residential properties that would be damaged.

Comparing to the outcome of house raising in table 7.1, we can see that the house purchasing option delivers an additional $13.9m in benefits. The costs increase by $280,000 per property for the 290 properties purchased, overshadowing the marginal additional reduction in AAD.

7.3 CBA results for voluntary house purchase

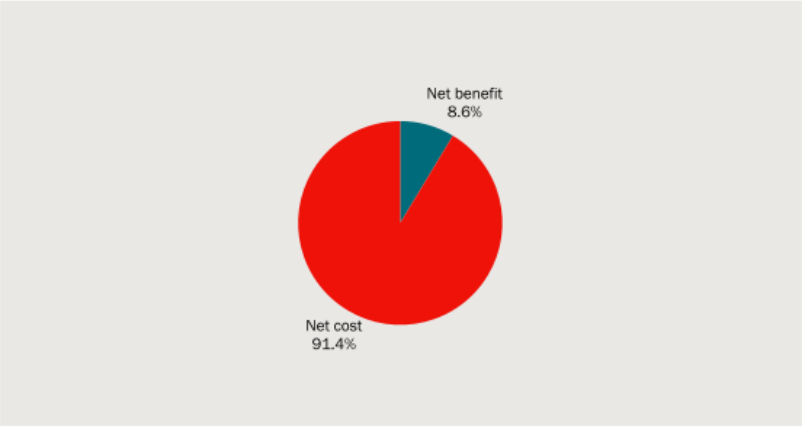
Discount Rate (p.a.)	Project Cost	Base Case stream of AAD	Project Case stream of AAD	Total Benefit	Net Benefit	BCR
	$m	$m	$m	$m	$m	
0.03	116.0	82.4	5.6	76.8	-39.2	0.7
0.05	**116.0**	**65.0**	**4.4**	**60.6**	**-55.4**	**0.5**
0.07	116.0	52.7	3.6	49.1	-66.9	0.4

Note: These results are reported exclusively for North Wagga Wagga.
Source: The CIE

The maximum potential gains from the VHP option would be realised by only purchasing the houses where expected damage exceeds the purchase price of $400,000.

There are only 25 such buildings across North Wagga Wagga. Purchasing only these properties would lead to a net gain of $10.2m.

7.4 Proportion of properties which receive net benefits from VHP scheme



Data source: The CIE

Option L4B

The cost of building the raised embankment and all other components of the L4B option outweighs the benefits from the risk reduction. This option only substantially impacts floods in the 5 per cent and 2 per cent AEPs, with larger floods being unaffected. Table 7.5 shows the net benefit every year of the examination period of 30 years.

Table 7.6 shows the main CBA results for this option, using our central assumptions. The L4B option generates a **net loss** of $40.8m, with a corresponding BCR below 1. Table 7.7 shows that the levee does not have a positive return even if we (very generously) assume every building incurs the same level of structural and internal damage.

7.5 Costs and benefits of L4B over time

Year	Project Cost	Base Case AAD	Project Case AAD	Residual Value	Total Benefit	Net Benefit
	$	$	$	$	$	$
2023	75,467,682	0	0	0	0	-75,467,682
2024	0	0	0	0	0	0
2025-2053	35,000	27,388,284	25,122,397	0	2,275,887	2,240,887
2054	35,000	27,388,284	25,122,397	8,555,580	10,831,467	10,796,467

Note: These costs and benefits use the central case for L4B in which every building is included.

Source: The CIE using NSW Treasury Flood Damage and Cost Benefit Assessment Tool.

7.6 CBA results of L4B (central assumptions)

Discount Rate (p.a.)	Project Cost	Base Case AAD	Project Case AAD	Residual Value	Total Benefit	Net Benefit	BCR
	$m	$m	$m	$m	$m	$m	
0.03	76.2	521.2	477.9	3.4	46.7	-29.4	0.61
0.05	**73.0**	**401.0**	**367.7**	**1.9**	**35.2**	**-40.8**	**0.46**
0.07	75.9	317.6	291.2	1.1	27.4	-48.4	0.36

Source: The CIE, using NSW Treasury Flood Damage and Cost Benefit Assessment Tool

7.7 CBA results of L4B (using all buildings)

Discount Rate (p.a.)	Project Cost	Base Case AAD	Project Case AAD	Residual Value	Total Benefit	Net Benefit	BCR
	$m	$m	$m	$m	$m	$m	
0.03	76.2	660.5	591.1	3.4	72.8	-3.3	0.96
0.05	**76.0**	**508.2**	**454.8**	**1.9**	**55.3**	**-20.7**	**0.73**
0.07	75.9	402.5	360.2	1.1	43.3	-32.5	0.57

Source: The CIE, using NSW Treasury Flood Damage and Cost Benefit Assessment Tool

Combined options

The combined options target properties that are high-risk, with raising or purchasing only being undertaken when it would result in a positive return. Consequently, by design, these options perform better than the blanket approach modelled in the individual risk mitigation strategies.

Table 7.8 shows the outcome of purchasing and raising at-risk properties across all of Wagga Wagga. The net benefit of $28.9m is the highest out of any option, with a BCR of 1.8.

This is a better result than using the levee L4B option to protect North Wagga Wagga and purchasing or raising properties in other parts of the township. Table 7.9 shows that the cost of this option remains prohibitively high, generating a **net cost** of $35.0m. Note that this is an improvement over L4B on its own, which had a net cost of $40.8m.

7.8 CBA results of combined VHR and VHP options

Discount Rate (p.a.)	Project Cost	Base Case AAD	Project Case AAD	Total Benefit	Net Benefit	BCR
	$m	$m	$m	$m	$m	
0.03	55.4	385.0	291.0	94.0	38.6	1.7
0.05	**37.2**	**299.5**	**233.5**	**66.0**	**28.9**	**1.8**
0.07	28.6	241.2	193.0	48.2	19.7	1.7

Source: The CIE

7.9 CBA results of combined L4B, VHR and VHP options

Discount Rate (p.a.)	Project Cost	Base Case AAD	Project Case AAD	Total Benefit	Net Benefit	BCR
	$m	$m	$m	$m	$m	
0.03	87.8	334.2	266.5	67.7	-20.1	0.8
0.05	**84.0**	**260.6**	**211.6**	**49.0**	**-35.0**	**0.6**
0.07	80.7	209.4	173.6	35.8	-44.8	0.4

Source: The CIE

Next steps

Following feedback from the Flood management committee, it was decided to model an additional option (L4A) with only the raised levee and no additional road raising or excavation. Revised flood modelling of this option is currently being undertaken. Revised economic modelling will also be incorporated.

Given that the L4A option is expected to negatively impact on some properties in the LGA, it will be important to identify both the positive and negative impacts on properties. This will include identifying properties that were previously not impacted by flooding but are flooded under L4A, as well as, properties that now experience a greater level/frequency of flooding.

These positive and negative impacts will need to be clearly discussed in the next phase of Woolcott's community engagement so that the community is aware of the tradeoffs and can make a decision.

Further refinement will also include identifying properties that can't be readily raised. These updates will be reflected in the next version of the report.

Other updates for the next version of the report will include:

- the potential biodiversity offset costs to compensate for land clearing associated with the L4B option (e.g. around Wilks Park).
- the potential impact on agricultural production if the levee option changes the flood extent/duration in different parts of the floodplain. Early modelling indicates that this impact is not expected to be material.

A Flood probability terminology

Annual exceedance probability (AEP) should be used to assess the likelihood of a disaster occurring. AEP estimates the probability of a particular type of disaster, equal to or larger than a given magnitude, occurring in any year. The table below presents the AEP flood events modelled and their common equivalent presentation in 1 in X years.

A.1 Flood probabilities modelled

AEP	AEP
%	1 in X years
20	5
10	10
5	20
2	50
1	100
0.5	200
0.2	500
PMF	PMF

Source: WMA Water

There are also alternative ways of expressing these probabilities which are a discussed further by Geosciences Australia.[20]

Average annual damage (AAD) estimates the expected yearly damage cost arising from all occurrences of a given natural hazard. AAD streamlines the calculation of expected damage and enables a like-for-like comparison between different risk mitigation options.

The expected AAD of any given year is the integration of the natural hazard risk density curve over all probabilities. Denoted by *D(p)*, the damage which occurs at the event with probability p, in the catchment with area A. The concept of AAD can be applied to all types of disasters.

$$AAD = \iint_{A\,p} D(p)dpdA$$

The NSW Government's *Disaster Cost-Benefit Framework TPG23-17* (section 3.5.2) issued in August 2023 presents an example of this calculation.

20 https://arr.ga.gov.au/__data/assets/pdf_file/0006/40398/New-ARR-Probability-Terminology_final.pdf

B CBA Tool Assumptions

This section discusses the key parameter values required to be used in the NSW Government's Flood Damage Assessment Tool and the assumptions adopted for this study.[21]

B.1 Residential

Direct Tangible: Avoided residential property and content damages (structural, internal and external)	Avoided property damage costs due to external and internal flooding. Data is needed on the ground and floor level of each property for accurate measurement as internal flooding causes most damage. Stage-Damage Curves calculate the amount of damage that is incurred for a property, using inputs such as land use type, building types, and flood characteristics such as depth and velocity	Property sizes (floor area, per m2): • Detached dwelling (single and double storey): 90 (small), 180 (medium), 240 (large), 220 (default) • Unit or apartment: 100 • Townhouse: 160 Structural replacement value (per m2): • Detached dwelling (single storey): $2,280 • Detached dwelling (double storey): $2,620 • Unit: $2,730 • Townhouse: $2,620 Contents value for residential properties (per m2): $550. External damage for residential properties (if ground flood depth exceeds 0.3 metres): $17,000 Damage downscale for units and townhouses: 30% Section 1.2.2 of Technical Note: Flood CBA Tool provides residential damage curve default values.

a

Note:

Source:

21 https://flooddata.ses.nsw.gov.au/flood-projects/nsw-flood-damage-assessment-tool-dt01

B.2 Direct Tangible damages

Direct Tangible: Avoided **RESIDENTIAL** property and content damages (structural, internal and external)	Avoided property damage costs due to external and internal flooding. Data is needed on the ground and floor level of each property for accurate measurement as internal flooding causes most damage. Stage-Damage Curves calculate the amount of damage that is incurred for a property, using inputs such as land use type, building types, and flood characteristics such as depth and velocity	Property sizes (floor area, per m2): • Detached dwelling (single and double storey): 90 (small), 180 (medium), 240 (large), 220 (default) • Unit or apartment: 100 • Townhouse: 160 Structural replacement value (per m2): • Detached dwelling (single storey): $2,280 • Detached dwelling (double storey): $2,620 • Unit: $2,730 • Townhouse: $2,620 Contents value for residential properties (per m2): $550. External damage for residential properties (if ground flood depth exceeds 0.3 metres): $17,000 Damage downscale for units and townhouses: 30% Section 1.2.2 of Technical Note: Flood CBA Tool provides residential damage curve default values.
Direct Tangible: Avoided **Commercial and Industrial** property and content damages	Commercial property damage depends on use. For instance, an electronics retailer would be expected to incur higher damages than a grocer. MM01 provides a practical approach categorising commercial property damage based on commercial use. The stage damage curve for commercial property is based on the square metreage of each property, which can be sourced from the local council. Data on the ground and floor levels of each property is also needed to determine when flooding overtops the external and internal components of the structure.	Property sizes (floor area, per m2), non-residential buildings: • Average (default): 418 • Low-to-medium value: 186 • Medium-to-high value: 650 • School: 17,000 • Hospital: 28,000 • Other public (government) buildings: 2,200 Section 1.2.3 of Technical Note: Flood CBA Tool provides commercial damage curve default values.
Direct Tangible: Avoided public infrastructure property and content damages	Public assets and infrastructure include high value assets such as bridges, roads, railways, and utility infrastructure (e.g. sewerage system, transmission lines and underground cabling).	Infrastructure damage uplift of total residential damage: 10% (drops to 5% if road damage is considered). External damage, road repair cost (per m2): $5.65. Section 1.2.4 of Technical Note: Flood CBA Tool provides public buildings stage-damage curve default values.

