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REPORT TYPE

Flood Mitigation Options for Wagga Wagga

Evaluation of options

Prepared for
Wagga Wagga City Council

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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 benefits* 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.

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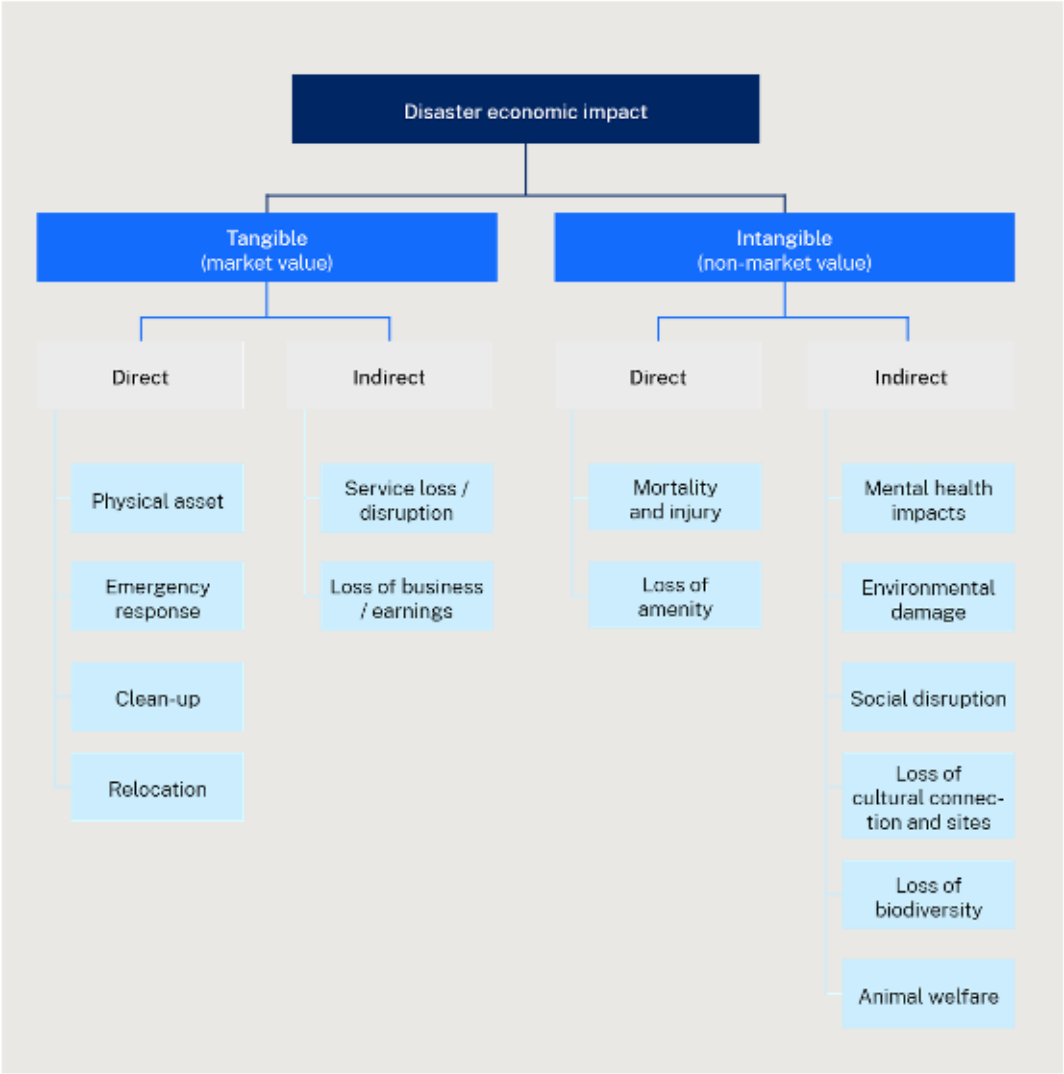
8 See page 94 of Treasury Guidelines https://www.treasury.nsw.gov.au/sites/default/files/2023-04/tpg23-08_nsw-government-guide-to-cost-benefit-analysis_202304.pdf

