FINAL REPORT

Cost Benefit and Distribution Analysis of Adaptation Planning Options

Pelican, Blacksmiths, Swansea and Surrounds

Prepared for
Lake Macquarie City Council

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THE CENTRE FOR INTERNATIONAL ECONOMICS
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CANBERRA

Centre for International Economics
Ground Floor, 11 Lancaster Place
Canberra Airport ACT 2609

SYDNEY

Centre for International Economics
Level 7, 8 Spring Street
Sydney NSW 2000

Telephone +61 2 9250 0800
Email ciesyd@TheCIE.com.au
Website www.TheCIE.com.au

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Abbreviations

AAD	Annualised Average Damages
ABS	Australian Bureau of Statistics
AEP	Annual Exceedance Probability
AHD	Australian Height Datum
BCR	Benefit Cost Ratio
CBA	Cost Benefit Analysis
CIE	Centre for International Economics
CZMP	Coastal Zone Management Plan
DCP	Development Control Plan
EY	Expected number of inundation occurrence per year
FPLs	Flood Planning Levels
LAP	Local Adaptation Plan
LEP	Local Environmental Plan
LiDAR	Light Detection and Ranging
LGA	Local Government Area
MCA	Multicriteria Assessment
PHA	Probability Hazard Assessment
PMF	Probable Maximum Flood
PV	Present Value
SLR	Sea Level Rise

Executive Summary

The task

Salients Pty Ltd, Umwelt Environmental and Social Consultants and The Centre for International Economics (The CIE) have been commissioned by Lake Macquarie City Council (the Council) in collaboration with the communities of Pelican, Blacksmiths and Swansea to evaluate adaptation pathways to coast and estuary change. This report covers the Cost Benefit Analysis (CBA) undertaken by the CIE to evaluate a subset of options to adapt to future inundation risks arising from the effects of catchment and/or tidal inundation, in Pelican, Blacksmiths, Swansea and surrounds (the case study area). The study evaluates the costs and benefits of alternative adaptation options to dynamic coast/estuary processes that are expected to increase the inundation risks faced by low lying communities in the case study area. The options proposed by the community and eventually tested are discussed below.

Options considered

The adaptation planning process for the case study area is led by a Steering Committee and supporting working groups which includes council, local community, and public authority representatives. The Pelican, Blacksmiths, Swansea, and surrounding areas working groups (a combined working group derived from two previously separate working groups) developed a suite of potential management options which were shared with the broader community via a community information evening and workshop in August 2019. On the basis of community engagement, the working group consolidated a list of 112 community options for further consideration in a subsequent formal three-stage evaluation process:[1]

1. **feasibility** — identify options that are practical, effective and align with legislation and policy
2. **viability** — economic evaluation using cost benefit assessment (this report)
3. **acceptability** — to the community in terms of capacity to deliver the community's objectives, funding and cost implications and timeliness.

1 Umwelt Pty Limited 2020, *Coastal Adaptation Options at Pelican, Blacksmiths, Swansea and Surrounds: Feasibility Assessment*. Report prepared with Salients Pty Limited, for Lake Macquarie City Council.

The technical feasibility of adaptation options was analysed in a Multicriteria Assessment (MCA) which identified:[2]

- options that were considered suitable i.e.: feasible, viable, and acceptable (such as tidal gates) – the working group recommended that these progress directly to be considered for incorporating into the Local Adaptation Plan (LAP)[3] or Council's Coastal Management Program without needing to be assessed for economic feasibility by a CBA
- options that were not feasible, viable and/or acceptable (for reasons outlined in the MCA report), and
- 13 options that were considered appropriate for further analysis with respect to economic feasibility by means of a CBA.

These 13 options are summarised in the following categories:

1. Options to Raise and Fill Land and Built Assets
2. Swansea Holiday Park and Wetland/Environmental Options
3. Channel and Foreshore Protection Works
4. Staged raising of Ungala Road, including the concurrent raising of the boat ramp car park and raising of residential land to avoid water pooling and inundation of the road and adjoining residential areas.

Before the CBA commenced, Council and the Steering Committee further developed the concept designs and parameters for these options, to which the majority of the steering committee agreed.[4] Graphics illustrating each option and a brief description were provided to the broader community (Appendix A). Further information is provided in the Lake Macquarie City Council document *Options guide for the cost benefit analysis: Pelican, Blacksmiths, Swansea and Surrounds*.[5] These designs, parameters and assumptions have continued to be reviewed as the CBA has been prepared. This resulted in refinement of the options to more closely align a conceptual design level, that can be costed and practically implemented. Refer to Table i for a broad overview of the options evaluated in the CBA.

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2 The methodology for community and technical review and the rational for narrowing down options is detailed in Umwelt Pty Limited 2020, *Coastal Adaptation Options at Pelican, Blacksmiths, Swansea and Surrounds: Feasibility Assessment*. Report prepared with Salients Pty Limited, for Lake Macquarie City Council, https://shape.lakemac.com.au/37415/widgets/210625/documents/167565

3 We note acceptability will continue to be considered through all parts of the LAP process.

4 References to the Steering Committee here after, denotes the majority of the Steering Committee.

5 Lake Macquarie City Council 2020, *Options guide for the cost benefit analysis: Pelican, Blacksmiths, Swansea and Surrounds*, https://shape.lakemac.com.au/37415/widgets/210625/documents/167956

i Options evaluated in the cost-benefit analysis (CBA)

Option	Description	Comments	Refined design parameters
Options to raise and fill land and built assets			
AC1	Raise and fill residential areas (house sites and yards)	A high-risk inundation area in Pelican was identified during the Local Adaptation Plan (LAP) development by the joint Council and Community Working Group. We understand this area is generally bounded by Soldiers Road, Lorna Street and Lakeview Parade.	▪ Mosaic raise and fill trigger.
AC2	Raise transport infrastructure (over and above gradual raising of roads through maintenance)	Local roads to be raised include the length of road near the intersection of Lakeview Parade and Soldiers Road Pelican. This will need to be done alongside raising residential land to maintain serviceability. It will also include local roads connecting to the Pacific Highway. This option is independent of any raise/fill of any residential properties.	▪ Raising roads in the Pelican area is intended to support maintaining serviceability of properties. However, residential land raising (option AC1) is not economically viable. Therefore, raising roads would not be adopted at this stage. The timing of any raising of the Pacific Highway by RMS is also unknown. ▪ Given this, we have modelled an alternative option of gradually raising roads (from the most to the least flood prone) over a specified time.
AC3	Raise other infrastructure (power, water, sewer, stormwater, telecommunications)	This option would reduce the disruption to properties if the assets are inundated. In practice, this option would need to be considered alongside the road raising option (AC2) given that infrastructure assets may be located within/alongside the roads.	▪ Many of these assets run alongside the road corridor. The sequencing of asset upgrades has been linked to the road raisings.
AC4	Raise and fill education land (schools)	This option is to reduce school disruption associated with inundation events. Three schools have been identified in the case study area for potential raise and fill: ▪ St Patricks ▪ Swansea Public School, and ▪ Pelican Flat Public School.	▪ A mosaic raise and fill modelling approach has been used, such that raising is triggered when the present-day property ground level is below the chosen trigger height. The school site and associated buildings are subsequently raised to the chosen raise height.
AC5	Raise and fill public recreation land such as foreshore reserves and playing fields	This option is to maintain access to recreational activities – including active and passive recreation: sporting facilities and public open space.	▪ The recreational land is assumed be raised in each year from 2021 based on the most inundation prone to the least inundation prone land. Recreational land would be raised to the 1% AEP event at 2050 height.
AC7	Raise and fill commercial land in the Central Business District (CBD)	Potential raise and fill of the commercial land in the CBD	▪ Mosaic raise and fill trigger on existing sites.

Option	Description	Comments	Refined design parameters
Swansea Holiday Park and Wetland/Environmental Options			
AC6	Raise and fill Swansea Holiday Park	Raise and fill the Swansea Holiday Park.	▪ Raise and fill based on inundation trigger heights
AC6B	Relocate Swansea Holiday Park	Maintain access to the foreshore, or allow adjoining wetlands and lake to encroach onto land currently occupied by Swansea Holiday Park, while relocating the Swansea Holiday Park to one of the following locations: ▪ Belmont Bayview Park, or ▪ Greenfield site adjacent to Belmont golf course	▪ Relocation at a specified time to occur in 2030
RA4	Allow wetlands to move landward on 'environmental land' around Pelican Inlet and other suitable areas	Locations for consideration: ▪ Coon Island ▪ Galgabba Point ▪ Pelican Inlet, and ▪ Black Neds Bay.	▪ Wetlands options not evaluated in full. There is uncertainty regarding how quickly wetlands are established with temporary inundation.
RA5	Allow wetlands to move landward into coastal use area, with land acquisition		
RA6	Offset losses of wetlands with wetland reservation elsewhere around the lake	Offsets are unlikely to be like for like, as the channel area is different to most other wetlands around the lake.	▪ Wetlands options not evaluated in full. There is uncertainty regarding how quickly wetlands are established with temporary inundation.
Channel and Foreshore Protection Works			
CP4	Inundation protection works (or a levee) inside Black Ned's Bay		▪ Construction of a vertical 1.7m AHD concrete wall along the western shore of Black Neds Bay.
Staged raising of Ungala Road			
CP8A/CP 14	Staged Raising of Ungala Road, first near the boat ramp	Stage raising would also need to coincide with stormwater drainage, tidal gates and/or residential raise/fill, similar to option (AC1), to avoid water pooling when Ungala Road is raised.	▪ The option description document notes this option is proposed in a sequence with raise and fill the Mankilli St area (part of AC1) and tidal gates on Ungala Road (CP8B). Both raise/fill of residential properties in Mankilli St and the tidal gates were not considered. Raise/fill triggers presented for illustrative purposes.

Source: Umwelt Pty Limited 2020, *Coastal Adaptation Options at Pelican, Blacksmiths, Swansea and Surrounds: Feasibility Assessment*. Report prepared with Salients Pty Limited, for Lake Macquarie City Council, https://shape.lakemac.com.au/37415/widgets/210625/documents/167565, and subsequent input from the Steering Committee.

For the purposes of this analysis, we have treated the options as discrete, although we recognise that there are interactions between them. For example, if inundation causes local road closures then this would reduce access to schools, the CBD and public recreation spaces. This would need to be considered further following a decision regarding which options to progress in the LAP.

Inundation risk

Salients, in consultation with the University of Queensland and Flood Focus Consulting undertook a Probabilistic Hazards Assessment (PHA)[4] to model the probability of future water level exceedance in the case study area and these results (or outputs) have been adopted for use in this CBA. The full methodology and results are detailed in Salients et al. 2020.[6] Salients et al. 2020 note that calculated water levels include the combined effect of catchment flooding and tidal inundation. As such, this report uses the broader term "inundation" to encompass the combined risk of these effects.

We note the recent (approximately 8 years of water level data) measured high-water levels at the water level gauges within Swansea Channel (downstream of Swansea Bridge) are somewhat higher than during previous measurement periods.[7] It is unclear at this stage whether these more recently measured high water levels are indicative of an acceleration in measured rates of global sea level rise (SLR), or whether they are representative of the inherent natural variability of local mean sea level in response to various drivers that influence peak records at the Swansea water level gauge (for example variability around El Niño/La Niña conditions, catchment flood and coastal storm frequency, and other conditions that raise local water levels).

Historically, water level data, from the Fort Denison gauge in Sydney (the most applicable long-term data available), show that there are medium term periods (years to decades) of both higher and lower water levels that occur relative to mean sea level and historic rates of measured SLR. That is, there are peaks and troughs in high-water levels that are irregularly spaced and unable to be accurately forecast. There is currently insufficient time-series climatic data available to test the extent to which recent observed high-water levels at Swansea are part of this natural variability or reflect a more permanent 'structural shift' compared to the historical data series. The known gradual increase in the Lake Macquarie tide range due to the increasing hydraulic efficiency of the Swansea channel over time also has an impact on changing water levels measured at the Swansea gauge.

6 Salients et al. 2020, *Probabilistic Hazard Assessment to Support Local Adaptation Planning for Pelican, Blacksmiths and Swansea – Final*

7 Hanslow, D (2019). Water level trends in NSW coastal lakes by use of exceedance probability analysis, *Australasian Coasts and Ports 2019 Conference: Future directions from 40 [degrees] S and beyond*, Hobart, 10-13 September 2019, https://search.informit.com.au/documentSummary;dn=799043410816316;res=IELENG

Following discussion with the Steering Committee, we present an alternate scenario for options AC1 (raise and fill residential areas (house sites and yards)), AC7 (raise and fill commercial land in the CBD) and CP4 (inundation protection works), in the form of a sensitivity test, where inundation levels are assumed to be 0.2m AHD higher than those predicted by the statistical PHA model. This is to provide additional information to understand how the results of the CBA would change if the inundation risks were higher than modelled.

CBA results

The key economic indicators of net benefits and benefit cost ratio (BCR) are presented for each option in Table ii. The CBA results show that the selected options (without sensitivity analysis applied) generate net costs (i.e. the costs outweigh the benefits) and all options have BCRs less than 1. This is because the inundation risks are expected to be relatively low in the short term and most options require significant structural intervention.

ii Net benefits and BCRs by option

Option	Total cost	Total benefit	Net benefit	Benefit cost ratio
	$, (PV)	$, (PV)	$, (PV)	BCR
AC1	443 439	196 202	-247 237	0.44
AC2	35 000 000	3 460 000	-31 540 000	0.1
AC3	9 500 000	1 700 000	-7 800 000	0.18
AC4	2 969 611	24 701	-2 944 909	0.01
AC5	28 000 000	9 600 000	- 18 400 000	0.34
AC6	5 582 410	200 881	-5 381 529	0.04
AC6B	3 797 227	2 730 321	-1 066 907	0.72
AC7	381 721	17 781	-363 940	0.05
CP4	1 425 278	34 689	-1 390 590	0.02
CP8A/CP14	150 000	not quantified		
RA4, 5, 6	Not quantified due to lack of information			

Note: Present value are based on a 30 year cashflow stream and a 7 per cent real discount rate.

Source: CIE.

Options related to allowing the landward movement of wetlands were considered qualitatively due to limitations on information and requirements.

Table iii shows the net benefits and BCRs for the +0.2m AHD water height sensitivities.

iii Net benefits and BCRs for water height sensitivities

Option	Total cost	Total benefit	Net benefit	Benefit cost ratio
	$, (PV)	$, (PV)	$, (PV)	BCR
AC1	607 914	941 176	333 262	1.55
AC7	3 889 146	456 629	-3 432 517	0.12
CP4	1 425 278	293 068	-1 132 210	0.21

Note: Present value are based on a 30 year cashflow stream and a 7 per cent real discount rate.

Source: CIE.

Table iii shows the CBA results are highly impacted by the underlying modelled inundation risk. The net benefit for Option AC1 becomes positive, along with a BCR greater than 1. However, the other two options still deliver a net cost for society.

Findings and recommendations

The central CBA results (without sensitivities) show that most of the options requiring significant structural intervention are not cost effective to implement now. That is, the current levels of risks and damage are not sufficiently large to warrant taking the identified action *immediately* from an economic assessment standpoint.

This CBA is one of a number of tools used to assess a limited number of options developed from the MCA, and it is highlighted that there are other options, drivers and considerations for discussion in the upcoming LAP.

Over the longer term, the modelling demonstrates that the level of risk and damage increases substantially after 2050. This may reflect a 'tipping point' has been reached such that the inundation levels for the frequent events become higher than existing floor levels. The projects could become viable at a future point in time as the inundation risks increase (due to SLR), therefore, there is value in delaying the decisions regarding the options to implement. This is also important where new technologies become available to manage the different risks.

While the findings above do not support the immediate implementation of the options, it is important that this is not interpreted as encouraging Council to 'do nothing'. Rather, the results imply that there is time to conduct further robust planning to ensure that the future actions provide the best 'value for money' for the community.

Given this, we recommend the following actions for Council's consideration.

Continued monitoring of inundation risks

As noted earlier, the conclusions of the CBA reflect the inundation risks modelled by Salients, in consultation with the University of Queensland and Flood Focus Consulting. The inundation modelling utilises statistical modelling based on recorded history. While this modelling was based on the best information currently available, these risks are not known with certainty. There is uncertainty regarding how climate change could impact on the inundation risks, including in the short to medium term.

Given this, it is important that there is ongoing monitoring of the inundation levels to understand whether any changes in the risks would alter the results of the CBA. Sensitivity analysis conducted for some of the options provides a guide on how changes in inundation risks can change the CBA results and conclusions.[8] If new information changes the risks in line with the sensitivity analysis, then there may be merit in implementing (in the short term) some of the options considered.

Continued planning of actions

There is significant value in having time to undertake robust planning in advance of a ‘crisis’. Therefore, given that the inundation risks are not imminent Council should take this opportunity to continue developing strategies to manage inundation risks.

Some actions that could be undertaken include:

- The CBA was based on the available elevation data (e.g. ground levels, property floor levels, roads, sewer main depths). Further data collection could be undertaken to help refine the analysis at a later stage. If there are significant changes to the elevation data, then additional analysis should be undertaken to test the extent of changes in inundation risk. If there are significant changes to inundation risks then additional economic analysis should be conducted to evaluate the options.
- Gathering additional information on the costs of the different actions should also be undertaken. The CBA was based on the best available information within the scope of the project. Further site-specific investigations may change some of the cost assumptions adopted in the CBA.
- Additional information is required to understand the extent of use of the different recreation areas.
- In regard to the wetlands, specific studies could also be undertaken to understand the value that the community places in expanding the wetlands. It would also be useful to gain further scientific information on the frequency of inundation required for wetlands to establish and how quickly wetlands could establish.
- Investigation of other actions should also be undertaken to understand whether there are ‘better’ actions than those considered in the CBA. This may arise where, for example, there are technological advancements which reduce the costs of managing inundation risks.

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8 This included options AC1 (raise and fill residential areas (house sites and yards)), AC7 (raise and fill commercial land in the CBD) and CP4 (storm surge protection works). Sensitivity analysis tested included where inundation levels are 0.2m AHD higher than those predicted by the statistical model.

- For all options, Council should consider when approvals should be sought from relevant authorities, and agreements in principle from property owners affected (including where access to a property is required for construction works).

Interlinkages between the different actions

There are significant interlinkages between property damage and damage to other assets (e.g. roads, electricity, water etc). For example, raising roads would be dependent on the raising of residential properties (or commercial properties). Likewise, any upgrading on sewer/water mains should be interlinked with any road raising.

In the options modelled, the property raisings are not triggered in the immediate future, reflecting the relatively low levels of risk currently faced by the properties. If the property raisings aren't triggered then raising roads could then have detrimental impacts on some locations (e.g. by causing pooling of water). Given this, it would be prudent to develop risk management strategies on a 'region by region' basis, covering all the assets. This will involve first understanding the inundation risks to each of the assets and then developing strategies that result in an 'optimised' staging/sequencing of works to manage risks in that region.

Given that different assets are owned by different service providers (e.g. Hunter Water Corporation, Department of Education) this will further complicate the coordination/sequencing of options to manage inundation risk. It will be important to work closely with these authorities to understand the risks to the different properties/assets and potential solutions to manage the risks. This will ensure alignment with the capital works programs of the different asset owners.

Funding options

There is considerable cost, lead time and further investigations to be undertaken in respect to several options under the CBA and implementation of any/all the LAP options. Consideration should be given to the approaches to funding the actions and whether the costs should be borne only by the beneficiaries of the actions or the wider community. The staging and sequencing of options could be undertaken to spread the costs of over several years. Council could also consider establishing a pooled fund to minimise 'spikes' in funds required in any particular year.

Implications for the LAP

As stated above, this CBA is one of a number of tools used to assess a limited number of options developed from the MCA, and it is highlighted that there are other options, drivers and considerations for discussion in the upcoming LAP. While the CBA results conclude that there are no specific actions that need to be incorporated into the LAP immediately, there are a range of other actions evaluated as part of the MCA that will be incorporated into the upcoming LAP.

PART I

Background, CBA and adaptation options

1 Background

The task

Salients Pty Ltd, Umwelt Environmental and Social Consultants and The Centre for International Economics (The CIE) have been commissioned by Lake Macquarie City Council (the Council) in collaboration with the communities of Pelican, Blacksmiths and Swansea to evaluate adaptation pathways to coast and estuary change. This report covers the Cost Benefit Analysis (CBA) undertaken by the CIE to evaluate a subset of options to adapt to future inundation risks arising from the effects of catchment and/or tidal inundation, in Pelican, Blacksmiths, Swansea and surrounds (the case study area). The study evaluates the costs and benefits of alternative adaptation options to dynamic coast/estuary processes that are expected to increase the inundation risks faced by low lying communities in the case study area.

The Case study area

Inundation risks in the region

The communities in the case study area were identified in the Lake Macquarie Waterway Flood Study, and the Lake Macquarie Coastal Zone Management Plan (CZMP) as high risk in relation to tidal and catchment flood related inundation hazards, with risks escalating as sea level rise (SLR).

These communities have particular social and economic characteristics that affect their interest in, preferred approach and capacity to adapt to climate change, SLR and other drivers of coastal hazards that affect their homes, their lifestyle and their community.

Precincts have been adopted from Salients et al. 2020[9] and are based on inundation characteristics, as indicated in Figure 1.1. Each inundation precinct has water levels expected to reach the same height, while water levels vary between precincts. The properties themselves have different ground levels/floor levels and hence they are not equally exposed to the same inundation risks.

9 Salients et al. 2020, *Probabilistic Hazard Assessment to Support Local Adaptation Planning for Pelican, Blacksmiths and Swansea – Final*

1.1 Inundation Precincts, case study area

Note: The boundary between Precincts 20 and 25 runs down the Pacific Highway, not Wood/Josephson St. This is because under the base case, there is no drainage or overland flow connection between Precincts 20 and 25 due to tidal gates and raising of the Pacific Highway respectively.

Data source: Salients, University of Queensland, Flood Focus Consulting, 2020. *Probabilistic Hazard Assessment to Support Local Adaptation Planning for Pelican, Blacksmiths and Swansea - Final*.

2 CBA

Context

The key decision choices for Council, community and other stakeholders in adapting to future SLR could be described as:

- '*What* actions to undertake' — This could include not adopting any new options.
- '*Where* to undertake these actions' — Each location would need to be considered separately based on their unique characteristics
- '*When* to undertake the actions' — In some cases, immediate action may be warranted. In other situations, options can be delayed until some future point (depending on the future risk profile). The decision on timing will be influenced by new information (e.g. on future climate risks) that becomes available. In this circumstance there may be 'value in delaying' taking action.[10]

The CBA seeks to provide information to guide each of these decisions noted above, by measuring the change attributable to an inundation adaptation strategy, relative to a situation without the proposed action (referred to as the base case), consistent with NSW Government guidelines.[11]

The CBA was developed in consultation with the Steering Committee (a consortium of members from the Community, Council, and NSW Department of Planning and Industries (DPIE)) to evaluate multiple options.[12] Refer to Appendix A for a graphical overview illustrating preliminary options publicly consulted on, noting further option refinement occurred after the public exhibition, as discussed in Chapter 3. The CBA assessed a selected subset of Local Adaptation Planning options independently, but in practice they will be implemented concurrently, or in a sequence, due to significant interlinkages.

The next steps involve the joint Council and Community Working Group and key stakeholders considering the CBA findings (along with the other options assessed in the MCA) as a guide to further steps and adaptation processes, including funding options to be included in the preparation of the Local Adaptation Plan (LAP).

Methodology

The CBA framework for evaluating the costs of inundation events and the costs of adaptation options should capture the following:

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10 Economists sometimes refer to this as a 'real options' approach.

11 NSW Government 2017, *NSW Government Guide to Cost-Benefit Analysis: Policy and Guidelines Paper* (TPP 17-03), March, Treasury, https://www.treasury.nsw.gov.au/sites/default/files/2017-03/TPP17-03%20NSW%20Government%20Guide%20to%20Cost-Benefit%20Analysis%20-%20pdf_0.pdf

12 References to the Steering Committee here after, denotes the majority of the Steering Committee.

- The costs of inundation events under the base case, as well as, each adaptation strategy, which comprises:
  - the *probability* of a given inundation height/speed occurring
  - the *consequences* of a given inundation height/speed occurring, such as:
    - property damage
    - loss of life/injury.
- The costs of each adaptation strategy including:
  - capital costs
  - ongoing operating costs

Discount rates and evaluation period

For this analysis:

- Costs of inundation events under alternative strategies and the costs of the actions that form part of a strategy are measured over a period of time and discounted back to $2020.
- A 7 per cent discount rate has been chosen for the central case, consistent with NSW Treasury's Guide to Cost-Benefit Analysis.[13] Sensitivity analysis using 3 per cent and 10 per cent discount rates has also been undertaken as per NSW Treasury guidance.
- A 30 year evaluation period is used for the central case analysis, with an additional analysis at 50 years undertaken for some options to consider longer term costs and benefits.
- We assume benefits accrue 1-year post option implementation, with no ramp up.

Outputs

The CBA presents two result outputs in accordance with standard practice:

1 **Present value (PV) of net benefits** — this is the difference between the PV of benefits and costs. The greater the difference, the greater the return to society from investment in the project.

2 **BCR** — this is a ratio of the PV of the project benefits to the PV of the project costs. Example BCR interpretation:
  - BCR of 0.5 – for every $1 of benefits, society must pay $2 in costs
  - BCR of 1 – for every $1 of benefits, society must pay $1 in costs
  - BCR of 1.5 – for every $1.5 of benefits, society must pay $1 in costs

13 NSW Treasury 2017, *TPP17-03 NSW Government Guide to Cost-Benefit Analysis – Appendix 7.1*, page 56, https://www.treasury.nsw.gov.au/sites/default/files/2017-03/TPP17-03%20NSW%20Government%20Guide%20to%20Cost-Benefit%20Analysis%20-%20pdf_0.pdf

Estimated Annualised Average Damages

For each option, Annualised Average Damages (AADs) have been calculated by determining the inundation above impact levels (sometimes beginning below property floor levels due to impacts on property in yards and associated structures) for each property, over a range of inundation probabilities. Data sources are as follows:

- Inundation water levels for each Precinct – Salients et al. 2020[14]
  - Charts 10.5 (Precinct 20), 10.6 (Precinct 25), 10.7 (Precinct 30), 10.8 (Precinct 40) and 10.9 (Lake Area) in Appendix B
- Residential building inundation stage damage curves – OEH 2016[15], with adjustments made by CIE to account for:
  - varying house sizes[16] (Charts 10.10 to 10.17 in Appendix C), and
  - multiple inundation events per year (described below).
- Education building inundation stage damage curves– Molino Stewart 2012,[17] with extrapolation between 0.25 metre heights by CIE, inflated to $2020 using the Australian Bureau of Statistics (ABS) Consumer Price Index (Chart 10.18 in Appendix C) [18]
- Commercial building inundation stage damage curves – Molino Stewart 2012,[19] with extrapolation between 0.25 metre heights by CIE, inflated to $2020 using the ABS Consumer Price Index (Chart 10.19 in Appendix C)[20]
- Residential property floor level heights – Lake Macquarie Council City Council[21]
- Residential ground level elevation - LiDAR[22]
- Commercial building floor heights and ground level elevation - LiDAR

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14 Salients, University of Queensland, Flood Focus Consulting, 2020, *Probabilistic Hazard Assessment to Support Local Adaptation Planning for Pelican, Blacksmiths and Swansea - Final.*

15 NSW Government 2016, Residential Flood Damages, https://www.environment.nsw.gov.au/-/media/OEH/Corporate-Site/Documents/Water/Floodplains/floodplain-risk-management-guideline-residential-flood-damages-160736.pdf?la=en&hash=4EB56ECD121150F64DD88BD3155E9E958CFB3E51

16 Residential properties are allocated to one of 10 groups based on the closest size decile, capped at 500m^2.

17 Molino Stewart 2012, *Hawkesbury-Nepean Flood Damages Assessment: Final Report*

18 ABS 2020, *6401.0 Consumer Price Index, Tables 3 and 4. CPI: Groups, Weighted Average of Eight Capital Cities, Index Numbers and Percentage Changes*, March to March

19 Molino Stewart 2012, Hawkesbury-Nepean Flood Damages Assessment: Final Report.

20 ABS 2020, *6401.0 Consumer Price Index, Tables 3 and 4. CPI: Groups, Weighted Average of Eight Capital Cities, Index Numbers and Percentage Changes*, March to March

21 Property floor elevations were derived from a database held by Council and date from circa 2014.

22 Ground elevations were estimated based on interrogation of property polygons with a DEM derived from LiDAR. The median ground level for each property polygon was estimated and represents half of the finished ground surface of the property being inundated.

- Property building m^2 floor area – Geoscape[23], and
- Property m^2 land area – Geoscape.

Inundation water levels

As noted above, our analysis is based on the estimated inundation risks faced by the region as calculated by Salients et al. 2020[24] for the period 2020 to 2070. Refer to Appendix B for Precinct water levels and their associated probabilities. The inundation modelling utilises statistical modelling based on recorded history to predict future inundation events expressed as Annual Exceedance Probabilities (AEP) and/or average number of exceedances per year (EY). AEPs and EYs are two ways of expressing the probability of inundation events:

- EYs are expressed as the number of probable exceedances above an inundation water level per year and are the recommended terminology for inundation events that occur more than once per year. For example, an EY of 6 represents an inundation water level that may be exceeded 6 times in any given year.
- AEPs are expressed as a percentage for probabilities less frequent than 1 EY. For example, an AEP of 1% represents a 1 in 100 probability that an inundation water level will be exceeded in any given year.

The risks increase over time, accounting for issues such as SLR, have been incorporated into the estimated water levels.

We note the recent (approximately 8 years of water level data) measured high-water levels at the water level gauges within Swansea Channel (downstream of Swansea Bridge) are somewhat higher than during previous measurement periods.[25] It is unclear at this stage whether these more recently measured high water levels are indicative of an acceleration in measured rates of global SLR, or whether they are representative of the inherent natural variability of local mean sea level in response to various drivers that influence peaks records at the Swansea water level gauge (for example variability around El Niño/La Niña conditions, catchment flood and coastal storm frequency, and other conditions that raise local water levels).

Historically, water level data, from the Fort Denison gauge in Sydney (the most applicable long-term data available), show that there are medium term periods (years to decades) of both higher and lower water levels that occur relative to mean sea level and historic rates of measured SLR. That is, there are peaks and troughs in high-water levels that are irregularly spaced and unable to be accurately forecast. There is currently insufficient time-series climatic data available to test the

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23 Geospatial data set of Australia's built environment. Refer to https://geoscape.com.au/.

24 Salients, University of Queensland, Flood Focus Consulting, 2020, *Probabilistic Hazard Assessment to Support Local Adaptation Planning for Pelican, Blacksmiths and Swansea - Final.*

25 Hanslow, D (2019). Water level trends in NSW coastal lakes by use of exceedance probability analysis, *Australasian Coasts and Ports 2019 Conference: Future directions from 40 [degrees] S and beyond*, Hobart, 10-13 September 2019, https://search.informit.com.au/documentSummary;dn=799043410816316;res=IELENG

extent to which recent observed high-water levels at Swansea are part of this natural variability or reflect a more permanent 'structural shift' compared to the historical data series. The known gradual increase in the Lake Macquarie tide range due to the increasing hydraulic efficiency of the Swansea channel over time also has an impact on changing water levels measured at the Swansea gauge.

Following discussion with the Steering Committee, we present an alternate scenario for options AC1 (raise and fill residential areas (house sites and yards)), AC7 (raise and fill commercial land in the CBD) and CP4 (inundation protection works), in the form of a sensitivity test, where inundation levels are assumed to be 0.2m AHD higher than those predicted by the statistical PHA model. This is to provide additional information to understand how the results of the CBA would change if the inundation risks were higher than modelled.

Accounting for multiple annual inundation occurrences

Consistent with Ball et. al 2019,[26] we account for multiple annual inundation occurrences for the high frequency (more than once per year) events in the AADs.[27] We do this by:

- converting EYs/AEPs to monthly exceedance probabilities (as shown Table 2.1)
- calculating monthly expected damages, and
- finally multiplying the monthly expected damages by 12 to obtain AADs.

2.1 Conversion of annual exceedance probabilities to monthly exceedance probabilities

EY	AEP	Monthly Exceedance Probability
	Per cent	Per cent
6	99.75	39.30
4	98.17	28.35
3	95.02	22.11
2	86.47	15.35
1	63.21	7.995
0.5	39.35	4.081
0.2	18.13	1.653
0.11	10	0.874
0.05	5	0.427
0.02	2	0.168
0.01	1	0.084
0.005	0.5	0.042

Source: Salients consulting; CIE.

26 Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors), 2019, *Australian Rainfall and Runoff: A Guide to Flood Estimation*, Commonwealth of Australia, http://www.arr-software.org/pdfs/ARR_190514.pdf

27 That is, events with an EY of 1 or more.

The adjustment to monthly exceedances is required, in comparison to traditional methods for AAD calculation in NSW, as the calculation intrinsically assumes that there is one "event of note" during each time period. A calculation purely on an annual basis needs to be corrected to handle more frequent events which become increasingly important as sea levels rise.

Current inundation management actions (base case)

As part of ongoing community inundation management, Council already undertakes a range of inundation mitigation measures. Current measures to manage coastal hazards and risks in the case study area were detailed in the MCA[28] and were generally identified to take three forms: AVOID, ACCOMMODATE and INFORM. Protection measures are also already in place along sections of Swansea Channel that are subject to tidal current scour and wave erosion.

Additionally, options already considered feasible, viable and acceptable from the MCA, are expected to be implemented as inundation adaptation strategies in the case study area and in the LGA more broadly.[29] 'Business as usual' (base case) means continuing existing measures and implementation of expected measures. Therefore, the base case is not a 'do nothing response'.

Table 2.2. presents existing and future (programmed) measures expected to form part of the base case. All options considered in this CBA are additional to the base case, with costs and benefits of each option evaluated by comparison to the base case.

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28 Umwelt Pty Limited 2020, *Coastal Adaptation Options at Pelican, Blacksmiths, Swansea and Surrounds: Feasibility Assessment*. Report prepared with Salients Pty Limited, for Lake Macquarie City Council, p. 36, https://shape.lakemac.com.au/37415/widgets/210625/documents/167565

29 Including in the Coastal Management Program currently being prepared by Council – scheduled for completion at the end of 2021.

2.2 Current and programmed measures (i.e. Base Case)

It is understood that current measures include:

- Programmed maintenance of road pavements and sealing of sewage infrastructure
- Stormwater management works
- Planning controls
  - Relevant clauses of Council's LEP and Development Control Plan (DCP) – related to inundation, SLR, zoning and development control
  - Council's flooding and tidal inundation policy
  - Apply Section 10.7 notations to properties with an elevation of <3m AHD. Applications for flood certificates and inundation certificates
  - New subdivisions and release areas to be outside the 3m flood planning area. Flood planning levels set for habitable dwellings, including 0.5 m freeboard
  - Merits review of site-specific flood studies if other planning levels are proposed for a development
  - Development controls for greenfield, infill and recent development (flood resilient asset design) – LEP and DCP controls
- Community involvement in expanding risk responses
- Emergency response planning for flooding

There are also a range of 'low regrets' responses that were considered feasible, viable, and acceptable as part of the MCA. It is understood proposed measures include:

- Infrastructure protection measures such as tidal gates
- Community awareness and education programs, including about coastal processes, hazards and risks.
- Early warning systems and preparedness; e.g. Council implements a local warning system for several natural hazards including inundation (see Lake Macquarie Local Emergency Management Plan 2017, and emergency action plan attached to the certified CZMP 2017)
- Monitoring and reporting changes to the coastal environment. In the local context, this includes sea level, shoreline condition, groundwater behaviour, seagrass and saltmarsh condition (coastal wetlands) and community attitudes and concerns
- Research to improve coastal knowledge and understanding. This could include trials of new techniques and technology
- Identify thresholds/triggers for possible future intervention (higher risk)
- The length of Pacific Highway to the north and south of the bridge (between the red dashed line) is also being considered for raising by NSW Government transport agencies. While no firm date for the Pacific Highway raising has been committed, this forms part of the base case.

3 Adaptation options for CBA and assumptions

The final subset of local adaptation options recommended to be addressed in the CBA are discussed below.

Options Progressed to CBA

The adaptation planning process for the case study area is led by a Steering Committee and supporting working groups which includes council, local community, and public authority representatives. The Pelican, Blacksmiths, Swansea, and surrounding areas working group (a now combined working group derived from two previously separate working groups) developed a suite of potential management options which were shared with the broader community via a community information evening and workshop in August 2019. Based on community engagement, the working group consolidated a list of 112 community options for further consideration in a subsequent formal three-stage evaluation process:[30, 31]

1. **feasibility** — identify options that are practical, effective and align with legislation and policy
2. **viability** — economic evaluation using cost benefit assessment (this report)
3. **acceptability** — to the community in terms of capacity to deliver the community's objectives, funding and cost implications and timeliness.

The feasibility of adaptation options was analysed in a MCA which identified:[32]

- options that were considered immediately feasible, viable, and/or acceptable (such as tidal gates) – the working group recommended that these be incorporated into the LAP or Council's Coastal Management Program without needing to be assessed by a CBA
- options that were not feasible, viable, and/or acceptable, and
- 13 options that were considered appropriate for further analysis by means of a CBA.

30 Umwelt Pty Limited 2020, *Coastal Adaptation Options at Pelican, Blacksmiths, Swansea and Surrounds: Feasibility Assessment*. Report prepared with Salients Pty Limited, for Lake Macquarie City Council.