	Valuing infrastructure damage can be challenging. One approach is to apply an uplift to residential damages. Practitioners may also estimate the total replacement value of the asset and account for the AEP level at which the asset is inundated. Assets may fall into multiple AEP levels depending on the scale and nature of the asset, as well as the land that it encompasses. Additional detail may be needed to apportion asset replacement values across each AEP level. Geoscience Australia has developed the National Exposure Information System (NEXIS) dataset to capture exposure information for physical infrastructure assets and populations. Future improvements to the dataset will aim to provide replacement values for infrastructure assets at the local government level (Geoscience Australia, 2022).	
Direct Tangible: Avoided transport damage (roads, railways, train stations, bridges)	Transport infrastructure is vulnerable to flood damage, particularly when inundated for prolonged periods (Bureau of Transport Economics, 2001). Direct impacts include the cost of reconstruction and removing debris (The World Bank, 2016) as well as damage to the underlying structures (Tao & Mallick, 2020). Semi-rural and rural roads tend to be less resilient to flood damage, as they typically use more cost-effective materials.	External damage, road repair cost (per m2): $5.65.
Direct Tangible: Avoided vehicle damages	Flood water can compromise a vehicle's structural and electrical integrity leading to them being written off. Both commercial and private use vehicles should be considered.	Section 1.2.4 of Technical Note: Flood CBA Tool provides further guidance.
Direct Tangible: Avoided agricultural losses (crops and livestock)	Loss of crops and livestock will depend on the type of crop and the nature and duration of the flooding event. The season can also be relevant, as a crop has a higher value prior to harvest than when just planted. Under extended conditions of inundation, fungal and bacterial pathogens can further impact the crop, including through soil borne diseases.	May be included as a bespoke element.
Direct Tangible: Avoided emergency services costs	An agricultural profile of the study area is required. The Australian Exposure Information Platform provides a summary of agriculture commodities by region.	Agriculture commodity (expected annual output per ha, per year):

Direct Tangible: Avoided clean-up costs	Clean-up costs relate to the time (opportunity cost of labour) and materials involved in cleaning up a property (residential or commercial). Estimated costs should reflect the extent of expected damage (e.g. ground floor flooding only).	Residential clean-up if affect by over-floor flooding (per property): $4,500. Non-residential clean-up cost and loss of trading: 30% of direct damage.

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Note:

Source:

B.3 Intangibles

Type: Example	Description and potential quantification approach	Default Parameters used within the Flood CBA Tool
Direct Intangible: Avoided mortality and injury	Floods have recorded one of the highest instances of fatalities, injuries and morbidities, among disasters in Australia (Commonwealth of Australia, 2020a).	Value of statistical life (Commonwealth Department of the Prime Minister and Cabinet, 2022) 2022 dollars:
Direct Intangible: Avoided environmental damages	Cost estimates should include the likely injury and loss of life. One method is the UK DEFRA Wallingford method, which estimates the potential reduction in risk to life associated with changes to flood behaviour (such as flood hazard: H1-H6). The method can be used to estimate losses across a study area but should not be used to estimate risk to life at the property scale.	•
Indirect Tangible: Avoided business activity interruptions and loss of production	Lost production and forgone profit (difference between the price that a producer would have received and the marginal cost of production) due to business disruption. Lost production does not include damaged inputs or inventory, as these would have already been accounted for in commercial property and contents damage.	Non-residential indirect costs, comprising of clean-up costs and loss of trading: 30% of direct damages.
Indirect Tangible: Avoided service losses (damage to infrastructure and telecommunication networks)	Displacement should be considered as some lost production may be picked up by a non-flood affected business (e.g. revenue lost by a supermarket in a flood zone may be offset by increased revenue to another supermarket.	N/A
Indirect Tangible: Avoided accommodation and relocation costs	Some businesses may benefit, particularly if their goods or services are related to flood recovery.	Relocation cost (per week): $0

Indirect Intangible: Avoided stress, mental health and other health related impacts	Impacts may be estimated based on the cost of treatment, cost of work absenteeism and presenteeism and estimated increased prevalence due to floods. Longer displacements and higher levels of direct damage are associated with greater mental health impacts than brief displacements (Shih, 2022).	Mental health impacts based on food level, cost per household (2022 dollars):
Indirect Intangible: Avoided loss of social and cultural values	Further details are provided in Technical Note: Flood CBA Tool.	•

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Note:

Source:

B.4 Option L4B Works required

Note:


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FRMAC North Wagga Flood Mitigation Option Timeline															
	12/02/2024	19/02/2024	26/02/2024	4/03/2024	11/03/2024	18/03/2024	25/03/2024	1/04/2024	8/04/2024	15/04/2024	22/04/2024	29/04/2024	6/05/2024	13/05/2024	20/05/2024	
Monday	12	19	26	Draft Report workshop Council	Council Meeting Public Exhibition	Public Exhibition Start	25	1	8	15	22	29	Final Report Council Workshop	Final Report to Council		
Tuesday	13	20	27	5	12	19	26	2	9	16	23	30	7	14		
Wednesday	14	21	28	6	13	20	27	3	Public Exhibition Dropin	17	24	1	8	15		
Thursday	FRMAC Meeting	22	Draft Report FRMAC workshop	7	14	21	28	4	FRMAC Meeting	18	25	Final Report to FRMAC workshop	9	16		
Friday	16	23	1	8	15	22	29	5	12	Public exhibition ends	26	3	10	17		

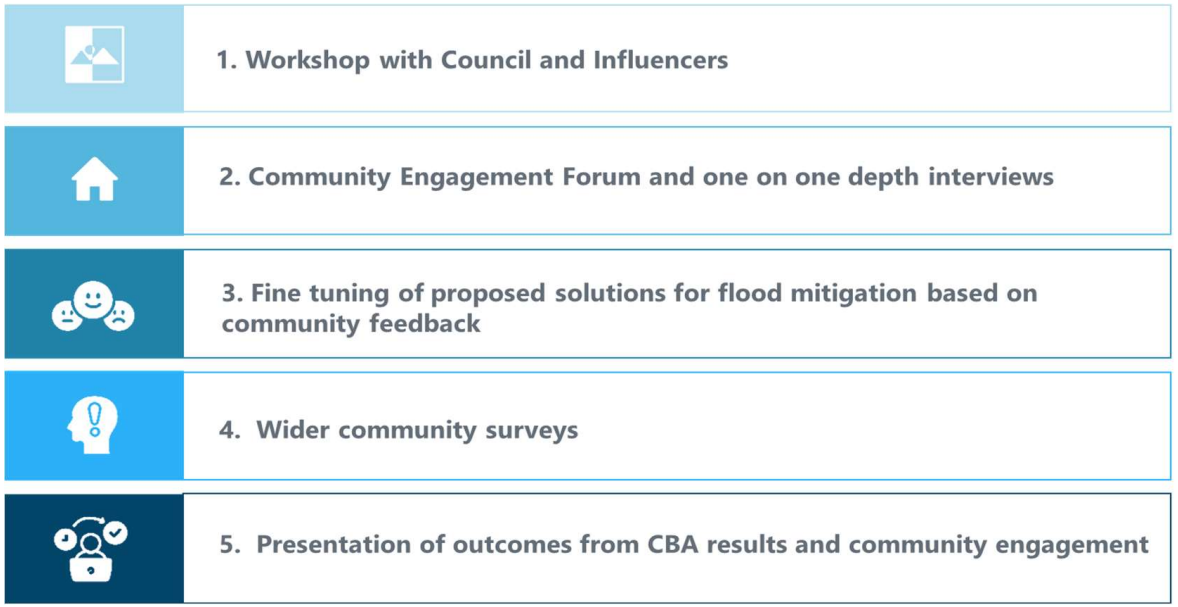
North Wagga Flood Risk Mitigation: **Community Engagement Surveys**

February 2024

WOOLCOTT RESEARCH & ENGAGEMENT

Wagga Wagga City Council

An overview of the Community Engagement Program

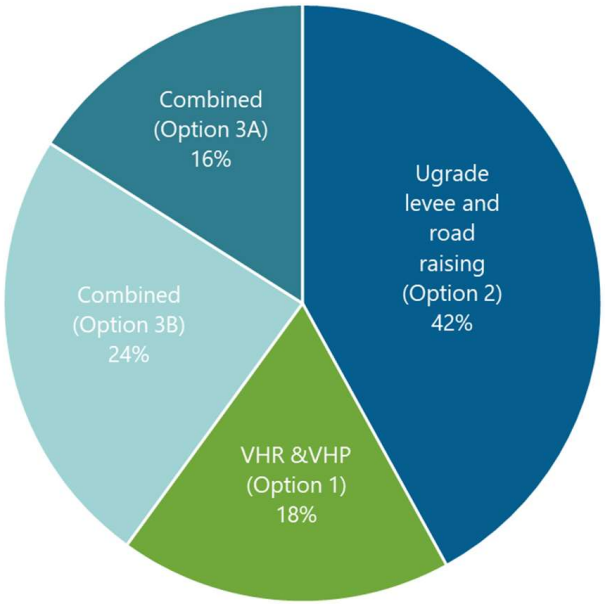


This presentation details the feedback from the Community surveys.