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

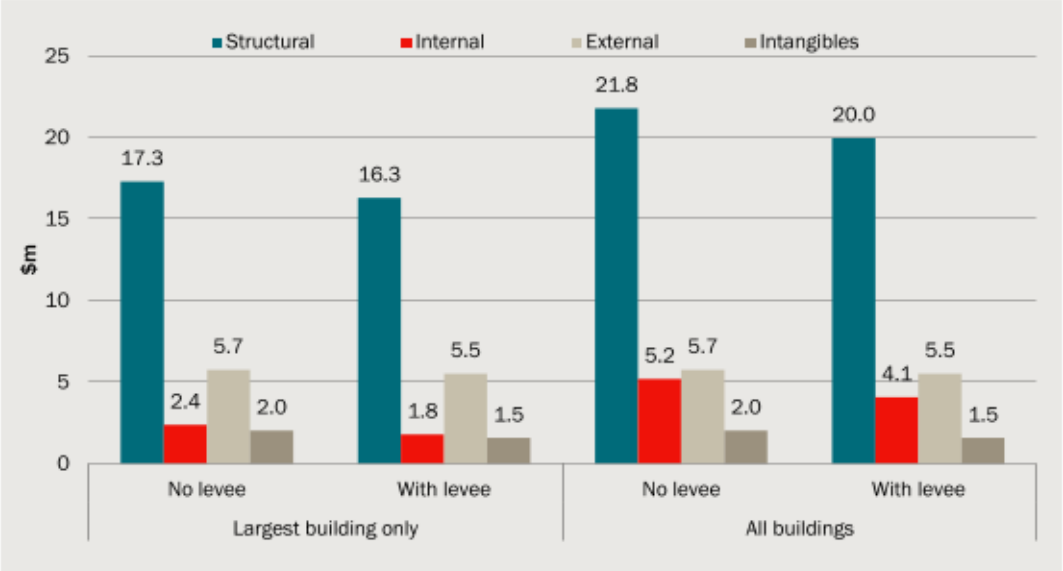
Assumptions	Central Case - Largest building	Sensitivity - All buildings
Which buildings are included	Damages are measured for the largest building on each residential property, based on flood height. For commercial/industrial properties this applies to all buildings on the lot.	Damages are measured for 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.

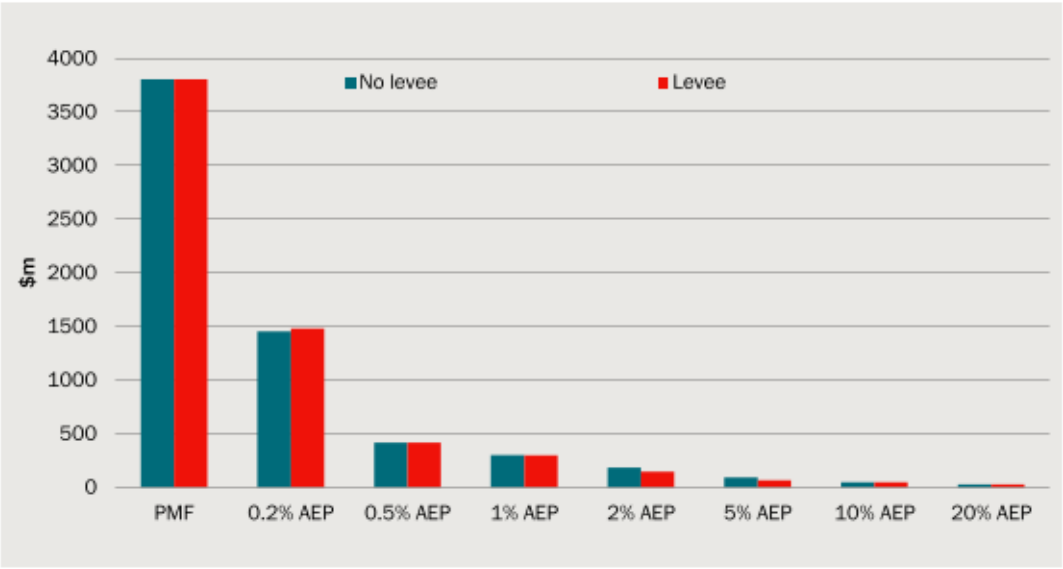
5.2 Impact of the L4B on annual average damage for a single year