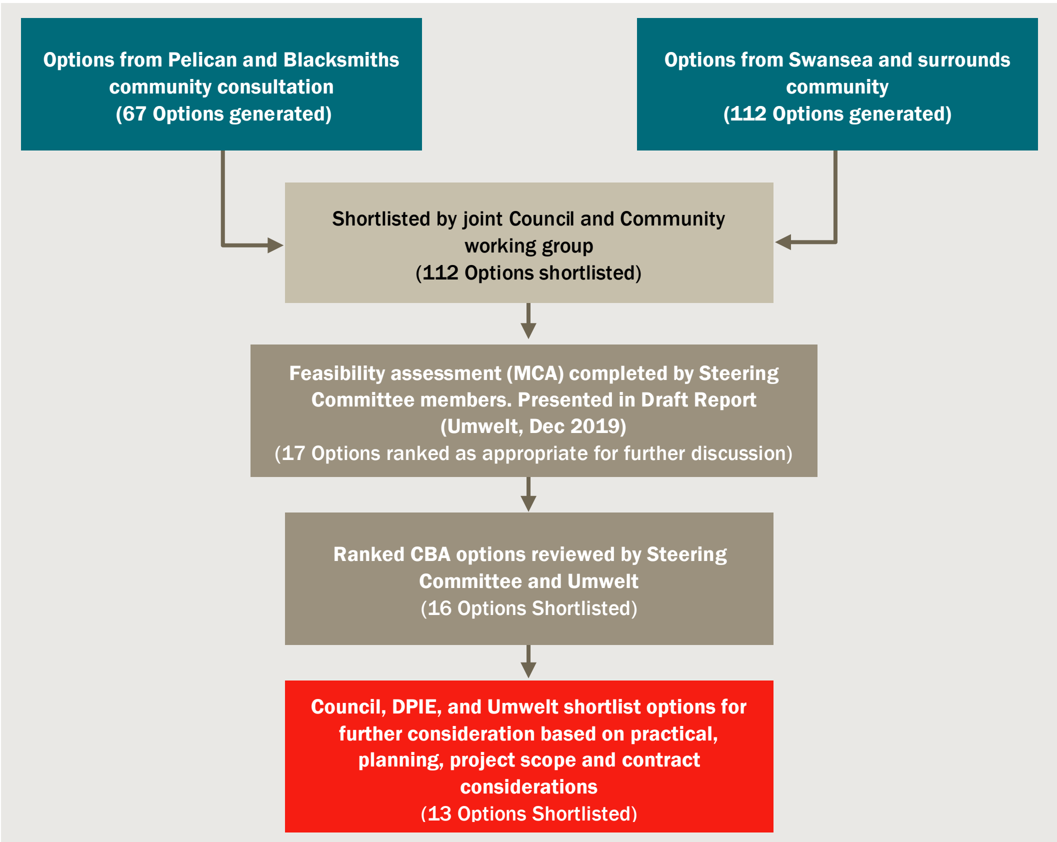
31 Consistent with the NSW Government 2019, Our Future on the Coast *NSW Coastal Management Manual Part B: Stage 3 – Identify and evaluate options*, NSW and Office of Environment and Heritage, https://www.environment.nsw.gov.au/research-and-publications/publications-search/coastal-management-manual-part-b

32 The methodology for community and technical review and the rational for narrowing down options is detailed in Umwelt Pty Limited 2020, *Coastal Adaptation Options at Pelican, Blacksmiths, Swansea and Surrounds: Feasibility Assessment*. Report prepared with Salients Pty Limited, for Lake Macquarie City Council, https://shape.lakemac.com.au/37415/widgets/210625/documents/167565

Graphics illustrating each option and a brief description were provided to the broader community (Appendix A). Further information is provided in the Lake Macquarie City Council document *Options guide for the cost benefit analysis: Pelican, Blacksmiths, Swansea and Surrounds*.[33]

Before the CBA commenced, Council and the Steering Committee further developed the concept designs and parameters for these options, to which the majority of the steering committee agreed.[34] These designs, parameters and assumptions have continued to be reviewed as the CBA has been prepared. This resulted in refinement of the options to more closely align a conceptual design level, that can be costed and practically implemented. Figure 3.1 provides an overview of the process of scoping and feasibility evaluation of options to manage coastal inundation risks in the project area. This Figure highlights the engagement and shortlisting of potential options by the working groups, Steering Committee, Council, agencies and consultants.

3.1 Options identification and shortlisting process



Data source: Umwelt Pty Limited 2020, *Coastal Adaptation Options at Pelican, Blacksmiths, Swansea and Surrounds: Feasibility Assessment*. Report prepared with Salients Pty Limited, for Lake Macquarie City Council, p. 6, https://shape.lakemac.com.au/37415/widgets/210625/documents/167565

33 Lake Macquarie City Council 2020, *Options guide for the cost benefit analysis: Pelican, Blacksmiths, Swansea and Surrounds*, https://shape.lakemac.com.au/37415/widgets/210625/documents/167956

34 References to the Steering Committee here after, denotes the majority of the Steering Committee.

The CBA options are summarised in the following categories (Table 3.2).

1 Options to Raise and Fill Land and Built Assets
2 Swansea Holiday Park and Wetland/Environmental Options
3 Channel and Foreshore Protection Works
4 Staged raising of Ungala Road, including the concurrent raising of the boat ramp car park and raising of residential land (option AC1) to avoid water pooling and inundation of the road and adjoining residential areas

3.2 Options evaluated in the CBA

Option	Description	Comments	Refined design parameters
Options to raise and fill land and built assets			
AC1	Raise and fill residential areas (house sites and yards)	A high-risk inundation area in Pelican was identified during the Local Adaptation Plan (LAP) development by the joint Council and Community Working Group. We understand this area is generally bounded by Soldiers Road, Lorna Street and Lakeview Parade.	▪ Mosaic raise and fill trigger.
AC2	Raise transport infrastructure (over and above gradual raising of roads through maintenance)	Local roads to be raised include the length of road near the intersection of Lakeview Parade and Soldiers Road Pelican. It will also include local roads connecting to the Pacific Highway. This option is independent of any raise/fill of any residential properties.	▪ Raising roads in the Pelican area is intended to support maintaining serviceability of properties. However, residential land raising (option AC1) is not economically viable. Therefore, raising roads would not be adopted at this stage. The timing of any raising of the Pacific Highway by RMS is also unknown. ▪ Given this, we have modelled an alternative option of gradually raising roads (from the most to the least flood prone) over a specified time.
AC3	Raise other infrastructure (power, water, sewer, stormwater, telecommunications)	This option would reduce the disruption to properties if the assets are inundated. In practice, this option would need to be considered alongside the road raising option (AC2) given that infrastructure assets may be located within/alongside the roads.	▪ Many of these assets run alongside the road corridor. The sequencing of asset upgrades has been linked to the road raisings.

Option	Description	Comments	Refined design parameters
AC4	Raise and fill education land (schools)	We understand this option is to reduce school disruption associated with inundation events. Three schools have been identified in the case study area for potential raise and fill: ▪ St Patricks ▪ Swansea Public School, and ▪ Pelican Flat Public School.	▪ A mosaic raise and fill modelling approach has been used, such that raising is triggered when the present-day property ground level is below the chosen trigger height. The school site and associated buildings are subsequently raised to the chosen raise height.
AC5	Raise and fill public recreation land such as foreshore reserves and playing fields	This option is to maintain access to recreational activities – including active and passive recreation: sporting facilities and public open space.	▪ The recreational land is assumed be raised in each year from 2021 based on the most inundation prone to the least inundation prone land. Recreational land would be raised to the 1% AEP event height at 2050.
AC7	Raise and fill commercial land in the Central Business District (CBD)	Potential raise and fill of the commercial land in the CBD	▪ Mosaic raise and fill trigger on existing sites.
Swansea Holiday Park and Wetland/Environmental Options			
AC6	Raise and fill Swansea Holiday Park	Raise and fill the Swansea Holiday Park.	▪ Raise and fill based on inundation trigger heights
AC6B	Relocate Swansea Holiday Park	Maintain access to the foreshore, or allow adjoining wetlands and lake to encroach onto land currently occupied by Swansea Holiday Park while relocating the Swansea Holiday Park to one of the following locations: ▪ Belmont Bayview Park ▪ Greenfield site adjacent to Belmont golf course	▪ Relocation to a specified location to occur in 2030
RA4	Allow wetlands to move landward on 'environmental land' around Pelican Inlet and other suiTable areas	Locations for consideration: ▪ Coon Island ▪ Galgabba Point ▪ Pelican Inlet, and ▪ Black Neds Bay.	▪ Wetlands options not evaluated in full. There is uncertainty regarding how quickly wetlands are established with temporary inundation.
RA5	Allow wetlands to move landward into coastal use area, with land acquisition		
RA6	Offset losses of wetlands with wetland reservation elsewhere around the lake	Offsets are unlikely to be like for like, as the channel area is different to most other wetlands around the lake.	▪ Wetlands options not evaluated in full. There is uncertainty regarding how quickly wetlands are established with temporary inundation.

Option	Description	Comments	Refined design parameters
Channel and Foreshore Protection Works			
CP4	Inundation protection works (or a levee) inside Black Neds Bay		▪ Construction of a vertical 1.7m AHD concrete wall along the western shore of Black Neds Bay.
Staged raising of Ungala Road			
CP8A/CP 14	Staged Raising of Ungala Road, first near the boat ramp	Stage raising would also need to coincide with stormwater drainage, tidal gates and/or residential raise/fill, similar to option (AC1), to avoid water pooling when Ungala Road is raised.	▪ The option description document notes this option is proposed in a sequence with raise and fill the Mankilli St area (part of AC1) and tide gates on Ungala Road (CP8B). Both raise/fill of residential properties in Mankilli St and the tide gates were not considered. Raise/fill triggers presented for illustrative purposes.

Source: Umwelt Pty Limited 2020, *Coastal Adaptation Options at Pelican, Blacksmiths, Swansea and Surrounds: Feasibility Assessment*. Report prepared with Salients Pty Limited, for Lake Macquarie City Council, https://shape.lakemac.com.au/37415/widgets/210625/documents/167565, and subsequent input from the Steering Committee.

Options in this CBA have been analysed separately. However, it is known that there are interlinkages between the options. For example, if inundation causes local road closures then this would reduce access to schools, the CBD and public recreation spaces. In practice, we understand that Council will consider the staged planning of any adaptation measures and the impact of any individual measures might have on another. Additionally, it is expected that any adaptation measures adopted will include consultation with all relevant stakeholders.

Options to raise and fill land and built assets

This series refers to the raise and fill of:

- residential land
- infrastructure (roads, power/gas lines, sewerage and water lines, and stormwater drainage, telephone)
- educational land
- commercial land, and
- public recreational land, such as foreshores and playing fields.

Raise and fill triggers and heights

In consultation with the Steering Committee, the inundation event which triggers the raising and filling of properties (**raise trigger**) and the height to which properties are raised (**raise height**) were determined, as shown in Table 3.3. The raise trigger and raise heights were chosen based on our understanding of the communities' risk tolerance and agreed by the Steering Committee. The subsequent Council survey, 'Planning for future flood risks: Pelican, Blacksmiths, Swansea and surrounds',[35] indicates our chosen raise triggers and raise heights are consistent with the communities' risk tolerance.

3.3 Raise and fill triggers and heights

Option	Raise trigger	Raise height (excluding freeboard and additional SLR)
AC1	10% AEP	1% AEP
AC2	This option is not trigger based as detailed below on pages 33-34	10% AEP in 2050
AC3	This option is not trigger based as detailed below on page 34	
AC4	1% AEP	1% AEP
AC5	This option is not trigger based as detailed below on page 36	1% AEP
AC6	18.13% AEP	2% AEP
AC7	1% AEP	1% AEP

Source: CIE

The most **risk averse** approach is to adopt a **raise trigger** of the **probable maximum flood (PMF)**. That is, choose a trigger level that raises properties with present-day impact levels (habitable floor levels and/or ground levels) below the PMF. At the other extreme, a more **risk-tolerant** approach is to adopt a **raise trigger of 6EY (99.75% AEP event)** best estimate of exceeded water level probability event, and its associated lower inundation water levels. That is, use the trigger threshold that raises properties with present-day impact levels below the lowest estimated inundation water levels.

Similarly, the most **risk averse** approach is to adopt a post triggered **raise height** of the **PMF** and its associated higher inundation water levels. That is, choose a raise height that ensures properties are above the highest estimated inundation water levels. At the other extreme, a far more **risk-tolerant** approach is to adopt a **raise height of 6EY (99.75% AEP event)** best estimate of exceeded water level probability event, and its associated lower inundation water levels. That is, raise properties to withstand the lowest estimated water inundation levels.

35 Lake Macquarie City Council 2020, 'Planning for future flood risks: Pelican, Blacksmiths, Swansea and surrounds, tidal inundation follow-up survey engagement summary', available at https://shape.lakemac.com.au/futurepelicanblacksmiths

Assumptions for raise heights of residential and commercial property raise and fill options

Council's flood planning levels (FPLs), shown in 'Lake Macquarie Waterway Flooding and Tidal Inundation Policy'[36], is set at 2.36m AHD in 2050 and 2.82m AHD in 2070. This is based on the 1% AEP flood elevation derived as part of the Lake Macquarie Waterway Flood Risk Management Study and Plan[37], plus a 0.5m freeboard. For example, 1.86m in 2050 (includes 0.4m SLR) was calculated in the Waterway Flood Risk Management Study and Plan[38], and adding 0.5m freeboard, resulted in a FPL of 2.36m AHD. This flood study included a conservative assumption relating to the impact of ocean wave set up inside the estuary. The conservative assumption of ocean wave set-up was not included in the Salients et al. 2020.[39]

Following discussions with the Steering Committee, Council agreed that for residential and commercial properties triggered for raise and fill under options AC1 Raise and fill residential areas (house sites and yards) and AC7 Raise and fill commercial land in the CBD:

- 0.2m SLR would be added to the data from Salients et al. 2020 to account for the difference in the Salients et al. 2020 output and the Council's FPLs, and
- 0.4m of SLR by 2050 would also be added (accepted SLR established from the former *NSW Sea Level Rise Policy Statement 2009*)

This results in a total of 0.6m SLR[40] added to the water levels, modelled by Salients et al. 2020, for each year from 2020 to 2070, plus the 0.5m of freeboard, to give an approximation of the 'property raise levels' i.e. the height to which properties would be raised if triggered for calculation purposes of this CBA.

Given the complexities and uncertainties of SLR projections, and differences in modelling data, the Steering Committee considered this was pragmatic approach which avoids adding complexity

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36 Lake Macquarie 2020, *Lake Macquarie Waterway Flooding and Tidal Inundation Policy: Council Policy,* Version 4, 27 July, https://www.lakemac.com.au/files/assets/public/hptrim/environmental-management-policy-protection-of-the-environment-policies-pep-climate-change-adaptation-lake-macquarie-sea-level-rise-preparedness-and-adaptation-policy/lake-macquarie-waterway-flooding-and-tidal-inundation-council-policy-version-3.pdf

37 WMA Water 2012, *Lake Macquarie Waterway Flood Risk Management Study and Plan*, June 2012, https://flooddata.ses.nsw.gov.au/flood-projects/lake-macquarie-waterway-flood-risk-management-study-plan

38 WMA Water 2012, *Lake Macquarie Waterway Flood Risk Management Study and Plan*, June 2012, https://flooddata.ses.nsw.gov.au/flood-projects/lake-macquarie-waterway-flood-risk-management-study-plan

39 Refer to Salients, University of Queensland, Flood Focus Consulting, 2020, *Probabilistic Hazard Assessment to Support Local Adaptation Planning for Pelican, Blacksmiths and Swansea - Final.*

40 SLR rise follows a projection similar to that of an exponential curve and is measured from mean sea level in 1990. Therefore, SLR for the year 2020 is calculated as a point along the exponential curve between the years 1990 (mean sea level) and 2050 (mean sea level + 0.4m).

to the analysis but provides post raise and fill property heights that are consistent with Council's existing FPLs. We note that this is not a reflection of how properties and facilities might be raised in the case study area, nor are we advocating a case for reducing or changing existing FPLs. For simplicity, we have not applied the 0.6m additional SLR to the post raise and fill triggered raise heights for any other option.

AC1 Raise and fill residential areas (house sites and yards)

This option refers to the potential raise and fill of residential land identified in Pelican (within Precinct 40). This study area is generally bounded by Soldier's Road, Lorna Street and Lakeview Parade (Figure 3.4).

3.4 Option AC1 approximate study area

Data source: Lake Macquarie City Council.

A mosaic raise and fill modelling approach has been used, such that raising is triggered when the present-day property (structure) habitable floor level is below the chosen raise trigger and the property is raised to the chosen raise height, independent of neighbouring properties being raised and filled.

Option AC1 Raise and fill residential areas assumptions are shown in Table 3.5.

3.5 Option AC1 assumptions

Description	Value
Chosen raise trigger	10% AEP
Chosen raise height (excluding freeboard and additional SLR)	1% AEP
Freeboard raising height (m)	0.5
Allowance for future SLR (m)	0.6
Cost to raise and fill properties ($/m^3)	105
Construction costs post raise & fill ($/m^2)	1 577

Sources: Construction costs - ABS 8752.0 - Building Activity, Australia, Dec 2019 (data cubes 'Building Activity: Average Cost' and 'Building Activity: Average Floor Area' for NSW; Raise and fil costs – quotes from local suppliers; CIE.

Note, the chosen raise trigger and raise height change every year as shown in Table 3.6.

3.6 Option AC1 annual raise and fill trigger and new raise height levels

Year	Property raise height trigger (10% AEP)	Property raise height (1% AEP + freeboard + additional SLR raise height)
	metres above AHD	metres above AHD
2020	0.87	2.37
2050	1.06	2.54
2070	1.24	2.71

Note: Water levels are for Precinct 40 as shown in Appendix B.

Source: Salients et al. (2020), *Probabilistic Hazard Assessment to Support Local Adaptation Planning for Pelican, Blacksmiths and Swansea - Final*; CIE

Sixteen residential properties were identified in the study area of AC1, with property details shown in Table 3.7. This also includes the estimated year which the property raising would occur, based on the assumed raise triggers.

3.7 Option AC1 identified residential properties

	Floor level	Ground level	Year property reaches raise trigger
	m AHD	m AHD	m AHD
Property 1	0.87	0.75	2020
Property 2	1.19	0.83	2066
Property 3	1.82	1.16	> 50 years
Property 4	1.39	0.91	> 50 years
Property 5	1.57	1.00	> 50 years
Property 6	1.94	1.62	> 50 years
Property 7	1.24	1.24	2070
Property 8	1.55	0.89	> 50 years
Property 9	1.43	0.98	> 50 years
Property 10	1.51	0.90	> 50 years
Property 11	1.91	1.02	> 50 years
Property 12	1.47	0.92	> 50 years
Property 13	1.62	0.88	> 50 years
Property 14	1.37	0.98	> 50 years
Property 15	1.59	1.00	> 50 years
Property 16	1.37	0.91	> 50 years

Source: CIE.

AC2 Raise transport infrastructure (over and above gradual raising of roads through maintenance)

The original option design focused on the local roads to be considered in the Pelican hotspot precinct, primarily at the intersection of Lakeview Parade and Soldiers Road. The original option specification document stated that this option will need to be done alongside raising residential land to maintain serviceability (option AC1) and it also needs to be linked to the raising of infrastructure assets.

The original option also specified that the local roads to be raised also include local arterial roads connecting to the Pacific Highway.

However, based on the evaluation of AC1 (discussed in the next section), there is only one property that will be raised. Therefore, raising roads would not occur given that road levels would be above neighbouring properties, causing pooling of water and additional costs to the property owner.

Given this, we have modelled an alternative option of gradually raising roads in the case study area (from the most to the least flood prone) over a specified time. This provides an illustration of the potential benefits that could be expected of raising roads in the region, assuming alignment could occur with any property raisings, if required. This would assist Council in consideration of any future road raising options.

For the purposes of our analysis, we assume that the target road height would be the 1.4m which equates to the 10% AEP inundation event at 2050. The level which the road would need to be raised would depend on the existing road level.

AC3 Raise other infrastructure (electricity, gas, water, sewer, stormwater, telecommunications)

There are a range of assets that service residential and non-residential properties in the region including power, water, gas, sewer, stormwater and telecommunications.

The option description states that we "need to know what would have to be raised to provide for functioning services as properties are raised within any precinct/sub-precinct area".

The decision regarding the potential relocation of assets to ensure the properties continue to be serviced is one that is undertaken by the utility service providers. Ideally any raising infrastructure would also be coordinated with road raisings, given that some of the assets are located within the road corridor.

We have adopted assumptions regarding which assets would be subject to raising, the level of raising required and links to road raising. In practice, however, these decisions will be subject to the asset management plans of each of the utility service providers.

AC4 Raise and fill education land (schools)

This option refers to the potential raise and fill of education land. Three schools have been identified in the case study area for potential raise and fill, across three inundation precincts and shown in the Table 3.8 and Figure 3.9 (red highlighted land).

A mosaic raise and fill modelling approach has been used, such that raising is triggered when the present-day property ground level is below the chosen raise trigger. The school site and associated buildings are subsequently raised to the chosen raise height, independent of neighbouring properties being raised and filled.

Option AC4 Raise and fill education land (schools) assumptions are shown in Table 3.8.

3.8 Option AC4 identified education properties

School	Address	Students	Precinct	Floor level	Ground level	Year raise trigger reached
		number		m (AHD)	m (AHD)	year
St Patricks	219, NORTHCOTE AVE, SWANSEA	152	20	1.82	1.25	2030
Swansea Public School	77, CHANNEL ST, SWANSEA	230	25	1.85	1.22	2028
Pelican Flat Public School	53A, KAROG ST, PELICAN	65	30	1.91	1.25	2032

Note: St Patricks student numbers are for 2018, Swansea and Pelican Flats Public School are for 2019.

Sources: Catholic Schools Office Diocese of Maitland-Newcastle 2018, *2018 Annual School report*; NSW Government 2020, *Swansea Public School 2019 Annual Report*, June; NSW Government 2020, *Pelican Flat Public School 2019 Annual Report*, April; Salients et al. 2020, *Probabilistic Hazard Assessment to Support Local Adaptation Planning for Pelican, Blacksmiths and Swansea - Final*; CIE

3.9 Option AC4 identified education property locations

Data source: CIE

3.10 Option AC4 assumptions

Description	Value
Chosen raise trigger	1% AEP
Chosen raise height (excluding freeboard)	1% AEP
Additional freeboard raising height (m)	0.5
Cost to raise and fill properties ($/m^3)	105
Construction costs post raise & fill ($/m^2)	1 577

Sources: Construction costs - ABS 8752.0 - Building Activity, Australia, Dec 2019 (data cubes 'Building Activity: Average Cost' and 'Building Activity: Average Floor Area' for NSW; Raise and fil costs – quotes from local suppliers; CIE.

The 1% AEP raise trigger and raise height change every year (as shown in Table 3.11).

3.11 AC4 annual raise and fill trigger height and raise levels

Year	Precinct 20 raise trigger	Precinct 25 raise trigger	Precinct 30 raise trigger	Precinct 20 raise height (1% AEP event + freeboard)	Precinct 25- raise height (1% AEP event + freeboard)	Precinct 30 raise height (1% AEP event + freeboard)
	m AHD	m AHD	m AHD	m AHD	m AHD	m AHD
2020	1.20	1.19	1.19	1.70	1.69	1.69
2050	1.39	1.37	1.37	1.89	1.87	1.87
2070	1.59	1.56	1.55	2.09	2.06	2.05

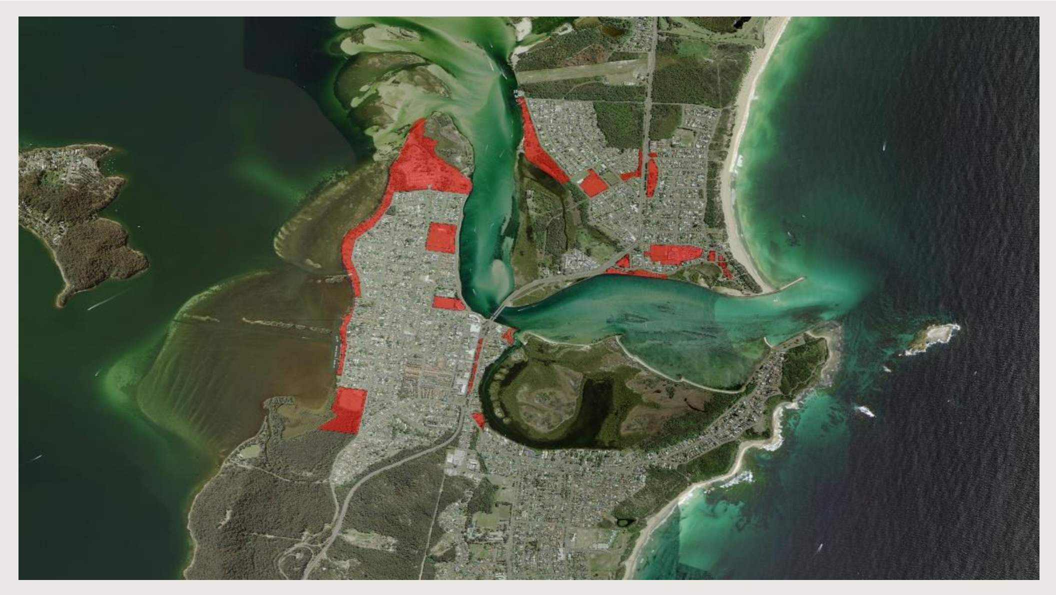
Source: Salients, University of Queensland, Flood Focus Consulting, 2020. *Probabilistic Hazard Assessment to Support Local Adaptation Planning for Pelican, Blacksmiths and Swansea - Final*; CIE

AC5 Raise and fill public recreation land such as foreshore reserves and playing fields

There are a range of different public recreation facilities identified that could be subject to raise and fill. These are highlighted in red in Figure 3.12 below. In many cases, the use of these lands would be diminished by frequent inundation. Raising the level of the areas is seen as a way to reduce the frequency of inundation, thereby protecting the use of these areas.

The recreational land is assumed be raised in each year from 2021 based on the most inundation prone to the least inundation prone land. Recreational land would be raised to the 1% AEP event at 2050 level. In practice, Council could choose different raise triggers for passive and active recreational land, reflecting the different needs and frequency of use. For example, more frequent inundation could be accepted at passive recreational land. A more nuanced raise height could be considered by Council at a later stage.

3.12 Public recreation spaces considered



Data source: Lake Macquarie City Council.

Visitation

The visitation of public green spaces is extremely variable across the sites. There is limited specific data on the visitation of the different sites and the reasons for these visits. From a range of sources, we have estimated the annual number of visitors per annum by different park types for the Sydney region (Table 3.13).[41] Local and district parks are most visited accounting for around 85 per cent of open space visitation, followed by regional parks and national parks.

3.13 Number of visitors by different types of open space, Sydney

	Visits per hectare per annum	Visits per annum
	Number	Million
Local/district parks	11 545	306.8
Regional parks	4 874	32.7
Golf courses	894	2.4
National Parks	56	16.0

Source: CIE, Roy Morgan 2015, Annual Visits to PWG Managed Parks in New South Wales, prepared for Office of Environment and Heritage; Centennial Parklands 2015, Centennial Parklands Annual Report 2014-15; Parramatta Park Trust 2015, Parramatta Park Trust Annual Report 2014-15; Western Sydney Parklands Trust 2015, Western Sydney Parklands Trust Annual Report 2014-15; Royal Botanic Gardens and Domain Trust 2014, Royal Botanic Gardens and Domain Trust Annual Report 2013-14; Golf Australia 2016, Golf Club Participation Report 2015; Veal 2006, The Use of Urban Parks, Annals of Leisure Research, 9(4).

41 Given this limitation the results need to be interpreted cautiously. Further data could be collected by Council at a later stage to understand visitation at the different recreational land.

There appears to be a mismatch between the type of open space that is most abundantly available and visits to different types of open space. Although bushland accounts for a large proportion of open space, this typology is the least visited. In contrast, local parks and regional parks account for a relatively small amount of open space area in Sydney, but account for over 95 per cent of open space visits.

Differences in visitation are likely driven by a range of factors, including proximity to population centres, characteristics and recreational opportunities provided by different open space typologies. Although National Parks and bushland are not as frequently visited, they provide other services such as air purification, carbon sequestration, and cultural and heritage values.

Local/district park visitation was estimated based on survey results conducted by the (now defunct) Sydney Parks Group in 2004 and reported by Veal (2006).[42] These indicate that 45 per cent of people surveyed had visited a park in the previous week on an average of 2.8 visits for users and 1.26 visits per person across the entire population. This is broadly in line with data for England, which indicates that in 2014-15 there were around 3.12 billion visits by adults (aged 16 years of age or older) to natural environments, which includes green open spaces in urban areas as well as the wider countryside and coastline. This corresponds to around 1.36 visits to open space per person per week.

For the purposes of our modelling we assume, on average, 2 visits to open space per person per week. However, this only applies to persons living within a 1 km radius of each of the parks.

Estimated loss of parkland access from inundation

Table 3.14 estimates the number of visitation days lost across the parklands for this project. This assumes that any inundation that occurs on the parkland results in lost visitation.

This relies on estimates of the ground level of the parkland. We have utilised LiDAR data and ground level elevation data from neighbouring residential properties to estimate the inundation at the parkland. This is an approximation and land elevation could vary within each park.

3.14 Number of visitation days lost

Precinct	2020	2030	2050
	days	days	days
10	-	-	-
15	17	17	18
20	17	18	20
25	0	0	0
30	0	1	11
40	1	2	17
LakeA	4	11	18

Source: CIE estimates based on Salients et al 2020.

42 Veal 2006, The Use of Urban Parks, Annals of Leisure Research, 9(4).

As inundation is expected to increase into the future, this increases the number of visitation days lost per annum.

AC7 Raise and fill commercial land in the CBD

This option refers to the potential raise and fill of the commercial land in the CBD. This includes both sides of Josephson and Wood streets. The initial proposal exhibited to the community involved constructing new commercial buildings on the existing carpark and then demolish the existing CBD, to be replaced by a carpark. For reasons of practicality and to estimate costings, the CBA has modelled an alternate mosaic CBD raise and fill, triggered when the respective present-day property (structure) floor level is below the chosen raise trigger. The property is then subsequently raised to the chosen height. The precise way in which raising and filling the CBD is undertaken requires:

- a detailed review of the site and costings of the alternative approaches, and
- input from
  - TfNSW for Pacific Road Raising timing and its impacts
  - property owners/investors on land/building renewal preferences and timing
  - Council/DPIE on current and future zoning.

For the modelled raise and fill of commercial land, eighty-five commercial properties have been identified in precincts 20 and 25. Eighteen properties are in Precinct 20 and 67 in Precinct 25 (highlighted red in Figure 3.15).

3.15 Option AC7 identified commercial properties

Data source: CIE.

Option AC7 assumptions are shown in Table 3.16.

3.16 Option AC7 assumptions

Description	Value
Chosen raise trigger	1% AEP
Chosen raise height (excluding freeboard and additional SLR)	1% AEP
Additional freeboard raising height (m)	0.5
Additional allowance for future SLR (m)	0.6
Cost to raise and fill properties ($/m3)	105
Construction costs post raise & fill $/m2	1 577

Sources: Construction costs - ABS 8752.0 - Building Activity, Australia, Dec 2019 (data cubes 'Building Activity: Average Cost' and 'Building Activity: Average Floor Area' for NSW; Raise and fil costs – quotes from local suppliers; CIE.

The 1% AEP raise trigger and raise height change every year as shown in Table 3.17.

3.17 AC7 annual raise and fill trigger height levels

Year	Precinct 20 raise trigger	Precinct 25 raise trigger	Precinct 20 raise height (1% AEP event + freeboard + additional SLR)	Precinct 25 raise height (1% AEP event + freeboard + additional SLR)
	metres above AHD	metres above AHD	metres above AHD	metres above AHD
2020	1.20	1.19	2.30	2.29
2050	1.39	1.37	2.49	2.47
2070	1.59	1.56	2.69	2.66

Source: Salients et al (2020), *Probabilistic Hazard Assessment to Support Local Adaptation Planning for Pelican, Blacksmiths and Swansea - Final*; CIE.

Swansea Holiday Park and Wetland/Environmental Options

Two alternative options have been considered to manage the holiday park, one option to raise/fill the park (accepting the loss of the wetland) and the other to relocate the park (allowing the wetland to move landward). The consideration of the wetland loss (and offset) and landward movement into environmental land or coastal use area (with land acquisition) also applies to other locations in the study area.

AC6 Raise and fill Swansea Holiday Park

This option refers to the potential raise and fill of Swansea Lakeside Holiday Park, located in precinct Lake A (Table 3.18 and Figure 3.19).

3.18 Option AC6 Swansea Holiday Park

Caravan Park	Address	Precinct	Floor level	Ground level	Year raise & fill trigger level exceeds ground level
			metres (AHD)	metres (AHD)	
Swansea Lakeside Holiday Park	1 DOBINSON DR, SWANSEA	Lake A	0.94[a]	0.94	2048

[a] Assumed level at which inundation causes total loss to all structures (camp sites, cabins and non-accommodation buildings) based on the average Lidar data for the entire Swansea Holiday Park site.

3.19 Option AC6 Swansea Holiday Park location

Data source: CIE.

Option AC6 assumptions are shown in Table 3.20.

3.20 Option AC6 assumptions

Description	Value
Chosen raise trigger	18.13% AEP
Chosen raise height (excluding freeboard)	2% AEP
Cost to raise and fill properties ($/m^3)	105
Construction costs post raise & fill ($/m^2) [a]	1 577
Caravan park area loss rate ($/m^2)	167
Cabin loss rate ($/cabin)	70 000

[a] Applied to offices, amenities block and other non-accommodation assets.

Sources: Construction costs - ABS 8752.0 - Building Activity, Australia, Dec 2019 (data cubes 'Building Activity: Average Cost' and 'Building Activity: Average Floor Area' for NSW; Raise and fil costs – quotes from local suppliers; Source: Salients et al (2019), Probabilistic Hazard Assessment to Support Local Adaptation Planning for Pelican, Blacksmiths and Swansea - Final Draft, p.94; *CIE.*

For reasons of practicality and estimating costings, the CBA has assumed raising is triggered when the present-day site ground level is below the chosen raise trigger. The entire site is then raised to the chosen height. The chosen raise trigger and raise heights change every year as shown in Table 3.21. Wetland impacts are discussed separately as part of Options RA4, RA5 and RA6.

3.21 Option AC6 annual raise and fill trigger and new raise height levels

Year	Raise Trigger (18.13% AEP event)	Raise height (2% AEP event)
	metres above AHD	metres above AHD
2020	0.78	1.68
2050	0.96	1.85
2070	1.15	2.03

Source: Salients, University of Queensland, Flood Focus Consulting, 2020. *Probabilistic Hazard Assessment to Support Local Adaptation Planning for Pelican, Blacksmiths and Swansea - Final*; CIE

Table 3.22 shows the number of cabins, camp sites, non-accommodation buildings and moveable caravans in the Swansea Holiday Park.

3.22 Option AC6 assets Swansea Holiday Park

Structure	Number	Comments
Cabins	15	
Camp sites	93	Assumed 45m^2/camp site
Moveable caravans	134	
Offices, amenities blocks etc		16 800m^2 based on Geoscape data

Source: https://lakemacholidayparks.imgix.net/assets/src/uploads/25976-Swansea-park-map-2.pdf; CIE.

AC6B Relocate Swansea Holiday Park

Option AC6B assumptions are shown in Table 3.23.

3.23 Option AC6B (Swansea Holiday Park relocation) assumptions

Description	Value
Relocation date	2030 [a]
Relocation sites [b]	▪ Belmont Bayview Park ▪ Greenfield site adjacent to Belmont golf course
Average Ground level at current site	0.9 metres (AHD)
Average Ground level at proposed sites	2.66 metres (AHD)

[a] Assumption based on the estimated relocation site approvals and development timeframes. Agreed by the Steering Committee as a working assumption. [b] As advised by Lake Macquarie City Council

Sources: Ground levels are sourced from LiDAR; CIE.

Council advised that:

- the existing Belmont Bayview Park requires an upgrade to host additional sites, and
- the greenfield site adjacent to Belmont golf course requires development prior to the relocation of Swansea Holiday Park.

The Council provided development costs for a 150 site Holiday Park, over a 25-year period. The total capital development costs are shown in Table 3.24. These costs have been included in the analysis. Note, upgrade costs for the existing Belmont Bayview Park have not been considered and, therefore, overall relocation costs are likely to be lower bound.

3.24 Greenfield Holiday Park development costs

Description	Cost
	$
Amenities	1 160 000
BBQ Shelter	160 000
Boom gates & Security fencing	85 000
CCTV/Security	16 000
Dump Point	20 000
Playground	190 000
Reception/Residence	330 000
Roads/Civil & Services	6 800 000
Street lighting	84 000
Tanks – Water	40 000
Landscaping	120 000
Total [a]	**9 005 000**

[a] For a 25-year period.

Note: Costs are undiscounted, real $2020.

Source: Lake Macquarie City Council.

Wetland protection (options RA4, RA5, RA6)

There are three separate options that have been identified. The options are designed to allow the wetlands to continue to move landward:

- on 'environmental land' around Pelican Inlet (option RA4)
- move landward into coastal use area, with land acquisition (option RA5)

Another option (RA6) seeks to limit the landward movement of the identified wetlands but to offset these losses with wetland reservation elsewhere around the lake.

Locations identified include Coon Island, Galgabba Point, Pelican Inlet and Black Neds Bay.

The wetlands options have been assessed qualitatively, given some limitations in available data for a more detailed quantitative assessment. This is discussed further in chapter 8.

Channel and Foreshore Protection Works

CP4 Inundation protection works inside Black Neds Bay

The modelled option refers to the construction of a permanent structure in Black Neds Bay to ameliorate tidal inundation for Swansea residents east of the Pacific Highway, as well as the Swansea CBD. For reasons of practicality and estimating costings, this differs to the broad channel and foreshore protection works exhibited to the community (Appendix A). Indicative modelled option parameters are described in Table 3.25.

3.25 Option CP4 Inundation protection works in Black Neds Bay parameters

Option parameters	Comments
Option description	Construct a vertical concrete wall along the western shore of Black Neds Bay
Related base case elements	Installation of tidal gates and raising of the Pacific Highway to ameliorate any increase in inundation in the Swansea CBD from Black Neds Bay
Additional design considerations for effectiveness	▪ Typical ground level is at around 1.2m AHD in the case study area. Assumed that 0.5 metres is added to this to allow for minimal chance of overtopping for approximately the next 50 years. – This results in an estimated inundation level protection of 1.7m AHD from the installed vertical concrete wall. ▪ Length of Wall is 1km wrapping around southern side of Peel St, along foreshore to north of Plains Gully Creek and then inland[a] ▪ To work, the properties to be protected need to be contained within a watertight barrier that encircles the group of properties. In effect, a "polder" of sorts is to be constructed that would keep out high tides. ▪ The water-tight barrier introduces some difficulties as follows: – Any open channels east of the highway will need to be capped and made watertight

Option parameters	Comments
	– Boat ramps will need to be filled (i.e. no-one along this shoreline could have a boat ramp through the wall) as it will be too difficult to provide a guaranteed seal to keep the tidal water outside the wall.
Design and construction requirements/constraints	▪ Construction out into the waterway requires multiple approvals, as it is located close to coastal wetlands under the CM SEPP. ▪ Construction access is also difficult. ▪ The wall has to be vertical as several buildings are too close to the water's edge to allow for a sloped earthen structure (or similar). To fit in a sloping structure, it is possible that some residences would need to be relocated (or moved backwards away from the water). The aim is to avoid relocation until the raise and fill option is necessary. ▪ Several properties have reclaimed beyond their seaward boundary, meaning that they might lose the landward most extent of their property (possibly a couple of metres for some properties) ▪ The wall will most likely be built from waterproof concrete constructed in situ ▪ The design of the wall needs to provide a structure that is robust enough to firstly provide a barrier, but then function as a retaining wall for fill when the property is raised.
Indicative costing	Total cost, including contingency is estimated to be $3 million ($2020).
Timing	It is assumed the structure will be installed in 2030.

[a] This excludes the RSL.

Note: 2030 installation date was determined in consultation with the Steering Committee, based on site approvals and development timeframes.

Source: Salients.

Forty-nine residential properties located in Precinct 20 were identified to be the primary beneficiaries from this option (Figure 3.26).