WOOLCOTT RESEARCH & ENGAGEMENT 2

Recap of findings from the Community Forum

Conclusions from the forum



- Option 2, Upgrading the Levee and Road Raising was the most popular (21/50 participants), however this was mostly amongst North Wagga residents (19/50 participants).
- A similar number preferred a Combined Option (either 3A or 3B) – 20/50 participants.
- Therefore, an option that included the levee was selected by 41 of the 50 participants (82%).
- House Raising and Voluntary Purchase as a standalone solution, appeared to be the least preferred (9/50 participants).

Findings from the Community Survey

Research Methodology

Two surveys were conducted from December 23- 31 January 24. The Open Survey closed on the 9th February.

- Representative Community Survey (Main Survey) n=401
- Open online survey via Council Website (Open Survey) n=148 (as of 31/1)

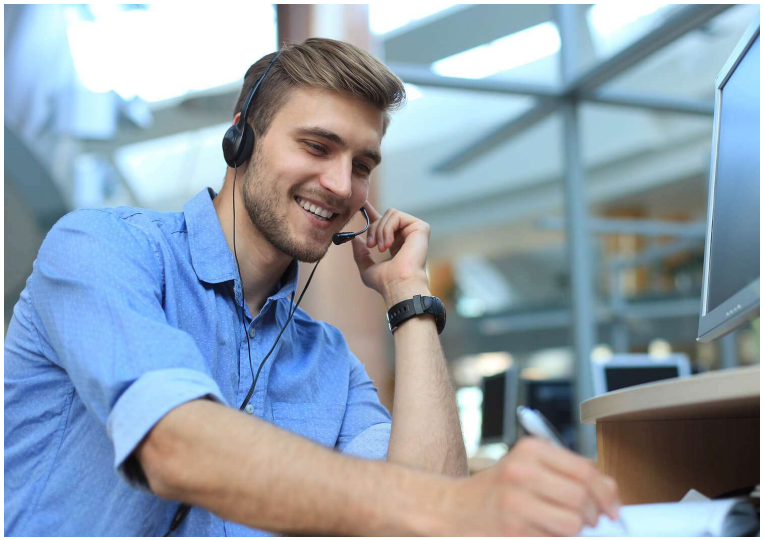
- Residents for the Main Survey were sourced via a combination of random telephone interviews and through an online research only panel.

- All respondents were required to be owners of a home in Wagga Wagga LGA

- As an adjunct to the Main survey, the survey was posted on the Council website to allow residents who weren't contacted as part of the main study to have their say.

**Results have been weighted in analysis to be representative of the population in terms of location.

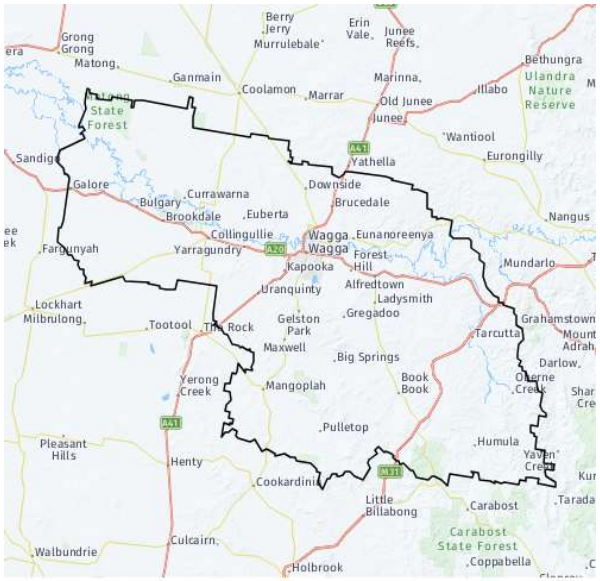
Who we spoke to



Unweighted Base: All Respondents – Main Survey (n=401), Open Survey (n=148)

		Main survey %	Open Survey %
Gender	Male	47	48
	Female	53	50
	Other (non gender specific/prefer not to say)	0	2
Age	18-34	16	14
	35-49	18	26
	50-69	33	49
	70+	33	11
CALD	Speak a language other than English at home	3	3
ATSI	Identify as being Aboriginal and/or Torres Strait Islander	4	6

Who we spoke to



Unweighted Base: All Main Survey Respondents (n=401) Open Survey (n=148)

Location	Main Survey %	Open Survey %
Wagga Urban		
Ashmont	6	7
Boorooma/Estella	6	6
Bourkelands/Tatton	6	3
Glenfield Park	8	5
Kooringal	10	2
Mount Austin	4	1
Tolland	5	3
Turvey Park	6	3
Wagga Central	10	3
Flood Impacted		
Forest Hill/Gumly/East Wagga	6	1
North Wagga/Bomen/Cartwrights Hill	5	53
South and Rural Wagga		
Rural West Wagga - Collongullie/Currawarna/ Galore/Gobbagombalin/ Uranquinty	9	6
Rural East Wagga - Humula/Ladysmith/Tarcutta/ Mangoplah	5	1
Lake Albert	10	3
Springvale/Lloyd	4	1

Voluntary House Purchase

Voluntary House Raising

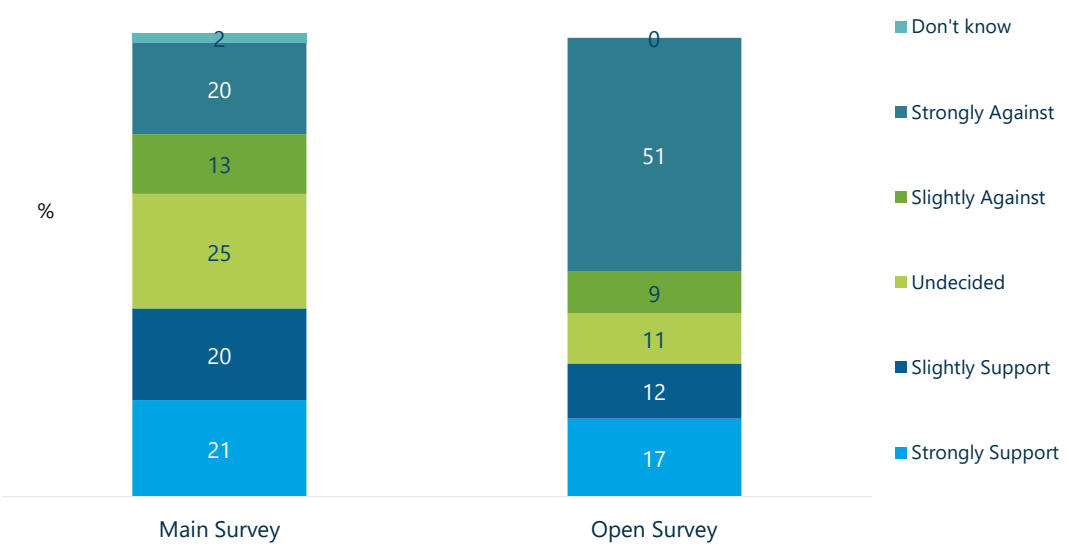
WOOLCOTT RESEARCH & ENGAGEMENT 9

Degree of Support for Voluntary House Raising (VHR) and Voluntary House Purchase (VHP)

In the Main Survey strong support was high in Wagga Urban (23%) and significantly lower in the flood impact areas (5%); in the Open Survey flood impacted residents were significantly more likely to be slightly against (64%)

Assumptions:

- All homes within North Wagga that can be raised take up Voluntary House Raising (160 homes)
- The remainder take up Voluntary House Purchase (100 homes)
- Total estimated cost $60 million
- The cost will be higher depending on how many homes outside North Wagga are raised or purchased.



Q1. How supportive are you of Council implementing this option of Voluntary House Purchase and Voluntary House Raising?
Base: All Respondents (Main survey respondents N=401; Open Survey n=148)

WOOLCOTT RESEARCH & ENGAGEMENT 10

Reasons for and against VHP & VHR

REASONS FOR:

	Main Survey %	Open Survey %
It's voluntary/gives people choice to move to out of a flood risk area or stay in their home	21	13
House raising is good/no need to leave the area	16	10
It helps people/NFI	14	7
There shouldn't be houses there/reducing the number of houses there is a good thing	6	4
House purchase/relocation is a good thing	6	7
It reduces the risk to people/fixes the problem	4	6
People chose to live in North Wagga knowing the risks/their problem not ours	3	0
Cost is reasonable/helps people financially	0	12
Other	7	5
Don't know/need more information	13	5
Nothing/I don't like it/I'm against it	23	51

REASONS AGAINST:

	Main Survey %	Open Survey %
Costs too much/increased rates/funds could be spent elsewhere	21	20
Ruins the North Wagga community/shortage of land elsewhere/don't want to move	17	13
People chose to live in North Wagga knowing the risks/their problem not ours	12	20
Unfair that others have to pay	11	0
There are better options than this/this option is not effective/feasible	9	16
I doubt homeowners would get market value/they would be offered a low price	6	6
Government shouldn't buy houses/land that can't be used	4	4
Timeframe is too long/will take too long	3	0
House purchase/buy back is a bad thing	3	4
Many houses can't be raised/doesn't suit elderly	0	8
Other	12	7
Don't know/need more information	12	5
Nothing/I like it/I'm not against it	15	14

Q2/3. What do you like/dislike about this option?
Base: All Respondents (Main survey respondents N=401; Open Survey n=148)

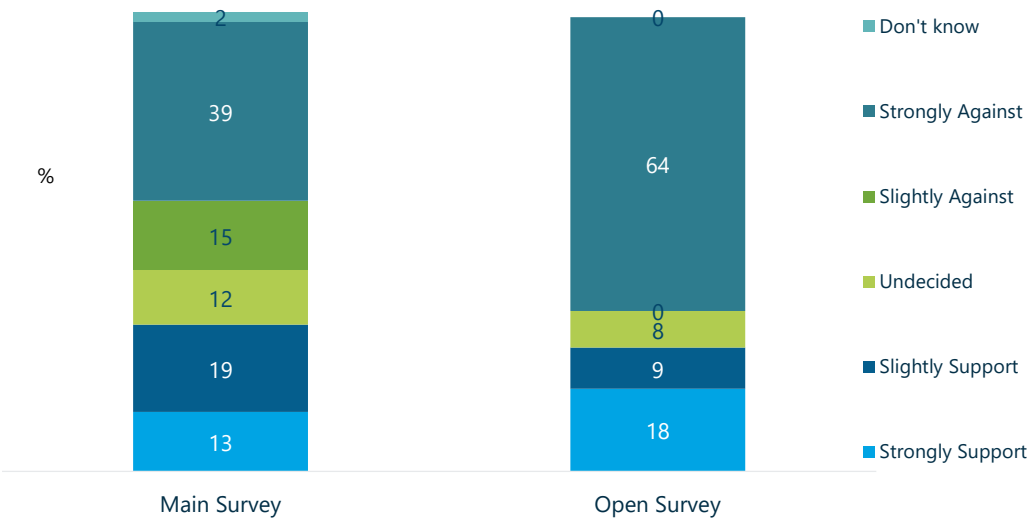
WOOLCOTT RESEARCH & ENGAGEMENT 11

Degree of Support for Voluntary House Raising and Voluntary Purchase with an associated SRV

Assumptions:

- Council might have to fund part of this cost through a special rate variation.
- It could mean an additional $128 per household on average on Council rates for seven years in the urban area of Wagga
- An extra $45 per year on average on Council rates for the Villages for seven years.