Data source: The CIE

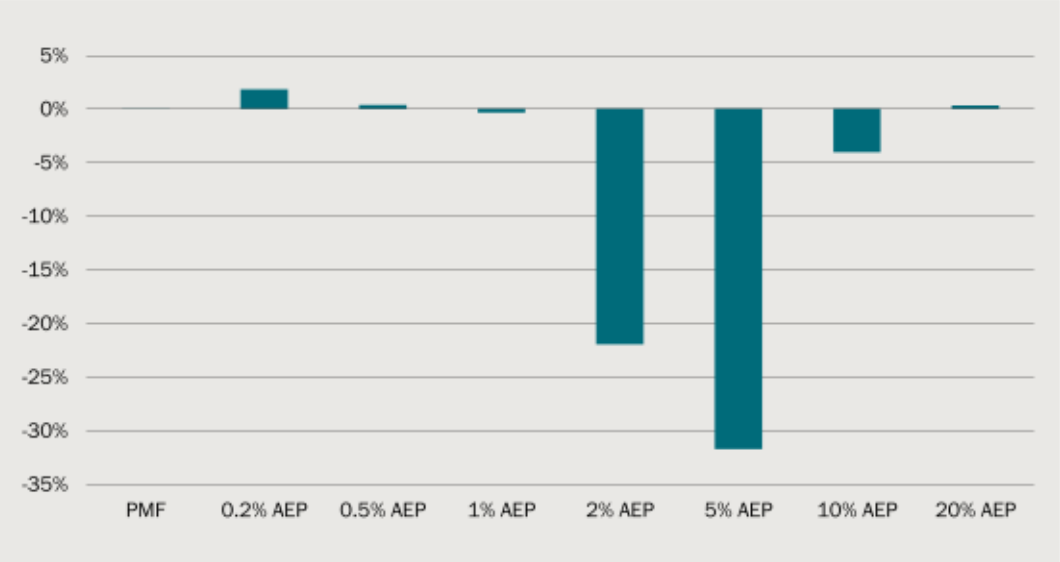
Breaking this damage down into contributions from each flood event, we can see that the benefits of the levee option are achieved in the AEP 2% and the AEP 5% events. Chart 5.3 shows the level of damage in each flood event, and chart 5.4 shows the percentage change.

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.

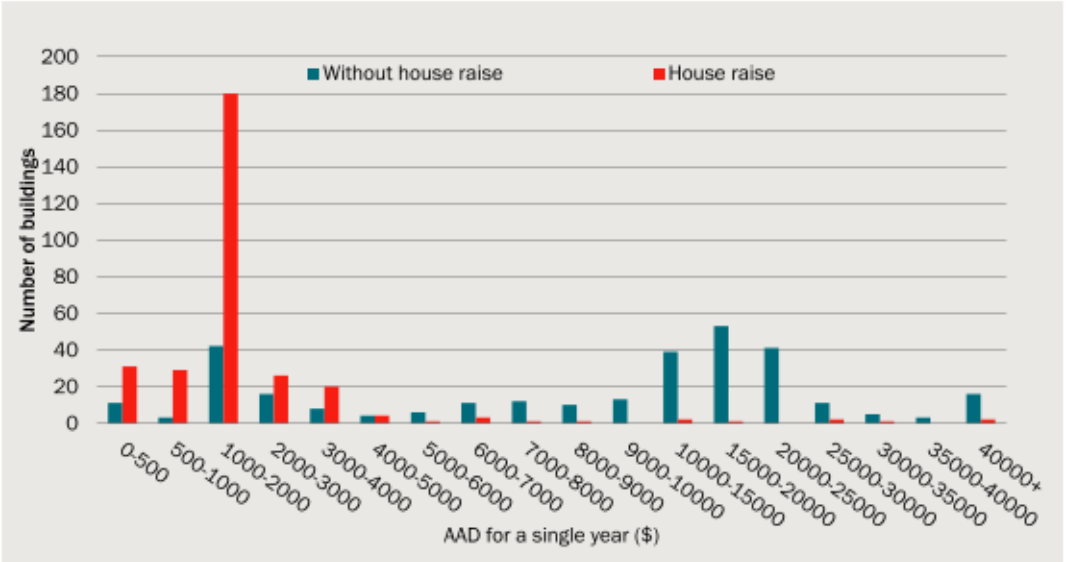
There is a range of eligibility criteria for the VHR scheme. This includes, for example:

- 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.