3.26 Option CP4 impacted residential properties

Data source: CIE.

CP8A/CP14 Staged Raising of Ungala Road

The aim of the option is to reduce inundation in Mankilli Street by raising Ungala Road (Bali Street to Grannies Pool) which is envisioned to act as a revetment. It will also be a staged process with sections of Ungala Road that are regularly inundated being raised first. The option description document notes this option is proposed in a sequence with raise and fill the Mankilli St area (part of AC1) and tidal gates on Ungala Road (CP8B).[43]

Figure 3.28 highlights the different road segment IDs for Ungala Road.

43 Note that option CP8B is not part of the range of options identified for the CBA.

3.27 Ungala Road Upgrade Segment

Note: The red line represents the component of Ungala Road to be upgraded.
Data source: CIE estimates based on LIDAR data.

Table 3.28 presents the current road heights at different segments of Ungala Road. For longer segments, we have taken measurements at two different points to gain an understanding of the slope of the road and taken the average elevation (mAHD) for that segment. The corner of Ungala Road, Bali and Mankilli Streets is at 1.59mAHD. However, the lower point is around 1.32m AHD, which we have considered to be the “point of weakness” on the road.

3.28 Ungala Road, length and elevation

Road Segment ID	Road length	Elevation point 1	Elevation point 2	Average
	m	mAHD	mAHD	mAHD
516992757 (Pacific Highway entrance)	24.46	2.08	.	2.08
517455180	20.12	2.02	.	2.02
505147314	72.70	1.82	1.98	1.90
517455179	35.99	1.75	1.69	1.72
501625258	89.22	1.74	1.65	1.69
515640528	**84.37**	**1.40**	**1.32**	**1.36**
501625247	**71.05**	**1.34**	**1.65**	**1.50**
511860730	314.02	1.68	1.59	1.63
515617478	102.51	1.83	1.93	1.88
505147305	60.60	1.91	2.20	2.05
505147320 (close to Granny's point)	184.00	1.30	1.07	1.19

Source: CIE estimates based on LiDAR and RMS Road Segments in GIS format.

The inundation data for Precinct 15 is presented in Table 3.29.

3.29 Exceedance probabilities, Precinct 15

EY	AEP	2020	2050
times	%	mAHD	mAHD
6	99.75	0.88	1.07
4	98.17	0.92	1.10
3	95.02	0.94	1.13
2	86.47	0.97	1.16
1	63.21	1.00	1.18
0.5	39.35	1.04	1.23
0.2	18.13	1.09	1.30
0.11	**10.00**	**1.14**	**1.34**
0.05	5.00	1.19	1.40
0.02	2.00	1.28	1.48
0.01	**1.00**	**1.35**	**1.56**
0.005	0.50	1.44	1.64
0.002	0.20	1.57	1.78
0.001	0.10	1.69	1.90
0.0005	0.05	1.83	2.04
0.0002	0.02	2.05	2.22
	PMF	2.19	2.51

Source: Salients Consulting.

For the purposes of our analysis, we assume that the road would need to be constructed to 1.59m AHD (the elevation at the corner of Ungala, Bali and Mankili Street) which equates to around a 0.2%AEP event in 2020, or a 1%AEP event by 2050. Based on this assumption, there's only a 155m segment of Ungala Road (approximately 6m wide) to be raised by an average of 0.24m.

3.30 Ungala Road Upgrade Segment

Note: The red line represents the component of Ungala Road to be upgraded.
Data source: CIE estimates based on LIDAR data.

PART II

Options analyses results

4 Options to raise and fill land and built assets

The options analysis is presented as follows:

- Chapter 4 below presents the options analysis for raise and fill of residential, commercial, public/recreation, and education properties (i.e. options AC1, AC4, AC5, and AC7).
- Chapter 5 presents the options analysis for the Swansea Holiday Park (AC6A, and AC6B).
- Chapter 6 presents the options analysis for Channel and Foreshore Protection works (CP4).
- Chapter 7 presents the options analysis for Road and Utility Infrastructure (Options AC2, AC3, CP8A/14). The road raisings presented here cover the whole case study area, including the raising of Ungala Road. The utility infrastructure raising options are linked to road raisings, given that utility infrastructure is often located within the road corridor.
- Chapter 8 presents the options analysis for wetlands (RA4, 5, and 6). This analysis is largely qualitative in nature and has, therefore, been treated separately.

Option AC1 Raise and fill residential areas

AADs - 30 years

For the scenario considered (limited to 16 properties), only one property is triggered under the 10% AEP raise trigger in the 30 year analysis, as shown in Table 4.1. The floor level at that property is already below the current (2020) 10% AEP raise trigger.

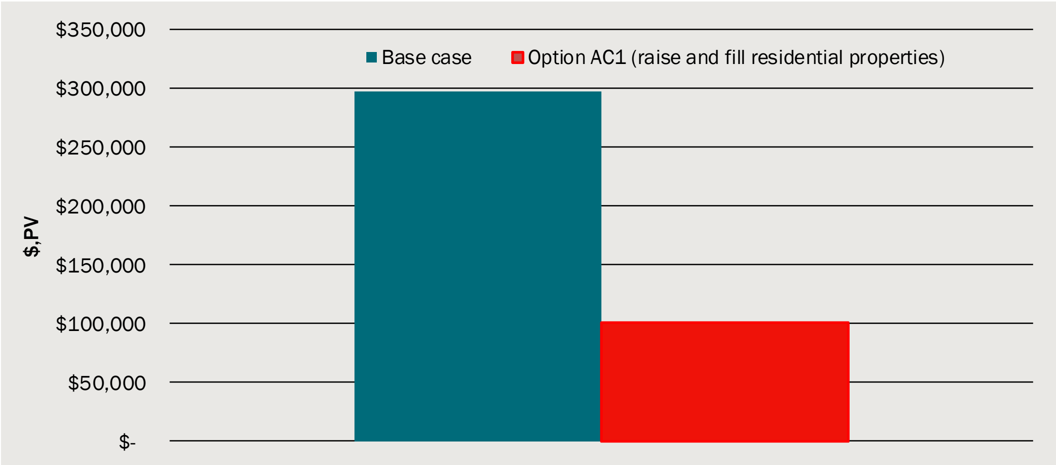
4.1 Option AC1 properties triggered - 30 year analysis

Property address	Precinct	Floor level	Ground level	Year raise & fill triggered
		metres above AHD	metres above AHD	Year
Property 1	40	0.87	0.75	2020

Source: CIE.

Chart 4.2 shows the estimated AADs under the base case and post raise/fill, over a 30 year evaluation period. Note, values are in PV terms. That is discounted to today's dollars.

4.2 Option AC1 AADs (PV) - 30 years



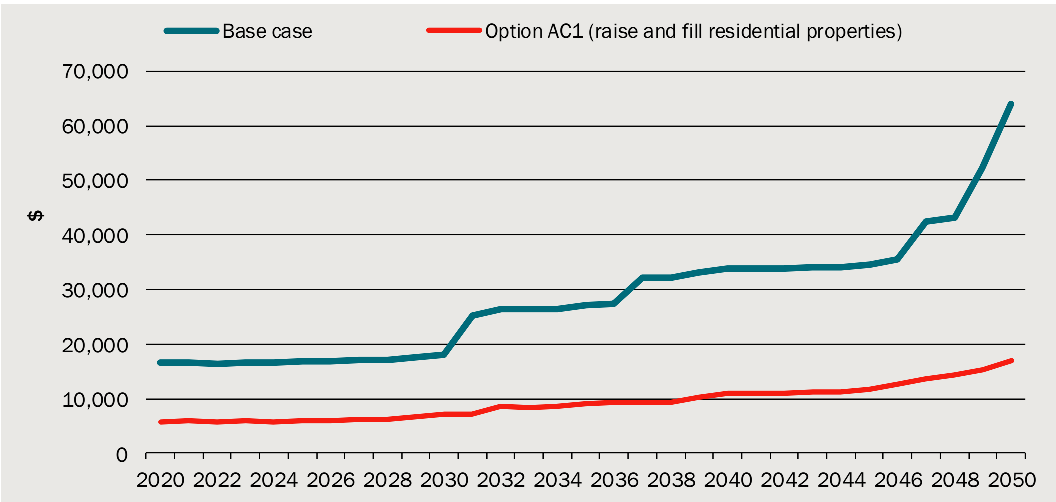
Note: AAD discounted by 7 per cent over a 30 year period.

Data source: CIE.

Undertaking raise and fill reduces AADs by $196,202 (PV) (Chart 4.2).

Chart 4.3 shows the estimated AADs (undiscounted), under the base case and post raise/fill, over the 30 year evaluation period.

4.3 Option AC1 AADs (undiscounted) - 30 years



Data source: CIE.

Most of the saved AADs occur in the last 10 years of the 30 year analysis (Chart 4.3).

AADs - 50 years

Three properties are triggered under the 10% AEP raise trigger in the 50 year analysis, as shown in Table 4.4.

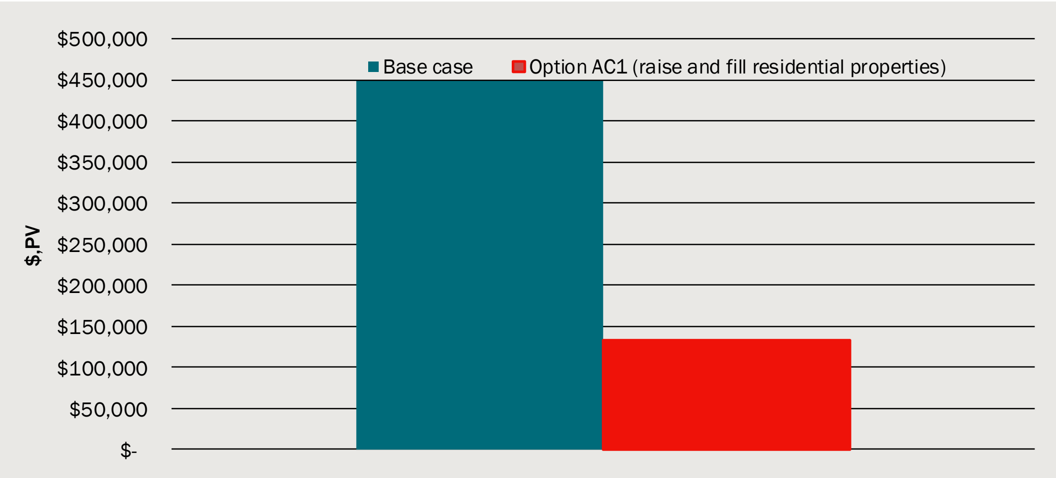
4.4 Option AC1 properties triggered - 50 year analysis

	Precinct	Floor level	Ground level	Year raise & fill triggered
Property 1	40	0.87	0.75	2020
Property 2	40	1.19	0.83	2066
Property 7	40	1.24	1.24	2070

Source: CIE.

Chart 4.5 shows the estimated PV AADs under the base case and post raise and fill, over a 50 year evaluation period.

4.5 Option AC1 AADs (PV) - 50 years



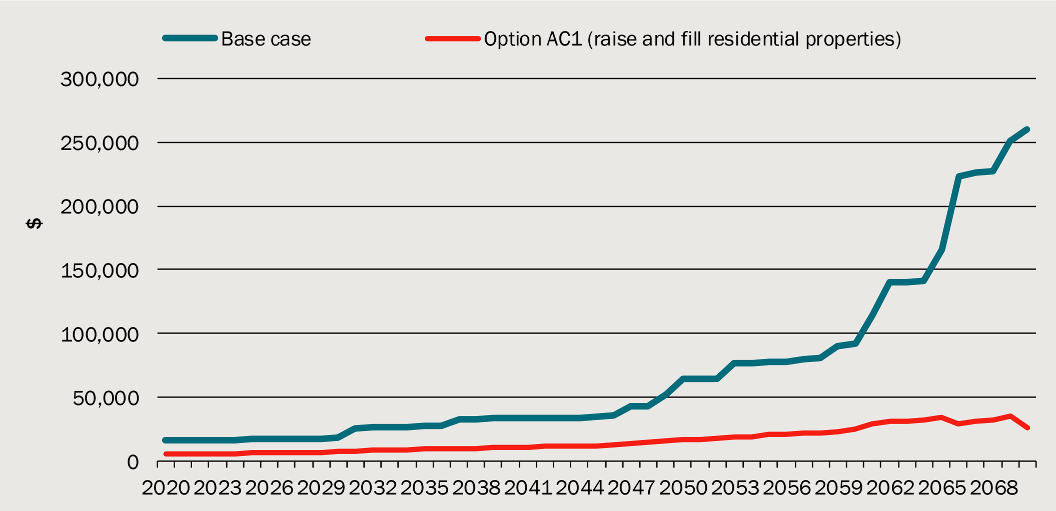
Note: AADs discounted by 7 per cent over a 50 year period.

Data source: CIE.

Undertaking raise and fill reduces AADs by $315,707 (Chart 4.5).

Chart 4.6 shows the estimated undiscounted AADs, under the base case and post raise and fill, over the 50 year evaluation period.

4.6 Option AC1 AADs (undiscounted) - 50 years



Data source: CIE.

Of interest, AADs increase at a faster rate beyond 2050 in the base case, with AADs roughly doubling every ten years in the chosen case study area, as shown in Chart 4.6 (blue line). This is associated with rising inundation levels over time, which in turn cause more properties to be inundated, at higher water levels. As such, most of the saved inundation costs (the difference between the blue and red lines) occurs in the later years of the 50 year analysis.

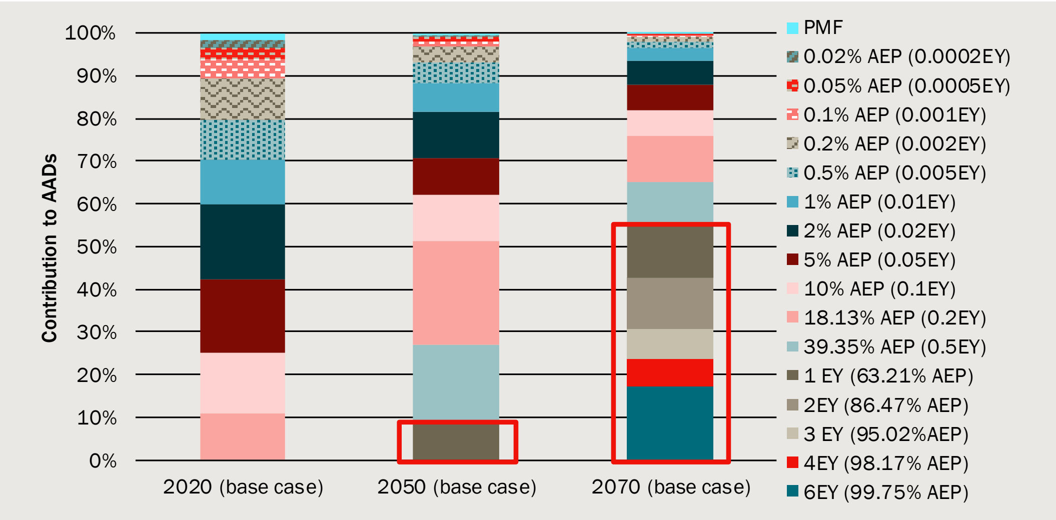
Although inundation costs increase significantly in the base case post 2050, these values are discounted more heavily than saved inundation costs that occur between 2020 and 2049, when calculating PVs.

Discounting explains why the difference in the AADs (in PV terms) between the base case (status quo) and raise/fill scenario are not as large as the observed difference between undiscounted AADs.

Inundation event probability contribution to AADs

Chart 4.7 shows the base case contribution of AADs by inundation events for the years 2020, 2050 and 2070. Chart 4.7 shows the same information post undertaking raise and fill. Multiple inundation events are those which occur with an EY of 1 or more (63.21% AEP event or higher).

4.7 Option AC1 contribution of inundation event probabilities to AADs (base case)



Note: Multiple annual event probabilities shown in red boxes.

Data source: CIE.

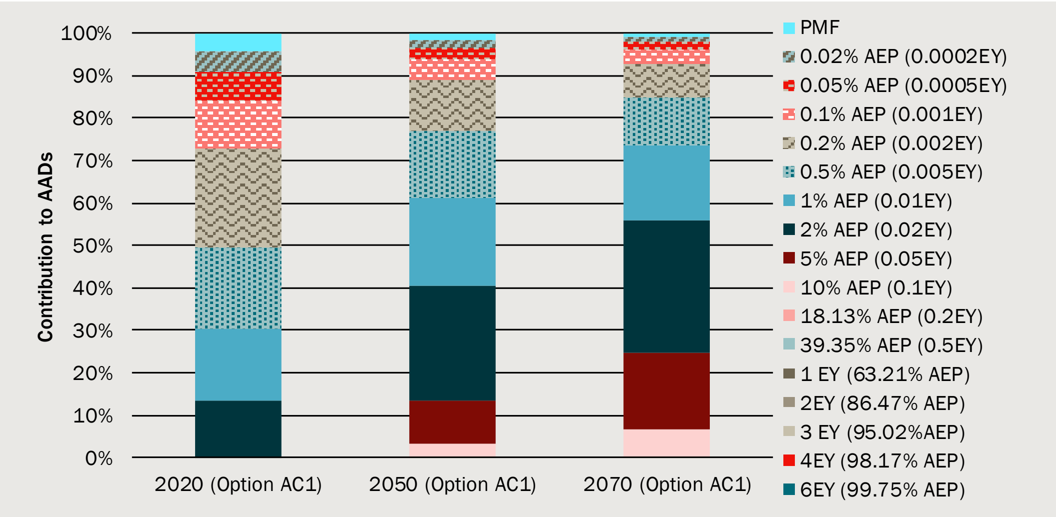
Chart 4.7 shows that in the base case the contribution of inundation events to AADs transitions from larger events in 2020, that is events with a low occurrence probability but high consequence, to more frequent events (1EY and greater) from 2050. For example, base case multiple annual inundation events increase from:

- 0 per cent ($0) of AADs in 2020
- 10 per cent ($5,442) of AADs in 2050, and
- 55 per cent ($144,709) of AADs in 2070.

Chart 4.7 indicates that the more frequent yearly inundation events (with higher probabilities and lower water levels) increasingly drive adaptive action for Option AC1, post 2050.

Chart 4.8 shows that undertaking raise and fill mitigates the growing risk from multiple inundation events (1EY, 63.21% AEP or higher), especially post 2050. This is because multiple inundation events, account for 0 per cent of AADs in 2020, 2050 and 2070 for Option AC1 (Chart 4.8), post raise and fill.

4.8 Contribution of inundation event probabilities to AADs (Option AC1)



Data source: CIE.

CBA – 30 years

Table 4.9 shows the CBA results for the 30 year analysis.

4.9 Option AC1 CBA - 30 years

Description		Comments
	$, (PV)	
Costs		
Raise and fill cost	49 098	140 m³ of ground area raised and filled
Construction costs	376 140	239 m² of building area constructed
Alternate accommodation costs	18 200	52 weeks in alternate accommodation
Total costs	443 439	
Benefits		
Avoided AADs	**196 202**	**$18 666 average saving per year (PV)**
Net benefit	**-247 237**	**1 property raised and filled**
BCR	**0.44**	

Note: 7 per cent discount rate.
Source: CIE.

Undertaking raise and fill for this option results in a net loss of $247,237 (PV), and BCR of 0.44 (Table 4.9).

CBA – 50 years

Table 4.10 shows the CBA results for the 50 year analysis.

4.10 Option AC1 CBA - 50 years

Description		Comments
	$, (PV)	
Costs		
Raise and fill cost	53 456	140 m³ of ground area raised and filled
Construction costs	405 644	239 m² of building area constructed
Alternate accommodation costs	19 534	52 weeks in alternate accommodation
Total costs	**478 634**	
Benefits		
Avoided AADs	**315 707**	**$55 253 average saving per year (PV)**
Net benefit	**-162 927**	**3 properties raised and filled**
BCR	**0.66**	

Note: 7 per cent discount rate.

Source: CIE

Undertaking raise and fill for this option results in a net loss of $162,927 (PV), and BCR of 0.66 (Table 4.10).

Option AC1 raise and fill residential properties sensitivity analyses

Discount rate sensitivity analysis

Tables 4.11 (30 year evaluation) and 4.12 (50 year evaluation) show the CBA results under alternate discount rates of 3 and 10 per cent, compared to the central analysis, which used 7 per cent.

4.11 Option AC1 CBA - 30 year discount rate sensitivity

Description	Central case (7 per cent)	Sensitivity (3 per cent)	Sensitivity (10 per cent)
	$, (PV)	$, (PV)	$, (PV)
Costs			
Raise and fill cost	49 098	49 098	49 098
Building construction costs	376 140	376 140	376 140
Alternate accommodation costs	18 200	18 200	18 200
Total costs	**443 439**	**443 439**	**443 439**
Benefits			
Avoided AADs	**196 202**	**338 627**	**141 790**
Net benefit	**-247 237**	**-104 811**	**-301 649**
BCR	**0.44**	**0.76**	**0.32**

Source: CIE.

4.12 Option AC1 CBA - 50 year discount rate sensitivity

Description	Central case (7 per cent)	Sensitivity (3 per cent)	Sensitivity (10 per cent)
	$, (PV)	$, (PV)	$, (PV)
Costs			
Raise and fill cost	53 456	76 010	50 263
Building construction costs	405 644	564 134	382 085
Alternate accommodation costs	19 534	26 767	18 547
Total costs	**478 634**	**666 911**	**450 896**
Benefits			
Avoided AADs	**315 707**	**942 617**	**180 011**
Net benefit	**-162 927**	**275 706**	**-270 884**
BCR	**0.66**	**1.41**	**0.40**

Source: CIE.

The results are heavily impacted from a change to the discount rate, with an improvement to the net benefit and BCR under lower discount rates (Table 4.11 for the 30 year analysis and Table 4.12 for the 50 year analysis). This is because the raise trigger is breached immediately for one property in the 30 year analysis, and as such the chosen discount rate has minimal impact on costs. However, a lower discount rate increases the PV of future saved AADs, which in turn increases the net benefits and BCR. Converse logic applies to higher discount rates.

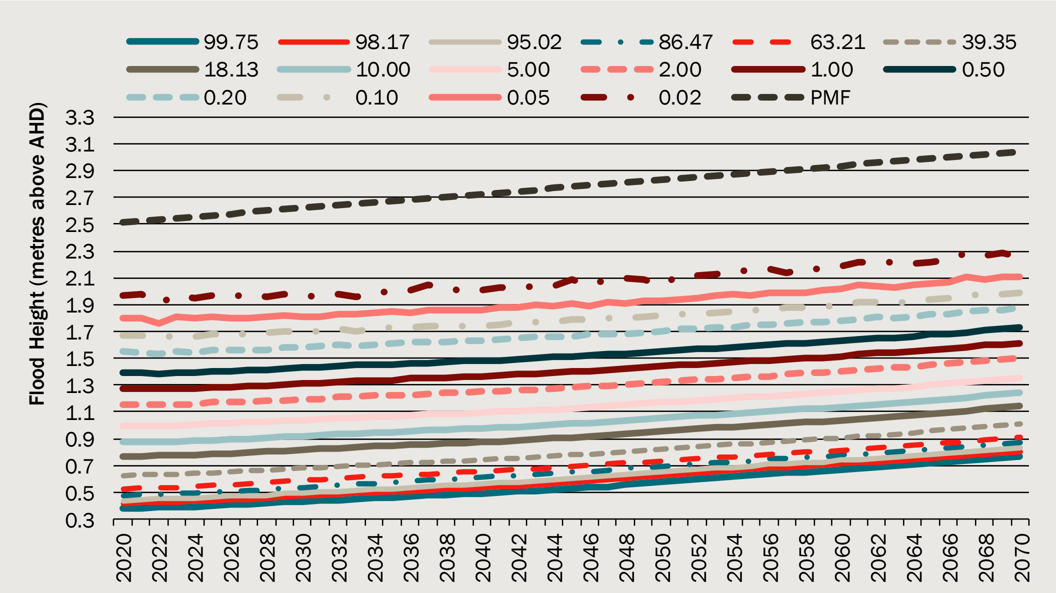
This suggests that raise and fill is a viable option for respective property owners under low interest rates and long-time frames.

Water level sensitivity analysis

As noted in chapter 2, inundation water level heights prepared by Salients et al. 2020[44] are a key input to calculating the estimated AADs. A sensitivity in which a uniform inundation water level increase of 0.2 metres (AHD) for assessed AEPs has been undertaken to test the impacts on AAD and CBA results. Inundation levels in Precinct 40 adopted from the core model are shown in Chart 4.13, with the sensitivity inundation water levels shown in Chart 4.14.

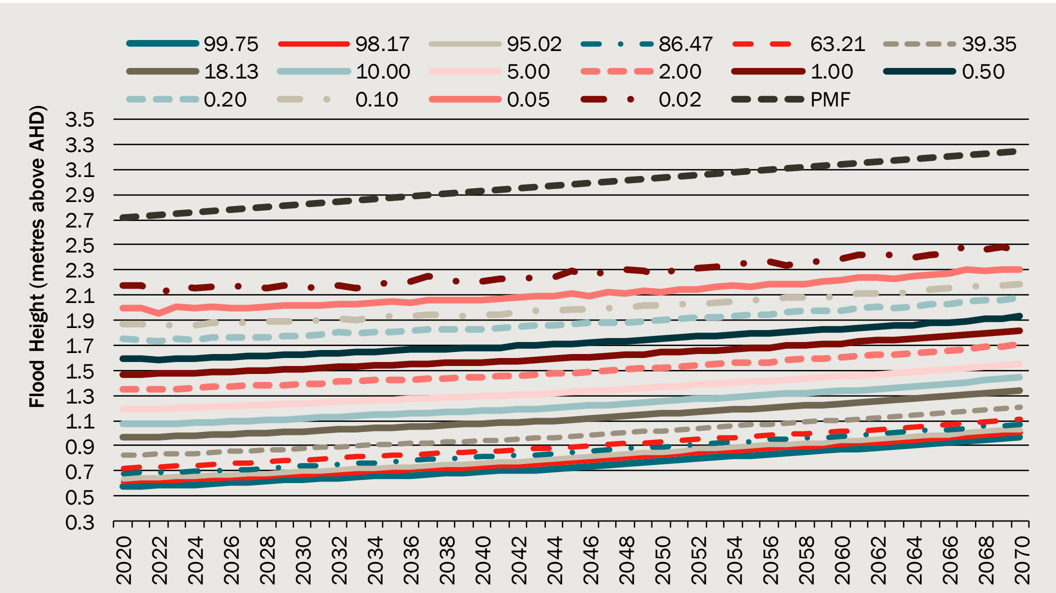
44 Salients, University of Queensland, Flood Focus Consulting, 2020. *Probabilistic Hazard Assessment to Support Local Adaptation Planning for Pelican, Blacksmiths and Swansea - Final.*

4.13 Inundation water level heights - Precinct 40



Data source: Data source: Salients et al. 2020.

4.14 Inundation water level heights sensitivity - Precinct 40

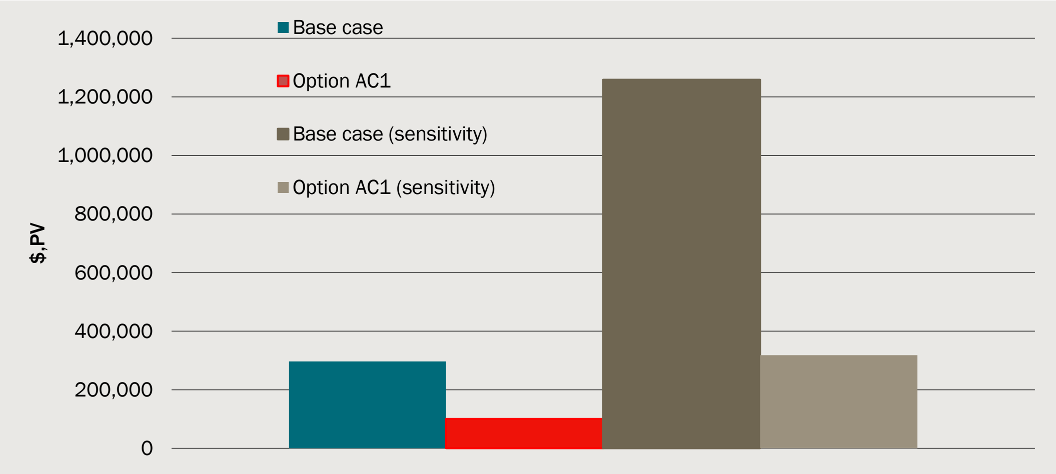


Data source: Data source: Salients et. al 2020; CIE.

AADs for Water Level sensitivity analysis

Chart 4.15 shows the 30 year AAD PV results for the base case and post raise and fill, assuming the central case and sensitivity water levels. Chart 4.16 shows the undiscounted AADs over the entire 30 year evaluation period.

4.15 Water height sensitivity AADs (PV) - 30 years



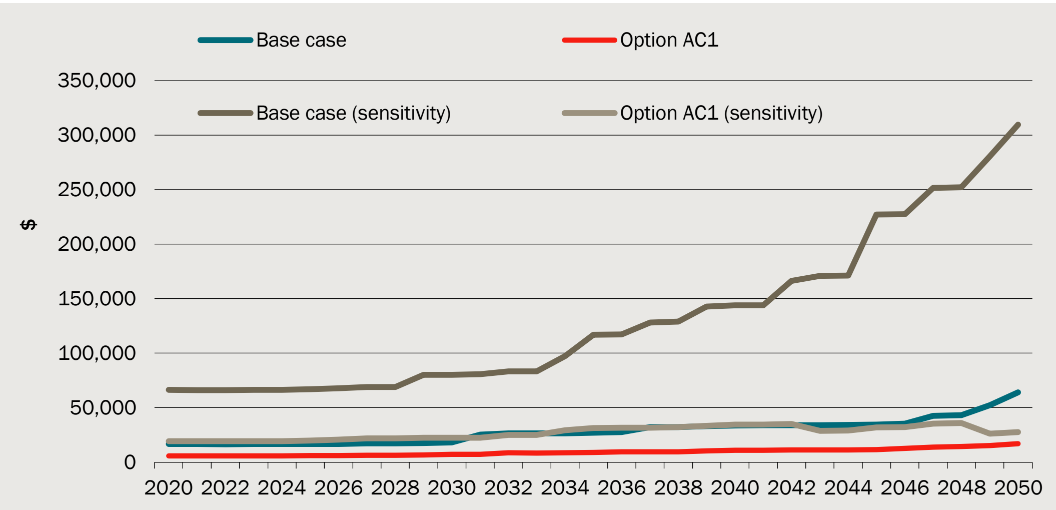
Note: AADs discounted by 7 per cent over a 30 year period.

Data source: CIE.

Chart 4.15 shows the estimated AADs in the sensitivity base case are four times greater than that estimated using the core water level heights. Further, the saved AADs in the sensitivity of $900,000 (difference between the grey bars) are also much greater than the core analysis of $200,000 (difference between the blue and red bars). Reasons for this are:

- In the sensitivity analysis, three properties are triggered for raise and fill, compared to 1 property under the original water level heights, and
- most of the saved AADs occur sooner, from 2033, compared to 2050 (Chart 4.16).

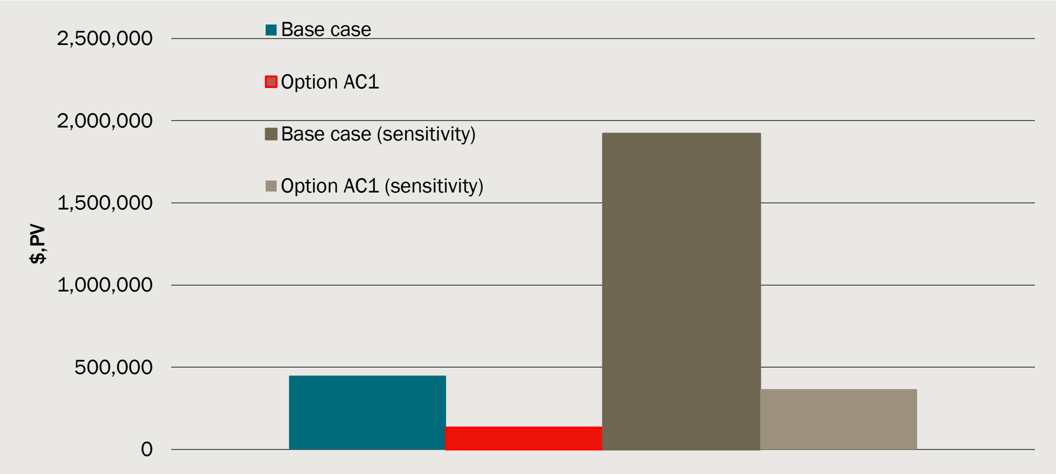
4.16 Water height sensitivity AADs (undiscounted) - 30 years



Data source: CIE.

50 year PV AADs for the central case and increased water level scenario are shown in Chart 4.17.

4.17 Water height sensitivity AADs (PV) - 50 years



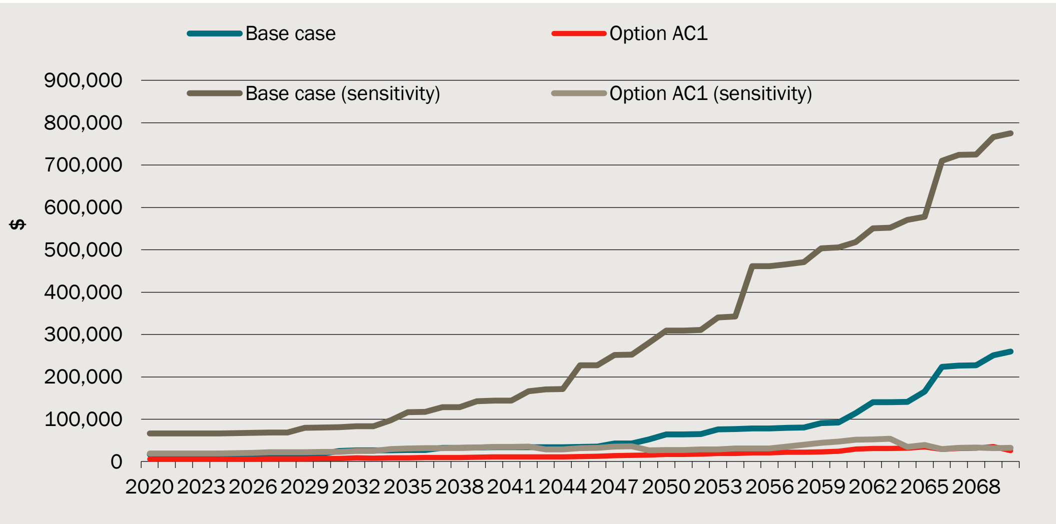
Note: AADs discounted by 7 per cent over a 30 year period.

Data source: CIE.

The difference between base case AADs are even greater ($1.9 million in the 50 year sensitivity analysis, compared to $450,000 under the central case 50 years analysis). Further, saved AADs from undertaking raise and fill are also larger at $1.6 million (50 year sensitivity), compared to $316,000 (50 year central case). Reasons for this are:

- In the sensitivity analysis, seven properties are triggered for raise and fill compared to three under the original water level heights, and
- AAD savings beyond 2050 are much higher than the core 50 year analysis (Chart 4.18).

4.18 Water height sensitivity AADs (undiscounted) - 50 years

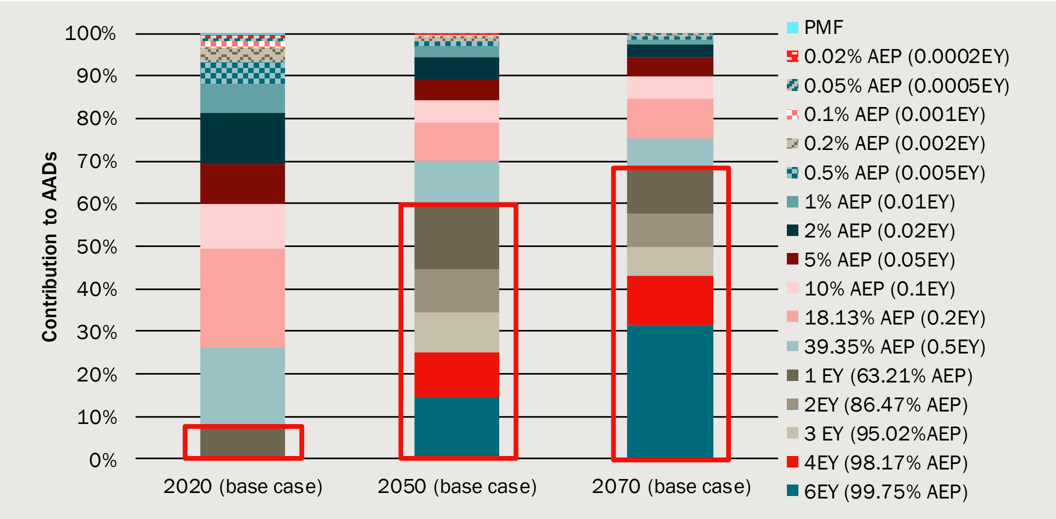


Data source: CIE.

Inundation event contribution to AADs

Charts 4.19 and 4.20 show the contribution of inundation events to AADs in 2020, 2050 and 2070, under a sensitivity of +0.2m AHD water levels for the base case and post raise and fill respectively.

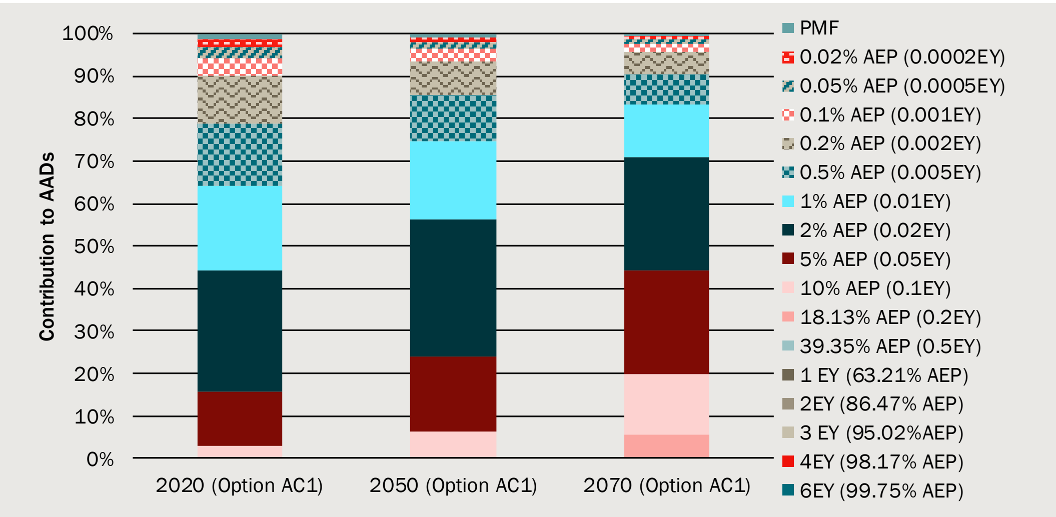
4.19 Option AC1 +0.2m AHD sensitivity contribution of inundation event probabilities to AADs (base case)



Note: Multiple annual inundation event probabilities shown in red boxes.