Within the Open Survey Flood impacted residents were more likely to strongly support this (39%).



Q4. How supportive are you of Council implementing this option of Voluntary House Purchase and Voluntary House Raising?
Base: All Respondents (Main survey respondents N=401; Open Survey n=148)

Levee Upgrade

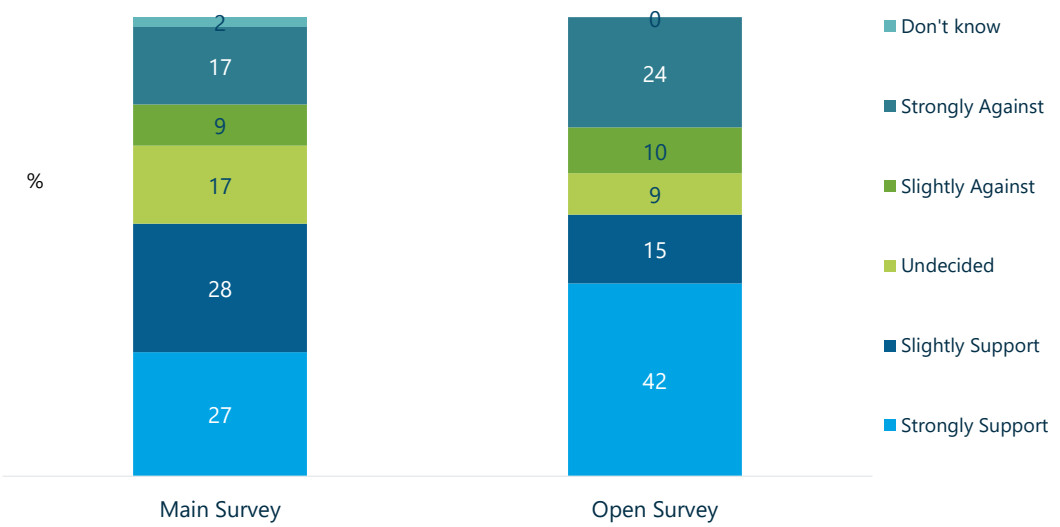
- Stage 1 - raising the levee to a 5% AEP level (or 1 in 20 chance of a flood event) to provide North Wagga with a greater level of protection.
- Stage 2 - the 'surrounding works' - raising a portion of Hampden Ave to provide a safe evacuation route for North Wagga residents and raising a section of Mill St to provide an evacuation route for residents within the East St Levee.
- Also involve the building of bridges and excavation works to offset the levee and embankment and enable equivalent water flow.
- The timing of stage 2 is unknown and subject to funding availability.

Degree of Support for Levee and Surrounding Works

Assumptions:

- When both Stages 1 and 2 are implemented, in the majority of floods there would be a benefit (i.e avoid flooding in a 5% AEP level or 1 in 20 chance of a flood event) to 237 properties, but in the most extreme floods (i.e. in a 0.5% AEP or 1 in 200 chance (overtopping the main city levee) there could be a small negative impact on up to 697 properties.
- The cost estimate is:
  - Stage 1: $10.3 million
  - Stage 2: $75.7 million

In the main survey there was no significant difference by location. Within the Open survey there were some flood impacted residents who were significantly more likely to support this (59%) and others who were strongly against (47%).



Q5. How supportive are you of Council implementing this option as a whole – Stages 1 and 2?
Base: All Respondents (Main survey respondents N=; Open Survey n=)

Reasons for and against Levee and Surrounding Works

REASONS FOR:

	Main Survey %	Open Survey %
People can stay in their houses/preserves North Wagga community	19	15
Stage 1/Raising the levee is good NFI	18	19
This option is cheaper/the better option	12	14
Helps people/gives reassurance/safety	11	16
Community solution/will benefit people outside N.Wagga too	11	6
Stage 2/Improved roads, bridges, evacuation route is good	9	1
Gives N.Wagga people more time to evacuate	8	3
It is fair/Wagga city had their levee increased so should N.Wagga	4	2
Long term/good future planning	4	2
Other	4	4
Don't know/need more information	9	0
Nothing/I don't like it/I'm against it	22	34

REASONS AGAINST:

	Main Survey %	Open Survey %
Costs too much/increased rates/funds could be spent elsewhere	28	17
Impacts on other areas outside the levee/just moves the problem	12	11
Won't solve the issue/there is still a risk of flooding/band aid approach	12	7
Unfair that others have to pay/taxpayers have to pay	11	18
Requires a lot of work/will take too long	6	0
People chose to live in North Wagga knowing the risks	4	12
Don't like the idea of raising the levee	3	12
Stage 2 is unnecessary/extra cost	0	15
The two stages shouldn't go together/overkill/waste of money	2	4
Other	1	12
Don't know/need more information	12	0
Nothing/I like it/I'm not against it	26	21

Q6/7. What do you like/dislike about this option?
Base: All Respondents (Main survey respondents N=401; Open Survey n=148)

WOOLCOTT RESEARCH & ENGAGEMENT 15

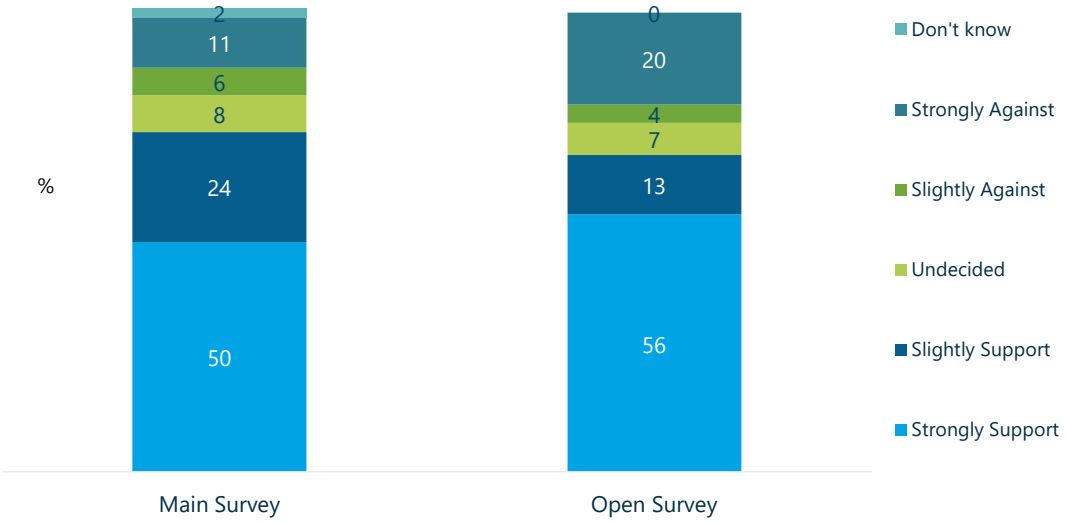
Degree of Support for Upgrading the Levee

- Completing Stage 1 (upgrading the levee only)

Assumptions:

- Council could complete Stage 1 with existing funds.

Within the Open Survey, support was significantly higher amongst Flood Impacted residents (95%) whereas in the main survey there were no significant differences by location.



Q8. Taking the funding of these stages separately, how supportive are you of Council implementing Stage 1 of this option (upgrading the levee only) using existing funds?
Base: All Respondents (Main survey respondents N=401; Open Survey n=148)

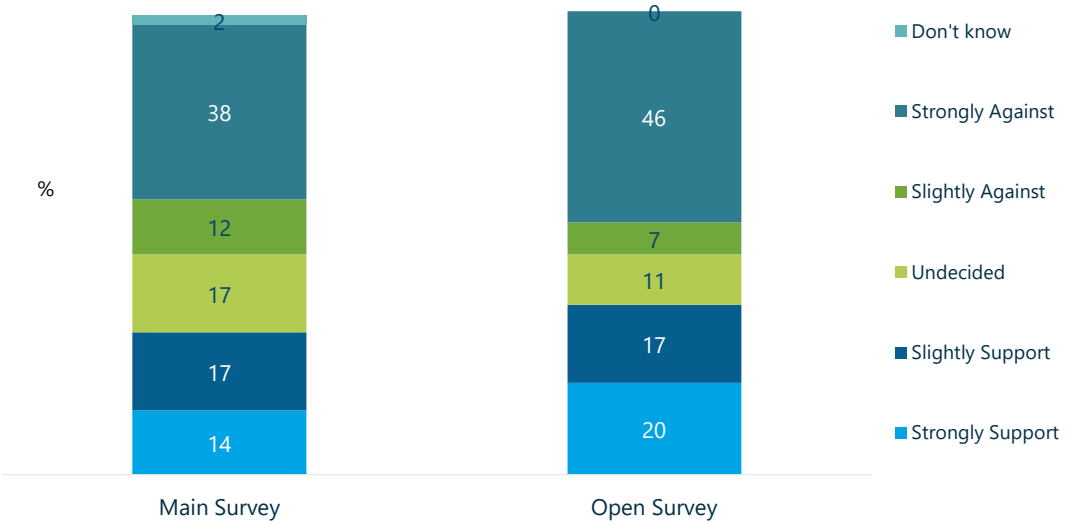
Degree of Support for the Surrounding Works

- Completing Stage 2 (the surrounding works – road raising, bridges and excavation)

Assumptions:

- Stage 2 is contingent upon Government funding and a special rate variation for Council to fund its share.
- It could mean an additional $173 per household on average on Council rates for seven years in the urban area of Wagga
- An extra $61 per year on average on Council rates for the Villages for seven years.

Flood impacted residents were more likely to support this in the Open Survey (53%), with again no significant differences in the main survey by location



Q9. How supportive are you of Council implementing Stage 2 of this option (the surrounding works – road raising, bridges and excavation), with the associated special rate variation?
Base: All Respondents (Main survey respondents N=; Open Survey n=)

WOOLCOTT RESEARCH & ENGAGEMENT 17

Combined Option

Option 3 would include three projects:

- Project 1
    - Upgrading the existing North Wagga Levees (stage 1)
    - Offering VHR and VHP to those outside the levee boundary (e.g. including eligible houses in and around North Wagga, Oura, Gumly Gumly).
- Project 2
    - 'Surrounding works' – raising roads, bridges and excavation between Wagga and North Wagga along Hampden Ave.
- Project 3
    - Offering VHR and VHP to residents inside the North Wagga Levee system, where the risk reduction is greater than the cost of the action.