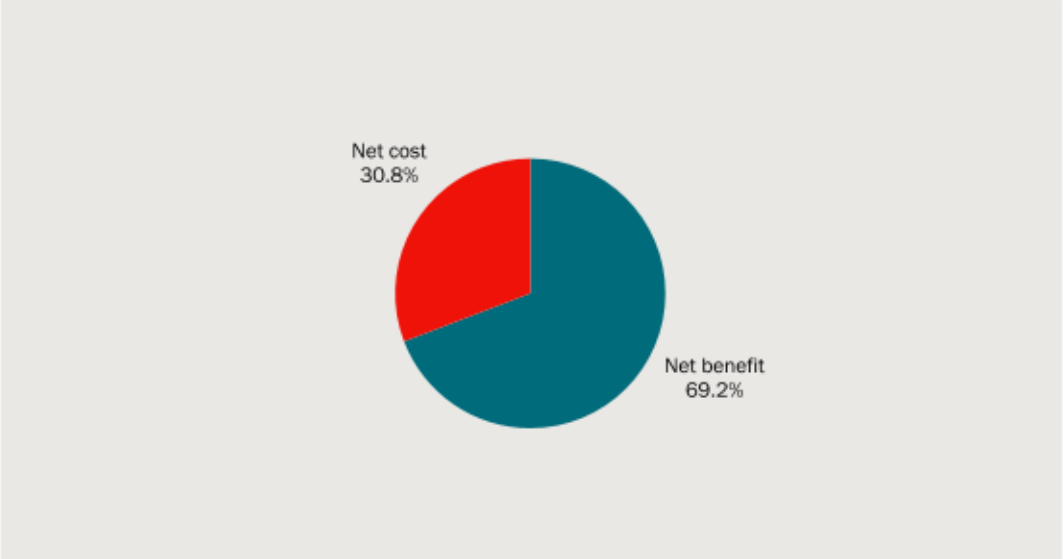
7.1 CBA results for voluntary house raising

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

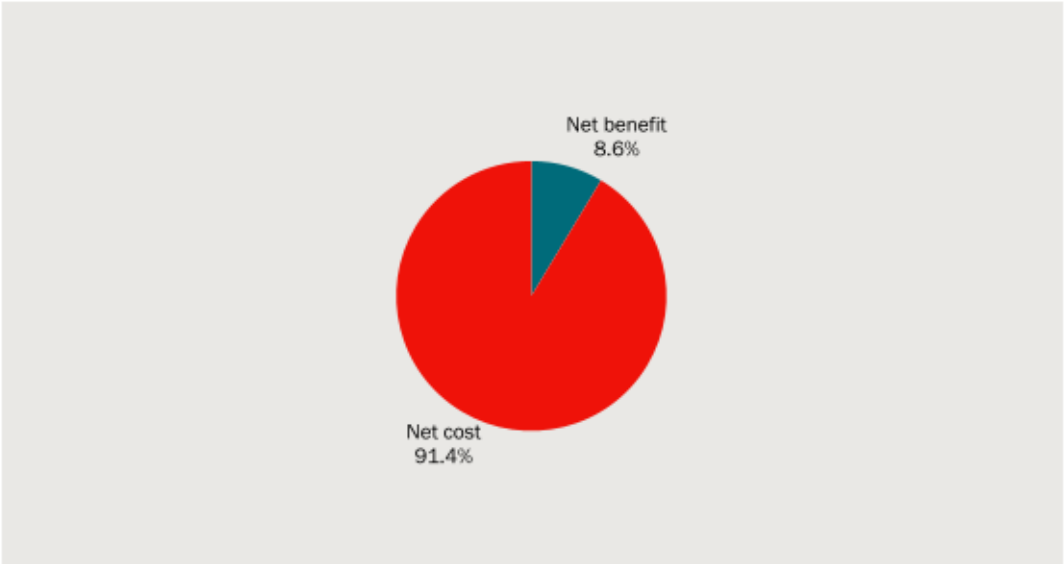
Discount Rate (p.a.)	Project Cost	Base Case stream of AAD	Project Case stream of AAD	Total Benefit	Net Benefit	BCR
	$m	$m	$m	$m	$m	
0.03	116.0	82.4	5.6	76.8	-39.2	0.7
0.05	**116.0**	**65.0**	**4.4**	**60.6**	**-55.4**	**0.5**
0.07	116.0	52.7	3.6	49.1	-66.9	0.4

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.