Data source: CIE.

4.20 Contribution of inundation event probabilities to AADs (Option AC1 +0.2m AHD sensitivity)



Data source: CIE.

Growing AADs in the base case, and subsequent increased temporal AAD savings post raise and fill, coincide with multiple inundation events (1EY (63.21% AEP) and greater) accounting for a growing share of AADs in the base case, which are subsequently mitigated post protection works installation. For example, base case multiple annual inundation events increase from (Chart 4.19):

- 8 per cent ($5,442) of AADs in 2020
- 60 per cent ($184,230) of AADs in 2050, and
- 68 per cent ($525,074) of AADs in 2070.

In contrast, 0 per cent of multiple inundation events account for AADs in 2070 for Option AC1 (Chart 4.20), post raise and fill.

This re-iterates that the more frequent yearly inundation events (with high probabilities and lower water levels) drive adaptive action for Option AC1, post 2050, especially under a higher water level sensitivity.

CBA – water level sensitivity analysis

The CBA results show an improvement to the net benefit and BCR for both the 30 year (Table 4.21) and 50 year analysis (Table 4.22) under the inundation water level sensitivity.

4.21 Water height sensitivity CBA results - 30 years

Description	Central case (core water levels)	Sensitivity (+0.2 mAHD water levels)
	$, (PV)	$, (PV)
Costs		
Raise and fill cost	49 098	78 302
Building construction costs	376 140	505 433
Alternate accommodation costs	18 200	24 179
Total costs	**443 439**	**607 914**
Benefits		
Avoided AADs	**196 202**	**941 176**
Net benefit	**-247 237**	**333 262**
BCR	**0.44**	**1.55**

Note: 7 per cent discount rate.

Source: CIE.

4.22 Water height sensitivity CBA results - 50 years

Description	Central case (core water levels)	Sensitivity (+0.2 mAHD water levels)
	$, (PV)	$, (PV)
Costs		
Raise and fill cost	53 456	90 960
Building construction costs	405 644	562 722
Alternate accommodation costs	19,534	27 287
Total costs	**478 634**	**680 969**
Benefits		
Avoided AADs	**315 707**	**1 552 717**
Net benefit	**-162 927**	**871 749**
BCR	**0.66**	**2.28**

Note: 7 per cent discount rate.

Source: CIE.

This sensitivity emphasizes:

- a clear need to continue to monitor water levels and gain more data to determine if a statistically significant structural break has occurred between recently observed water levels and the longer historical record[45]
- the need to take future water levels into account and revisit adaptation options and models including, CBA as needed, and
- the need to tie water level analysis and potential deviations from current modelling outputs to the ongoing LAP review.

Trigger levels and property raise height sensitivity analysis

Option AC1 raise trigger and raise height sensitivity AADs

Table 4.23 shows the range of raise trigger and raise heights in 2020 and 2050, as well as the number of properties triggered by 2050. The central case uses a raise:

- trigger of a 10% AEP event inundation probability level, and
- height of a 1% AEP event inundation probability level.

45 We understand that such work is already being undertaken with numerous continuous water level gauges already used to monitor both local water levels (Swansea bridge, Belmont being key to this specific study area), as well as ocean tides (Sydney and Shoal Bay being key gauges to the region).

4.23 Option AC1 raise trigger and raise height thresholds and risk tolerance

EY	AEP event	2020 inundation level (Precinct 40)	2050 inundation level (Precinct 40)	Number of properties triggered by 2050 [a]	Raise level risk tolerance
#	%	m AHD	m AHD	#	
6	99.75	0.38	0.58	0	High risk tolerance
4	98.17	0.41	0.62	0	
3	95.02	0.44	0.65	0	
2	86.47	0.48	0.69	0	
1	63.21	0.52	0.73	0	
0.5	39.35	0.63	0.82	0	
0.2	18.13	0.77	0.95	1	
0.1	10	0.87	1.06	1	
0.05	5	1.00	1.17	1	
0.02	2	1.15	1.32	1	
0.01	1	1.27	1.44	7	
0.005	0.5	1.39	1.55	9	
0.002	0.2	1.55	1.70	13	
0.001	0.1	1.67	1.80	13	
0.0005	0.05	1.80	1.93	15	
0.0002	0.02	1.97	2.05	16	
	PMF	2.52	2.83	16	Most risk averse

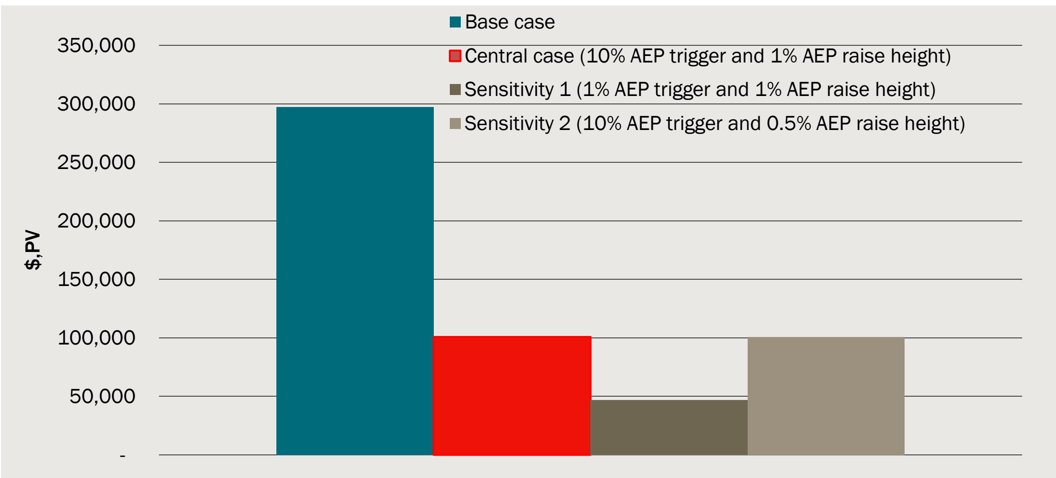
[a] 30 year analysis.

Note: Excludes freeboard and additional raise allowance for SLR.

Sources: Salients, University of Queensland, Flood Focus Consulting, 2020. *Probabilistic Hazard Assessment to Support Local Adaptation Planning for Pelican, Blacksmiths and Swansea - Final*; CIE.

The 30 year AAD PV results for the base case, central case, sensitivity 1 (1% AEP trigger and 1% AEP raise height) and sensitivity 2 (10% AEP raise trigger and 0.5% AEP raise height) are shown in Chart 4.24.

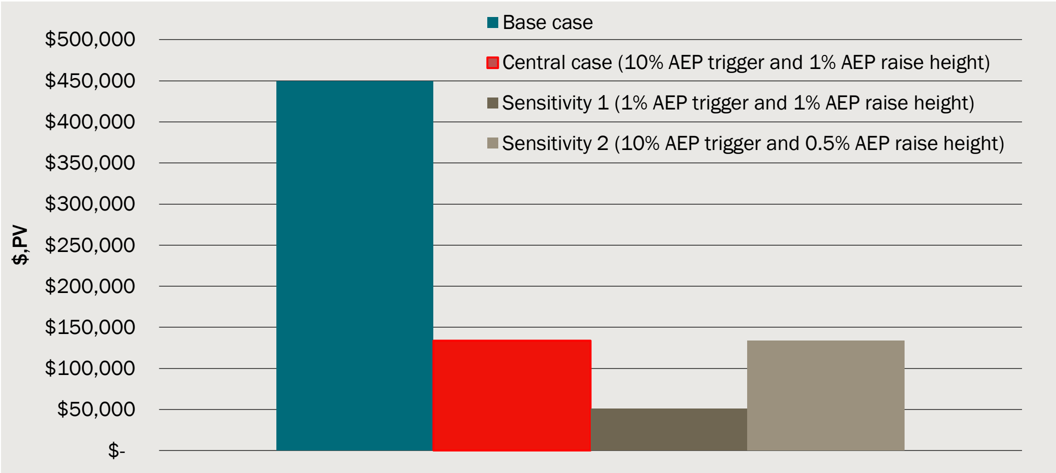
4.24 Option AC1 raise trigger and raise height sensitivity AADs - 30 years



Note: AADs discounted by 7 per cent over a 30 year period.

The 50 year AAD PV results for the base case, central case (without sensitivities), sensitivity 1 (1% AEP trigger 1% AEP raise height) and sensitivity 2 (10% trigger height and 0.5% raise height) are shown in Chart 4.25.

4.25 Option AC1 raise trigger and raise height sensitivity AADs - 50 years



Note: AADs discounted by 7 per cent over a 50 year period.

Data source: CIE.

Option AC1 raise and fill trigger and raise height sensitivity analysis CBA results

CBA results for the chosen sensitivities for a 30 year evaluation period and 50 year evaluation period are shown in Tables 4.26 and 4.27 respectively.

4.26 Option AC1 raise trigger and raise height sensitivity CBA results - 30 years

Description	Central case - 10% AEP trigger and 1% AEP raise height	Sensitivity 1 - 1% AEP trigger and 1% AEP raise height	Sensitivity 2 – 10% AEP trigger and 0.5% AEP raise height
	$, (PV)	$, (PV)	$, (PV)
Costs			
Raise and fill cost	49 098	165 922	54 306
Building construction costs	376 140	1 435 693	376 140
Alternate accommodation costs	18 200	67 803	18 200
Total costs	**443 439**	**1 669 418**	**448 646**
Benefits			
Avoided AADs	**196 202**	**250 261**	**196 213**
Net benefit	**-247 237**	**-1 419 156**	**-252 433**
BCR	**0.44**	**0.15**	**0.44**

Note: 7 per cent discount rate.

Source: CIE.

4.27 Option AC1 raise and fill trigger and raise height sensitivity CBA results - 50 years

Description	Central case - 10% AEP trigger and 1% AEP raise height	Sensitivity 1 - 1% AEP trigger and 1% AEP raise height	Sensitivity 2 – 18.13% AEP trigger and 5% AEP raise height
	$, (PV)	$, (PV)	$, (PV)
Costs			
Raise and fill cost	53 456	182,020	59 106
Building construction costs	405 644	1 527 794	405 644
Alternate accommodation costs	19 534	72 872	19 534
Total costs	**478 634**	**1 782 686**	**484 284**
Benefits			
Avoided AADs	**315 707**	**398 532**	**315 719**
Net benefit	**-162 927**	**-1 384 153**	**-168 565**
BCR	**0.66**	**0.22**	**0.65**

Note: 7 per cent discount rate.

Source: CIE.

Tables 4.26 and 4.27 indicate that raise and fill under Option AC1 are sensitive to the chosen raise trigger and raise heights, as well as the analysis period. In general:

1 the more risk averse raise trigger chosen, the more AADs saved, as more properties are raised. Higher raise heights also save more AADs. However, the saved AADs are offset by even higher raise and fill and construction costs. The result is no improvement to the net benefit (or BCR)
   – This indicates that marginal saved AADs are disproportionately lower than marginal raise and fill and construction costs. The central case scenario raise trigger and raise heights are, therefore, optimal for the 30 year analysis. For example:
      … six more properties (7 in total) are triggered under Scenario 1, compared to the central case, over the 30 year analysis, thus increasing raise and fill and construction costs marginally more than saved AADs.
      … an additional $12 (PV) worth of AADs are saved by choosing a 0.5% AEP raise height (scenario 2), compared to a 1% AEP raise height (central case). This is completely offset however, by an additional $5,208 (PV) in raise and fill cost.

2 the longer the analysis period, the higher the net benefit and BCR.
   – For example, 1 property is triggered under scenario 2 for both the 30 and 50 year analysis, however more saved AADs are included in the 50 year analysis for the same costs as the 30 year analysis, thus improving the net benefit and BCR.

Construction cost sensitivity analysis

Construction costs account for over 80 per cent of total costs. The central case uses average construction costs sourced from the *ABS 8752.0 - Building Activity.*[46] In practice, construction costs are often context specific, associated with the type of property, location, and availability of trades at a particular point in time.

Tables 4.28 and 4.29 show CBA results of reduced construction costs of $1,262/m^2 and $1,104/m^2, for 30 year and 50 years respectively.

4.28 Option AC1 construction cost sensitivity CBA results - 30 years

Description	Central case ($1 577/m^2)	Sensitivity ($1 262/m^2)	Sensitivity 2 ($1 104/m^2)
	$, (PV)	$, (PV)	$, (PV)
Costs			
Raise and fill cost	49 098	49 098	49 098
Building construction costs	376 140	301 008	262 130
Alternate accommodation costs	18 200	18 200	18 200
Total costs	**443 439**	**368 306**	**329 428**
Benefits			
Avoided AADs	**196 202**	**196 202**	**196 202**
Net benefit	**-247 237**	**-172 202**	**-133 226**
BCR	**0.44**	**0.53**	**0.60**

Note: 7 per cent discount rate.

Source: CIE.

4.29 Option AC1 construction cost sensitivity CBA results - 50 years

Description	Central case ($1 577/m^2)	Sensitivity ($1 262/m^2)	Sensitivity 2 ($1 104/m^2)
	$, (PV)	$, (PV)	$, (PV)
Costs			
Raise and fill cost	53 456	53 456	53 456
Building construction costs	405 644	324 618	282 690
Alternate accommodation costs	19 534	19 534	19 534
Total costs	**478 634**	**397 608**	**355 680**
Benefits			
Avoided AADs	**315 707**	**315 707**	**315 707**
Net benefit	**-162 927**	**-81 901**	**-39 974**
BCR	**0.66**	**0.79**	**0.89**

Note: 7 per cent discount rate.

Source: CIE.

46 ABS 8752.0 2020, *Building Activity, Australia, Dec 2019* (data cubes 'Building Activity: Average Cost' and 'Building Activity: Average Floor Area' for NSW)

Reducing these costs by 20 per cent, from $1,577/m^2 to $1,262/m^2 improves the net benefit and BCR, as shown in Tables 4.28 (30 year analysis) and 4.29 (50 year analysis).

Reducing construction costs by 30 per cent to $1,104/m^2, improves the net benefit and BCR even further, such that the net benefit is almost positive in the 50 year analysis, with a BCR close to 1.

Given this, site specific construction costs should be explored prior to undertaking raise and fill options.

Option AC1 raise and fill residential areas CBA summary discussion

For the scenario considered (limited to 16 properties), only one property is triggered under the 10% AEP raise trigger in the 30 year analysis, and 3 properties over 50 years. Most of the saved AADs occur post 2050, with multiple annual inundation events accounting for a growing share of AADs over time.

The CBA results and subsequent sensitivity analyses highlight that the greatest chance of achieving a positive net benefit and BCR greater than 1 is when:

- raise and fill adaptation is delayed, since avoided damages occur predominately post 2050
- a lower discount rate is used, as this increases the PV of future saved AADs
- higher inundation water levels are used, as this increases the saved AADs post raise and fill, noting the need to:
  - continue to monitor water levels and gain more data to determine if a statistically significant structural break has occurred between recently observed water levels and the longer historical record used for the CBA
  - take future water levels into account and revisit adaptation options and models including, CBA as needed, and
  - tie water level analysis and potential deviations from current modelling outputs to the ongoing LAP review.
- a longer evaluation period is considered, as this results in more saved AADs included in the analysis, and
- lower construction costs are assumed, noting they account for over 80 per cent of costs.

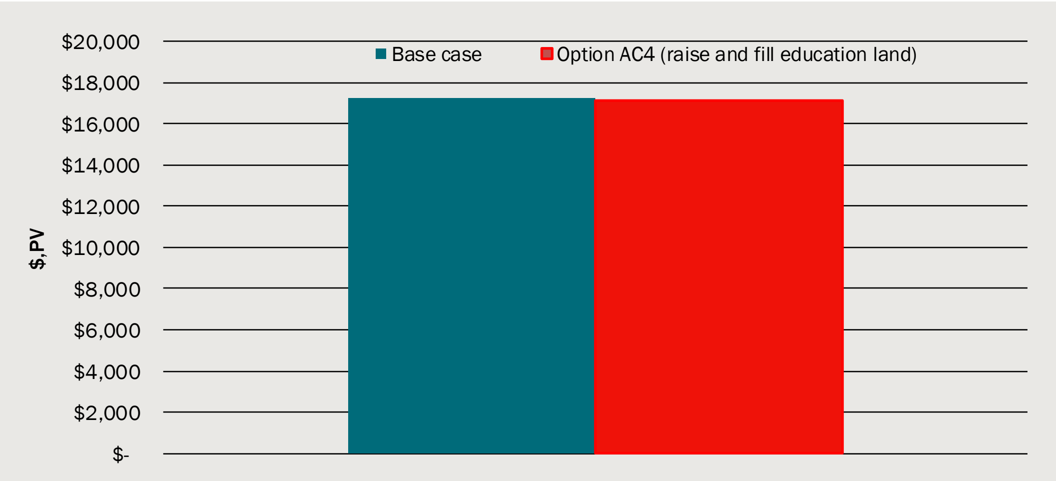
The chosen trigger and raise heights have mixed impact on the CBA results, with the more risk averse trigger chosen, the more AADs are saved, as more properties are raised. However, the saved AADs are offset by even higher raise and fill and construction costs. The result is no improvement to the net benefit or BCR. This indicates that marginal saved AADs are disproportionately lower than marginal raise and fill and construction costs. The central case scenario raise trigger and raise height are therefore optimal for the 30 year analysis.

Option AC4 Raise and fill education land (schools)

AC4 AADs (PV) - 30 years

Chart 4.30 shows the PV AADs under the base case and post raise and fill.

4.30 Option AC4 AADs - 30 years

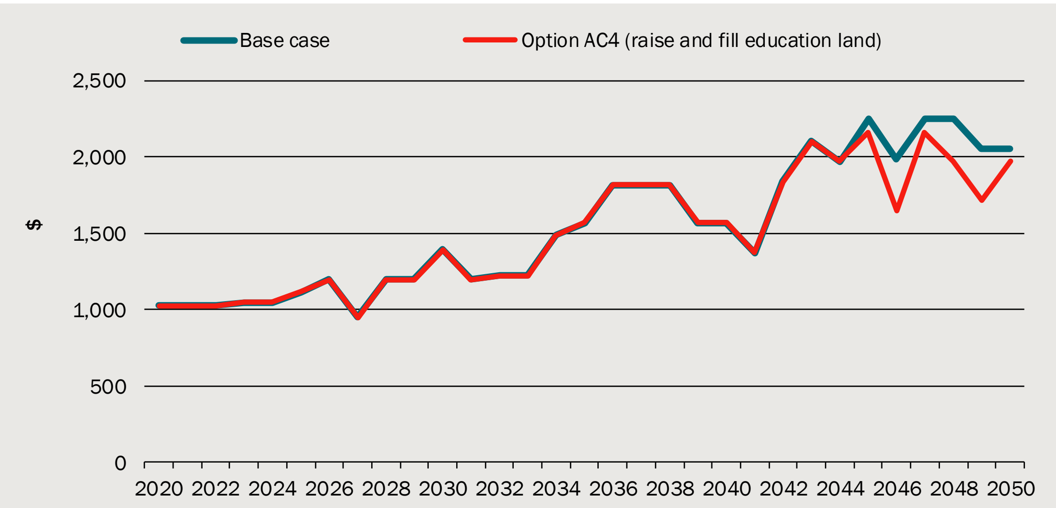


Note: AADs discounted by 7 per cent over a 30 year period. Raise heights include an additional 0.5 metres freeboard.

Data source: CIE.

Chart 4.31 shows the AADs under the base case and post raise and fill over 30 years.

4.31 Option AC4 AADs (undiscounted) - 30 years



Data source: CIE.

Chart 4.30 shows that undertaking raise and fill reduces AADs by $166 (PV). Of interest:

- most of the saved AADs occur in the last six years of the 30 year analysis (Chart 4.31), and
- saved AADs do not occur immediately post raise and fill, because the present-day floor level in all cases are above the chosen raise height, at the time the ground level

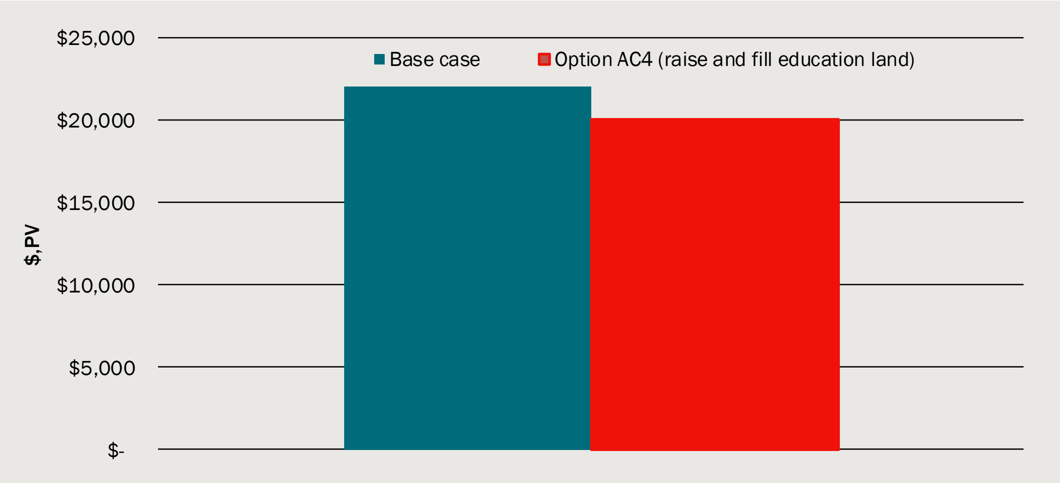
raise test is triggered.[47] That is, although the ground level trigger is reached, the proposed floor height is below the present-day floor height.

– We have, therefore, assumed that the habitable floor levels will be raised at the time when the chosen raise height is above the present-day floor level.

AC4 AADs - 50 years

Chart 4.32 shows the PV AADs under the base case and post raise and fill using a 50 year analysis period. Undertaking raise and fill reduces AADs by $1,984 (PV).

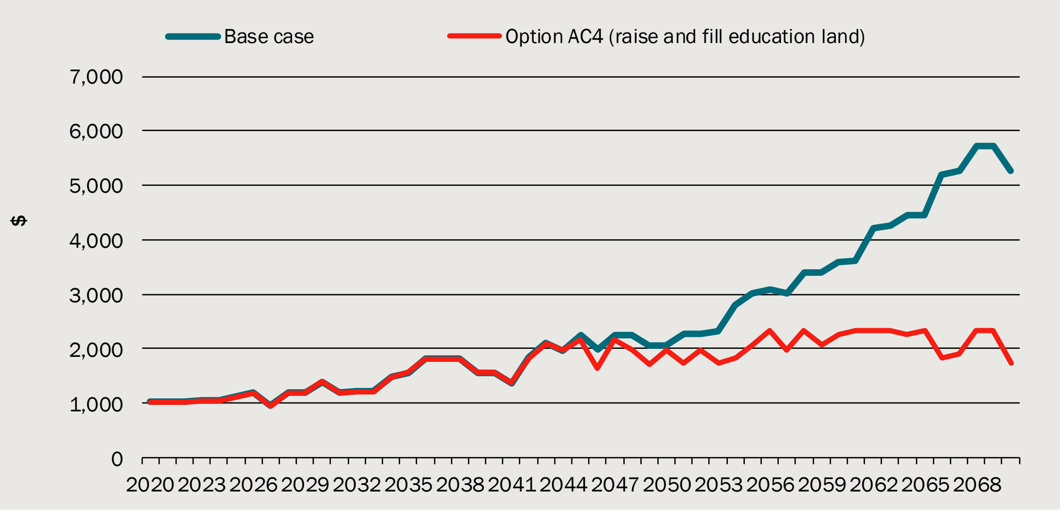
4.32 Option AC4 AADs (PV) - 50 years



Note: AADs discounted by 7 per cent over a 30 year period. Raise heights include an additional 0.5 metres freeboard.
Data source: CIE.

Chart 4.33 shows the AADs under the base case and post raise and fill over 50 years.

4.33 Option AC4 AADs (undiscounted) - 50 years



Data source: CIE.

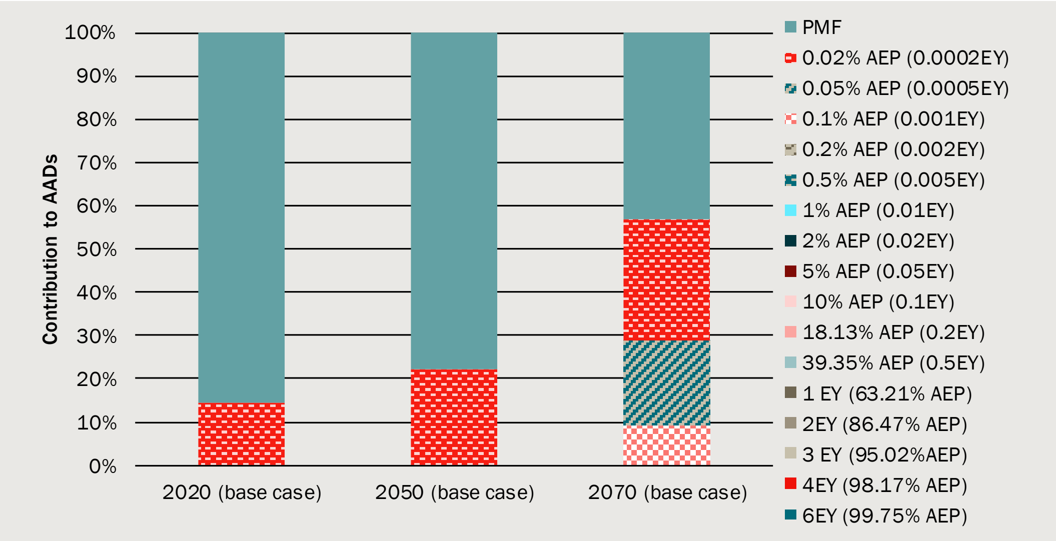
47 2028 for Swansea Public School, 2030 for St Patricks and 2032 for Pelican Flat Public School.

Of interest, most saved AADs occur beyond 2050 (Chart 4.33).

Inundation event contribution to AADs

Chart 4.34 shows the base case contribution of AADs by inundation events for the years 2020, 2050 and 2070. Chart 4.35 shows the same information post undertaking raise and fill. Multiple inundation events are those which occur with an EY of 1 or more.

4.34 Option AC4 contribution of inundation events to AADs (base case)

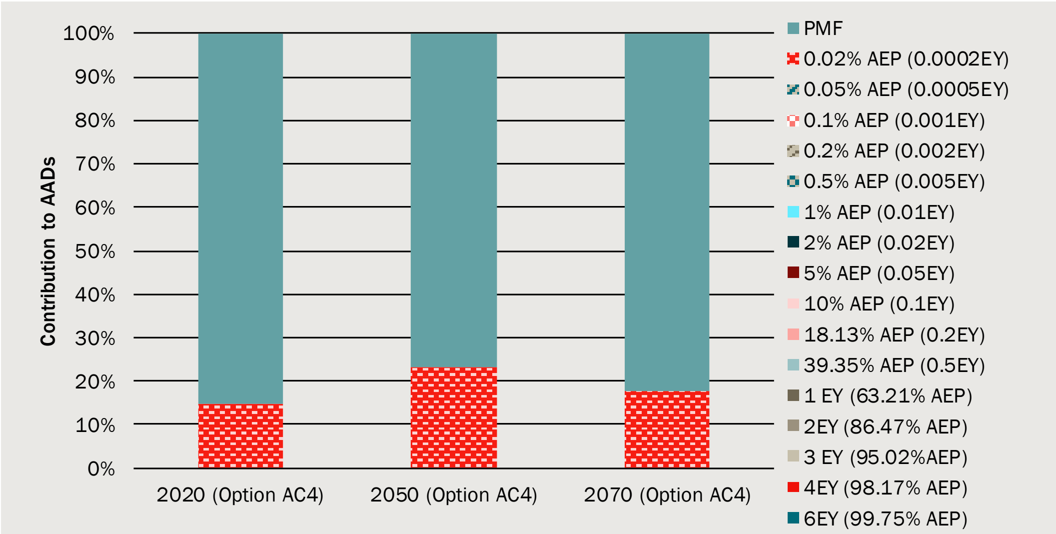


Data source: CIE.

Chart 4.34 shows that the less frequent 'big events' (major storms with high water levels) drive adaptive action for Option AC4 raise and fill education land. For example, the PMF and 0.02% AEP event account for:

- all (100 per cent) base case AADs in 2020 ($1,022) and 2050 ($2,053), and
- 70 per cent of AADs in 2070, with the 0.05% AEP and 0.1% AEP events accounting for the remaining 30 per cent ($5,273 AAD in total).

4.35 Contribution of inundation events to AADs (Option AC4)



Data source: CIE.

Chart 4.35 shows that undertaking raise and fill mitigates some of the 'big event' AADs, with the PMF and 0.02% AEP events accounting for 100 per cent of AADs in 2020 ($1,022), 2050 ($1,966) and 2070 ($1,736).

Lost earnings from school disruption

We have estimated the future earnings loss incurred by students when they are prevented from attending school due to water inundation above ground level. This is done as follows:

- We determine the inundation probability events at which the respective schools are inundated for each separately identified school land parcel (that is land parcels with unique land and property database ID numbers).[48]
- This is then converted to annual lost school days using the expected number of occurrences per year. For example, the 2020 estimated school lost days are shown in Table 4.36.
- The number of lost school days are multiplied by the estimated value of a school day using the return to education from World Bank 2018[49] and the average weekly wage.[50] Values are shown in Table 4.37.
- The per student lost value is multiplied by the number of students at the respective school (Table 4.37).

48 Note: Swansea Public School and St Patricks each have three separate land parcels with unique land and property data ID numbers and Pelican Flat has 1 parcel of land.

49 World Bank 2018, *Returns to Investment in Education*, p. 5, http://documents1.worldbank.org/curated/en/442521523465644318/pdf/WPS8402.pdf

50 We assume that students are aged 9 at the time of disruption and commence earning an income at 18. We, therefore, delay the lost earnings incurred by 9 years and discount this back to today's dollars.

4.36 Calculation of estimated lost school days in 2020

Annual AEP Event	Number of school land parcels inundated (A)	Expected Number of Occurrences per year (EY) (B)	Estimated lost school days (A x B)
Per cent	Number	Number	Number
99.75	0	6	0.0
98.17	0	4	0.0
95.02	0	3	0.0
86.47	0	2	0.0
63.21	0	1	0.0
39.35	0	0.5	0.0
18.13	0	0.2	0.0
10	0	0.11	0.0
5	4	0.05	0.2
2	7	0.02	0.1
1	7	0.01	0.1
0.5	7	0.005	0.0
Total			**0.4**

Note: Swansea Public School and St Patricks each have three separate land parcels with unique land and property data ID numbers and Pelican Flat has 1 parcel of land.

Source: CIE.

4.37 Estimation of future earnings loss incurred by students from inundation events

Measure	Value	Source
Estimated value of a school day		
Return to an additional year of schooling [c]	8.8%[a]	World Bank 2018
Full time adult average ordinary time annual earnings	$86 237[b]	ABS
School students		
St Patricks	152	Catholic Schools Office Diocese of Maitland-Newcastle 2018, *2018 Annual School report*
Swansea Public School	230	NSW Government 2020, *Swansea Public School 2019 Annual Report*, June
Pelican Flat Public School	65	NSW Government 2020, *Pelican Flat Public School 2019 Annual Report*, April

[a] We convert this to a daily return by dividing by 365.

[b] $1,658 average weekly wage as per, *ABS: Table 2 Average Weekly Earnings, Australia (Dollars) - Seasonally Adjusted*, multiplied by 52.

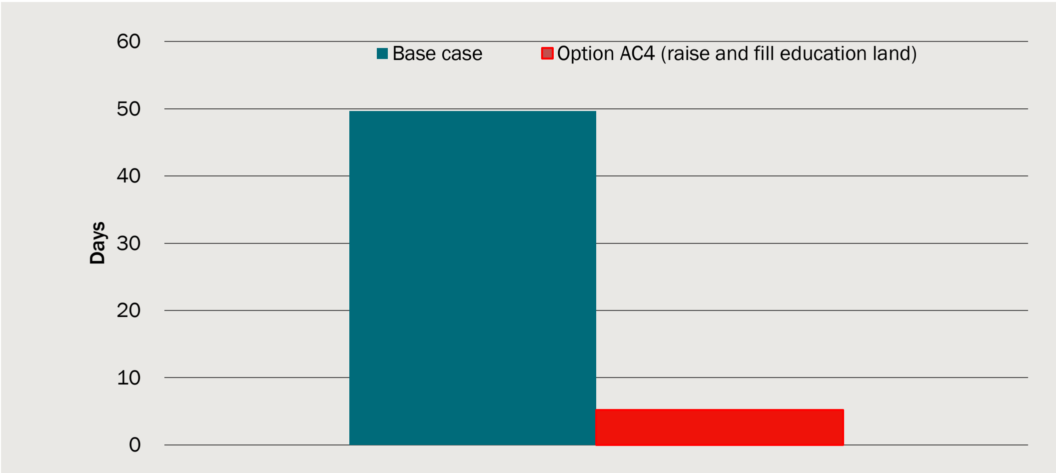
Sources: Salients, University of Queensland, Flood Focus Consulting, 2020. *Probabilistic Hazard Assessment to Support Local Adaptation Planning for Pelican, Blacksmiths and Swansea - Final*; Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors), 2019, *Australian Rainfall and Runoff: A Guide to Flood Estimation*, Commonwealth of Australia, http://www.arr-software.org/pdfs/ARR_190514.pdf; World Bank 2018, Returns to Investment in Education, p. 5, http://documents1.worldbank.org/curated/en/442521523465644318/pdf/WPS8402.pdf; ABS: Table 2 Average Weekly Earnings, Australia (Dollars) - Seasonally Adjusted; CIE.

The estimated value of lost school days is likely to be an upper bound, as alternative school content delivery methods are made available, such as on-line learning. However, we note the economic and social outcomes of on-line, versus face to face teaching, is an ongoing field of research.[51]

Lost school days

Chart 4.38 shows the avoided lost school days in the base case and post raise and fill under a 30 year evaluation period.

4.38 Avoided lost school days - 30 years



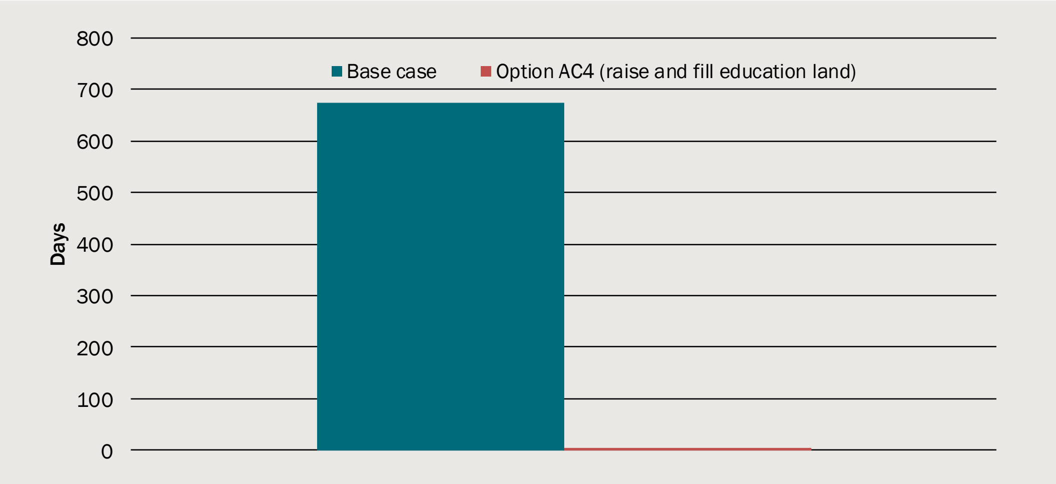
Data source: CIE.

Undertaking raise and fill saves 44 school days over 30 years, with 50 lost school days in the base case, compared to 5 post raise and fill.

669 school days are saved by undertaking raise and fill over 50 years, with 674 lost school days in the base case, compared to 5 lost school days in the option (Chart 4.39)

51 For example: Drane, C et al. 2020, 'The impact of learning at home on the educational outcomes of vulnerable children in Australia during the COVID-19 pandemic, National Centre for Student Equity in Higher Education, https://www.dese.gov.au/system/files/doc/other/final_literaturereview-learningathome-covid19-final_28042020.pdf

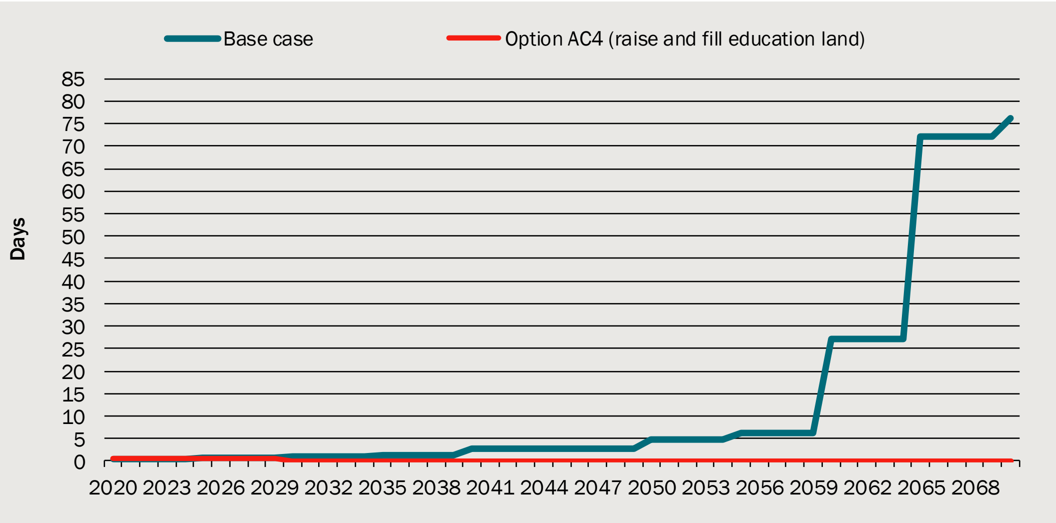
4.39 Avoided lost school days - 50 years



Data source: CIE.

Chart 4.40 shows annual lost school days over a 50 year period.

4.40 Annual lost school days - 50 years



Data source: CIE.