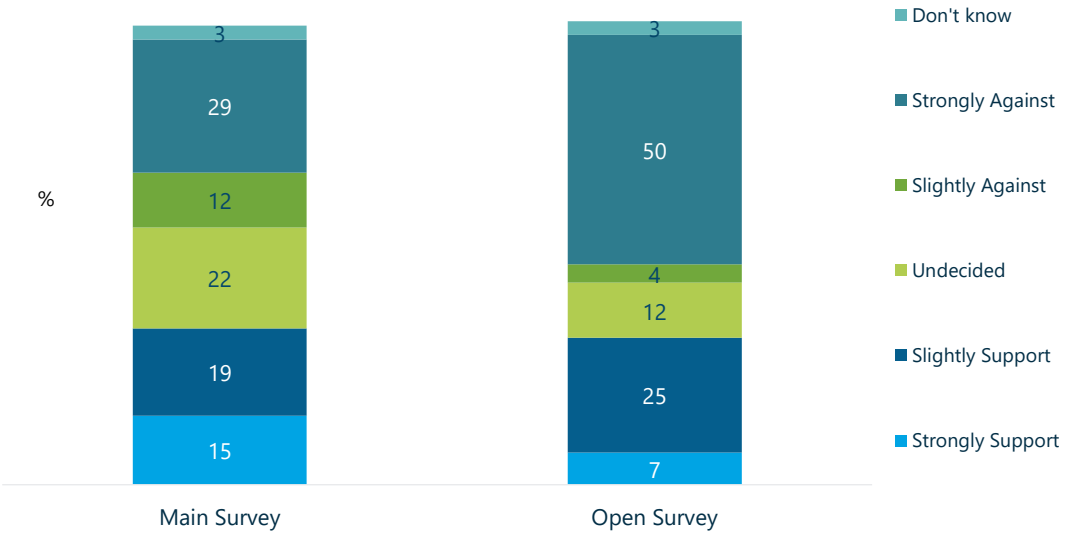
WOOLCOTT RESEARCH & ENGAGEMENT 18

Degree of Support for a Combined Option

Assumptions:

- In the majority of floods there would be a benefit (i.e. avoid flooding in up to 5% AEP level or 1 in 20 chance of a flood event) to 237 properties, but in the most extreme floods (i.e. 0.5% AEP or 1 in 200 chance (overtopping the main city levee) there could be a small negative impact (increased flood height) on up to 697 properties.
- The cost estimate is:
  - Project 1 $20M
  - Project 2 $75.7M
  - Project 3 $10M

Flood impacted residents were significantly more likely to support this in the Open Survey (79%), with again no significant differences in the main survey by location



Q10. How supportive are you of Council implementing Option 3 as a whole?
Base: All Respondents (Main survey respondents N=401; Open Survey n=148)

Reasons for and against Combined Option

REASONS FOR:

	Main Survey %	Open Survey %
All inclusive option/variety of solutions/there's a benefit for everyone	22	17
It's voluntary/gives people choice to move out of flood risk area or stay in their home	13	6
It reduces the risk/fixes the problem/helps people	7	6
Cost is cheaper by combining the options	6	2
Raising the levee is good	5	20
Improving roads and bridges/providing escape routes is good	4	0
House purchase/relocation is good	4	1
House raising is good	4	5
Other	2	4
Don't know/need more information	17	3
Nothing/I don't like it/I'm against it	37	42

REASONS AGAINST:

	Main Survey %	Open Survey %
Costs too much/increased rates/funds could be spent elsewhere	32	23
Unfair that others have to pay/taxpayers have to pay	18	9
Doesn't make sense to combine options 1 and 2/double dipping/overkill	11	8
Not feasible/not practical/not going to fix the problem	8	23
Raising the levee is bad	7	6
People chose to live in North Wagga knowing the risks	6	9
Don't trust the council with money/to do the right thing/get it done	4	7
House purchase/relocation is bad	3	<1
Moving people from N.Wagga destroys the community/don't want to move	0	6
Other	5	8
Don't know/need more information	18	1
Nothing/I like it/I'm not against it	13	8

Q11/12. What do you like/dislike about this option?
Base: All Respondents (Main survey respondents N=401; Open Survey n=148)

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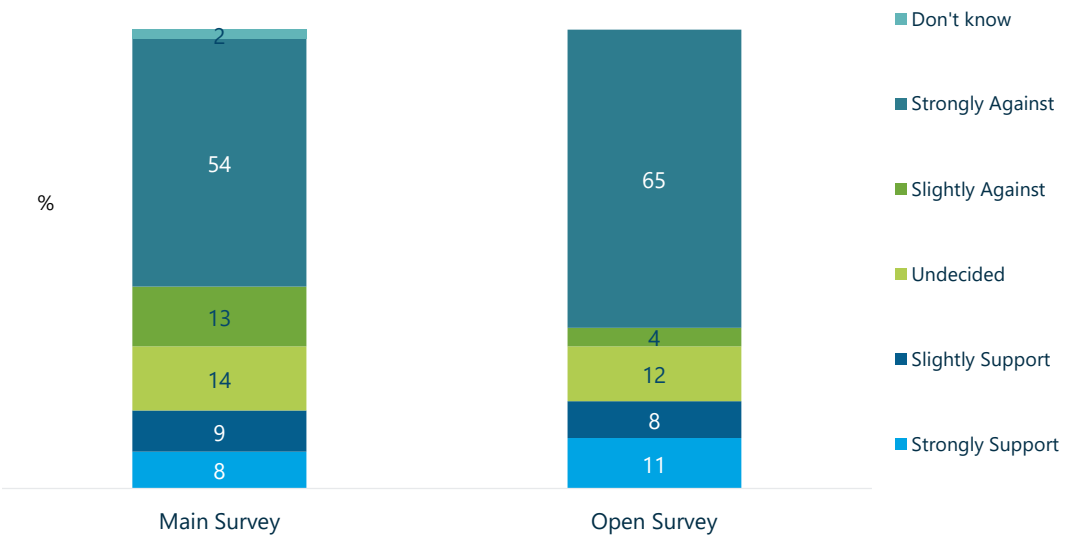
Degree of Support for a Combined Option with a SRV

Open Survey flood impacted residents were less likely to be against a SRV (45%) and more likely to be undecided (38%)

Assumptions:

- Council will have to fund part of this through an SRV.
- This could be $321 extra per year for seven years for residents in Urban Wagga
- Around $114 a year extra for seven years for village residents.

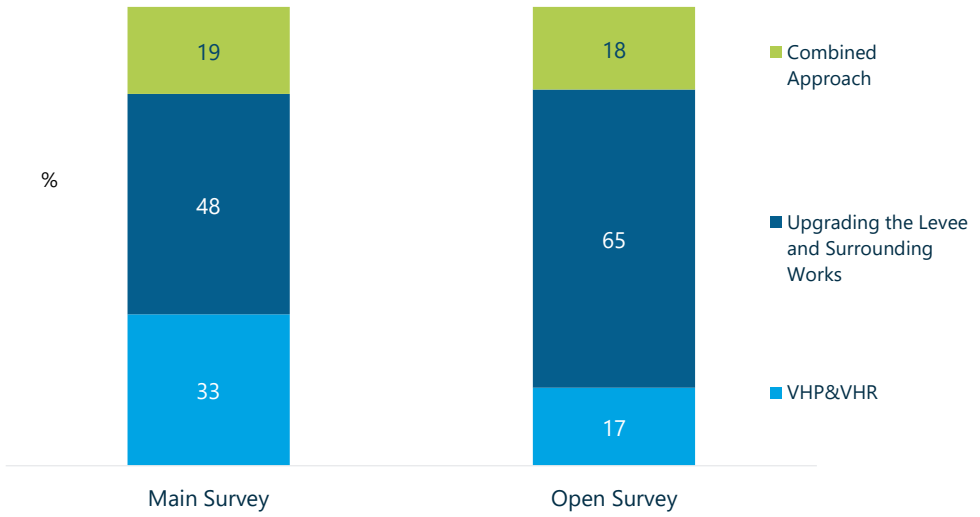


Q13. How supportive are you of Council implementing this option with an associated SRV?
Base: All Respondents (Main survey respondents N=401; Open Survey n=148)

Preferred Option

Preferred Option - % ranked first

In the Open Survey flood impacted residents were significantly more likely to rank VHR/VHP last (89%) and the combined approach first (37%)



Q14. Now that you have been introduced to each of the three options being considered, please rank the three options in order of preference, Which option would be your most preferred? And which would be your least preferred option?
Base: All Respondents (Main survey respondents N=401; Open Survey n=148)

Conclusions

- Within the community forums there was support for the upgrading of the levee along with VHP and VHR in Oura, Gumly Gumly and the floodplains at the least.
- The community survey seems to support this view, with Option 2, particularly Stage 1 (upgrading the levee only) whereby it is funded by Council, having strong appeal (74%).

% Strongly/slightly supporting	Main Survey %	Open Survey %
Option 1		
VHR and VHP	41	29
VHR and VHP (funded by SRV)	31	27
Option 2		
Levee Upgrade and Surrounding Works (Stage 1 & 2)	**55**	**57**
Stage 1: Levee upgrade only (funded by Council)	**74**	**69**
Stage 2: Surrounding works (funded by SRV)	31	37
Option 3		
Stage 1 & 2 plus VHR and VHR for those inside and outside the levee	34	32
Combined option (funded by SRV)	17	19

Conclusions

- In terms of overall preference, Option 2 again comes through as the most popular option in both the main and particularly, the open survey.
- However, amongst flood impacted residents, a combined option that includes VHR & VHP also has strong appeal.