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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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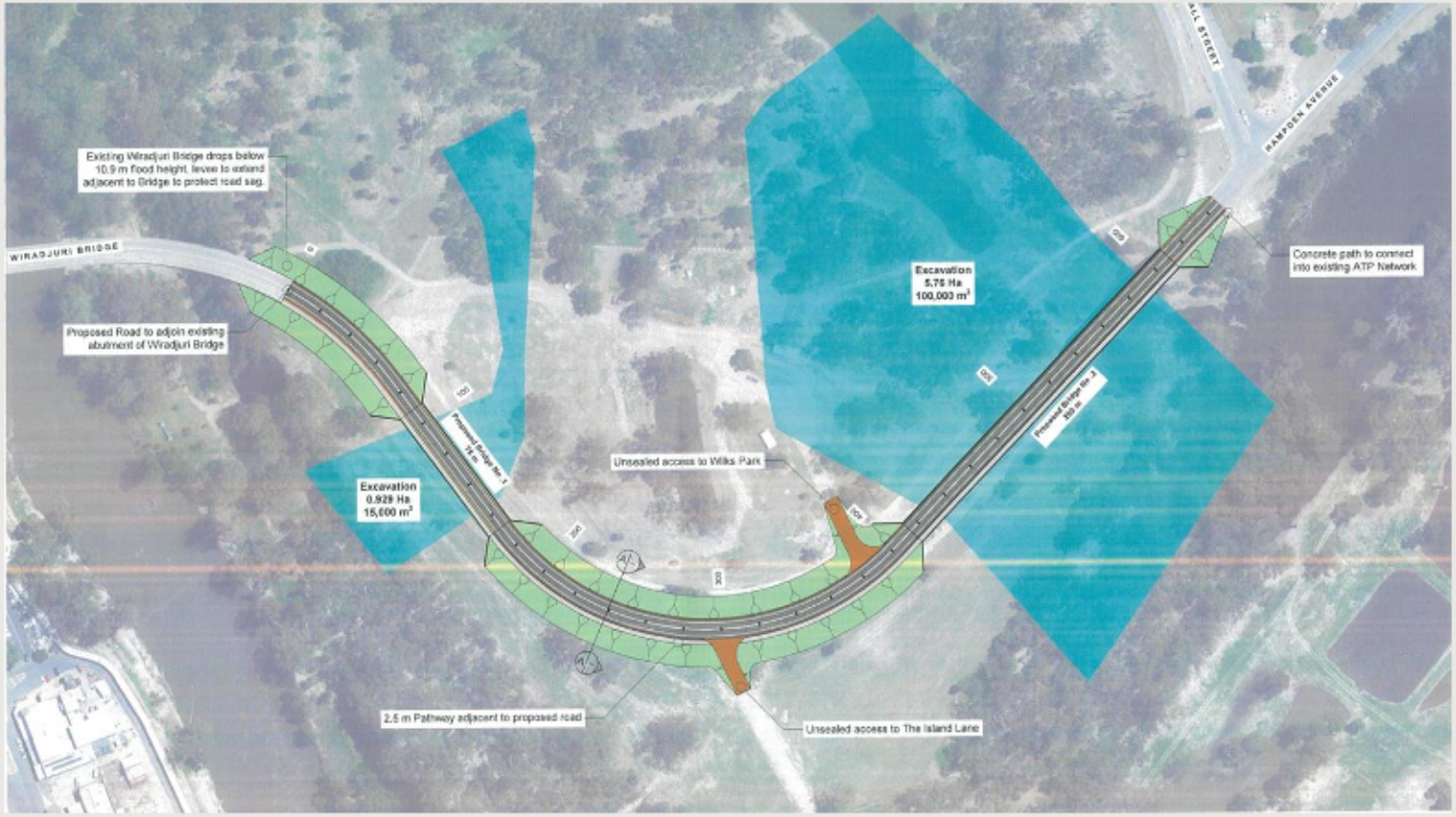
Note:

Source:

B.4 Option L4B Works required



Note:

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