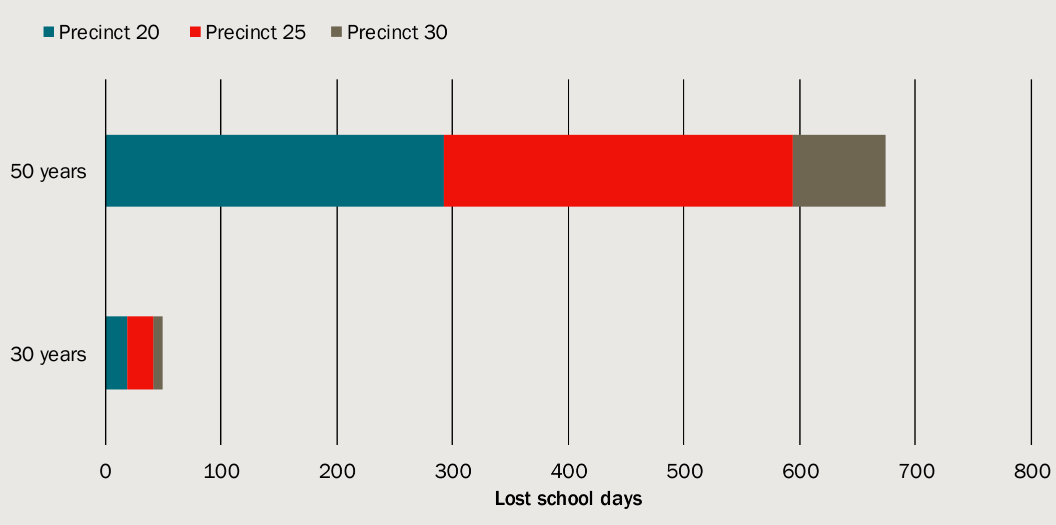
Most saved school days occur post 2059, when inundation is forecast to occur more frequently, and at higher water levels.

Chart 4.41 shows the base case lost school days by precinct:

- Precinct 20 (St Patricks)
  - 19 days over 30 years (38 per cent)
  - 293 days over 50 years (43 per cent)
- Precinct 25 (Swansea Public School)
  - 23 days over 30 years (46 per cent)
  - 302 days over 50 years (45 per cent)
- Precinct 30 (Pelican Flat Public School)

– 8 days over 30 years (15 per cent)
– 81 days over 50 years (12 per cent).

4.41 Base case lost school days by Precinct

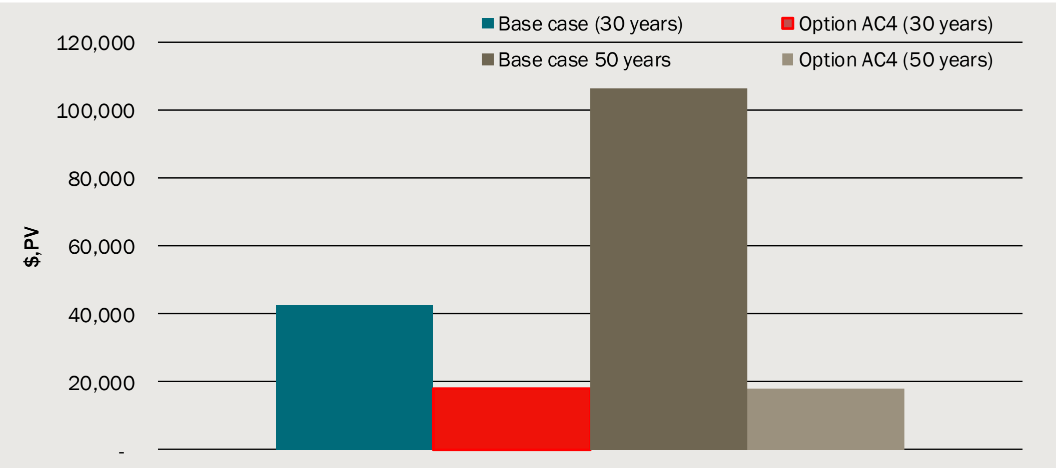


Note: Precinct 20 (St Patricks), Precinct 25 (Swansea Public School), Precinct 30 (Pelican Flat Public School).
Data source: CIE.

Value of lost school days

Chart 4.42 shows the value of lost earnings from missed school days for the base case and post raise and fill option under 30 and 50 year evaluation periods.

4.42 Value of lost earnings from missed school days



Note: Lost earnings discounted by 7 per cent over a 30 year and 50 year period.
Data source: CIE.

An estimated $25,000 (PV) of future lost earnings is avoided by undertaking raise and fill over 30 years (Chart 4.42). The saved future lost earnings increase to $88,000 (PV) over 50 years.

CBA – 30 years

Table 4.43 shows the CBA results for the 30 year analysis.

4.43 Option AC4 CBA - 30 years

Description		Comments
	$, (PV)	
Costs		
Raise and fill cost	16 195	305 m^3 of ground area raised and filled
Construction costs	2 953 416	3 849 m^2 of building area constructed
Total costs	**2 969 611**	
Benefits		
Avoided AADs	166	$38 average saving per year (PV)
Avoided disruption to future earnings	24 536	
Total benefits	**24 701**	
Net benefit	**-2 944 909**	
BCR	**0.01**	

Note: 7 per cent discount rate.

Source: CIE.

Undertaking raise and fill for this option results in a net loss of $2.9 million (present value), and BCR of 0.01 (Table 4.43).

CBA – 50 years

Table 4.44 shows the CBA results for the 50 year analysis.

4.44 Option AC4 CBA - 50 years

Description		Comments
	$, (PV)	
Costs		
Raise and fill cost	16 195	305 m^3 of ground area raised and filled
Construction costs	2 953 416	3 849 m^2 of building area constructed
Total costs	**2 969 611**	
Benefits		
Avoided AADs	1 984	$729 average saving per year (PV)
Avoided disruption to future earnings	88 308	
Total benefits	**90 292**	
Net benefit	**-2 879 319**	
BCR	**0.03**	

Note: 7 per cent discount rate.

Source: CIE.

Undertaking raise and fill for this option results in a net loss of $2.9 million (PV), and BCR of 0.03 (Table 4.44).

Option AC4 sensitivity analysis

Discount rate sensitivity analysis

Tables 4.45 and 4.46 show the CBA results under a 3 per cent and 10 per cent discount rate for the 30 year and 50 year analysis respectively.

4.45 Option AC4 CBA - 30 year discount rate sensitivity

Description	Central case (7 per cent)	Sensitivity (3 per cent)	Sensitivity (10 per cent)
	$, (PV)	$, (PV)	$, (PV)
Costs			
Raise and fill cost	16 195	23 759	12 282
Building construction costs	2 953 416	4 426 973	2 204 973
Total costs	**2 969 611**	**4 450 732**	**2 217 255**
Benefits			
Avoided AADs	166	487	76
Avoided disruption to future earnings	24 536	64 290	12 317
Total benefits	**24 701**	**64 777**	**12 393**
Net benefit	**-2 944 909**	**-4 385 956**	**-2 204 862**
BCR	**0.01**	**0.01**	**0.01**

Source: CIE.

4.46 Option AC4 CBA - 50 year discount rate sensitivity

Description	Central case (7 per cent)	Sensitivity (3 per cent)	Sensitivity (10 per cent)
	$, (PV)	$, (PV)	$, (PV)
Costs			
Raise and fill cost	16 195	23 759	12 282
Building construction costs	2 953 416	4 426 973	2 204 973
Total costs	**2 969 611**	**4 450 732**	**2 217 255**
Benefits			
Avoided AADs	1 984	9 998	639
Avoided disruption to future earnings	88 308	397 306	32 330
Total benefits	**90 292**	**407 303**	**32 969**
Net benefit	**-2 879 319**	**-4 043 429**	**-2 184 286**
BCR	**0.03**	**0.09**	**0.01**

Source: CIE.

Tables 4.45 and 4.46 show that a negative net benefit and BCR less than one still occur under both 3 per cent and 10 per cent discount rate sensitivities. Although future saved AADs are discounted at a lower rate under the 3 per cent discount rate sensitivity, so too are future raise and fill and construction costs. As such, the higher PV benefits are offset by higher PV costs, resulting in no improvement to the net benefits. Similar logic applies to the 10 per cent discount rate sensitivity where although PV costs are lower, so too are PV benefits.

Option AC4 raise and fill education land (schools) CBA summary discussion

The CBA results and subsequent sensitivity analysis highlight that undertaking this option is unlikely to result in a positive net benefit or BCR greater than 1. This is because raise and fill mitigates a small amount of AADs, associated with low probability, high water level events, for a disproportionate cost.

Option AC5 Recreation land

Based on discussions with the Steering Committee, it was judged that the action to raise and fill parkland would likely not be trigger based. Rather, we have assumed that the recreational land starts to be raised in each year from 2021 based on the most inundation prone to the least inundation prone land. Recreational land would be raised to the 1% AEP event at 2050 level. Based on these assumptions there is approximately 720,661 sqm of parkland nominated in AC5. However, only 397,602 sqm is currently below the 1% AEP event at 2050 level. Therefore, only 55% of the parkland would need to be raised under this approach.

Assuming a raise and fill cost of $\$105/m^3$, this results in costs of around $28m in PV terms.

Benefits arise from reducing the number of days where parkland is inundated, allowing for greater visitation of the park. Without the raise and fill option, there are around 594 lost visitation days from 2020-2070. However, with the raise and fill options, there are only 181 lost visitation days over the period.

Based on the studies available, the assumed recreational visit is valued at $9/visit.[52] Table 4.47 presents the results of the analysis based on alternative discount rates. Using a 7% discount rate, for example, results in benefits of $9.6m in PV terms. This would result in a net cost of $18.8m in PV terms. The options result in net costs (costs greater than benefits) irrespective of different discount rates are used.

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52 Varcoe, T et al. 2015, Valuing Victoria's Parks - Accounting for ecosystems and valuing their benefits: Report of first phase findings, p. 107, https://www.forestsandreserves.vic.gov.au/__data/assets/pdf_file/0027/57177/Valuing-Victorias-Parks-Report-Accounting-for-ecosystems-and-valuing-their-benefits.pdf

4.47 Option AC5 CBA - 30 year discount rate sensitivity

Description	Central case (7 per cent)	Sensitivity (3 per cent)	Sensitivity (10 per cent)
	$m, (PV)	$m, (PV)	$m, (PV)
Costs			
Raise and fill cost	28.4	35.2	24.4
Total costs	**28.4**	**35.2**	**24.4**
Benefits			
Avoided lost visitation	9.6	18.7	6.2
Total benefits	**9.6**	**18.7**	**6.2**
Net benefit	**-18.8**	**-16.5**	**-18.2**
BCR	**0.34**	**0.53**	**0.26**

Source: CIE.

It is important to recognise that the analysis above was based on use of recreational land from Sydney, which could be different to the recreational land in this area. Further work could be undertaken to understand the extent of use of use of recreational land in the LGA. Further analysis could also be undertaken to test different fill heights for the passive and active recreational land. This is likely to improve the net benefits as the raising could be targeted to the recreational land with high usage and requiring limited inundation to enable use.

Option AC7 Raise and fill commercial land in CBD

AADs - 30 years

For the modelled scenario (limited to 85 commercial properties), two properties are triggered under the 1% AEP raise trigger in the 30 year analysis, as shown in Table 4.48.

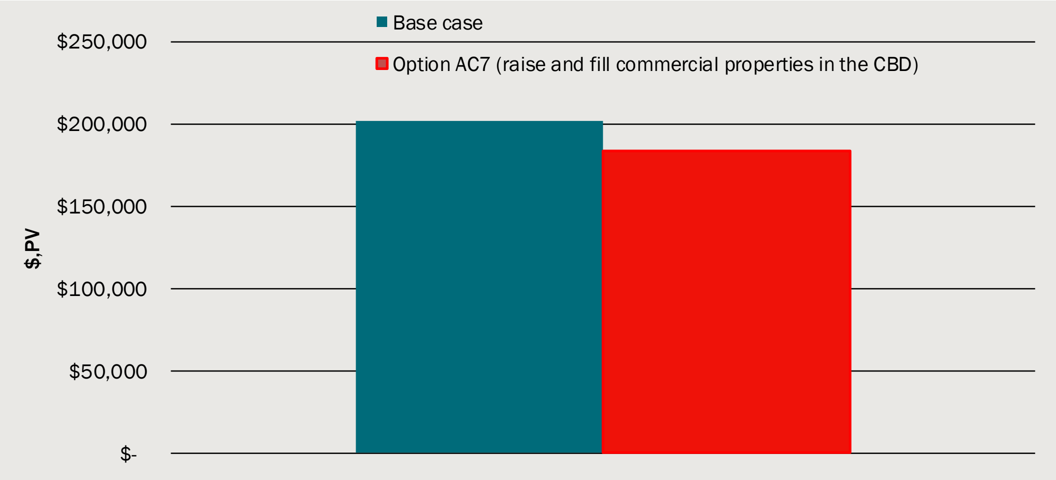
4.48 Option AC7 properties triggered for raise and fill - 30 year analysis

Property address	Precinct	Floor level	Ground level	Year raise trigger reached
		metres above AHD	metres above AHD	Year
Commercial property 1	25	1.35	1.18	2048
Commercial property 2	25	1.28	1.18	2038

Source: CIE

Chart 4.49 shows the estimated PV AADs under the base case and post raise and fill, over a 30 year evaluation period.

4.49 Option AC7 AADs (PV) - 30 years



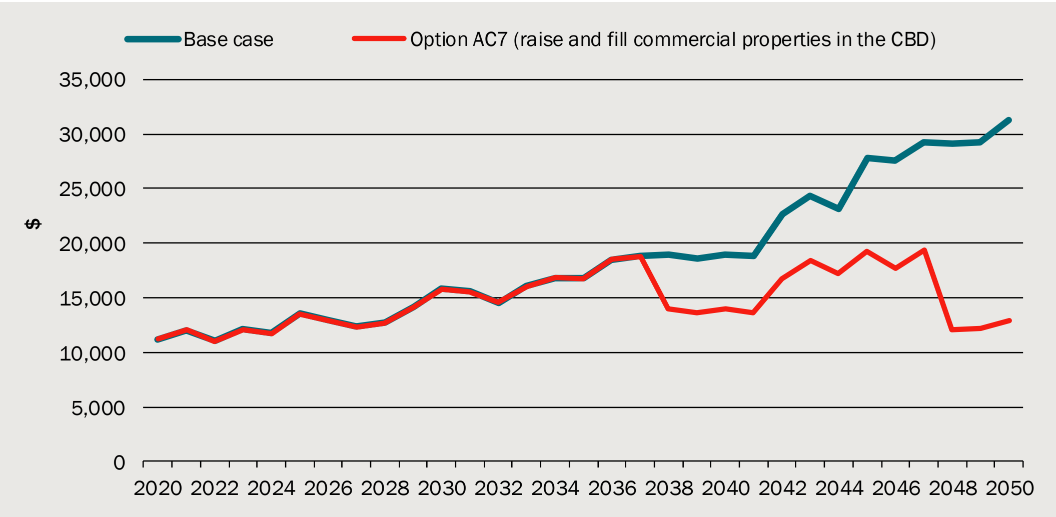
Note: AADs discounted by 7 per cent over a 30 year period. Raise heights include an additional 0.5 metres freeboard and 0.6 metres for additional SLR.

Data source: CIE

Undertaking raise and fill reduces AADs by $16,242 (PV).

Chart 4.50 shows the estimated AADs, under the base case and post raise and fill, over the 30 year evaluation period.

4.50 Option AC7 AADs (undiscounted) - 30 years



Data source: CIE.

Most of the saved AADs occur in the last 10 years of the 30 year analysis.

AADs - 50 years

Ten properties are triggered under the 1% AEP raise trigger in the 50 year analysis, as shown in Table 4.51.

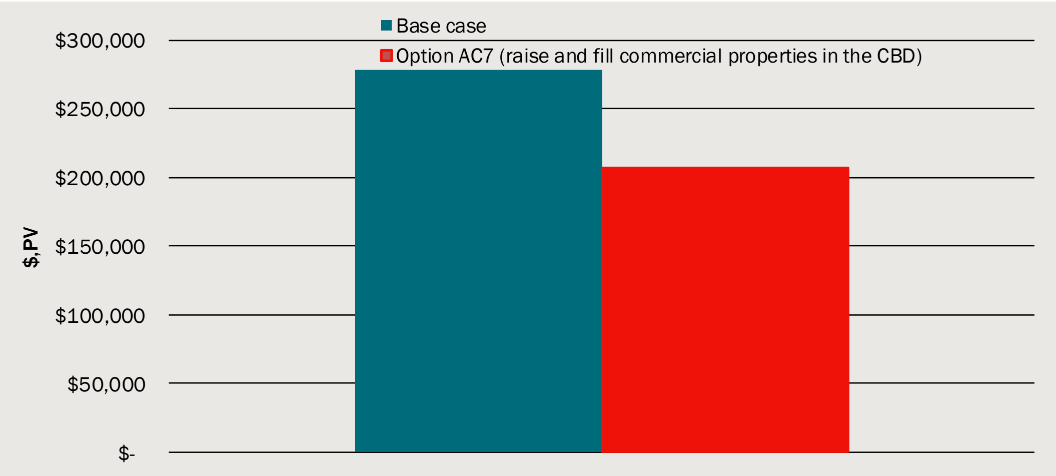
4.51 Properties triggered for raise and fill - 50 year analysis

Property address	Precinct	Floor level	Ground level	Year raise & fill trigger threshold exceeds floor level
Commercial property 1	25	1.35	1.18	2048
Commercial property 2	25	1.28	1.18	2038
Commercial property 3	25	1.43	1.21	2057
Commercial property 4	25	1.45	1.28	2060
Commercial property 5	25	1.47	1.27	2061
Commercial property 6	25	1.48	1.31	2063
Commercial property 7	20	1.53	1.38	2065
Commercial property 8	20	1.53	1.38	2068
Commercial property 9	25	1.53	1.45	2068
Commercial property 10	20	1.56	1.22	2068

Source: CIE.

Chart 4.52 shows the estimated PV AADs under the base case and post raise and fill, over a 50 year evaluation period.

4.52 Option AC7 AADs (PV) - 50 years



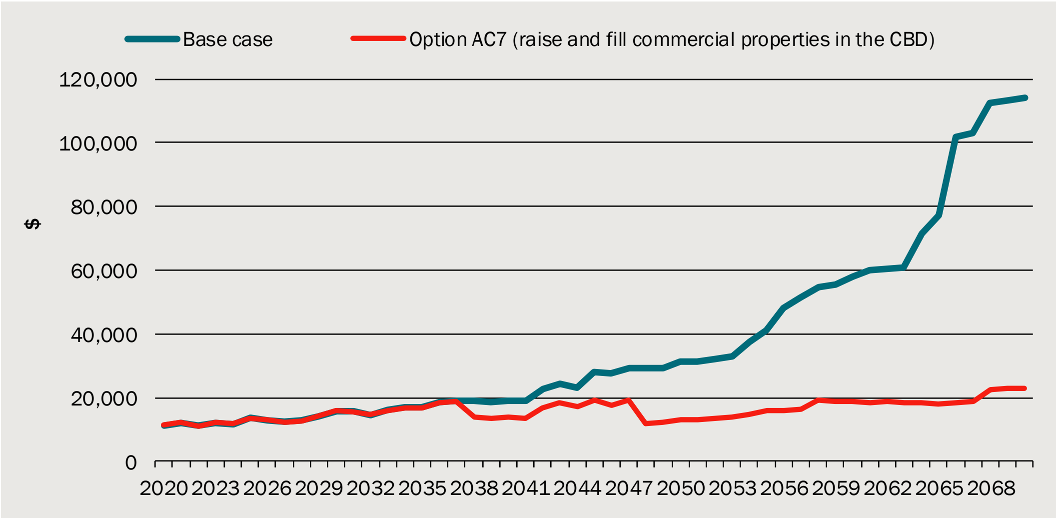
Note: AADs discounted by 7 per cent over a 30 year period. Raise heights include an additional 0.5 metres freeboard and 0.6 metres for additional SLR.

Data source: CIE.

Undertaking raise and fill reduces AADs by $64,740.

Chart 4.53 shows the estimated undiscounted AADs, under the base case and post raise and fill, over the 50 year evaluation period.

4.53 Option AC7 AADs (undiscounted) - 50 years



Data source: CIE.

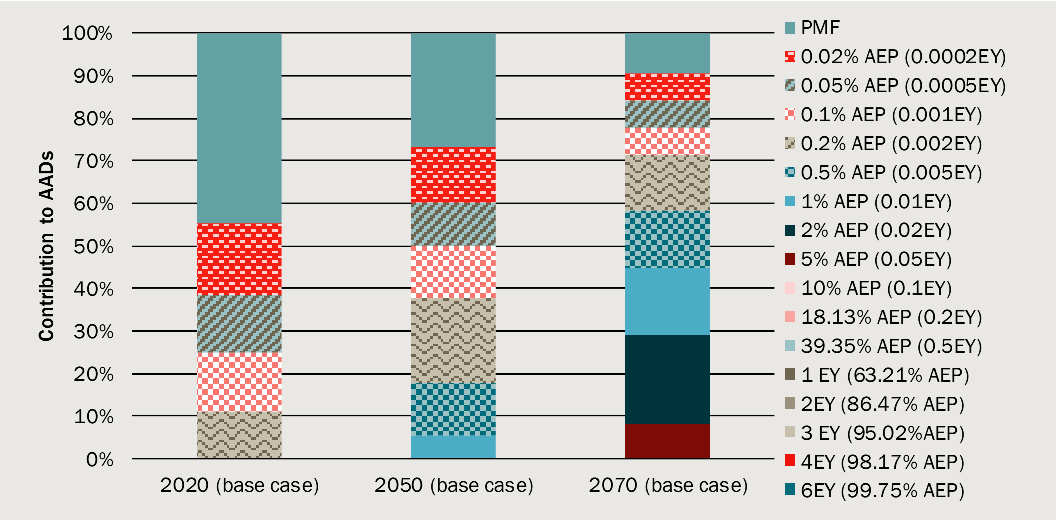
Of interest, AADs increase at a faster rate beyond 2050 in the base case, with AADs roughly doubling every ten years in the chosen case study area, as shown in the Chart 4.53 (blue line). This is associated with rising inundation levels over time, which in turn cause more properties to be inundated at higher water levels. As such, most of the saved inundation costs (the difference between the blue and red lines) occurs in the later years of the 50 year analysis.

Although inundation costs increase significantly in the base case post 2050, these values are discounted more heavily than saved inundation costs that occur between 2020 and 2050, when calculating PVs. Discounting explains why the difference in the PV AADs between the base case (do nothing scenario) and raise and fill scenario are not as large as the observed difference between undiscounted AADs.

Inundation event contribution to AADs

Chart 4.54 shows the base case contribution of AADs by inundation events for the years 2020, 2050 and 2070. Chart 4.55 shows the same information post undertaking raise and fill. Multiple inundation events are those which occur with an EY of 1 or more.

4.54 Option AC7 contribution of inundation events to AADs (base case)

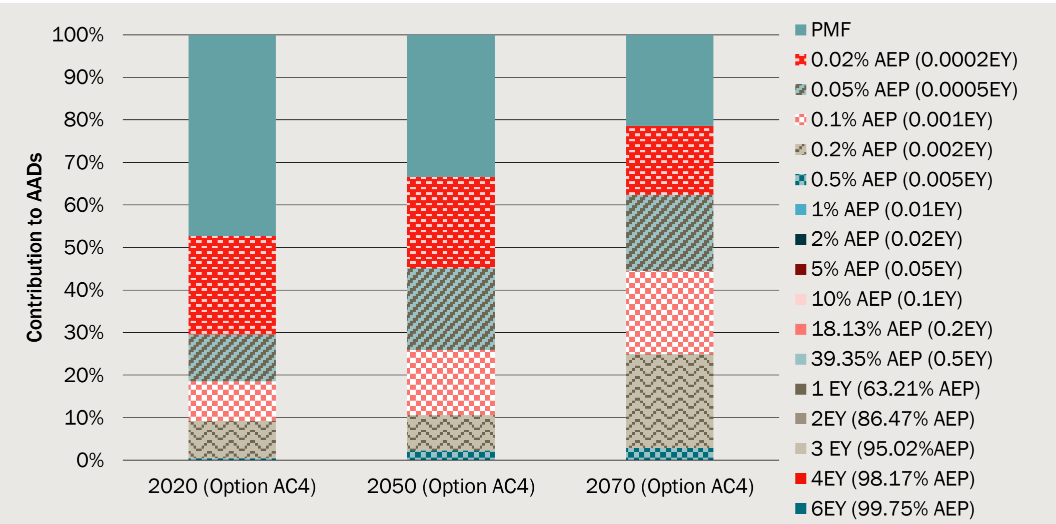


Data source: CIE

Chart 4.54 indicates that the 'big events' (low frequency but large inundation events) drive adaptive action for Option AC7. For example, all AADs are attributed to 5% AEP events or less in 2070, and even lower events in 2050 and 2020. The largest contributors to 2070 AADs are:

- 18.13% AEP event – 21 per cent ($23,768)
- 10% AEP event – 16 per cent ($17,938)
- 5% AEP event – 14 per cent ($15,507), and
- 2% AEP event – 13 per cent ($14,888).

4.55 Contribution of inundation events to AADs (Option AC7)



Data source: CIE.

Chart 4.55 shows that undertaking raise and fill mitigates some of the 'big event' AADs. For example, 2070 AADs post raise and fill are made up of:

- 0.5% AEP event – 4 per cent ($908)

- 0.2% AEP event – 11 per cent ($2,515)
- 0.1% AEP event – 10 per cent ($2,175)
- 0.05% AEP event – 17 per cent ($3,933)
- 0.02% AEP event – 22 per cent ($4,927), and
- PMF – 36 per cent ($8,268).

CBA – 30 years

Table 4.56 shows the CBA results for the 30 year analysis.

4.56 Option AC7 CBA - 30 years

Description		Comments
	$, (PV)	
Costs		
Raise and fill cost	22 258	1 032m³ of ground area raised and filled
Construction costs	359 462	1 011 m² of building area constructed
Total costs	**381 721**	
Benefits		
Avoided AADs	**17 781**	**$3 352 average saving per year (PV)**
Net benefit	**-363 940**	**2 properties raised and filled**
BCR	**0.05**	

Note: 7 per cent discount rate.

Undertaking raise and fill for this option results in a net loss of $363,940 (PV), and BCR of 0.05.

CBA – 50 years

Table 4.57 shows the CBA results for the 50 year analysis.

4.57 Option AC7 CBA - 50 years

Description		Comments
	$, (PV)	
Costs		
Raise and fill cost	49 209	6 021 m³ of ground area raised and filled
Construction costs	754 154	6 170 m² of building area constructed
Total costs	**803 362**	
Benefits		
Avoided AADs	**71 172**	**$21 587 average saving per year (PV)**
Net benefit	**-732 191**	**10 properties raised and filled**
BCR	**0.09**	

Note: 7 per cent discount rate.

Undertaking raise and fill for this option results in a net loss of $732,191 (PV), and BCR of 0.09.

Option AC7 raise and fill commercial land in the CBD sensitivity analyses

Discount rate sensitivity analysis

Tables 4.58 (30 year evaluation) and 4.59 (50 year evaluation) show the CBA results under alternate discount rates of 3 and 10 per cent, compared to the central analysis, which used 7 per cent.

4.58 Option AC7 CBA - 30 year discount rate sensitivity

Description	Central case (7 per cent)	Sensitivity (3 per cent)	Sensitivity (10 per cent)
	$, (PV)	$, (PV)	$, (PV)
Costs			
Raise and fill cost	22 258	53 523	12 025
Building construction costs	359 462	821 966	200 525
Total costs	**381 721**	**875 489**	**212 549**
Benefits			
Avoided AADs	**17 781**	**46 841**	**8 908**
Net benefit	**-363 940**	**-828 647**	**-203 641**
BCR	**0.05**	**0.05**	**0.04**

Source: CIE.

4.59 Option AC7 CBA - 50 year discount rate sensitivity

Description	Central case (7 per cent)	Sensitivity (3 per cent)	Sensitivity (10 per cent)
	$, (PV)	$, (PV)	$, (PV)
Costs			
Raise and fill cost	49 209	196 072	20 141
Building construction costs	754 154	2 979 175	316 675
Total costs	**803 362**	**3 175 247**	**336 817**
Benefits			
Avoided AADs	**71 172**	**316 224**	**25 960**
Net benefit	**-732 191**	**-2 859 023**	**-310 857**
BCR	**0.09**	**0.10**	**0.08**

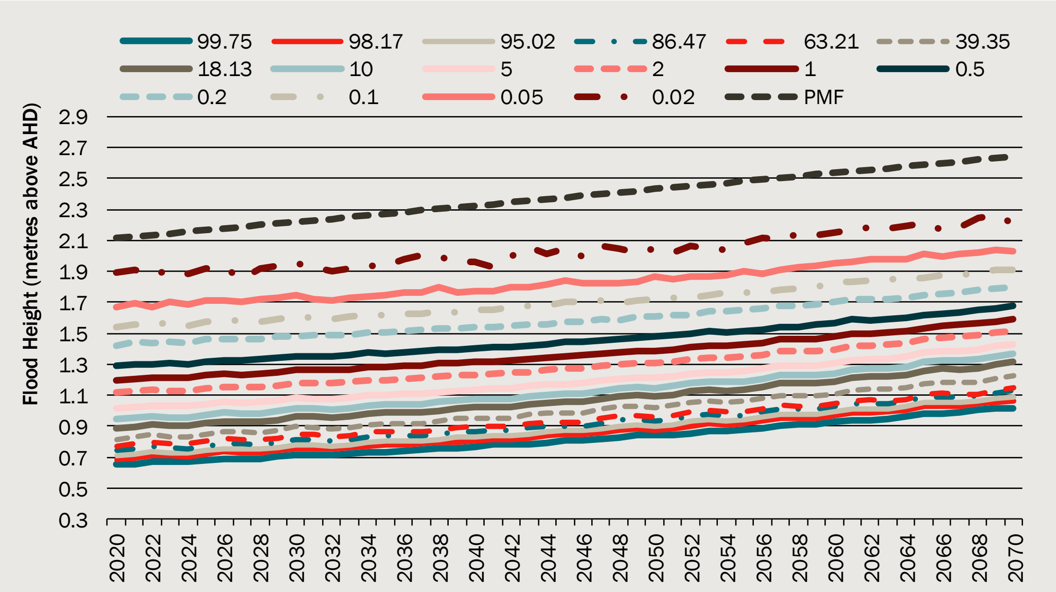
Source: CIE.

The results do not change under 3 per cent and 10 per cent discount rate sensitivities (Table 4.58 for the 30 year analysis and Table 4.59 for the 50 year analysis). Although future saved AADs are discounted at a lower rate under the 3 per cent discount rate sensitivity, so too are future raise and fill and construction costs. As such, the higher PV benefits are offset by higher PV costs, resulting in minimal differences in BCRs. Similar logic applies to the 10 per cent discount rate sensitivity where although PV costs are lower, so too are PV benefits.

Water level sensitivity analysis

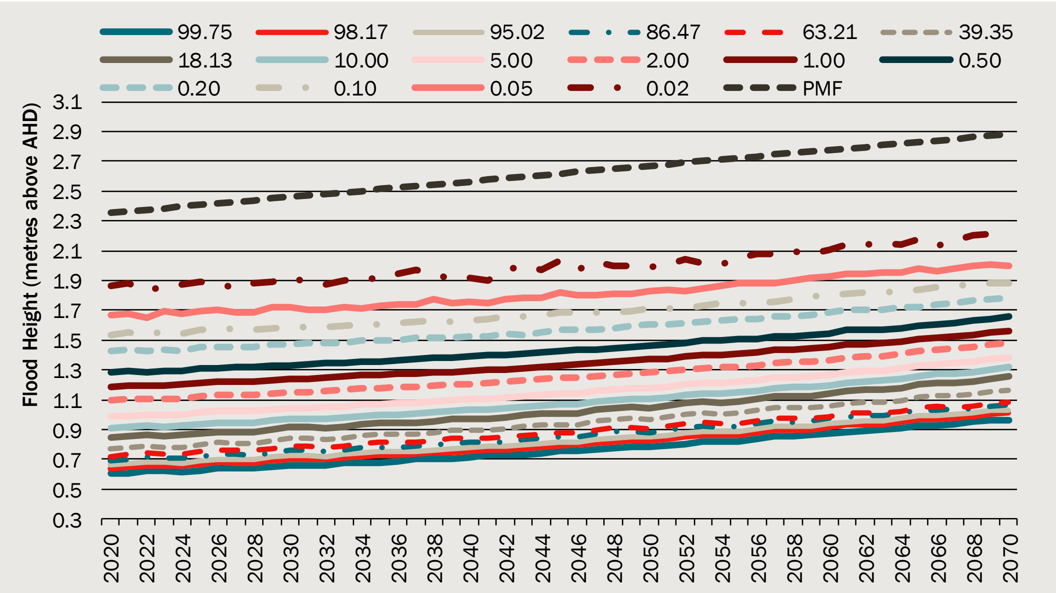
Council has requested a sensitivity to test the impacts of a uniform inundation water level increase of 0.2 metres (AHD) on AAD and CBA results. Inundation levels used in the core modelling results are shown in Charts 4.60 (Precinct 20) and 4.61 (Precinct 25). Sensitivity inundation water levels are shown in Charts 4.62 (Precinct 20) and 4.63 (Precinct 25).

4.60 Inundation water level heights - Precinct 20



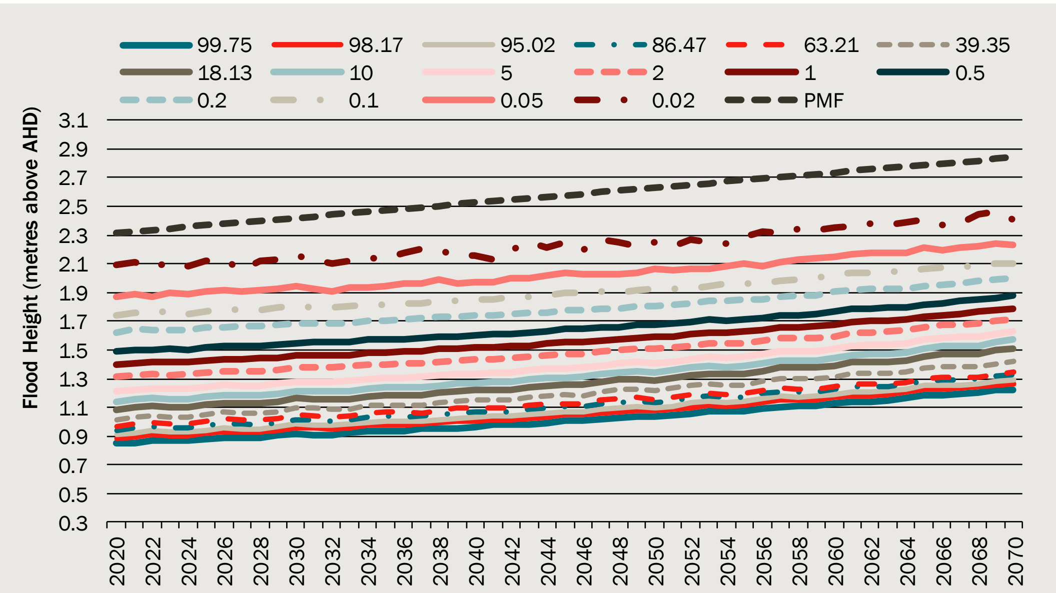
Data source: Salients et. al 2020.

4.61 Inundation water level heights - Precinct 25



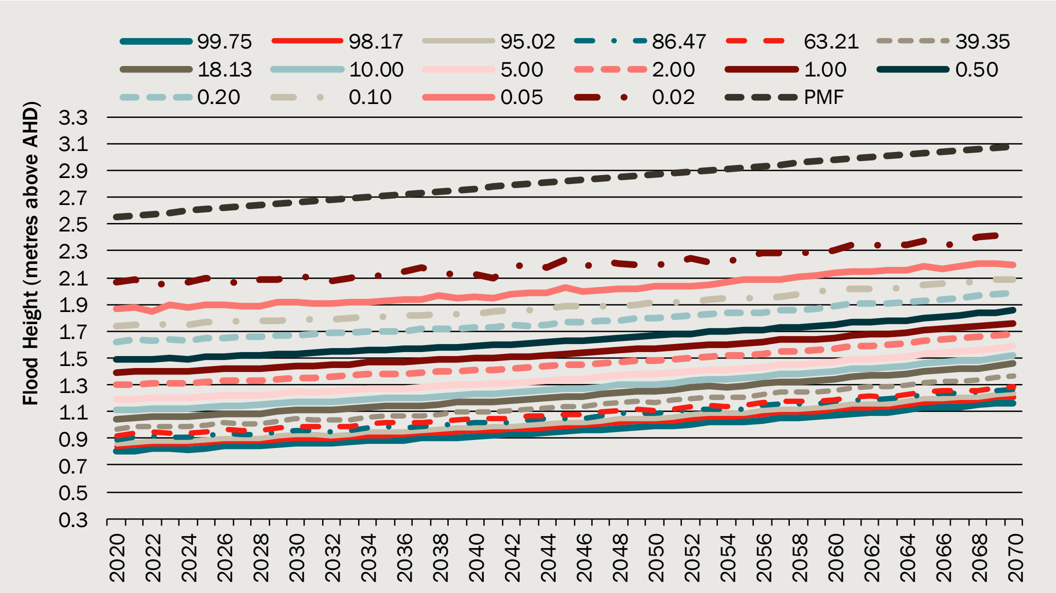
Data source: Salients et. al 2020.

4.62 Sensitivity inundation water level heights - Precinct 20



Data source: Salients et. al 2020; CIE.

4.63 Sensitivity inundation water level heights - Precinct 25

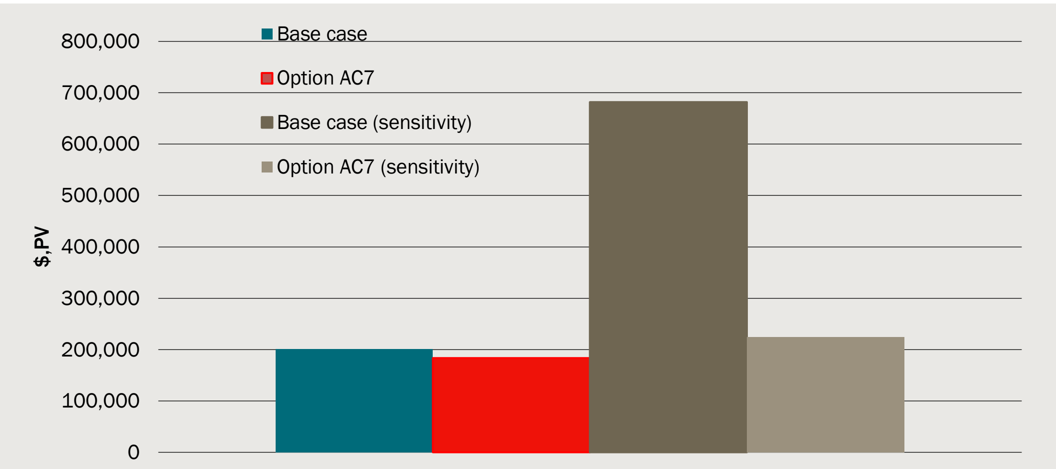


Data source: Salients et. al 2020; CIE.

AADs for Water Level sensitivity analysis

The 30 year AAD PV results for the base case and raise and fill options under the central case modelled water levels and sensitivity water levels are shown in Chart 4.64.