Option 1 Voluntary House Raising and Purchase appeals as:

- It's voluntary/ gives choice
- No need to leave the area
- Helps people

However,
- The cost is unappealing
- Ruins the NW community/ shortage of land elsewhere
- People live there knowing the risks, so it is not others' problem

Option 2 levee upgrade (both stage 1 and 2) appeals as:

- People can stay in their houses and it preserves the community
- Stage 1 only is a good option

However,
- The cost of Stage 2 is unappealing
- It is felt to be unfair to ask others/taxpayers to pay

The Option 3 (combined approach), is felt to be:

- All inclusive/ benefits everyone
- Includes levee raising which is good

However,
- It costs too much/funds could be spent elsewhere
- Unfair that everyone must pay
- Not feasible/practical/going to fix the problem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REF	Option	Description	Benefits	Concerns	Priority		Responsibility	Status
PR1	Feasibility study to investigate a Voluntary House Raising & Voluntary Purchase Scheme in Wagga Wagga Study Area. The feasibility study is to be investigated in conjunction with Option L4B (see below)*.	Residential properties located outside leveed areas may be eligible for voluntary house raising which aims to reduce property damages to residential dwellings, or voluntary purchase, which aims to remove residents from high hazard areas and prevent future development of the purchased lot.Feasibility study is to include economic appraisal of both options, eligibility criteria for participation, identification of construction constraints and extensive community consultation to determine likely participation rates.	The frequency of overfloor inundation (and hence property damage) is significantly reduced by raising the dwelling above the Flood Planning Level. This option can provide benefits to many dwellings across the floodplain without impacting others. Voluntary purchase reduces the number of residents in high hazard areas and can improve conveyance by removing dwellings and rezoning lots to prevent future development.	Suitability for house raising depends on building footings (slab on ground not appropriate), which may limit participation.Some residents may not want stairs due to health and mobility issues.Economic viability of this scheme would be directly linked with participation rates.Raised houses could encourage residents to 'shelter in place' during floods, however isolation and long durations of floods put them at high risk. Significant ongoing education efforts will be required to ensure any evacuation orders are heeded.	**High***		Strategy and Projects	The feasibilty study is nearing completion
L4B	Feasibility Study to investigate North Wagga Levee Upgrade to 5% AEP level of protection including upgrade to Hampden Avenue to equivalent level (as embankment and conveyance improvements through Wilks Park. Feasibility study is to be conducted in conjunction with Option PR1 (see above)*.	Undertake a study to further investigate and determine the feasibility of raising the North Wagga Levee to a 5% AEP level of protection, and raising Hampden Avenue to an equivalent level with some excavation of Wilks Park to improve conveyance and offset upstream flood impacts. The feasibility study is to include EIS for the park excavation, geotechnical assessment of existing levee, site-by-site assessment of third party impacts and extensive community consultation.	Moderate reduction in frequency of inundation and property damages in North Wagga and minor benefits upstream due to increased flow conveyance beneath the newly excavated Wilks Bridge.	Significant concerns regarding risk to life of residents inside levee: ongoing education required to ensure residents fully understand the level of protection the levee would offer. Raising the levee has external adverse flood impacts on a number of properties which require further investigation. The upgrade involves additional excavation beneath Wilks Park Bridge which is likely to have associated environmental impacts. Other concerns include the high capital	**High***		Strategy and Projects	The feasibilty study is nearing completion
VMP	Update the recently completed Vegetation Management Plan to consider new state biodiversity legislation instruments, then draft Standard Operation Procedures for selected recommended activities.	The recently completed VMP was written in accordance with new biodiversity legislation, however implementation guides and instruments were not available at the time of writing. Following completion, Council is to select recommended activities to progress, and draft Standard Operating Procedures for these items.	Controlled vegetation management ensures that in the long term, vegetation does not roughen the riparian zone excessively, and to protect areas of ecological value (especially habitat for native fauna).	There is a perception that broadscale clearing may occur, however vegetation management activities will be targeted and controlled. Vegetation management will not explicitly reduce flood affectation, however will ensure that over time flood behaviour is not worsened by increased riparian roughness due to increased vegetation density.	**High**		Environment and Regulatory Services	Implementation of actions from the Vegetation Management Plan are being progressed including management of exotic plant species and weeds. Grant funding was received and willows in the floodplain were removed.
RE1	Improve Flood Warning System	Various measures to continue and improve on Wagga Wagga's existing flood warning systems, both to enhance flood forecasting and dissemination of information to the public, including investigation of "DipStik" to be installed at Oura to provide water level alerts.	Improved warning systems will better increase the accuracy and timeliness of flood predictions and improve the communication methods to deliver accurate and persuasive messages during flooding.	BOM is responsible for issuing Flood Watch and Flood Warnings.	**High**		Strategy and Projects	Stantec have completed this report and its recommendations are an addition to this implementation program

RE2	Flood Emergency Management Planning	Review and update current Council and SES emergency flood response documents, drawing from latest modelling and recent floods.	Improved flood planning reduces flood risk to life and property, assisting residents of flood prone areas better prepare themselves and their property for flooding.	There are a number of documents to be updated and coordinated.	**High**		Strategy and Projects. SES	SES have finalised work on updating their floodplans. Council staff have completed updating the Levee Owners Manual and Flood Emergency Response Operations Plan
RE3	Community Flood Education	Ongoing community engagement is key to maintaining flood awareness, which can wane as time between flood events increases.	A flood aware community is generally better prepared for flooding, more responsive to evacuation orders and more resilient in recovery.	Levee upgrades can cause increased complacency in residents, which needs to be gently targeted with ongoing flood education campaigns.	**High**		SES	
A1	Future consideration of increasing conveyance beneath Wiradjuri Bridge by extending span and/or excavating beneath the bridge.	Future Option: use planned upgrades to Wiradjuri Bridge (maintenance/ traffic capacity upgrade etc.) as an opportunity to improve flood conveyance between North and South Wagga.	Increasing flow conveyance reduces flood levels across the floodplain upstream of Wiradjuri Bridge and reduces flood damages in the CBD, Wagga Floodplain and parts of North Wagga.	There may be adverse impacts downstream of the bridge, high capital costs and ongoing maintenance costs. Would have to be undertaken in conjunction with other bridge works.	**Low**		Strategy and Projects	Will be incorporated into the outcome of the North Wagga Flood Mitigation feasibilty Study
R1	Improved Access to Oura	Long term, staged upgrades to raise Oura Road (or other route) above the 1% AEP flood level.	Flood free access east-west across Wagga Wagga to Oura is beneficial not only to residents of Oura but to communities across the Riverina.	This road intersects several major flow paths and would require significant culverts/ bridge sections. Costs would be significant.	**Low**		Strategy and Projects	Initial investigations have highlighted significant issues with this proposal. This does not look to be a feasible option in the short-term
R2	Improved Access to Gumly Gumly	Long term, staged upgrades to raise or divert the Sturt Highway (or other route) above the 1% AEP flood level between East Wagga and Gumly Gumly.	Flood free access east-west across Wagga Wagga to Oura is beneficial not only to residents of Gumly Gumly but to communities across the Riverina.	This road intersects several major flow paths and would require significant culverts/ bridge sections. Costs would be significant. Sturt Highway is owned by RMS.	**Low**		Strategy and Projects TfNSW	This was raised with TfNSW and they will investigate options for flood proofing the Sturt Highway as the road is rehabilitated as part of the future roadworks programs
PL1	Move Flood Planning Area mapping into the Wagga Wagga DCP, whilst retaining the definition of the Flood Planning Area and Flood Planning Level in the LEP.	A general definition of both FPL and FPA is to remain in LEP, with details and FPA mapping provided in the DCP for ease of updating following the completion of future studies.	By keeping the FPA mapping in the DCP, Council would not be required to prepare a Planning Proposal each time the FPA map is updated (e.g. with completion of future flood studies).	This amendment to the LEP would require Council to submit a planning proposal.	**High**			Awaiting finalisation of the update to the LEP to allow reference to the FPA map in DCP.

PL2	Reformat DCP to Matrix style document	The Development Control Plan (DCP) is currently a long, wordy and cumbersome document. Reverting to a matrix style format will make it easier for Council and the public to apply and understand.	Matrix style with controls dependent on hydraulic categorisation and hydraulic hazard will be clearer and simpler to interpret. Controls specific to each precinct are not necessary.	There may be resistance to moving away from precinct-centric controls, however the proposed format would be more equitable and clearer about which controls apply to a proposed development.	**High**	General Changes	Regional Activation	Engaged consultants in August 2018 to update flooding controls in DCP - process identified issues with completion prior to completion of VOFFs and MOFFs. These issues are yet to be resolved.
PL3	Add clause to LEP to control critical facilities and vulnerable land uses between the FPA and PMF extent.	This clause empowers Council to apply appropriate flood related controls to critical facilities within the PMF extent that fall outside the FPA (which are not subject to the DCP).	Critical facilities including schools, aged care facilities, childcare facilities outside of the FPA are not currently subject to development controls, however are vulnerable to flood risk in events greater than the 1% AEP. This clause will require development of critical facilities to consider and prepare for flooding during the development application stage	This amendment to the LEP would require Council to submit a planning proposal, which could be lodged in conjunction with Option PL1.	**High**	Controls to reduce risk to life	Regional Activation	NSW Planning are currently in the process of reviewing standard flood clause. Council has been involved in this process. It is anticipated this will be updated automatically in the LEP without the need for Council to prepare an amendment. Expected completion 2021.
PL4	Requirement of Site Specific Flood Emergency Plans	Certain types of developments will be required to provide site specific emergency flood plans to demonstrate how occupants and stock will be kept safe during and after flood events.	Preparation of a plan increases the flood awareness of the business owner and reduces risk to life of staff or occupants by improving evacuation efficiency and preparedness. Increased awareness can also reduce property damages by preparing the site for flooding.	There may be resistance from developers, as preparation of a site-specific flood plan may be considered onerous to prospective developers.	**High**			Similar controls currently exist in the DCP. Any review and update of these controls will retain this provision.
PL5	Flood Risk Info on s149 Planning Certificates	Increase depth of flood information to be provided on s149(2) and (5) certificates to identify the property's flood hazard, hydraulic category and whether or not flood related development controls apply.	The more informed a home owner is, the greater the understanding of their flood risk. During a flood event this information can help prepare residents to evacuate and reduces the number of residents that elect to take shelter in high hazard areas.	None -s149 certificates already contain basic information, Council to provide further detail from current FRMS results.	**High**		Planning	Flood related development controls are provided on certificates. Further investigation is required to determine whether flood hazard and hydraulic category can be provided under liability requirements.

PL6	Controls to set Minimum Floor Levels	The Flood Planning Level (FPL) for a variety of types of development is set at a design flood event level plus a freeboard.	Incidences of overfloor inundation can be reduced for new developments by ensuring their floor levels are set at the FPL (as a minimum).	FPL and FPA to be updated based on results from this FRMS and applied appropriately to various types of development.	**High**	Controls to reduce proposed development	Planning	Completed. Controls currently exist in DCP. New data from FRMP&S is currently being used when assessing development applications.
PL7	Controls to set Minimum Flood Proofing Levels	Flood proofing to the FPL is to be required for certain types of development to reduce flood damages.	Implementation of a minimum flood proofing level can lead to reduced flood damages. Wet or dry flood proofing could be allowed at the developer's discretion.	FPL and FPA to be updated based on results from this FRMS and applied appropriately to various types of development.	**High**		Planning	Completed. Controls currently exist in the DCP. Updates to the DCP controls resulting from adoption of final FRMP&S, VOFF & MOFF will retain provisions for flood proofing levels.
PL8	Controls to ensure appropriate building design and materials	Certain developments are to be certified by an engineer to ensure they can withstand flooding forces, buoyancy and debris.	Developments in higher hazard areas or the floodway may be subject to fast flowing or deep floodwaters, and buoyant debris. This control will ensure such buildings are constructed suitably to withstand such forces and reduce damages and hazard.	There may be resistance from developers, as engineering certification may be considered onerous to prospective developers.	**High**		Planning	Completed. Controls currently exist in the DCP. Updates to the DCP controls resulting from adoption of final FRMP&S, VOFF & MOFF will retain provisions for building design and materials.
PL9	Controls to Manage Offsite Impacts: Flood Impact Assessment	A flood impact assessment can be used to demonstrate that a proposed development will not have any adverse flood impacts elsewhere in the floodplain (e.g. on a neighbouring property).	Developments in higher hazard areas or the floodway may cause adverse flood impacts to other properties and contribute to impacts of cumulative development. This control requires developments of a certain size to submit an impact assessment to demonstrate no offsite flood impacts occur	There may be resistance from developers, as a flood impact assessment may be considered onerous to prospective developers.	**High**	to the wider floodplain		Completed. Controls currently exist in the DCP. Updates to the DCP controls resulting from adoption of final FRMP&S, VOFF & MOFF will retain provisions for flood impact assessment.

PL10	Appropriate Dwelling Design	Redevelopment of existing dwellings should be undertaken so as to improve flood risk where possible, and development controls can be used to achieve improvement over time.	The proposed controls seek to reduce the flood impacts of a replaced dwelling by, for example, locating it on the part of the lot with the lowest hazard, orienting the dwelling to cause least obstruction of flow, requiring minimum floor levels above the FPL, and using open piers to allow flow beneath the property.	There may be limited scope to change the siting of the dwelling or resistance to having open space beneath houses.	**High**	Controls to reduce risk		Completed. Controls currently exist in the DCP. Updates to the DCP controls resulting from adoption of final FRMP&S, VOFF & MOFF will retain provisions for appropriate dwelling design.

Reference	Option and report Reference	Description
PM01	Flood Planning Area and Level for each town (PM01)	A designated area in each town where Council planning controls, including minimum floor levels, apply to development.
RM01 RM04	Update the Wagga Wagga Local Flood Plan section for each town (RM01, RM04,	Incorporate the consequences of flooding observed in the 2010 and 2012 floods in the Local Flood Plan, as well as flood risk information from
RM02 RM05 RM08	Update Flood Intelligence Cards for each town (RM02, RM05, RM08)	Updated information will list consequences of flooding in each town in relation to particular creek depths.
RM03	Install an automatic water level recorder on Umbango Creek (RM03)	Improve the warning system for flooding at Tarcutta by including the Umbango Creek catchment, which currently has no gauge.
RM10	Community Flood Education (RM10)	Undertake various activities aimed at raising and maintaining public awareness of flooding.
TD01	Maintenance for Levee Cross-drainage for Tarcutta (TD01)	Undertake regular maintenance of the cross-drainage structures including clearing vegetation and sediment. SES own and maintain mobile pumps for use during a flood.
UL01	Uranquinty Levee System Upgrade (UL01)	Upgrade the levee by raising it to protect against the 1% AEP flood.
S06	Sandy Creek Regular Clearing of Sedimentation (S06)	Regularly remove built-up sediment from the creek bed to prevent blockage of the channel.

UD01	Maintenance for Levee Cross-Drainage for Uranquinty (UD01)	Undertake regular maintenance of the cross-drainage structures including clearing vegetation and sediment. SES own and maintain mobile pumps for use during a flood.
		MEDIUM PRIORITY
PM02	Updated information in the Local Environment Plan (PM02)	Revision of the LEP text to improve functionality and separate overland and mainstream flood risk.
PM03	Adoption of matrix style Development Control Plan and related DCP changes (PM03)	Revision of the current planning controls to improve their clarity and prescribe specific controls on development based on its type and the flood risk present.
PM04	Inclusion of Flood Risk Information on Section 10.7 (2) & (5) Planning Certificates (PM04)	Provision of detailed information on a site's flood risk via the existing planning certificates.
RM07	Install a telemetered pluviometer in the Sandy Creek catchment (RM07)	Improve the warning system for flooding at Uranquinty by installing a new rain gauge in the Sandy Creek catchment (currently none exists).
RM09	Requirement for Site Specific Flood Emergency Plans (RM09)	For development in areas of high flood risk, require a site specific plan be prepared that details flood risk and evacuation.
LK01	Improved drainage on Cunningdroo Street (LK01)	Construct a kerb-gutter system at the end of Cunningdroo St, Ladysmith, to reduce ponding on the road area.
		LOW PRIORITY

TL04	Upgrade Existing Tarcutta Levee (TL04)	Upgrade the levee by raising it to protect against the 1% AEP flood.

Priority	Responsibility	Status
High	WWCC Regional Activation	Amendments proposed to the DCP will incorporate FPA's identified in the 2021 VOFFS.
High	SES	
High	SES	
High	WWCC in consultation with SES and BOM	
High	WWCC	
High	WWCC Operations and SES	
High	WWCC Projects	DPIE grant received 2021-22-FM-0032. project awarded to RHDHV, initial design and freeboard analysis is underway
High	WWCC Operations	

High	WWCC Operations	
Medium	WWCC Regional Activation	Recent changes to the LEP were undertaken by NSW Department of Planning & Environment. These changes resulted in two new clauses in the LEP dealing with flooding. These clauses provide controls on how Council must assess development applications that occur on land within the Flood Planning Area and provides flood risk considerations for certain types of developments that have a higher risk of life.
Medium	WWCC Regional Activation	The existing DCP controls cover Riverine Flooding only. An update to these controls commenced and was deferred until the completion of the 2021 MOFFS & VOFFS studies being completed. Changes to the existing flooding controls will recommence and include MOFFS and VOFFS.
Medium	WWCC Regional Activation	Planning certificates identify whether the land is below the 1% Average Recurrence Interval and therefore flood related development controls may apply.
Medium	WWCC in consultation with SES and BOM	
Medium	WWCC	
Medium	WWCC Projects	

	Low	WWCC Projects

Option ID	Option	Description	Benefits	Concerns	Priority	Responsibilty	Status
RM01	Amend Flood Plans to include Overland Flow Flood Information	Amend local flood plans and operational plans to include information on flood risk due to overland flow, drawing on modelling and information provided in this FRMS&P	Detailed information will allow for better management of overland flow flood risk and will increase understanding of the different levels and types of risk present in Wagga Wagga.	Modelled results should be used as a guide only, as real flood behaviour may vary from modelled design results.	High	WWCC and SES	Currently underway with information added inot the Flood Emergency Operational Response Plan
RM04	Community Flood Awareness	Establish and implement ongoing and collaborative education to improve flood awareness.	Flood awareness significantly improves preparedness for and recovery from flood events, building a more flood resilient community.	Ongoing efforts to ensure information is not forgotten. Potential for residents to become bored or complacent with messaging.	High	WWCC and SES	Council has recently updated the information on the Council webpage and has engaged a contractor to develop our community information further.
RM05	Improvements to Driver Safety	Undertake an investigation using the outputs from the FRMS&P to identify locations for the installation of road flood signage.	The installation of appropriate road signage pointing to routes likely to be cut and alternate routes, reduces the risk to drivers during floods, reducing the number of incidences of motorists driving through floodwater. Could potentially reduce demand on SES with a reduced number of incidents.	Community attitudes, awareness of, and behaviour during overland flood events will need to be considered. Signage needs to be as automated as possible to reduce additional demand on Council resources.	High	WWCC and SES	Council currently has 72 Water Over Road signs installed across the LGA
P01	Adoption of Overland Flow Flood Planning Area	Adopt the Overland Flow Flood Planning Area developed in the FRMS&P.	FPLs are effective tools to limit property damage to new development and redevelopment. FPLs may pertain to minimum floor levels or flood proofing levels depending on the type of development.	A planning proposal is required to amend the LEP and implement the new FPL. May be considered more onerous for developers.	High	WWCC Regional Activation	The existing DCP controls cover Riverine Flooding only. An update to these controls commenced and was deferred until the completion of the 2021 MOFFS & VOFFS studies being completed. Changes to the existing flooding controls will recommence and include MOFFS and VOFFS and relevant FPLs. Recent updates to Council's LEP by NSW Department of Planning includes a definition of FPA by directly referencing it to have the same meaning as the Floodplain Development Manual.

P02	Adoption of Overland Flow Flood Planning Level	Adopt the Overland Flow (Residential) Flood Planning Level developed in the FRMS&P defined as the 1% AEP level plus 0.3 m freeboard. Modify the Wagga Wagga LEP to contain the definition consistent with Reference 7.	The FPA will provide clear guidance on the properties subject to flood related development controls.	A planning proposal is required to amend the LEP and implement the new FPA definition. Consultation would be required.	High	WWCC Regional Activation	The existing DCP controls cover Riverine Flooding only. An update to these controls commenced and was deferred until the completion of the 2021 MOFFS & VOFFS studies being completed. Changes to the existing flooding controls will recommence and include MOFFS and VOFFS and relevant FPLs. Recent updates to Council's LEP by NSW Department of Planning includes a definition of FPA by directly referencing it to have the same meaning as the Floodplain Development Manual.
P05	Appropriate Land Use Zoning in Future Development Areas	For areas not covered by existing flood mapping, undertake a flood investigation to develop flood mapping and allow for an appropriate assessment of flood risk. Ensure Planning Proposals for the rezoning of future growth areas are undertaken with due consideration of flood risk using information available to Council through its various Floodplain Risk Management Studies and Plans. If no flood information is available, consideration should be given to undertaking further analysis prior to determining land use zoning for future development areas. Ensure Development Planning Controls are implemented to manage development in areas of new growth in relation to flooding. This may include, for example, guidelines relating to the permissible proportion of impervious surfaces in areas of new development.	Considering flood risk in future development areas will allow early decisions to be made to reduce flood risk and minimise the impacts of flooding.	There may be resistance from developers who consider new controls to be onerous or likely to reduce the development yield.	High	WWCC Regional Activation	This is currently being undertaken with all Planning Proposals and will continue to be done.