4.64 Option AC7 water height sensitivity AADs - 30 years (PV)

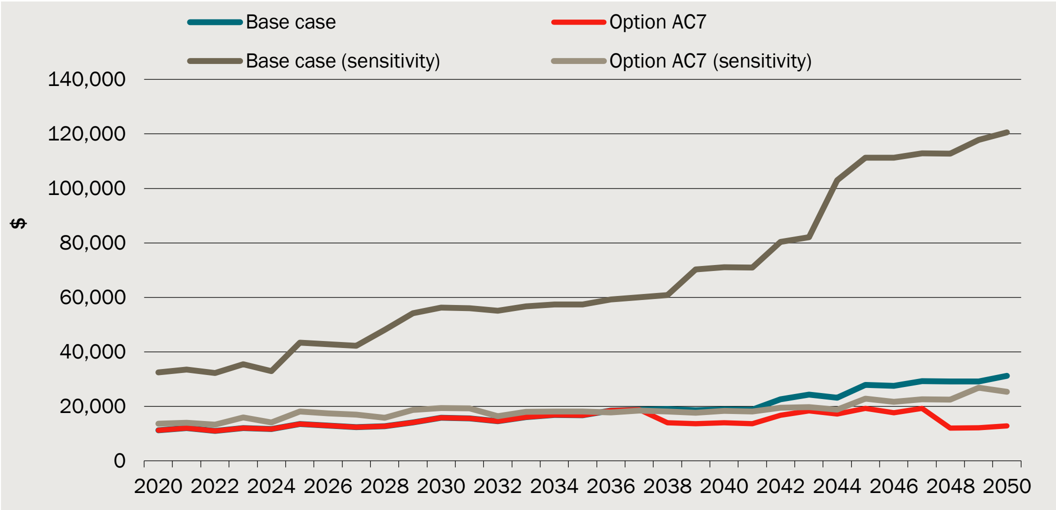


Note: AADs discounted by 7 per cent over a 30 year period.

Chart 4.64 shows the estimated AADs in the sensitivity base case are more than three times greater than that estimated using the core water level heights. Further, the saved AADs in the sensitivity ($456,629) are also much greater than the core analysis ($17,781). Reasons for this are:

- Ten properties are triggered for raise and fill assuming a 1% raise trigger, compared to two under the core water level heights, and
- most of the saved AADs occur from 2020, compared to 2038 (Chart 4.65).

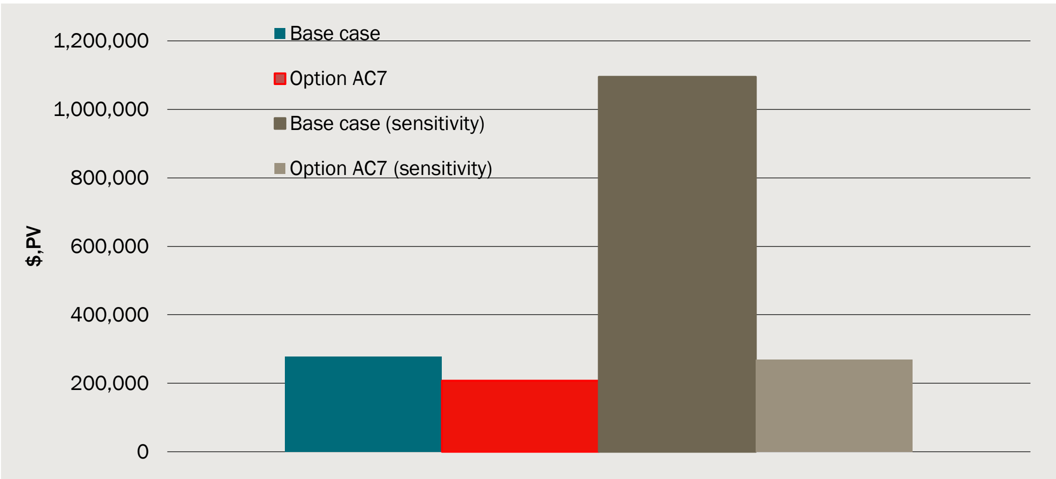
4.65 Option AC7 water height sensitivity AADs - 30 years (undiscounted)



Data source: CIE.

50 year AADs for the central case and increased water level sensitivity are shown in Chart 4.66.

4.66 Option AC7 water height sensitivity AADs - 50 years (PV)



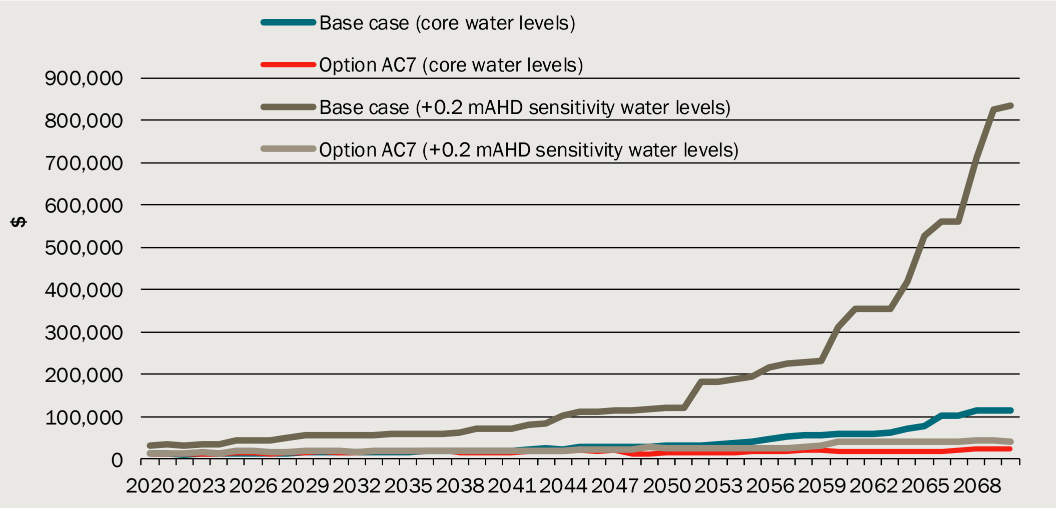
Note: AADs discounted by 7 per cent over a 50 year period. Raise heights include an additional 0.5 metres freeboard and 0.6 metres for additional SLR.

Data source: CIE.

The difference between base case AADs are even greater ($1.1 million, compared to $280,000) and saved AADs from undertaking raise and fill are also larger at $830,000, compared to $71,000. Reasons for this are:

- Twenty-nine properties are triggered for raise and fill assuming a 10% AEP raise trigger, compared to ten under the core water level heights, and
- AAD savings beyond 2050 are much higher than the core 50 year analysis (Chart 4.67).

4.67 Option AC7 water height sensitivity AADs - 50 years (undiscounted)

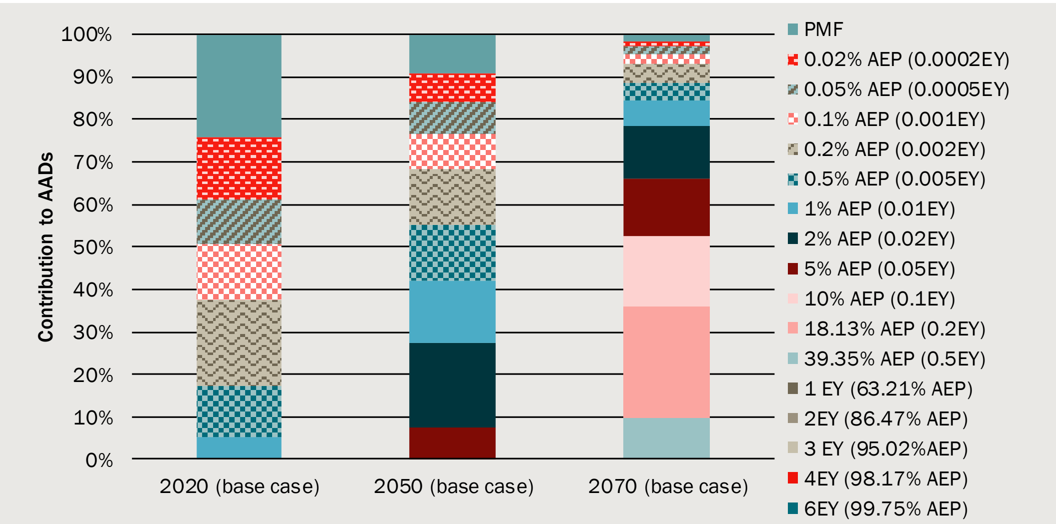


Data source: CIE.

Inundation event contribution to AADs

Charts 4.68 and 4.69 show the contribution of inundation events to AADs in 2020, 2050 and 2070, under a sensitivity of +0.2m AHD water levels for the base case and post raise and fill respectively.

4.68 Option AC7 +0.2m AHD sensitivity contribution of inundation event probabilities to AADs (base case)



Data source: CIE.

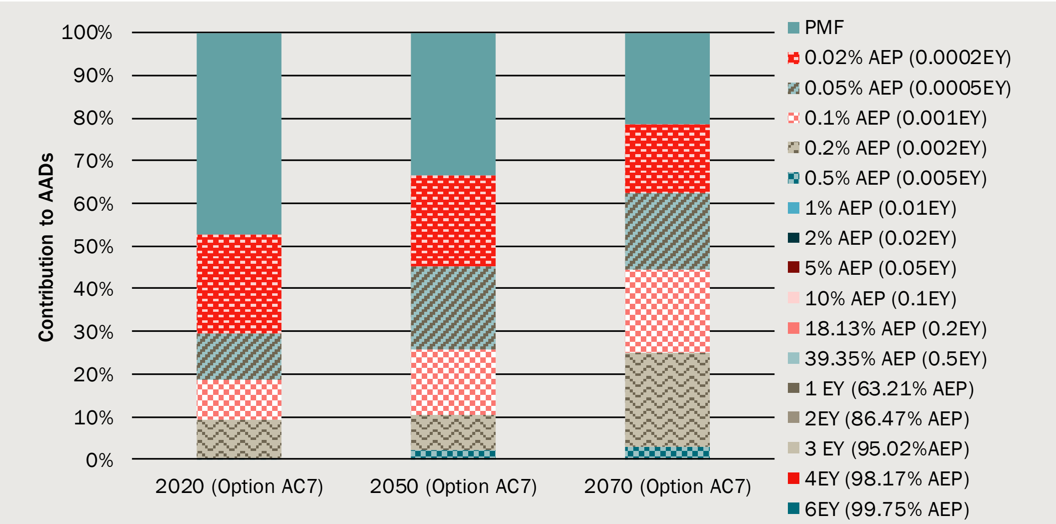
Chart 4.68 indicates that the 'big events' (less frequent but larger AEP events) continue to drive adaptive action for Option AC7 during the analysis period. For example, all AADs are attributed to 39.35% AEP events or less in 2070 and less frequent events than the 39.35% AEP event are the main contributors to AADs in 2050 and 2020. The largest contributor to 2070 AADs are:

- 18.13% AEP – 26 per cent ($219,616)
- 10% AEP – 17 per cent ($139,006)

- 5% AEP – 14 per cent ($113,619), and
- 2% AEP – 12 per cent ($100,822).

However, the low probable, high water level events result in higher AADs, compared to the central analysis.

4.69 Contribution of inundation event probabilities to AADs (Option AC7 +0.2m AHD sensitivity)



Data source: CIE.

Chart 4.69 shows that as per the central case, undertaking raise and fill mitigates some of the 'big event' AADs when you compare results in 2050 and 2070 to Chart 4.68. For example, in the year 2070, implementing Option AC7 will mitigate damages from the 39.35% AEP to the 1% AEP events.

CBA – water level sensitivity analysis

Tables 4.70 and 4.71 show the sensitivity CBA results for the 30 year and 50 year analysis respectively.

4.70 Option AC7 water height sensitivity CBA results - 30 years

Description	Central case (core water levels)	Sensitivity (+0.2 mAHD water levels)
	$, (PV)	$, (PV)
Costs		
Raise and fill cost	22 258	261 399
Building construction costs	359 462	3 627 747
Total costs	**381 721**	**3 889 146**
Benefits		
Avoided AADs	**17 781**	**456 629**
Net benefit	**-363 940**	**-3 432 517**
BCR	**0.05**	**0.12**

Note: 7 per cent discount rate.

4.71 Option AC7 water height sensitivity CBA results - 50 years

Description	Central case (core water levels)	Sensitivity (+0.2 mAHD water levels)
	$, (PV)	$, (PV)
Costs		
Raise and fill cost	49 209	338 380
Building construction costs	754 154	4 611 496
Total costs	**803 362**	**4 949 876**
Benefits		
Avoided AADs	**71 172**	**826 315**
Net benefit	**-732 191**	**-4 123 561**
BCR	**0.09**	**0.17**

Note: 7 per cent discount rate.

Source: CIE.

Tables 4.70 and 4.71 show an improvement to the BCR under the inundation water level sensitivity. However, the net benefit does not improve in the sensitivity. This contrasting result is due to total costs increasing proportionately less than saved AADs. Total costs increase by 5.2 times, compared to an 11 time increase in saved AADs. This in turn improves the BCR. However, total costs increase by a larger amount in absolute terms, $4.1 million (PV) (from $803,000 to 4.2 million), compared to saved AADs which increase by $755,100 (PV) (from 71,200 to 826,300). This in turn reduces the net benefit.

This sensitivity emphasizes:

- a need to continue to monitor water levels and gain more data to determine if a statistically significant structural break has occurred between recently observed water levels and the longer historical record
- the need to take future water levels into account and revisit adaptation options and models including, CBA as needed, and
- the need to tie water level analysis and potential deviations from current modelling outputs to the ongoing LAP review.

Raise triggers and raise height sensitivity analysis

Option AC7 raise trigger and raise height sensitivity AADs

Table 4.72 shows the range of raise triggers and raise heights in 2020 and 2050, as well as the number of properties triggered by 2050. The central case uses a raise:

- trigger of a 1% AEP event inundation probability level, and
- height of a 1% AEP event inundation probability level.

4.72 Option AC7 raise trigger and raise height and risk tolerance

EY	AEP event	2020 inundation level (precinct 20)	2020 inundation level (precinct 25)	Number of properties triggered by 2050 [a]	Raise level risk tolerance
#	Per cent	m (AHD)	m (AHD)		
6	99.75	0.65	0.60	0	High risk tolerance
4	98.17	0.69	0.64	0	
3	95.02	0.71	0.66	0	
2	86.47	0.74	0.69	0	
1	63.21	0.77	0.72	0	
0.5	39.35	0.82	0.77	0	
0.2	18.13	0.89	0.85	0	
0.1	10	0.94	0.91	0	
0.05	5	1.01	0.99	0	
0.02	2	1.11	1.10	0	
0.01	1	1.20	1.19	2	
0.005	0.5	1.29	1.29	4	
0.002	0.2	1.42	1.42	13	
0.001	0.1	1.54	1.54	17	
0.0005	0.05	1.67	1.67	35	
0.0002	0.02	1.90	1.86	72	
	PMF	2.12	2.36	85	Most risk averse

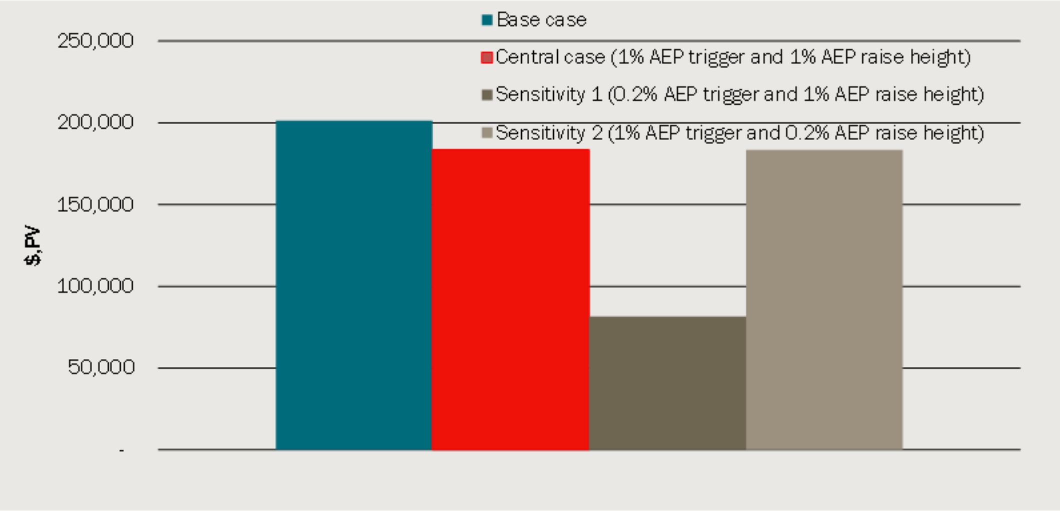
[a] 30 year analysis.

Note: Excludes freeboard and additional raise allowance for SLR. No properties are raised for 2 per cent events or higher in the 30 year analysis, as the present-day building heights are above these trigger levels.

Source: Salients; CIE

The 30 year AAD PV results for the base case, central case, sensitivity 1 (0.2% AEP raise trigger and 1% AEP raise height) and sensitivity 2 (1% AEP raise trigger and 0.2% AEP raise height) are shown in the Chart 4.73.

4.73 Option AC7 raise and fill trigger and raise height sensitivity AADs - 30 years

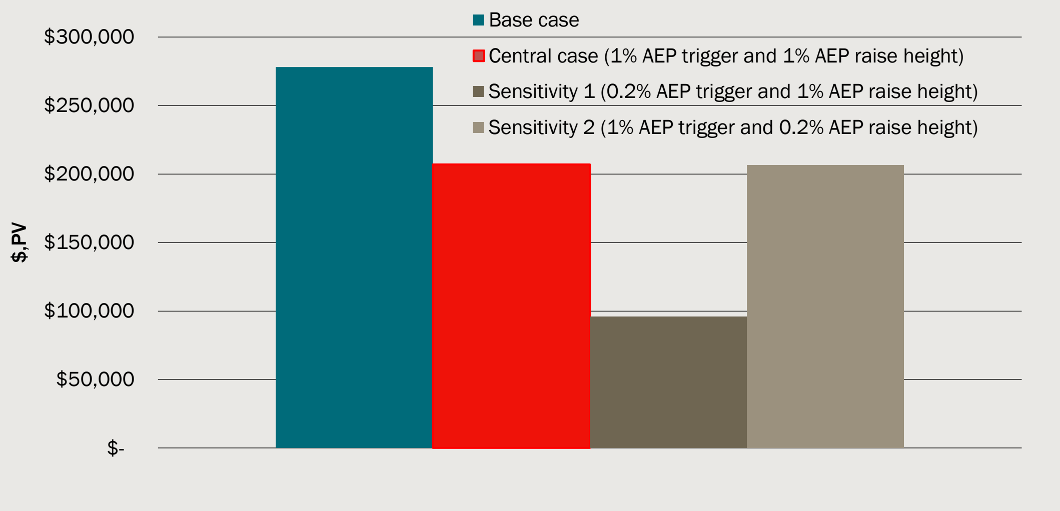


Note: AADs discounted by 7 per cent over a 30 year period. No properties are raised for 2 per cent events or higher in the 30 year analysis, as the present day building heights are above these trigger levels.

Data source: CIE.

The 50 year AAD PV results are shown in the Chart 4.74.

4.74 Option AC7 raise and fill trigger and raise height sensitivity AADs - 50 years



Note: AADs discounted by 7 per cent over a 50 year period.

Option AC7 raise trigger and raise height sensitivity analysis CBA results

CBA results for the chosen sensitives are shown in Tables 4.75 (30 years) and 4.76 (50 years).

4.75 Option AC7 raise and fill trigger and raise height sensitivity CBA results - 30 years

Description	Central case (1% AEP raise trigger and 1% AEP raise height)	Sensitivity 1 (0.5% AEP raise trigger and 0.2% AEP event raise height)	Sensitivity 2 (0.1%AEP raise trigger and 0.1% AEP raise height)
	$, (PV)	$, (PV)	$, (PV)
Costs			
Raise and fill cost	22 258	260 254	29 200
Building construction costs	359 462	4 858 891	359 462
Total costs	**381 721**	**5 119 144**	**388 662**
Benefits			
Avoided AADs	**17 781**	**119 880**	**17 967**
Net benefit	**-363 940**	**-4 999 264**	**-370 695**
BCR	**0.05**	**0.02**	**0.05**

Note: 7 per cent discount rate.

Source: CIE.

4.76 Option AC7 raise and fill trigger and raise height sensitivity CBA results - 50 years

Description	Central case (1% AEP raise trigger and 1% AEP event raise height)	Sensitivity 1 (0.5% AEP raise trigger and 0.2% AEP event raise height)	Sensitivity 2 (0.1%AEP raise trigger and 0.1% AEP raise height)
	$, (PV)	$, (PV)	$, (PV)
Costs			
Raise and fill cost	49 209	318 002	63 841
Building construction costs	754 154	5 719 981	754 154
Total costs	**803 362**	**6 037 983**	**817 995**
Benefits			
Avoided AADs	**71 172**	**182 218**	**71 620**
Net benefit	**-732 191**	**-5 855 765**	**-746 375**
BCR	**0.09**	**0.03**	**0.09**

Note: 7 per cent discount rate.

Source: CIE.

The CBA results indicate that a more risk averse raise trigger saves more AADs, as more properties are raised. However, the saved AADs are offset by even higher raise and fill and construction costs. That is, marginal saved AADs are disproportionately lower than marginal raise and fill and construction costs. The result is no improvement to the net benefit or BCR from adopting an earlier raise trigger. The central case raise trigger and raise heights are therefore optimal for the 30 year analysis.

Construction cost sensitivity analysis

Construction costs account for over 90 per cent of total raise and fill costs in the central case. The central case uses average construction costs sourced from the *ABS 8752.0 - Building Activity.*[53] In practice, construction costs are often context specific, associated with the type of property, location, and availability of trades at a particular point in time.

Table 4.77 and 4.78 show CBA results of reduced construction costs of $1,262/m^2$ and $1,104/m^2$, for 30 year and 50 years respectively.

4.77 Option AC7 construction cost sensitivity CBA results - 30 years

Description	Central case ($1 577/m²)	Sensitivity ($1 262/m²)	Sensitivity 2 ($1 104/m²)
	$, (PV)	$, (PV)	$, (PV)
Costs			
Raise and fill cost	22 258	22 258	22 258
Building construction costs	359 462	287 661	250 507
Total costs	**381 721**	**309 920**	**272 765**
Benefits			
Avoided AADs	**17 781**	**17 781**	**17 781**
Net benefit	**-363 940**	**-292 139**	**-254 984**
BCR	**0.05**	**0.06**	**0.07**

Note: 7 per cent discount rate.

Source: CIE.

4.78 Option AC7 construction cost sensitivity CBA results - 50 years

Description	Central case ($1 577/m²)	Sensitivity ($1 262/m²)	Sensitivity 2 ($1 104/m²)
	$, (PV)	$, (PV)	$, (PV)
Costs			
Raise and fill cost	49 209	49 209	49 209
Building construction costs	754 154	603 514	525 564
Total costs	**803 362**	**652 723**	**574 773**
Benefits			
Avoided AADs	**71 172**	**71 172**	**71 172**
Net benefit	**-732 191**	**-581 551**	**-503 602**
BCR	**0.09**	**0.11**	**0.12**

Note: 7 per cent discount rate.

Source: CIE.

53 ABS 8752.0 2020, *Building Activity, Australia, Dec 2019* (data cubes 'Building Activity: Average Cost' and 'Building Activity: Average Floor Area' for NSW)

Reducing these costs by 20 per cent, from \$1,577/m^2 to \$1,262/m^2 marginally improves the net benefit and BCR.

Reducing construction costs by 30 per cent to \$1,104/m^2, improves the net benefit and BCR even further, however the net benefit remains negative.

Given this, site specific construction costs should be explored prior to undertaking raise and fill options.

Option AC7 raise and fill commercial land in the CBD CBA summary discussion

For the scenario considered (limited to 85 properties in the Swansea CBD), two properties are triggered under the 1% AEP (0.01EY) raise and fill threshold in the 30 year analysis and ten properties in the 50 year analysis. As per other adaptation options, most of the saved AADs occur post 2050. However, low probable events with higher water levels account for all the estimated AADs.

The CBA results and subsequent sensitivity analyses highlight that the greatest chance of achieving a positive net benefit and BCR greater than 1 is when:

- raise and fill adaptation is delayed, since avoided damages occur predominately post 2050
- a longer evaluation period is considered, as this results in more saved AADs included in the analysis
- higher inundation water levels are used, as this increases the saved AADs associated with the higher water level events, post raise and fill, noting the need to:
  - continue to monitor water levels and gain more data to determine if a statistically significant structural break has occurred between recently observed water levels and the longer historical record used for the CBA
  - take future water levels into account and revisit adaptation options and models including, CBA as needed, and
  - tie water level analysis and potential deviations from current modelling outputs to the ongoing LAP review, and
- lower construction costs are assumed, noting they account for over 90 per cent of costs.

The chosen raise trigger and raise heights have mixed impact on the CBA results, with the more risk averse trigger chosen, the more AADs are saved, as more properties are raised. However, the saved AADs are offset by even higher raise and fill and construction costs. The result is no improvement to the net benefit or the BCR. This indicates that marginal saved AADs are disproportionately lower than marginal raise and fill and construction costs. The central case scenario trigger and raise levels are therefore optimal for the analysis.

As noted earlier, the modelled option of mosaic raise and fill differs to the initial proposal exhibited to the community, which involved constructing new commercial buildings on the existing carpark and then demolish the existing CBD, to be replaced by a carpark.

The modelled scenario was altered for reasons of practicality and to estimate costings. The precise way in which raising and filling the CBD is undertaken requires:

- input from impacted stakeholders on their:
  - timeframes
  - preferences
  - investment outlook
  - future zoning restrictions, and
- a detailed review of the site and costings of the alternative approaches.

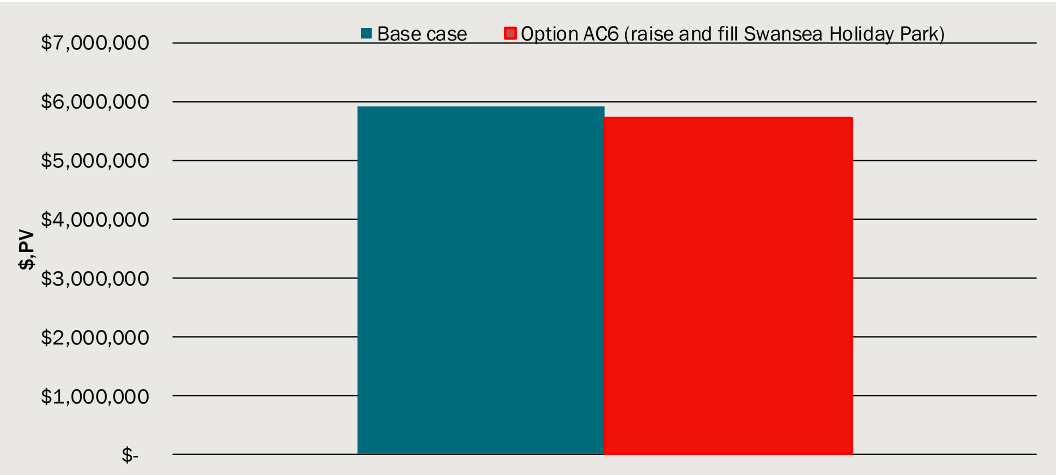
5 Swansea Holiday Park Options

Option AC6 Raise and fill Swansea Holiday Park

AADs - 30 years

Chart 5.1 shows the estimated AADs under the base case and post raise and fill, over a 30 year evaluation period.

5.1 Option AC6 AADs (PV) - 30 years



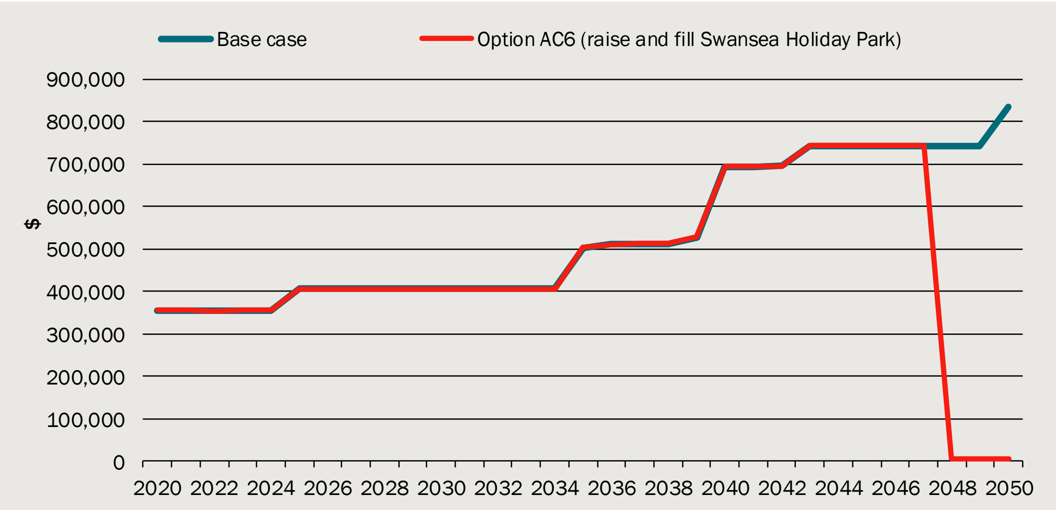
Note: AADs discounted by 7 per cent over a 30 year period.

Data source: CIE

Undertaking raise and fill reduces AADs by $201,000 (PV) (Chart 5.1).

Chart 5.2 shows the estimated AADs, under the base case and post raise and fill, over the 30 year evaluation period.

5.2 Option AC6 AADs (undiscounted) - 30 years



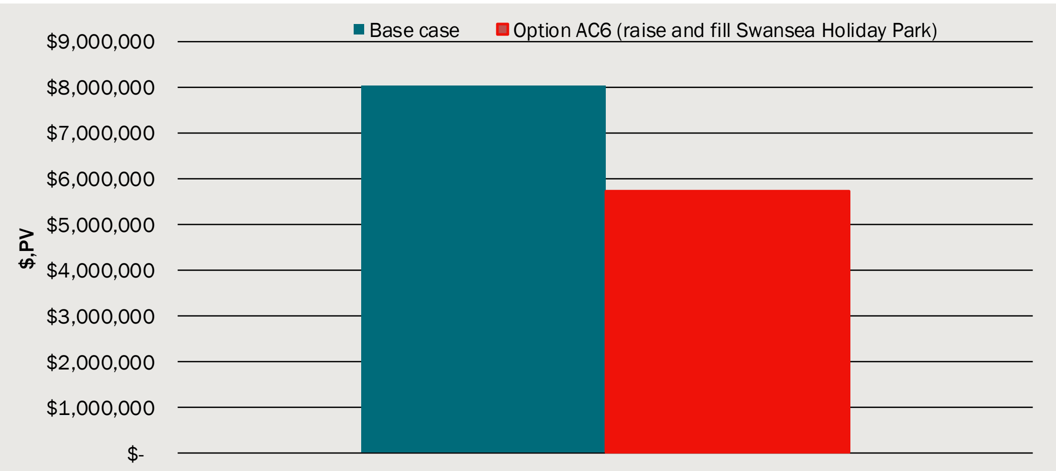
Data source: CIE

The saved AADs occur in the last 2 years of the 30 year analysis (Chart 5.2), as the raise trigger is reached in 2048.

AADs - 50 years

Chart 5.3 shows the estimated AADs, under the base case and post raise and fill, over the 50 year evaluation period.

5.3 Option AC6 AADs (PV) - 50 years



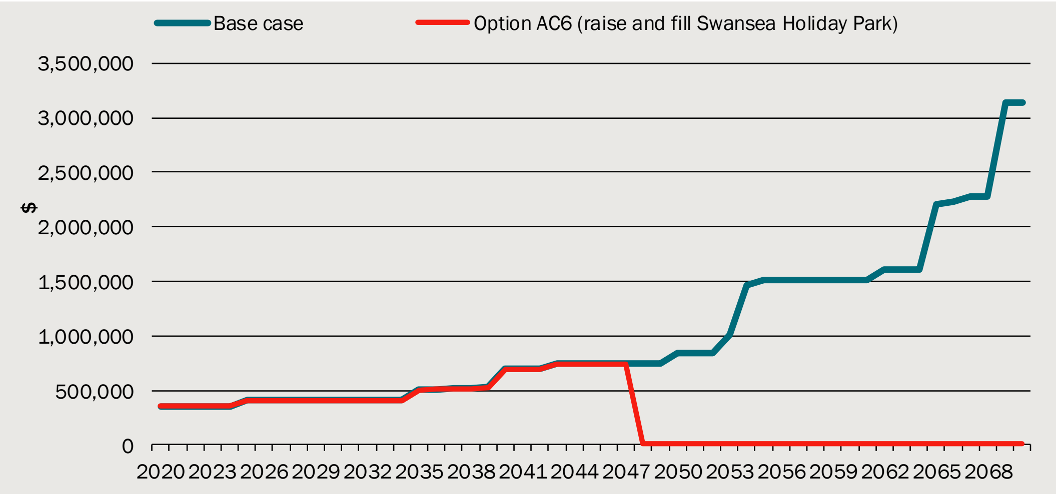
Note: AADs discounted by 7 per cent over a 30 year period.

Data source: CIE

Undertaking raise and fill reduces AADs by $2.3 million (Chart 5.3).

Chart 5.4 shows the estimated AADs, under the base case and post raise and fill, over the 50 year evaluation period.

5.4 Option AC6 AADs (undiscounted) - 50 years



Data source: CIE

Of interest, AADs increase at a faster rate beyond 2050 in the base case, with AADs roughly doubling every ten years in the chosen case study area, as shown in the Chart 5.4 (blue line). This is associated with rising inundation levels over time, which in turn cause greater inundation damage. As such, most of the saved inundation costs (the difference between the blue and red lines) occurs in the later years of the 50 year analysis.

Although inundation costs increase significantly in the base case post 2050, these values are discounted more heavily than saved inundation costs that occur between 2020 and 2050, when calculating PVs. Discounting explains why the difference in the PV AADs between the base case and raise and fill scenario are not as large as the observed difference between undiscounted AADs.

CBA – 30 years

Table 5.5 shows the CBA results for the 30 year analysis.

5.5 Option AC6 CBA - 30 years

Description		Comments
	$, (PV)	
Costs		
Raise and fill cost	1 858 395	125 915 m³ of ground area raised and filled
Construction costs	3 724 015	16 800 m² of building area constructed
Total costs	**5 582 410**	
Benefits		
Avoided AADs	**200 881**	**$49 248 average saving per year (PV)**
Net benefit	**-5 381 529**	
BCR	**0.04**	

Note: 7 per cent discount rate.

Source: CIE.

Undertaking raise and fill for this option results in a net loss of $5.4 million (PV), and BCR of 0.04 (Table 5.5).

CBA – 50 years

Table 5.6 shows the CBA results for the 50 year analysis.

5.6 Option AC6 CBA - 50 years

Description	$, (PV)	Comments
Costs		
Raise and fill cost	1 858 395	125 915 m^3 of ground area raised and filled
Construction costs	3 724 015	16 800 m2 of building area constructed
Total costs	**5 582 410**	
Benefits		
Avoided AADs	**2 301 245**	**$741,397 average saving per year (PV)**
Net benefit	**-3 281 166**	
BCR	**0.41**	

Note: 7 per cent discount rate.

Source: CIE.

Undertaking raise and fill for this option results in a net loss of $3.3 million (PV), and BCR of 0.41 (Table 5.6). The improvement to the net benefit and BCR is due to the 2048 triggered raise and fill accompanied by more annual saved inundation damages from the longer analysis period.

Option AC6 sensitivity analyses

Discount rate sensitivity analysis

Tables 5.7 and 5.8 show the CBA results under a 3 per cent and 10 per cent discount rate for the 30 year and 50 year analysis respectively.

5.7 Option AC6 CBA - 30 year discount rate sensitivity

Description	Central case (7 per cent)	Sensitivity (3 per cent)	Sensitivity (10 per cent)
	$, (PV)	$, (PV)	$, (PV)
Costs			
Raise and fill cost	1 858 395	5 610 327	833 451
Building construction costs	3 724 015	11 242 463	1 670 141
Total costs	**5 582 410**	**16 852 790**	**2 503 591**
Benefits			
Avoided AADs	**200 881**	**617 819**	**88 904**
Net benefit	**-5 381 529**	**-16 234 970**	**-2 414 687**
BCR	**0.04**	**0.04**	**0.04**

Source: CIE.

5.8 Option AC6 CBA - 50 year discount rate sensitivity

Description	Central case (7 per cent)	Sensitivity (3 per cent)	Sensitivity (10 per cent)
	$, (PV)	$, (PV)	$, (PV)
Costs			
Raise and fill cost	1 858 395	5 610 327	833 451
Building construction costs	3 724 015	11 242 463	1 670 141
Total costs	**5 582 410**	**16 852 790**	**2 503 591**
Benefits			
Avoided AADs	**2 301 245**	**10 744 812**	**782 059**
Net benefit	**-3 281 166**	**-6 107 978**	**-1 721 532**
BCR	**0.41**	**0.64**	**0.31**

Source: CIE.

The net benefit reduces with a 3 per cent discount rate and increases with a 10 per cent discount rate under both the 30 year (Table 5.7) and 50 year analysis (Table 5.8). Although future saved AADs are discounted at a lower rate under the 3 per cent discount rate sensitivity, so too are future raise and fill and construction costs. As such, the higher PV benefits are offset by higher PV costs, resulting in a lower net benefit. Similar logic applies to the 10 per cent discount rate sensitivity where although PV costs are lower, so too are PV benefits.

Raise triggers and raise heights sensitivity analysis

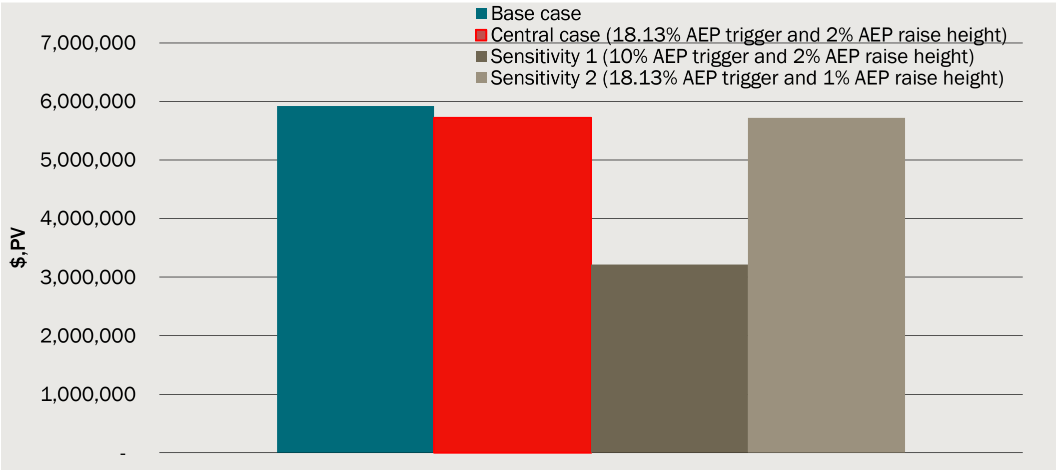
Option AC6 raise trigger and raise height sensitivity AADs

The central case uses a raise:

- trigger of a 18.13% AEP inundation probability level, and
- height of a 2% AEP inundation probability level.

The 30 year AAD PV results for the base case, central case, sensitivity 1 (10% AEP raise trigger and 2% AEP raise height) and sensitivity 2 (18.13% AEP raise trigger and 1% AEP raise height) are shown in Chart 5.9.

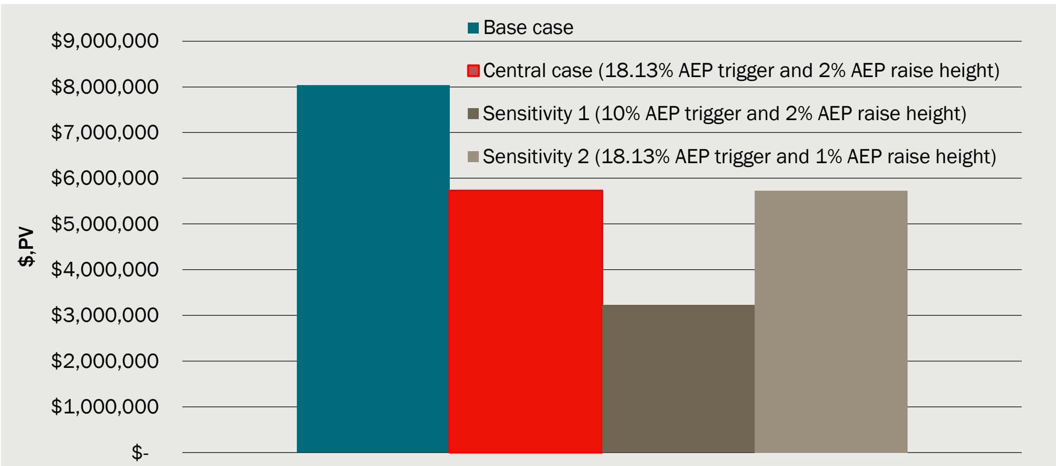
5.9 Option AC6 raise and fill trigger and raise height sensitivity AADs - 30 years



Note: AADs discounted by 7 per cent over a 30 year period.
Data source: CIE.

The 50 year AAD PV sensitivity results are shown in the Chart 5.10.

5.10 Option AC6 raise and fill trigger and raise height sensitivity AADs - 50 years



Note: AADs discounted by 7 per cent over a 50 year period.
Data source: CIE.

Charts 5.9 and 5.10 show that choosing a raise trigger associated with a higher inundation water height saves more AADs, as Swansea Holiday Park is triggered for raise and fill earlier. That is, the current ground level is breached faster in the analysis period. The trigger years for the Central case, Sensitivity 1 and Sensitivity 2 are as follows:

- Central case trigger (18.13% AEP event height) occurs in 2048
  – saving 22 years' worth of AADs post raise and fill for the 50 year analysis
- Sensitivity 1 trigger (10% AEP event height) occurs in 2031

  – saving 39 years' worth of AADs post raise and fill for the 50 year analysis, and
- Sensitivity 2 trigger (18.13% AEP event height) occurs in 2048 (same as the central case).
  – again saving 22 years' worth of AADs post raise and fill for the 50 year analysis.

Option AC6 raise trigger and raise height sensitivity analysis CBA results

CBA results for the chosen raise trigger and raise height sensitivities are shown in Tables 5.11 (30 years) and 5.12 (50 years).

5.11 Option AC6 raise and fill trigger and raise height sensitivity CBA results - 30 years

Description	Central case (18.13% AEP raise trigger and 2% AEP raise height)	Sensitivity 1 (10% AEP raise trigger and 2% AEP raise height)	Sensitivity 2 (18.13% AEP raise trigger and 1% AEP raise height)
	$, (PV)	$, (PV)	$, (PV)
Costs			
Raise and fill cost	1 858 395	4 247 446	2 421 489
Building construction costs	3 724 015	11 763 475	3 724 015
Total costs	**5 582 410**	**16 010 922**	**6 145 504**
Benefits			
Avoided AADs	**200 881**	**2 707 919**	**201 372**
Net benefit	**-5 381 529**	**-13 303 002**	**-5 944 132**
BCR	**0.04**	**0.17**	**0.03**

Note: 7 per cent discount rate.

Source: CIE.

5.12 Option AC6 raise and fill trigger and raise height sensitivity CBA results - 50 years

Description	Central case (18.13% AEP trigger and 2% AEP raise height)	Sensitivity 1 (10% AEP trigger and 2% AEP raise height)	Sensitivity 2 (18.13% AEP trigger and 1% AEP raise height)
	$, (PV)	$, (PV)	$, (PV)
Costs			
Raise and fill cost	1 858 395	4 247 446	2 421 489
Building construction costs	3 724 015	11 763 475	3 724 015
Total costs	**5 582 410**	**16 010 922**	**6 145 504**
Benefits			
Avoided AADs	**2 301 245**	**4 808 283**	**2 304 378**
Net benefit	**-3 281 166**	**-11 202 639**	**-3 841 126**
BCR	**0.41**	**0.30**	**0.37**

Note: 7 per cent discount rate.

Source: CIE.

Tables 5.11 and 5.12 indicate that although a higher inundation trigger raises Swansea Holiday Park earlier and saves more AADs over the analysis period, the raise and fill and construction costs also occur sooner. The result is no improvement to the net benefit.

Construction costs sensitivity analysis

Construction costs account for over 67 per cent of total costs. In practice, construction costs are often context specific, associated with the type of property, location, and availability of trades at a particular point in time.

Tables 5.13 and 5.14 show CBA results of reduced construction costs of $1,262/m^2 and $1,104/m^2, for the 30 year and 50 year analysis respectively.

5.13 Option AC6 construction cost sensitivity CBA results - 30 years

Description	Central case ($1 577/m^2)	Sensitivity ($1 262/m^2)	Sensitivity 2 ($1 104/m^2)
	$, (PV)	$, (PV)	$, (PV)
Costs			
Raise and fill cost	1 858 395	1 858 395	1 858 395
Building construction costs	3 724 015	2 979 212	2 606 811
Total costs	**5 582 410**	**4 837 607**	**4 465 206**
Benefits			
Avoided AADs	**200 881**	**200 881**	**200 881**
Net benefit	**-5 381 529**	**-4 636 726**	**-4 264 325**
BCR	**0.04**	**0.04**	**0.04**

Note: 7 per cent discount rate.

Source: CIE.

5.14 Option AC6 construction cost sensitivity CBA results - 50 years

Description	Central case ($1 577/m^2)	Sensitivity ($1 262/m^2)	Sensitivity 2 ($1 104/m^2)
	$, (PV)	$, (PV)	$, (PV)
Costs			
Raise and fill cost	1 858 395	1 858 395	1 858 395
Building construction costs	3 724 015	2 979 212	2 606 811
Total costs	**5 582 410**	**4 837 607**	**4 465 206**
Benefits			
Avoided AADs	**2 301 245**	**2 301 245**	**2 301 245**
Net benefit	**-3 281 166**	**-2 536 363**	**-2 163 961**
BCR	**0.41**	**0.48**	**0.52**

Note: 7 per cent discount rate.

Source: CIE.

Reducing these costs from $1,577/m^2 to $1,262/m^2 marginally improves the net benefit, as shown in Tables 5.13 (30 year analysis) and 5.14 (50 year analysis).

Reducing construction costs applied to non-accommodation buildings by 30 per cent to $1,104/m^2, improves the net benefit and BCR even further, however the net benefit remains negative.

Given this, site specific construction costs should be explored prior to undertaking raise and fill options.

Raise and fill costs sensitivity analysis

Raise and fill costs account for the remaining 33 per cent of total costs in the central case. Tables 5.15 and 5.16 show CBA results of reduced raise and fill costs of $95/m^2 and $85/m^2, for the 30 year and 50 year analysis respectively.

5.15 Option AC6 raise and fill cost sensitivity CBA results - 30 years

Description	Central case ($105/m^3)	Sensitivity ($95/m^3)	Sensitivity 2 ($85/m^3)
	$, (PV)	$, (PV)	$, (PV)
Costs			
Raise and fill cost	1 858 395	1 681 405	1 504 415
Building construction costs	3 724 015	3 724 015	3 724 015
Total costs	**5 582 410**	**5 405 420**	**5 228 430**
Benefits			
Avoided AADs	**200 881**	**200 881**	**200 881**
Net benefit	**-5 381 529**	**-5 204 539**	**-5 027 549**
BCR	**0.04**	**0.04**	**0.04**

Note: 7 per cent discount rate.

Source: CIE.

5.16 Option AC6 raise and fill cost sensitivity CBA results - 50 years

Description	Central case ($105/m^3)	Sensitivity ($95/m^3)	Sensitivity 2 ($85/m^3)
	$, (PV)	$, (PV)	$, (PV)
Costs			
Raise and fill cost	1 858 395	1 681 405	1 504 415
Building construction costs	3 724 015	3 724 015	3 724 015
Total costs	**5 582 410**	**5 405 420**	**5 228 430**
Benefits			
Avoided AADs	**2 301 245**	**2 301 245**	**2 301 245**
Net benefit	**-3 281 166**	**-3 104 176**	**-2 927 186**
BCR	**0.41**	**0.43**	**0.44**

Note: 7 per cent discount rate.

Source: CIE.

Reducing these costs from $105/m^3 to $95/m^3, marginally improves the net benefit and BCR, as shown in Table 5.15 (30 year analysis) and 5.16 (50 year analysis). Reducing raise and fill costs to $85/m^3, improves the net benefit and BCR even further, however the net benefit remains negative.

Option AC6 raise and fill Swansea Holiday Park CBA summary discussion

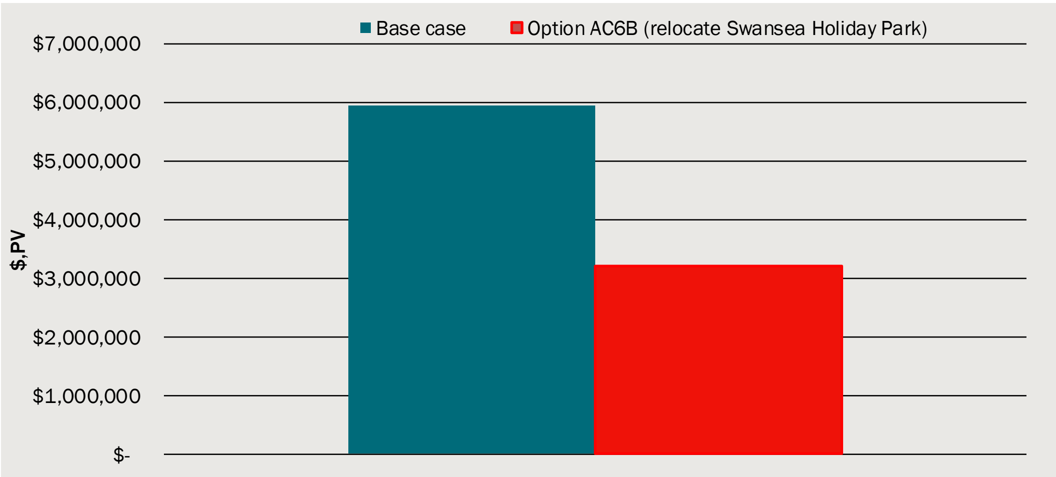
The CBA results and subsequent sensitivity analysis highlight that undertaking this option is unlikely to result in a positive net benefit or BCR greater than 1. This is because raise and fill mitigate a small amount of AADs, compared to the cost of adaptation.

Option AC6B Relocate Swansea Holiday Park

AADs – 30 years

Chart 5.17 shows the estimated AADs under the base case and post relocation, over a 30 year evaluation period.

5.17 Option AC6B (relocate Swansea Holiday Park) AADs (PV) - 30 years



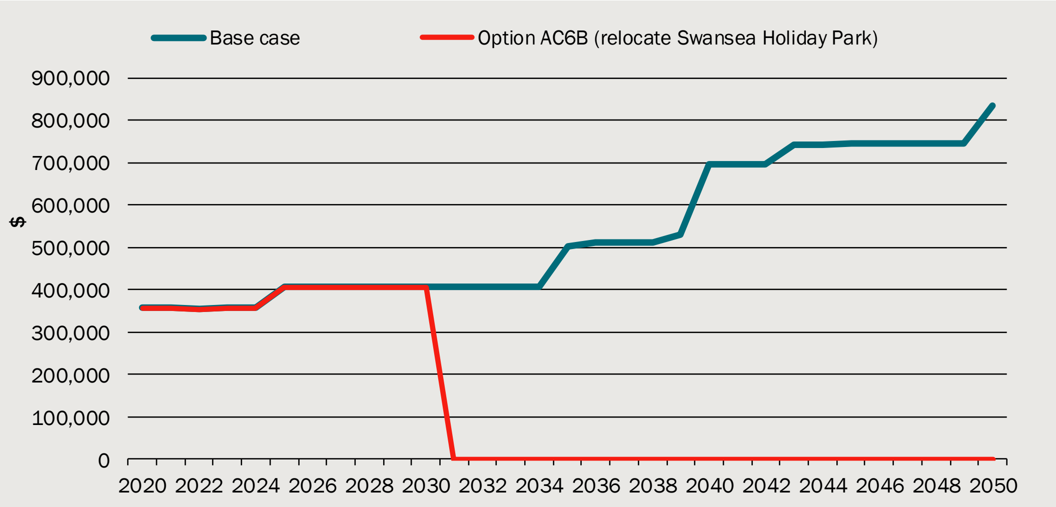
Note: AADs discounted by 7 per cent over a 30 year period.

Data source: CIE.

Relocating the Swansea Holiday Park reduces AADs by $2.7 million (PV) (Chart 5.17).

Chart 5.18 shows the estimated AADs, under the base case and post relocation, over the 30 year evaluation period.

5.18 Option AC6B (relocate Swansea Holiday Park) AADs (undiscounted) - 30 years



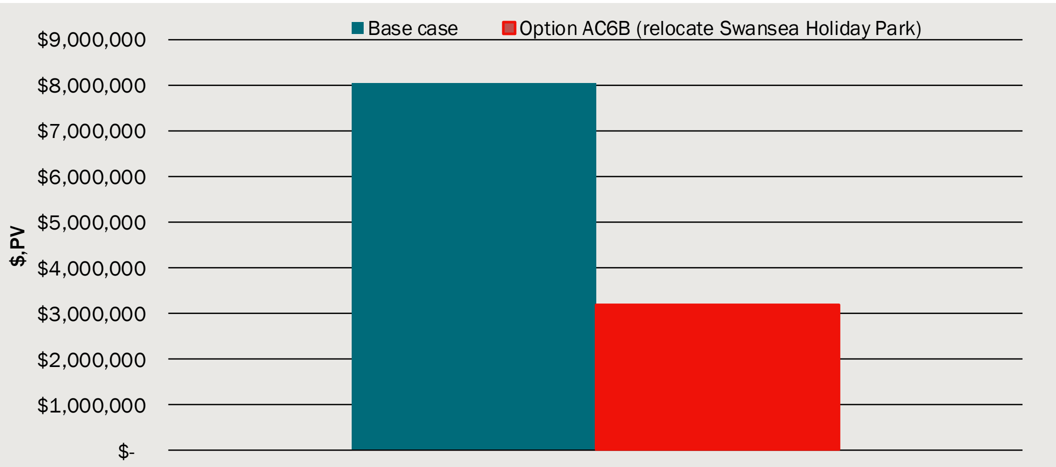
Data source: CIE.

The saved AADs commence 1-year post relocation (Chart 5.18).

AADs - 50 years

Chart 5.19 shows the estimated AADs under the base case and post relocation, over a 50 year evaluation period.

5.19 Option AC6B (relocate Swansea Holiday Park) AADs (PV) - 50 years



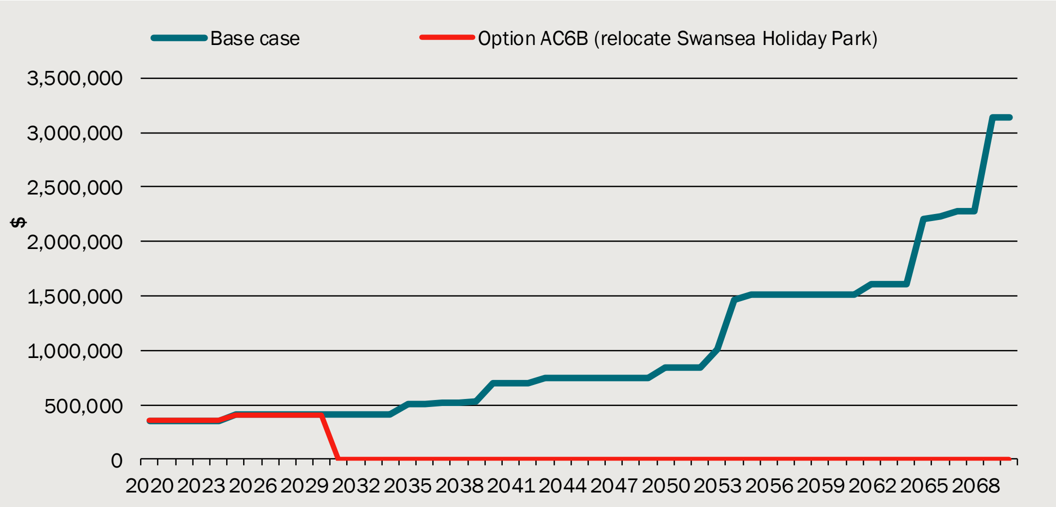
Note: AADs discounted by 7 per cent over a 50 year period.

Data source: CIE

Relocating Swansea Holiday Park reduces AADs by $4.8 million (Chart 5.19).

Chart 5.20 shows the estimated AADs, under the base case and post relocation, over the 50 year evaluation period.

5.20 Option AC6B (relocate Swansea Holiday Park) AADs (undiscounted) - 50 years



Data source: CIE.

As described in AC6 raise and fill of Swansea Holiday Park, AADs increase at a faster rate beyond 2050 in the base case, with AADs roughly doubling every ten years in the chosen case study area Chart 5.20 (blue line). As such, most of the saved inundation costs (the difference between the blue and red lines) occur in the later years of the 50 year analysis.

CBA – 30 years

Table 5.21 shows the CBA results, over a 30 year evaluation period.

5.21 Option AC6B CBA - 30 years

Description	
	$, (PV)
Costs	
Holiday Park development capital costs	3 797 227
Total costs	**3 797 227**
Benefits	
Avoided AADs	**2 730 321**
Net benefit	**-1 066 907**
BCR	**0.72**

Note: 7 per cent discount rate.
Source: CIE.

Relocating Swansea Holiday Park results in a net loss of $1.1 million (PV), and BCR of 0.72 (Table 5.21).

CBA – 50 years

Table 5.22 shows the CBA results, over a 50 year evaluation period.

5.22 Option AC6B CBA - 50 years

Description	
	$, (PV)
Costs	
Holiday Park development capital costs	3 797 227
Total costs	**3 797 227**
Benefits	
Avoided AADs	**4 836 670**
Net benefit	**1 039 442**
BCR	**1.27**

Note: 7 per cent discount rate.

Source: CIE.

Relocating Swansea Holiday Park results in a net benefit of $1.0 million (PV), and BCR of 1.27 (Table 5.22). The improvement to the net benefit and BCR is due to the inclusion of increased saved AADs post relocation from the longer analysis period. However, the CBA results are likely to be an upper bound as they do not include upgrade costs for the existing Belmont Bayview Park..

Option AC6B sensitivity analysis

Discount rate sensitivity analysis

Tables 5.23 and 5.24 show the CBA results under a 3 per cent and 10 per cent discount rate for the 30 year and 50 year analysis respectively.

5.23 Option AC6B CBA - 30 year discount rate sensitivity

Description	Central case (7 per cent)	Sensitivity (3 per cent)	Sensitivity (10 per cent)
	$, (PV)	$, (PV)	$, (PV)
Costs			
Holiday Park development capital costs	3 797 227	6 086 815	2 736 162
Total costs	**3 797 227**	**6 086 815**	**2 736 162**
Benefits			
Avoided AADs	**2 730 321**	**6 030 845**	**1 576 312**
Net benefit	**-1 066 907**	**-55 970**	**-1 159 850**
BCR	**0.72**	**0.99**	**0.58**

Source: CIE.

5.24 Option AC6B CBA - 50 year discount rate sensitivity

Description	Central case (7 per cent)	Sensitivity (3 per cent)	Sensitivity (10 per cent)
	$, (PV)	$, (PV)	$, (PV)
Costs			
Holiday Park development capital costs	3 797 227	6 086 815	2 736 162
Total costs	**3 797 227**	**6 086 815**	**2 736 162**
Benefits			
Avoided AADs	**4 836 670**	**16 184 380**	**2 271 558**
Net benefit	**1 039 442**	**10 097 565**	**-464 603**
BCR	**1.27**	**2.66**	**0.83**

Source: CIE.

The net benefit improves with a 3 per cent discount rate and decreases with a 10 per cent discount rate (Table 5.23). The lower discount rate increases the value of future costs and benefits in today's terms. In this scenario, the future stream of benefits is greater than the future stream of costs. The net result is an improvement to the net benefit and BCR. The improvement to the net benefit and BCR are particularly strong in the 50 year analysis (Table 5.24), which incorporates a longer time series of annual saved inundation costs, and those savings increase over time.

The value of the future saved AADs is reduced under a 10 per cent discount rate. The reduction in the value of future saved AADs is greater than the reduction in future costs. The result is an overall reduction to the net benefit and BCR.

Option AC6B relocate Swansea Holiday Park CBA summary discussion

The CBA results and subsequent sensitivity analyses highlight that the greatest chance of achieving a positive net benefit and BCR greater than 1 is when:

- a lower discount rate is used, as this increases the PV of future saved AADs, and
- a longer evaluation period is considered, as this results in more saved AADs included in the analysis.

However, the CBA results are likely to be an upper bound as they do not include upgrade costs for the existing Belmont Bayview Park.

The CBA analysis indicates relocation of the Swansea Holiday Park to the identified site locations, is economically preferable to raise and fill at the current site. This is attributed to:

- the higher ground level of 2.66 metres (AHD) at the proposed new sites, saving proportionately more AADs than the raise and fill option, and
- lower estimated costs of relocation versus raise and fill, to achieve the saved AADs.

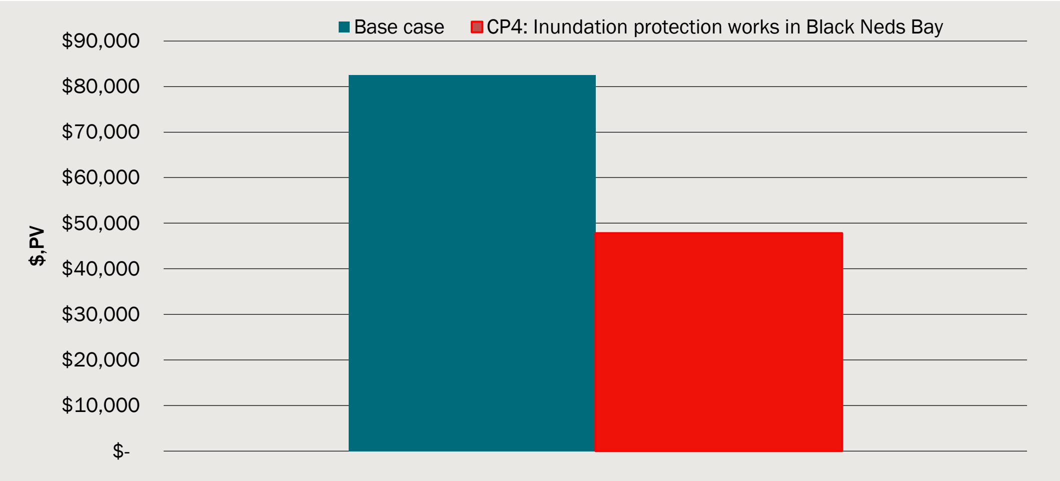
6 Channel and Foreshore Protection Works

Option CP4 Black Neds Bay inundation protection works

AADs - 30 years

Chart 6.1 shows the estimated PV AADs under the base case and post installation of inundation protection works, over a 30 year evaluation period.

6.1 Option CP4 AADs (PV) - 30 years



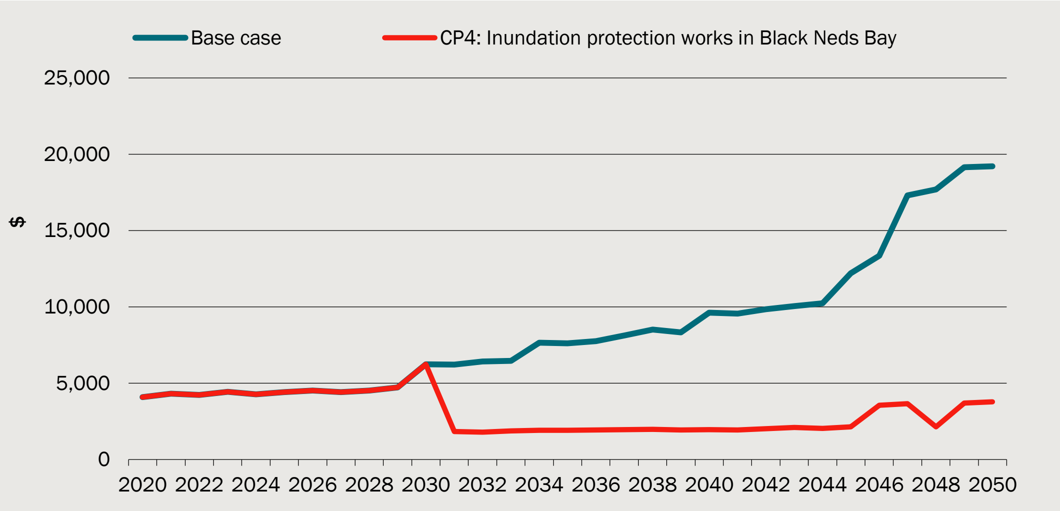
Note: AADs discounted by 7 per cent.

Data source: CIE.

Inundation protection works reduce AADs by $35,000 (PV).

Chart 6.2 shows AADs over the 30 year evaluation period.

6.2 Option CP4 AADs (undiscounted) - 30 years



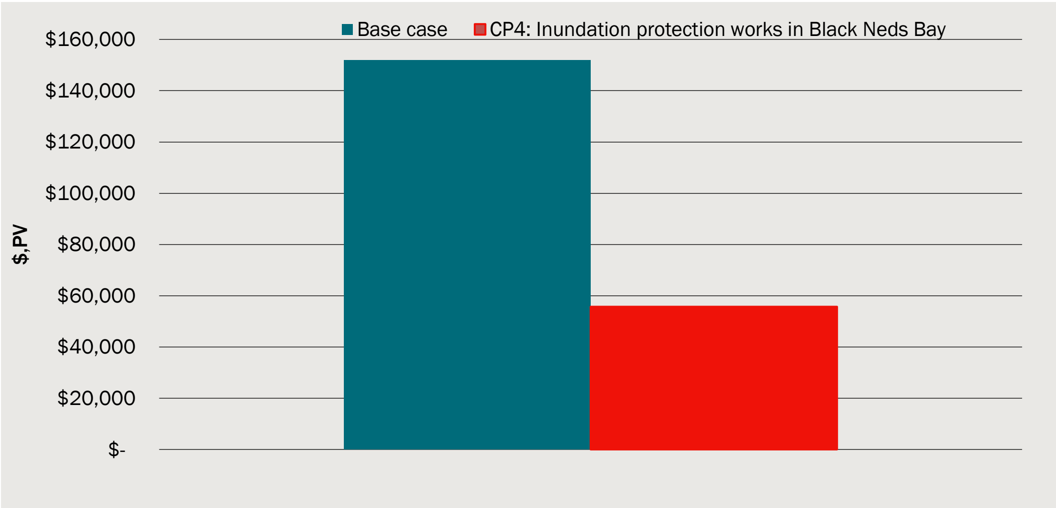
Data source: CIE.

Saved AADs commence 2031 (1 year post the assumed installation date of the protection works), with the largest difference between the base case and post inundation works occurring in the later years (post 2044).[54]

AADs - 50 years

Chart 6.3 shows the estimated PV AADs under the base case and post installation of inundation protection works, over a 50-year evaluation period.

6.3 Option CP4 AADs (PV) - 50 years



Note: AADs discounted by 7 per cent.

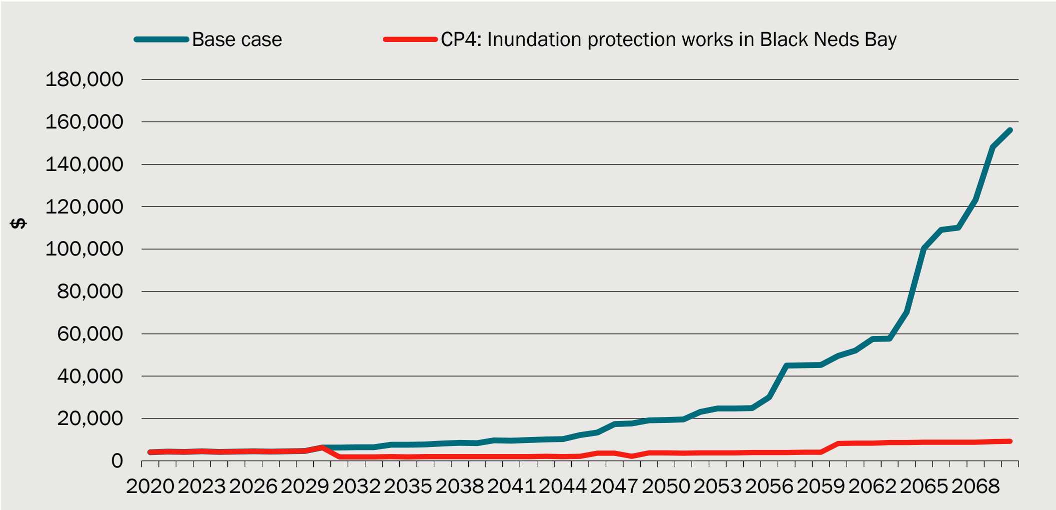
Data source: CIE.

Inundation protection works reduce AADs by $96,000 (PV) (Chart 6.3).

Chart 6.4 shows AADs over the 50 year evaluation period.

54 Changing the assumed installation date which would have a flow on impact to the subsequent timing of the saved AADs.

6.4 Option CP4 AADs (undiscounted) - 50 years



Data source: CIE.

Of interest, AADs increase at a faster rate beyond 2050 in the base case, with AADs roughly doubling every ten years in the chosen case study area, as shown in Chart 6.4 (blue line).

This is associated with rising inundation levels over time, which in turn cause more properties to be inundated at higher water levels. As such, most of the saved inundation costs (the difference between the blue and red lines) occurs in the later years of the 50 year analysis.

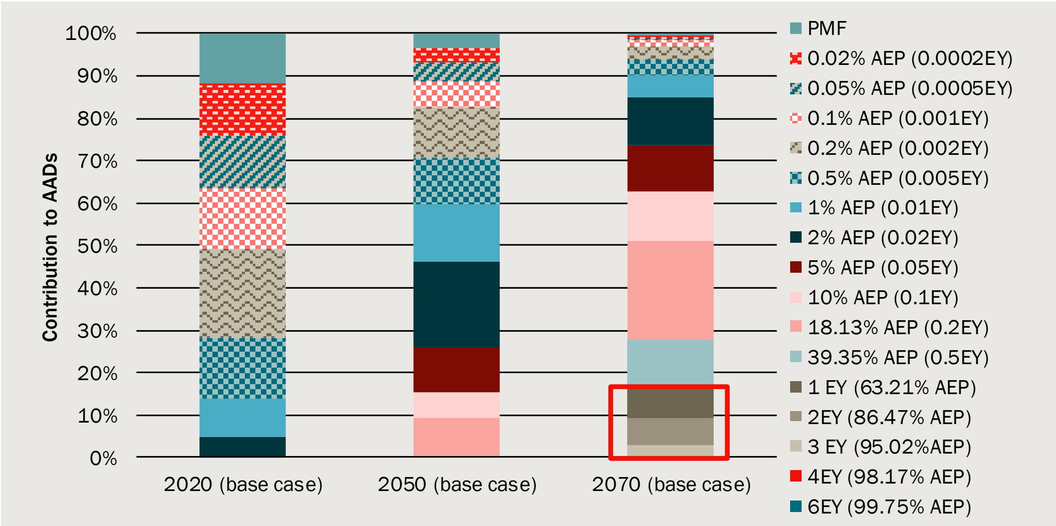
Although inundation costs increase significantly in the base case post 2050, these values are discounted more heavily than saved inundation costs that occur between 2030 and 2049, when calculating PV.

Discounting explains why the difference in the PV AADs between the base case (do nothing scenario) and protection works are not as large as the observed difference between undiscounted AADs.

Inundation event probability contribution to AADs

Chart 6.5 shows the base case contribution of AADs by inundation events for the years 2020, 2050 and 2070. Chart 6.6 shows the same information post installing inundation protection works. Multiple inundation events are those which occur with an EY of 1 or more.

6.5 Option CP4 contribution of inundation event probabilities to AADs (base case)



Note: Multiple annual event probabilities shown in red boxes.

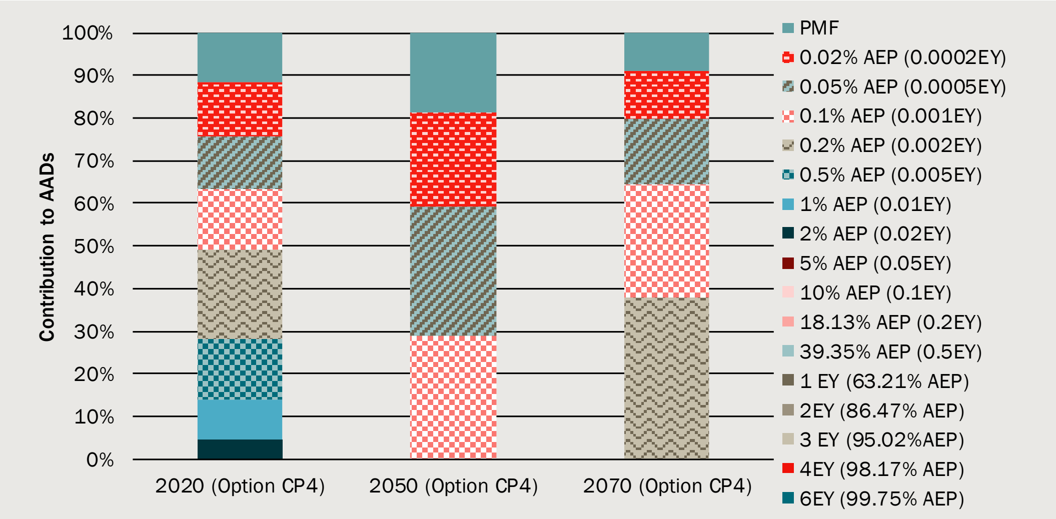
Data source: CIE.

Chart 6.5 shows that in the base case AADs are dominated by events with a low occurrence probability, but high water levels. However, multiple annual inundation events do start to contribute to AADs in the later part of the 50 year analysis. For example, multiple annual inundation events account for:

- 0 per cent ($0) of AADs in 2020
- 0 per cent ($0) of AADs in 2050, and
- 16 per cent ($25,497) of AADs in 2070.

As such, the ‘big events’ (low probability major storms with high water levels) drive adaptive action for Option CP4, especially pre-2050, with 0.1% AEP and less likely events making up over 50 per cent of 2020 AADs. However, frequent yearly inundation events (with high probabilities and lower water levels) become a more significant consideration over time, especially post 2050.

6.6 Contribution of inundation event probabilities to AADs (Option CP4)



Data source: CIE

Chart 6.6 shows that installing inundation protection works mitigates:

- some of the 'big event' AADs (ranging from the PMF to 1% AEP), and
- the post 2050 growing multiple inundation event risk.

For example, 2070 AADs are made up of:

- 0.2% AEP (0.002EY) event – 38 per cent ($3,484)
- 0.1% AEP (0.001EY) event - 26 per cent ($2,420)
- 0.05% AEP (0.0005EY) event - 15 per cent ($1,413)
- 0.02% AEP (0.0002EY) event - 11 per cent ($1,030), and
- PMF - 9 per cent ($822)

CBA – 30 years

Table 6.7 shows the CBA results for the 30 year analysis.

6.7 Option CP4 CBA - 30 years

Description	
	$, (PV)
Costs	
Inundation protection works	1 425 278
Total costs	**1 425 278**
Benefits	
Avoided AADs	**34 689**
Net benefit	**-1 390 590**
BCR	**0.02**

Note: 7 per cent discount rate.

Source: CIE.

Installing inundation protection works results in a net loss of $1.4 million (PV), and BCR of 0.07.

CBA – 50 years

Table 6.8 shows the CBA results for the 50 year analysis.

6.8 Option CP4 CBA - 50 years

Description	
	$, (PV)
Costs	
Inundation protection works	1 425 278
Total costs	**1 425 278**
Benefits	
Avoided AADs	**96 312**
Net benefit	**-1 328 967**
BCR	**0.07**

Note: 7 per cent discount rate.
Source: CIE

Installing inundation protection works this option results in a net loss of $1.3 million (PV), and BCR of 0.07.

The CBA results indicate the cost of adaptation in the form of inundation protection works, is an order of magnitude greater than the estimated AAD savings. A higher net benefit and BCR will be achieved if a cheaper solution can be found to mitigate similar inundation costs.

Option CP4 sensitivity analyses

Discount rate sensitivity analysis

Tables 6.9 (30 year evaluation) and 6.10 (50 year evaluation) show the CBA results under alternate discount rates of 3 and 10 per cent, compared to the central analysis, which used 7 per cent.

6.9 Option CP4 CBA - 30 year discount rate sensitivity

Description	Central case (7 per cent)	Sensitivity (3 per cent)	Sensitivity (10 per cent)
	$, (PV)	$, (PV)	$, (PV)
Costs			
Inundation protection works	1 425 278	2 167 264	1 051 482
Total costs	**1 425 278**	**2 167 264**	**1 051 482**
Benefits			
Avoided AADs	**34 689**	**78 868**	**19 668**
Net benefit	**-1 390 590**	**-2 088 396**	**-1 031 814**
BCR	**0.02**	**0.04**	**0.02**

Source: CIE.