P07	Appropriate Management of areas subject to both riverine and overland flow flood risk.	Proposed development is to be assessed (and designed) with due consideration of the full range of flood risk present at the site, i.e., riverine, overland flow, or both mechanisms. For residential development both Riverine and Overland Flow FPAs are to be considered, while critical utilities or vulnerable facilities may warrant consideration of the PMF for either or both flood mechanisms, particularly when considering Flood Planning Levels, evacuation constraints and other methods to manage the full range of flood risk.	Considering flood risk from all mechanisms will ensure development is appropriate given the prevailing risk, minimising flood risk and the impacts of flooding.	There may be resistance from developers who consider new controls to be onerous.	High	WWCC Regional Activation	The existing DCP controls cover Riverine Flooding only. An update to these controls commenced and was deferred until the completion of the 2021 MOFFS & VOFFS studies being completed. Changes to the existing flooding controls will recommence and include MOFFS and VOFFS and ensure all flood risks are considered.
P08	Confirm suitability of riverine flood related development controls within the overland flow PMF extent.	Controls to reduce riverine flood risk (e.g. by filling above a particular level) may inadvertently exacerbate the flood risk due to overland flow. It is recommended that Council's flood related development controls are assessed for their suitability in relation to overland flow flood information provided in this Study.	Considering flood risk from all mechanisms will ensure development is appropriate given the prevailing risk, and ensuring impacts are not worsened by controls to protect against one mechanism.	Individual consideration may be required.	High	WWCC Regional Activation	The existing DCP controls cover Riverine Flooding only. An update to these controls commenced and was deferred until the completion of the 2021 MOFFS & VOFFS studies being completed. Changes to the existing flooding controls will review suitability of controls.
P09	Inclusion of Overland Flow flood information on Section 10.7 Planning Certificates	In Section 10.7 Planning Certificates, notations regarding flooding should provide information on all mechanisms of flood risk at the site, including riverine, overland flow, or if appropriate, both. A greater level of detail can be provided via Section 10.7(5) certificates using high-resolution outputs from this Study and Council's other Floodplain Risk Management Studies.	The more informed a home owner is, the greater the understanding of their flood risk. During a flood event this information can help prepare residents to evacuate and reduces the number of residents that elect to take shelter in high hazard areas.	Limited -s10.7(2) certificates already contain basic information, Council to provide further detail from current FRMS&P results. May increase demand on Council staff, however GIS systems can be established to provide this information efficiently.	High	WWCC Regional Activation	Planning certificates identify whether the land is below the 1% Average Recurrence Interval and therefore flood related development controls may apply. No further details is provided on whether this is Riverina or overland flow.
GD01 (Glenfield Drain)	Red Hill Road and Glenfield Road Basin (further investigation)	Aim: To reduce peak flows entering Glenfield Drain by temporarily storing runoff and releasing it at a lower flow rate,	Reduced flood levels on and adjacent to Glenfield Road up to the railway in the 1% AEP event,	Increased flood depths upstream of the embankments, both in the	High	WWCC Projects	Contract awarded to Lyalls
GD02 (Glenfield Drain)	Adjin Street & Maher Street Intersection Civil Works (further investigation)	Suite of civil works intended to reduce inundation of properties and roads between Maher Street and Glenfield	Removes external flood affectation for 47 properties and over-floor flooding for 4	Minor increase in flood levels in the industrial properties and	High	WWCC Projects	Contract awarded to Lyalls
GD03 (Glenfield Drain)	Anderson Oval Basin and Swale Augmentation (further investigation)	Aim: Increase flood storage capacity at Anderson Oval to reduce flooding on Finch Place and to reduce (and delay)	The extent of reductions in flood levels is significant and can be observed up to the northern	Public safety concerns as a significant depth (> 1 m) would be	High	WWCC Projects	Contract awarded to Lyalls

GD05 (Glenfield Drain)	Flowerdale Lagoon Drainage Improvements	Aim: Improve drainage of the Flowerdale Storage Area by installing an additional major levee pipe	Significant flood level reductions along Spring Street and the Olympic Highway up to Evans	Construction at this location would interfere with the	High	WWCC Projects	Contract awarded to Lyalls
SW01	Incarnie Crescent Stormwater Line	Aim: Reduce flood levels along Incarnie Crescent; Connect existing drainage line along Incarnie Crescent via a new	Peak flood level reductions can be observed from Incarnie Cres all the way west to the Wiradjuri	Incarnie Crescent will require closure while works are underway.	High	WWCC Projects	Grant received, design completed
LA01 (Lake Albert)	Raising Lake Albert Road	Raise Lake Albert Road at the north east corner of Lake Albert by approximately 1 m-1.5 m over a length	Reduces peak flood levels downstream of Lake Albert in the 1% AEP by up to 0.47 m	Increases flood levels by up to 0.45 m in the 1% AEP event in Lake	High	WWCC Projects	Contract awarded to Stantec
LA02 (Lake Albert)	Augmentation of Crooked Creek Diversion into Lake Albert	Increase capacity of the existing Crooked Creek diversion south of Craft Street, to reduce flood risk	The extent of reductions in flood levels is significant and can be observed	Environmental factors including retention of 'low flow' through the	High	WWCC Projects	Contract awarded to Stantec
LA03 (Lake Al	Augmentation of Stringybark Creek Diversion into Lake Albert	Increase capacity of the Stringybark Creek diversion south of Nelson Drive and reduce flood risk along Plumpton	Reductions in peak flood levels observed from Nelson Drive through to East Wagga.	Environmental factors including retention of 'low flow' through the	High	WWCC Projects	Contract awarded to Stantec

Medium Priority

Option ID	Option	Description	Benefits	Concerns	Priority		
RM02	Flood Emergency Response Coordination	The ongoing improvement of the coordination within and between the response agencies to ensure: •Roles	Ongoing improvements to the coordination between and within emergency service agencies.	Challenges include change of personnel, difficulty in organising	Medium	WWCC and SES	
RM03	Flood Warning System	Utilise Severe Weather Warnings from the BOM to prepare for potential flash flooding events, couple with	Improve current system using outputs from the FRMS&P. Potentially increase warning time	May not be possible to increase warning time in overland	Medium	WWCC and SES	
P03	Adoption of Flood Related Development Controls for development within the Overland Flow FPA	Incorporation of flood related development controls in the Wagga Wagga DCP to manage development in areas of Wagga Wagga prone to flood risk from overland flow. The intent and objectives of the development controls is to be consistent with those applied to the riverine FPA, however adjustment of the phrasing or implementation criteria may be necessary to better suit the context of overland flow flood risk.	Improve clarity of DCP (Flood for the benefit of both developers and Council assessors/approvers. Enable proponents to design, build and manage development using the best available flood information.	There may be resistance from developers who consider new controls to be onerous.	Medium	WWCC Regional Activation	The existing DCP controls cover Riverine Flooding only. An update to these controls commenced and was deferred until the completion of the 2021 MOFFS & VOFFS studies being completed. Changes to the existing flooding controls will recommence and include MOFFS and VOFFS and ensure all flood risks are considered.

P04	Development Controls on Low Flood Risk Areas	Modify the Wagga Wagga LEP to enable Council to apply flood related development controls to critical facilities and vulnerable land uses between the FPA and PMF extent, as defined in this study and the Revised Murrumbidgee River at Wagga Wagga FRMS&P for overland flow and riverine flood risk, respectively.	Ensure critical utilities and vulnerable facilities are designed, constructed and managed in such a way as to minimise flood risk to the structure and (if relevant) its occupants.	This amendment to the LEP would require Council to submit a planning proposal, which could be lodged in conjunction with Option PM01.	Medium	WWCC Regional Activation	Recent changes to the LEP were undertaken by NSW Department of Planning & Environment. These changes resulted in two new clauses in the LEP dealing with flooding. These clauses provide controls on how Council must assess development applications that occur on land within the Flood Planning Area and provides flood risk considerations for certain types of developments that have a higher risk of life.
SW02	Bolton Park Drainage Gate Automation	Aim: To allow control of the outlet flow from the existing Bolton Park storage to alleviate pressure on the	Minor flood reductions along Morgan Street and Berry Street for frequent events, potential	Ineffective in rarer events. Public safety risks, and changes to	Medium	WWCC Projects	
FM01	Willans Hill Overland Flow Options Assessment	Aim: To ultimately develop mitigation strategies for properties impacted by rainfall runoff in the Willans Hill area.	A more appropriate scaled hydraulic model will allow strategies to be developed that	Very targeted area, there may be other areas which require a	Medium	WWCC Projects	
FM02	McNickle Roach Road and Intersection	Aim: To improve flood immunity at the Roach and McNickle Road intersection to improve access for residents in	Relatively minor upgrades to the culvert at the intersection and reinstatement of a channel	Very targeted area, there may be other areas which require a	Medium	WWCC Projects	

Low Priority

Option ID	Option	Description	Benefits	Concerns	Priority		
GD04 (Glenfield Drain)	Rabaul Place Trunk Drainage Line (further investigation)	Aim: Reduce inflows into Glenfield Drain to reduce demand on the existing open channel, by diverting flows to Ashmont Drain; Significant trunk drain installation, involving 3 x 1.8m diameter pipes from immediately	Significant reductions in peak flood levels along Pearson Street and Dobney Avenue with some areas showing a 0.2 m reduction in flood level for the 1% AEP event. Effective in reducing peak	Increases peak flood levels at and around the northern end of the channel near the Sturt Highway. Staged construction would be	Low	WWCC Projects	Contract awarded to Lyalls

Reference	Option and report Reference	Priority	DPE Funding available	Responsibility
Improving Understanding and Knowledge of the Influence of tributaries on Flooding	Option 3 Monitoring and prediction	High	Probably	WWCC
Review the existing rating Curve	Option 6 Monitoring and prediction	High	Yes	WaterNSW
Review Flood Forecasting and warning services	Option 8 Interpretation	High	No	WWCC and BOM
Revise Flood Intelligence Card and Local Flood Plan for Oura	Option 9 Interpretation	High	No	WWCC and SES
Review the need for new targetted prediction and Warning Services for graziers and water licence holders	Option 10 Message Construction	High	No	WWCC and BOM
Incorporate GIS mapping within warning services and products	Option 11 Message Construction	High	Yes	WWCC BOM SES
Community Education materials	Option 13 Communication	High	No	SES WWCC
Expand the use of CATS	Option 14 Protective behaviour	High	No	SES WWCC
Targetted Review and change to the Minor Flood Level for the Wagga Wagga gauge	Option 7 Interpretation	Low	No	WWCC and BOM

Automatic gauge at Oura	Option 1 Monitoring and prediction	Medium	Yes	WWCC WaterNSW BOM
Level Sensors and Flow Gauges at Key Culverts	Option 2 Monitoring and prediction	Medium	Possibly	WWCC
Extend the model boundary	Option 4 Monitoring and prediction	Medium	Yes	WWCC
Automate the floodgates	Option 5 Monitoring and prediction	Medium	No	WWCC
Communication of road closures	Option 12 Communication	Medium	No	WWCC TfNSW

Status	
Ongoing development of internal flood forecasting capability recently completed by WaterNSW	
Grant applied for through DPE FMP	This grant has been placed on the reserve list for 2023

The gauge at Eringoarrah is programmmed for review by BOM under a federally funded program

Council has a plan to extend the model boundary in 2028

This option is very expensive and currently deemed not feasible

TfNSW have fast-tracked a statewide program