6.10 Option CP4 CBA - 50 year discount rate sensitivity

Description	Central case (7 per cent)	Sensitivity (3 per cent)	Sensitivity (10 per cent)
	$, (PV)	$, (PV)	$, (PV)
Costs			
Inundation protection works	1 425 278	2 167 264	1 051 482
Total costs	**1 425 278**	**2 167 264**	**1 051 482**
Benefits			
Avoided AADs	**96 312**	**401 131**	**38 827**
Net benefit	**-1 328 967**	**-1 766 133**	**-1 012 655**
BCR	**0.07**	**0.19**	**0.04**

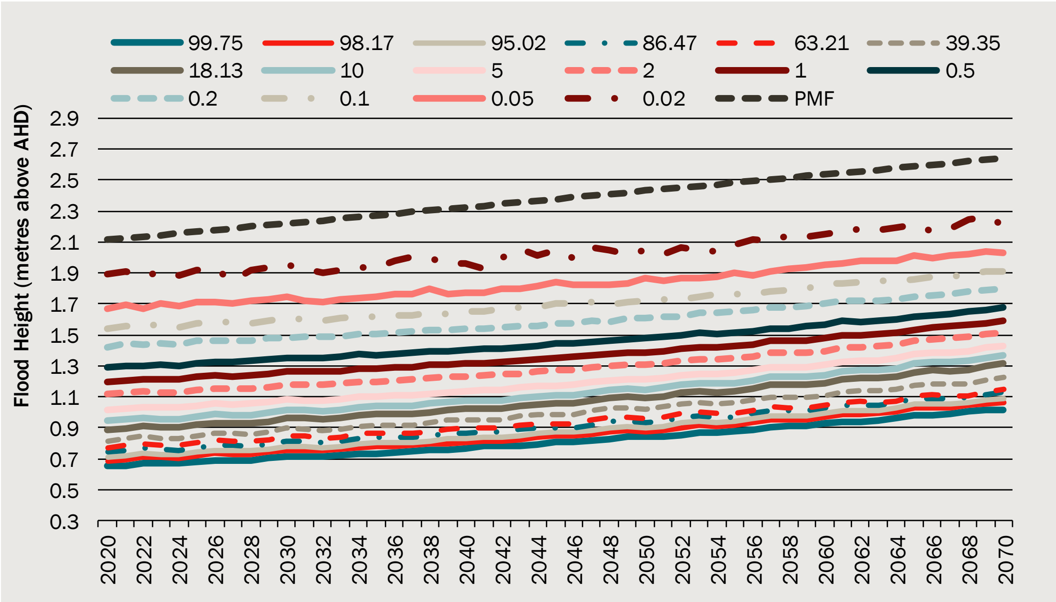
Source: CIE.

The CBA results marginally change under 3 per cent and 10 per cent discount rate sensitivities). Although future saved AADs are discounted at a lower rate under the 3 per cent discount rate sensitivity, so too are construction costs. As such, the higher PV benefits are offset by higher PV costs, resulting in minimal differences in net benefits and BCRs. Similar logic applies to the 10 per cent discount rate sensitivity where although PV costs are lower, so too are PV benefits.

Water level sensitivity analysis

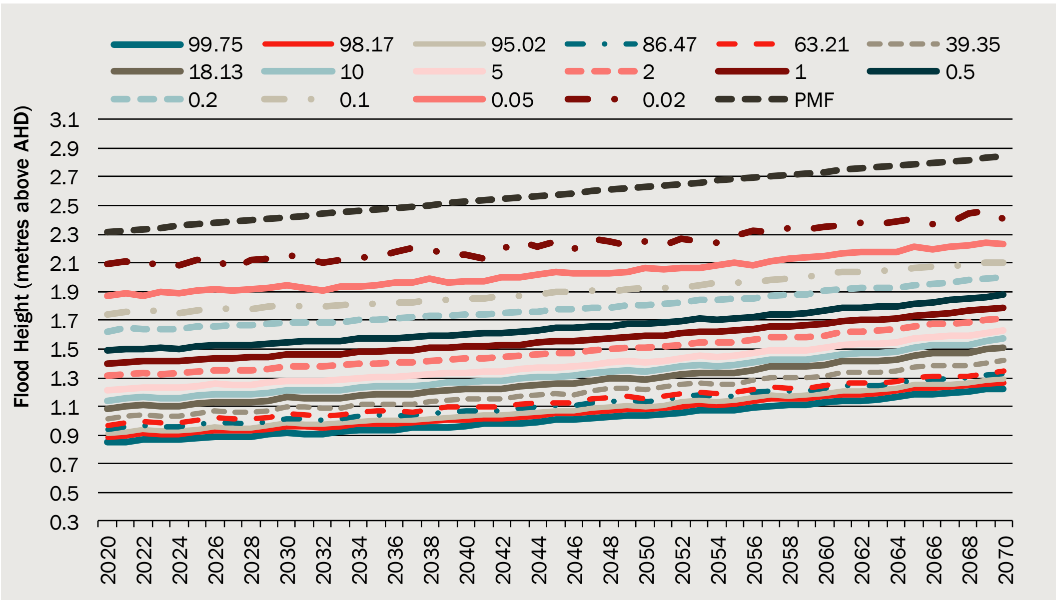
Council has requested a sensitivity to test the impacts of a uniform inundation water level increase of 0.2 metres (AHD) on AAD and CBA results. Inundation levels used in the core modelling results are shown in Chart 6.11 (Precinct 20) and sensitivity inundation water levels shown in Chart 6.12 (Precinct 20).

6.11 Inundation water level heights - Precinct 20



Data source: Salients et. al 2020.

6.12 Sensitivity inundation water level heights - Precinct 20

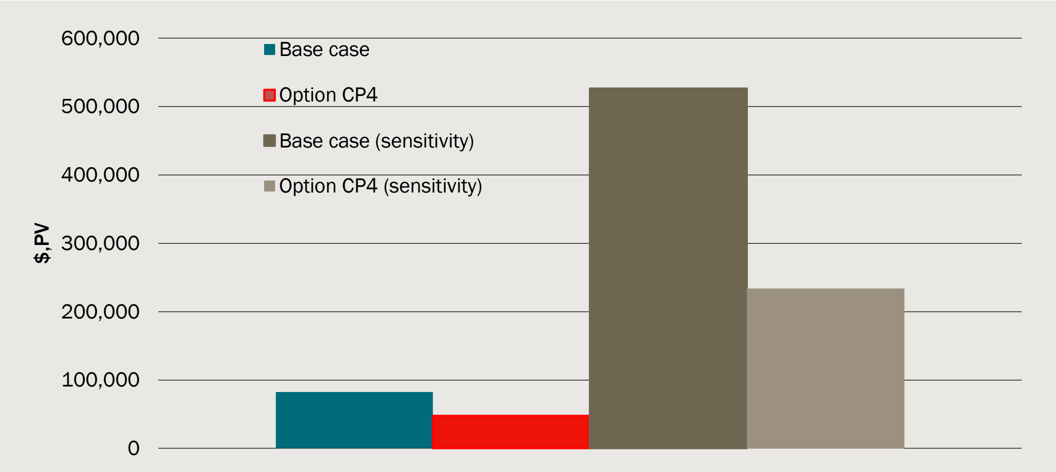


Data source: Salients et. al 2020; CIE.

AADs for Water Level sensitivity analysis

Chart 6.13 shows the 30 years AAD PV results for the base case and installation of inundation protection works, assuming the central case and sensitivity water levels. Chart 6.14 shows the AADs under each scenario over the entire 30 year analysis.

6.13 Option CP4 water height sensitivity AADs (PV) - 30 years



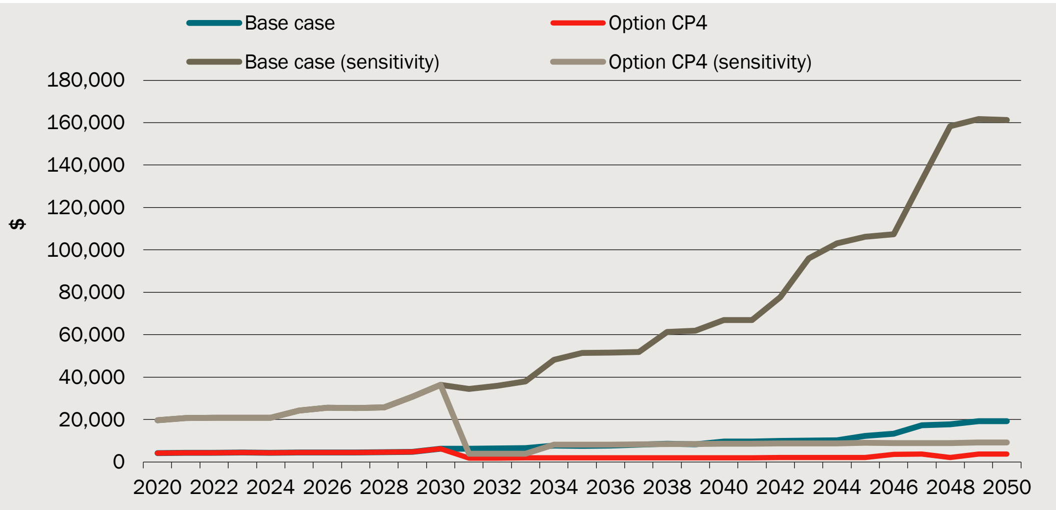
Note: AADs discounted by 7 per cent over a 30 year period.

Data source: CIE.

Chart 6.13 shows the:

- estimated AADs in the sensitivity base case are more than six times greater than that estimated using the core water level heights, and
- saved AADs post installation of inundation protection works in the sensitivity ($293,000), are also much greater than the core analysis ($35,000).

6.14 Option CP4 water height sensitivity AADs (undiscounted) - 30 years

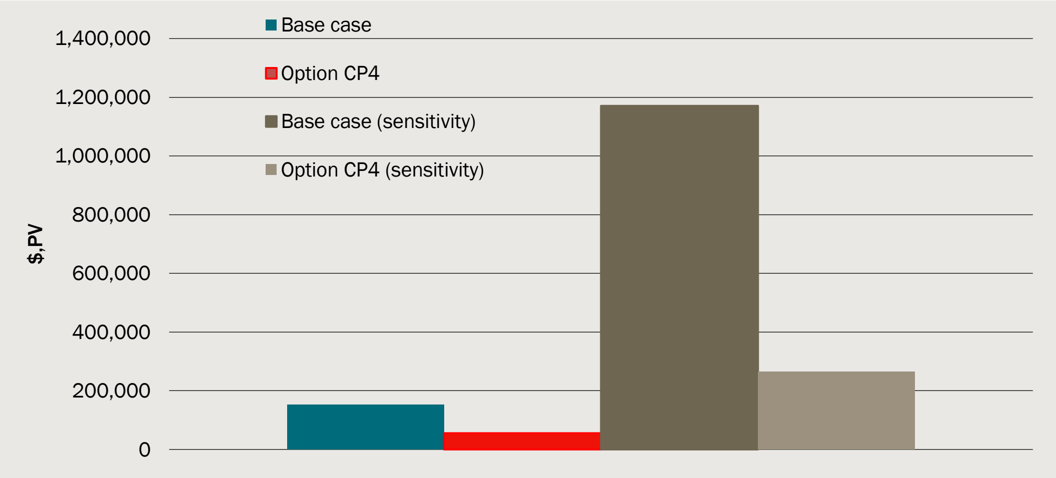


Data source: CIE.

Chart 6.14 shows the annual difference between saved AADs increases significantly over time. For example, the installation of inundation protection works saves AADs of $31,000 in 2031 under the sensitivity (the year following installation), compared to $4,000 in the core analysis. Saved AADs increase to $152,000 in 2050 under the sensitivity, compared to $15,000 in the core analysis.

50 year AADs are shown in Chart 6.15.

6.15 Option CP4 water height sensitivity AADs (PV) - 50 years



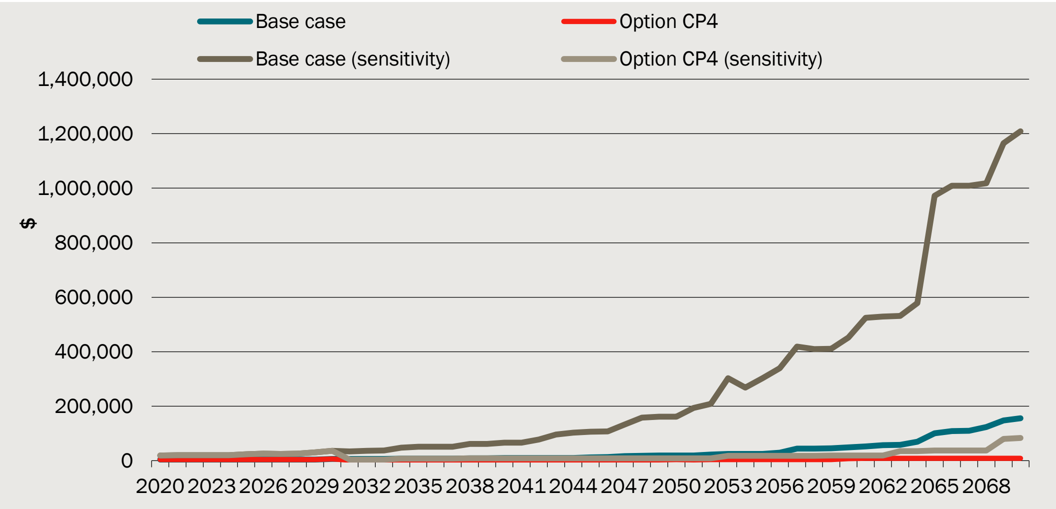
Note: AADs discounted by 7 per cent over a 50 year period.

Data source: CIE.

The difference between base case AADs are even greater under the sensitivity ($1.2 million), compared to $152,000 in the core analysis. Saved AADs from protection works installation are also larger at $906,000, compared to $96,000.

Chart 6.16 shows the AADs under each scenario over the entire 50 year analysis.

6.16 Option CP4 water height sensitivity AADs (undiscounted) - 50 years



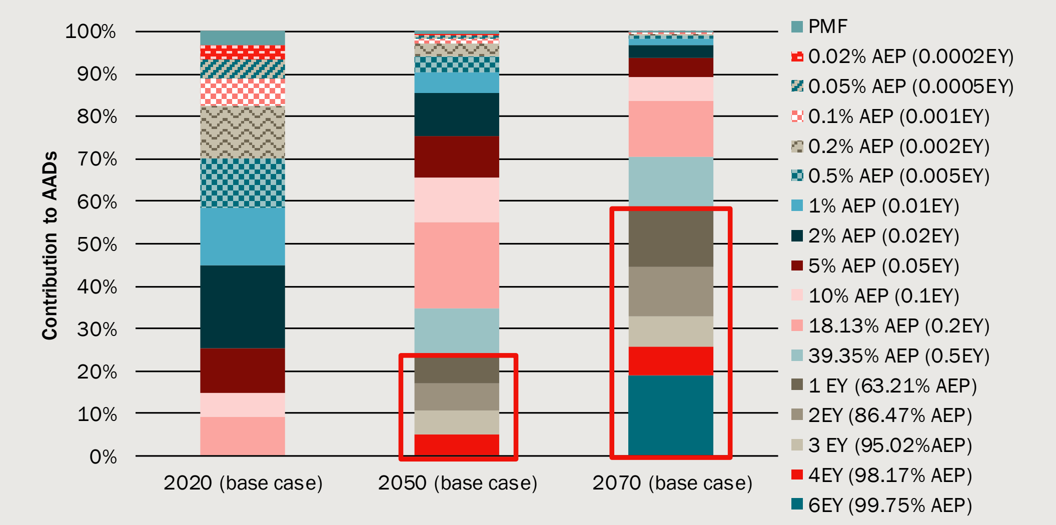
Data source: CIE.

A key point is that AAD savings beyond 2050 are much higher under the sensitivity, compared to the core 50 year analysis.

Inundation event contribution to AADs

Charts 6.17 and 6.18 show the contribution of inundation events to AADs in 2020, 2050 and 2070, under a sensitivity of +0.2m AHD water levels for the base case and post installation of inundation protection works.

6.17 Option CP4 +0.2m AHD sensitivity contribution of inundation event probabilities to AADs (base case)



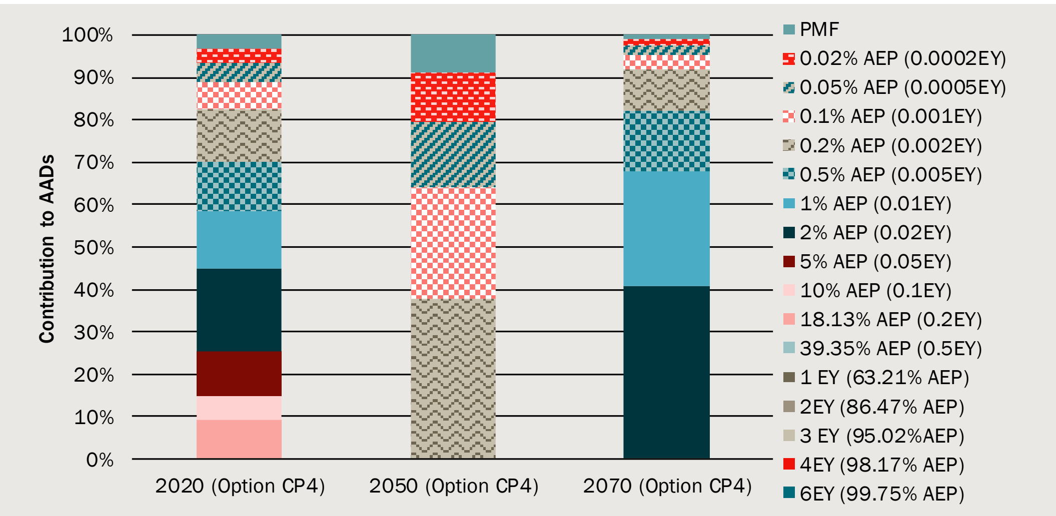
Note: Multiple annual event probabilities shown in red boxes.

Data source: CIE.

Chart 6.17 shows that multiple inundation events (1EY and greater) account for a growing share of AADs in the base case. Therefore, frequent yearly inundation events (with high probabilities and lower water levels) drive adaptive action for Option CP4 post 2050, under the sensitivity water levels. For example, base case multiple annual inundation events increase from:

- 0 per cent ($0) of AADs in 2020, to 60 per cent ($709,149) of AADs in 2070.

6.18 Contribution of inundation event probabilities to AADs (Option CP4 +0.2m AHD sensitivity)



Data source: CIE.

Chart 6.18 shows that installing inundation protection works subsequently mitigates the growing risk from multiple inundation events, as they account for 0 per cent of multiple AADs in 2070, post installation of protection works.

CBA – water level sensitivity analysis

The CBA results show an improvement to the net benefit and BCR for both the 30 year (Table 6.19) and 50 year analysis (Table 6.20) under the +0.2m AHD water level sensitivity.

6.19 Option CP4 water height sensitivity CBA results - 30 years

Description	Central case (core water levels)	Sensitivity (+0.2 mAHD water levels)
	$, (PV)	$, (PV)
Costs		
Protection works	1 425 278	1 425 278
Total costs	**1 425 278**	**1 425 278**
Benefits		
Avoided AADs	**34 689**	**293 068**
Net benefit	**-1 390 589**	**-1 132 210**
BCR	**0.02**	**0.21**

Note: 7 per cent discount rate.
Source: CIE.

6.20 Option CP4 water height sensitivity CBA results - 50 years

Description	Central case (core water levels)	Sensitivity (+0.2 mAHD water levels)
	$, (PV)	$, (PV)
Costs		
Protection works	1 425 278	1 425 278
Total costs	**1 425 278**	**1 425 278**
Benefits		
Avoided AADs	**96 312**	**905 771**
Net benefit	**-1 328 966**	**-519 507**
BCR	**0.07**	**0.64**

Note: 7 per cent discount rate.
Source: CIE.

This sensitivity analysis suggests a clear need to monitor water levels and gain more evidence to determine if a statistically significant structural break has occurred between currently observed water levels and historical records.

Option CP4 inundation protection works CBA summary discussion

This option is to undertake inundation protection works by installing a vertical concrete wall along the western shore of Black Neds Bay. This is assumed to be installed in 2030. Forty-nine residential properties located in Precinct 20 were identified to benefit from this option. Most of the saved AADs occur post 2050, resulting from mitigating low probable high-water level inundation events.

The CBA results and subsequent sensitivity analyses highlight that the greatest chance of achieving a positive net benefit and BCR greater than 1 is when:

- installation of inundation protection works is delayed, since avoided damages occur predominately post 2050
- a longer evaluation period is considered, as this results in more saved AADs included in the analysis, and
- higher inundation water levels are used, as this increases the saved AADs post installation of inundation protection works, noting the need to:
  - continue to monitor water levels and gain more data to determine if a statistically significant structural break has occurred between recently observed water levels and the longer historical record used for the CBA
  - take future water levels into account and revisit adaptation options and models including, CBA as needed, and
  - tie water level analysis and potential deviations from current modelling outputs to the ongoing LAP review.

7 *Options analysis - road and utility infrastructure*

There are a range of options related to road and utility infrastructure that are particularly linked to the raise and fill options for the residential properties (AC1). That is, when the residential properties are raised and filled, then there would be an opportunity to consider raising/filling the infrastructure that services these properties. However, given that there is only one residential property where action to raise/fill is required under option AC1, then the road and utility infrastructure would not be raised.

Given this, our analysis below does not strictly adopt all aspects of the options as presented earlier. Instead, the analysis presents alternative assumptions on the timing of the different actions to illustrate the potential implications of these alternative actions to assist in the further refinement of the options in the future. This relates to options AC2 (raise transport infrastructure), CP8A/CP14 (staged raising of Ungala Road) and AC3 (raise other infrastructure).

Option AC2 Raise and fill transport infrastructure

This option is designed to alleviate some of the disruptions to local roads caused by inundation.[55]

Given that there are multiple different routes and access points raising a small number of the roads would not remove the disruption from inundation disruption across all the local roads. We have, therefore, modelled the options of raising *all* the roads in the areas so as to reduce disruption.

For the purposes of our analysis, the Pacific Highway to the north and south of the bridge is assumed to be raised in the base case. While this has not been fully confirmed by RMS it is a reasonable assumption, given the importance of the highway as a major thoroughfare. Similarly, we assume any local roads that connect to the Highway would also be raised to ensure access to this major route.

Characteristics of region

Table 7.1 provides information on the road pavement area within the hydraulic Precincts, as well as the number of residential properties and persons that could potentially be disrupted if roads were inundated.

55 As noted earlier, in the report the inundation risks arise from the effects of catchment and/or tidal inundation in Pelican, Blacksmiths, Swansea and surrounds (the case study area).

7.1 Summary characteristics of Precincts

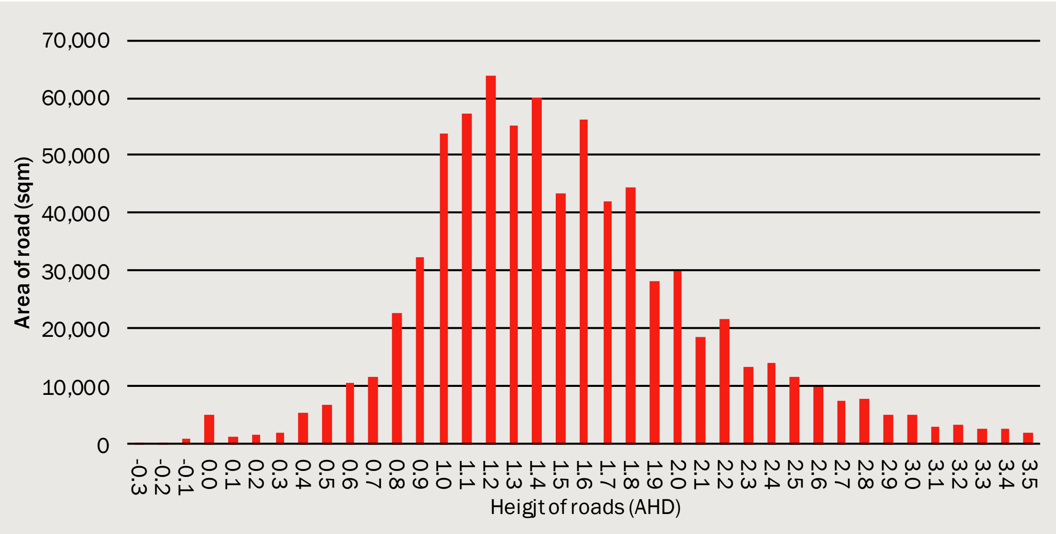
Precinct	Road pavement area	Residential properties	Number of persons	Over 65
	sqm	no.	no.	no,
10	12 152	21	133	11
15	122 316	442	1 050	98
20	79 140	410	1 138	158
25	155 820	334	1 477	464
30	142 352	260	841	227
40	116 560	448	1 045	132
LakeA	133 956	1 026	2 572	408
Total	**762 296**	**2 941**	**8 256**	**1 498**

Source: Salients Consulting Pty Ltd, ABS Census, NSW Land and Property Information.

Potential road inundation

Chart 7.2 presents the area of roads at different elevations. Some of these roads would be face risks of inundation.

7.2 Road Heights in all Precincts



Data source: Salients Consulting Pty Ltd.

Table 7.3 presents data on the ‘expected’ proportion of roads in the case study area that would be inundated by the different AEP events. This is the proportion of road inundated by different events, weighted by the probability of occurrence of each event. In 2020, for example, 3% of the roads in Precinct 10 is expected to experience some level of inundation. In Precinct 20, 28% of roads are expected to experience some level of inundation during the year.

7.3 'Expected' proportion of roads inundated by all events

Precinct	2020	2050
	%	%
10	3	21
15	5	14
20	28	40
25	16	21
30	15	38
40	23	44
LakeA	21	68
Total	**17**	**34**

Note: The 'expected' impact is the weighted average proportion of roads inundated by any AEP event, with the 'weights' based on the probability of occurrence of the event.

Source: CIE estimates.

Inundation does not necessarily mean that roads are cut-off, although the SES strongly discourages driving in any depth of flood waters.[56] For example, vehicles may be able to still utilise the roads if the inundation level is, say, 0.2m above the road pavement. This is discussed below.

Annual maintenance costs

As roads are inundated there will be a cost to Council for maintaining the roads. Based on the extent of road inundation presented in Table 7.3, we have estimated the expected annual cost to Council of maintaining the roads. In 2020, for example, the maintenance cost to Council in that year is expected to be $1.7m. By 2050, the annual road maintenance bill (associated with inundation events) in the Precinct is expected to be $3.6m. This assumes that roads are only repaired once per annum (even though the inundation event may occur several times a year), at a cost of $35/sqm.

56 Studies have demonstrated that some vehicles will effectively float in water depths as low a 15cm. See, for example, Smith GP; Modra BD; Felder S, 2019, 'Full-scale testing of stability curves for vehicles in flood waters', *Journal of Flood Risk Management*, vol. 12, pp. e12527 - e12527, http://dx.doi.org/10.1111/jfr3.12527. See also https://www.engineering.unsw.edu.au/news/unsw-engineers-demonstrate-the-dangers-of-floodwaters

7.4 Estimated average maintenance costs

	2020		2050	
Precinct	Average Area to be repaired (pa)	Expected Cost	Average Area to be repaired (pa)	Expected Cost
.	sqm, pa	$, pa	sqm, pa	$, pa
10	195	6 828	782	27 378
15	1 737	60 788	5 545	194 088
20	4 392	153 703	7 038	246 318
25	5 635	197 226	9 525	333 387
30	7 843	274 521	26 136	914 754
40	9 241	323 441	15 253	533 846
LakeA	19 185	671 461	37 241	1 303 426
Total	**48 228**	**1 687 967**	**101 520**	**3 553 196**

Note: Assumes $35/sqm repair costs for road pavement and roads only get repaired once a year, even though the road may be inundated several times a year from small inundation events.

Source: CIE Estimates.

Extent of disruption due to inundation

The extent of disruption would depend on the extent of inundation in the area, as well as, the travel patterns of different households in the case study area.

Existing trip patterns

The Australian Bureau of Statistics (ABS) has collected data on the trip patterns of all households in the Lake Macquarie Local Government Area (LGA) undertaken in 2018-19, and we have assumed that this data is representative of the case study area. Table 7.5 presents the number of trips across the different trip patterns, converted into a trip per household per day.

7.5 Trip patterns, Lake Macquarie households (2018-19)

Trip type	Trips	Trips per household	Trips per day
	'000, pa	'000, pa	no., per household
Commute	89	1.11	3.05
Education/childcare	46	0.58	1.58
Personal business	66	0.83	2.26
Serve passenger	108	1.35	3.70
Shopping	126	1.58	4.32
Social/recreation	178	2.23	6.10
Work related business	49	0.61	1.68
Other	10	0.13	0.34
Total	**672**	**8.40**	**23.01**

Source: ABS.

Table 7.6 presents the share of trips and the average distance and travel time. A large proportion of the trips are by car, either as a passenger or as the driver. For the purpose of our analysis we assume that 85% of the trips could be disrupted (assuming that 'vehicle driver', 'vehicle passenger' and 'bus' trips could be disrupted).

7.6 Share of trips by mode (2018-19)

Trips 2018-19	Share of trips	Average distance	Average time
	%	Km	mins
Vehicle driver	58	10.60	18.10
Vehicle passenger	25	8.10	14.40
Train	1	95.00	72.00
Bus	2	9.40	21.50
Walk only	9	0.90	12.70
Walk linked	3	0.90	9.00
Other	2	9.90	41.90

Source: ABS.

Road disruption

For the purposes of our analysis, we assume that vehicles can still utilise the roads if the inundation level is 0.2m above the road pavement. Therefore, an event only starts to disrupt travel once inundation levels exceed 0.2m above the road pavement.

Table 7.7 below shows the proportion of roads (on average) within each Precinct estimated to be inundated above 0.2m (by any AEP event) in 2020 and 2050. It also shows the proportion of roads inundated (above 0.2m) in a 10% AEP event in 2020 and 2050. Across all roads in the case study area, approximately 4.5% of roads would be disrupted by a 10% AEP event in 2020 and 8.7% of roads by 2050.[57]

7.7 Road inundation above 0.2m

Precinct	Average road area inundated, 2020	Average road area inundated, 2050	10% AEP event 2020	10% AEP event 2050
	%	%	%	%
10	0.2	1.8	0.1	3.8
15	2.7	4.4	0.7	2.4
20	19.8	28.4	5.4	7.5
25	15.4	16.8	3.2	0.1
30	9.4	14.5	2.3	7.0
40	8.9	23.2	7.3	12.0
LakeA	6.0	21.3	9.4	24.7
Across all Precincts	**9.8**	**17.1**	**4.5**	**8.7**

Source: CIE estimates based on data from Salients.

57 The road inundation for the 10% AEP is presented in this table as (as discussed in the next section) this is the assumed level which the roads are raised to.

Tables 7.8 to 7.10 present the current loss in value associated with inundation (in 2020 and 2050) that impacts on social/recreational activities, shopping trips and work trips. For the purposes of our analysis we assume that the where a road is inundated above 0.2m, that 50% of the trips can find an alternative route and is not disrupted. Further information would be required to test this assumption.

Further, for the work trips we also assume that there is scope to work from home without disruption and that 50% of trips would not result in any loss in income. Again, further testing of this assumption could be undertaken at a later stage.

7.8 Value of maintaining social/recreation activities

Lost recreation	2020	2050
% of trips to social/recreational activities	26.50%	26.50%
% of trips with no alternative access	50.00%	50.00%
Number of recreation trips impacted	23 732	51 350
Value of social trip (per trip)	$20	$20
Lost value (per annum)	**$474 646**	**$1 026 991**

Source: CIE estimates.

7.9 Value of maintaining shopping activities

Lost shopping	2020	2050
% of trips to shops	18.70%	18.70%
% of trips with no alternative access	50.00%	50.00%
Number of shopping trips impacted	16,747	36,235
Value of travel to shop (per trip)	$20	$20
Lost value (per annum)	**$334 939**	**$724 707**

Source: CIE estimates.

7.10 Value of maintaining work trips

Lost work opportunity	2020	2050
% of trips to work	21%	21%
% of trips with no alternative access	50.00%	50.00%
% of working from home	50.00%	50.00%
% of total trips resulting in lost income from floods	4.38%	4.38%
Number work trips impacted	7,841	16,965
Average daily household income	$278	$278
Lost value (per annum)	**$2 181 463**	**$4 720 027**

Note: Average household income based on average weekly earnings reported in the 2016 Census, inflated to current dollars.

Source: CIE estimates.

Road raising options

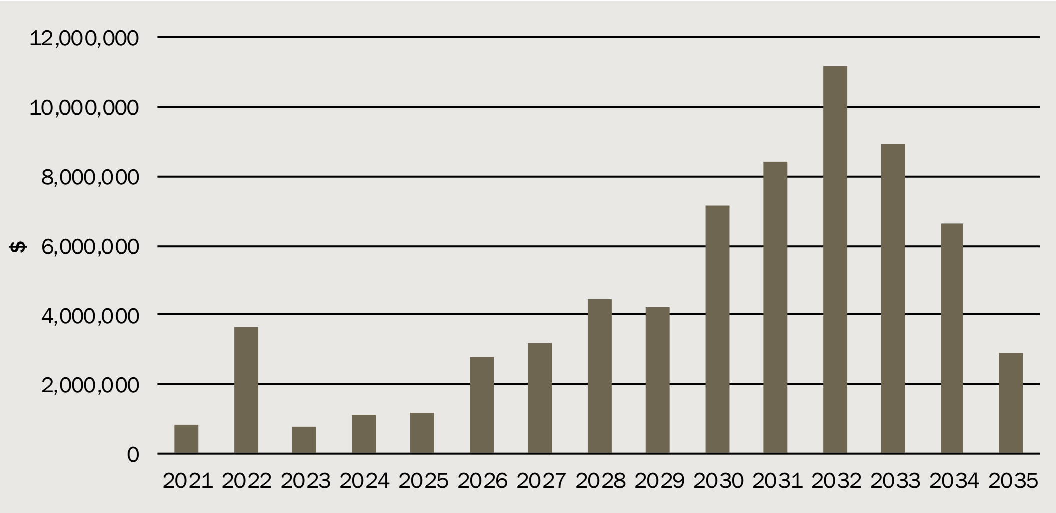
The road raising options will reduce the inundation risk, thereby reducing the value loss through disrupted work trips.

For the purposes of our analysis, we assume that the target road height would be 1.4m which equates to the 10% AEP inundation event in 2050. The level which the road would need to be raised would depend on the existing road level.

Based on this, 43% of the roads within the case study area would need to be raised over the next 30 years. We assume that the raisings would commence in 2021, starting with the lowest lying roads.

Based on Council data we estimate that the cost of raising a road by 1m is $520/m^2 of road surface. We assume that the raising costs are proportional irrespective of the level of raising (e.g. raising the road by 1.5m is 1.5 times the cost for a 1m raising). Chart 7.11 presents the expenditure profile of the road raising based on the assumptions above. In PV terms this equates to $35m.

7.11 Road raising expenditure profile



Data source: CIE estimate.

The expected reduction in risk on an inundation event that causes trip disruptions will vary from year to year depending on the change in probability of inundation and the additional road raisings undertaken. Based on the reduction in risk in each year, this results in a $2.16m benefit (in PV terms) from reducing trip disruptions.

Similarly, the reduction in the risk of road inundation due to the road raising is also expected to reduce the annual maintenance costs associated with repairing the road pavement. The reduction in risk will vary over time, consistent with the proposed road raising expenditure profile. In PV terms this is expected to reduce the maintenance costs by $1.3m.

In summary, the proposed level of road raising and timing of the expenditure equates to $35m in PV terms. However, the reduction in risk of trip disruption and annual maintenance costs only delivers benefits of $2.16m and $1.3m, respectively.

While the road raising option, as modelled, does not deliver net benefits to the community, further work should be undertaken to assess whether there are more targeted road raising options that deliver net benefits to the community. These should also consider whether there are any associated property raisings. Any upgrades to other assets (e.g. sewer, stormwater) should be considered along with any road raising. Any road raising options could be coordinated with periodic road maintenance to achieve cost savings but also to reduce disruption associated with any raising.

Further, the assessment of any future road raisings would also need to better understand the factors that are likely to damage roads and increase maintenance requirements. For example, rising groundwater (rather than overland inundation) could be a factor in causing increased road damages.[58] However, the impact of depth is likely to be highly variable and changes depending on the natural sub-surface profile.

Option CP8A/14 Ungala Road Staged Raising

The aim of the option is to reduce inundation in Mankilli Street. Mankilli Street is a dead-end street and the only access out of the area is via Ungala Road. If Mankilli Street is inundated it would disrupt residents in around 16 properties in both Kembry Lane and Mankilli Street from gaining access to Ungala Road. Raising segments of Ungala Road (including near the boat ramp) is required to prevent inundation on Mankilli St.

After raising Ungala Road to protect Mankilli Street, the raising would then continue from Bali Street to Granny's Pool with the intention to minimise inundation of Ungala Road. This is proposed in a sequence with raise and fill the Mankilli St area and tidal gates on Ungala Road (CP8B).[59]

Based on estimates of the cost of raising roads provided by Council, the cost is anticipated to be $161.07 ($/sqm, no kerb guttering) to raise it by 0.24m, which equates to around $150,000. [60]

Given the very low probability of an inundation event that would reach a sufficient height, and the relatively few properties that would be disrupted by inundation on Mankili Street Road, this option is unlikely to pass a cost benefit test. Instead, Council should consider this option as part of its routine maintenance of the road. It would also need to consider the elevation of the properties neighbouring the road raising to ensure that these properties are not inadvertently impacted.

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58 That is, rising groundwater may impact the consistency of the sub-base soils causing movement of the road surface (e.g. shrinking/swelling of fine grained soils or settlement of soils).

59 Note that option CP8B is not part of the range of options identified for the CBA.

60 The square metre rates were based on Council estimates of based on a 100m x 10m section of road. Email dated 23 July 2020.

Option AC3 Raise other infrastructure

There are a range of infrastructure that has been identified as potentially being impacted by inundation. This includes power, water, sewer, gas, stormwater and telecommunications. The option notes that assets would need to be raised "to provide for functioning services as properties are raised within any precinct/sub-precinct area".

However, given that under the other options (e.g. AC1), there is limited raising/filling of properties that would occur. Therefore, given that the raising of utility infrastructure would be triggered by property raising, this option would not be implemented.

Given this, we have adopted the following assumptions to provide indicative illustration of the potential impacts of asset relocation:

- Power infrastructure at the property level is typically above ground ('poles and wires') and would not be significantly impacted by inundation. Substations could be impacted but the decision to relocate these assets would be undertaken separately by the utility provider. A similar situation applies to telecommunications assets.
- In regard to water assets, the mains are pressurised and would typically not be impacted by inundation. Pumping stations could be impacted. However, the water pumping stations are located outside the hydraulic Precincts and, therefore, outside the scope of this study.
- Wastewater mains could be impacted as they are not pressurised, resulting in increases in wet weather overflows to the environment and potentially impacting on household waste disposal. Wastewater pumping stations could also be impacted.
- Stormwater assets would require a substantial redesign. Given that these assets rely on gravity, these are linked to road levels as well as property levels. This is a major design task which would need to be considered separately by Council.[61]

Our focus on the remainder of this section is on the wastewater mains and pumping stations. In practice, however, this is a decision for Hunter Water Corporation taking account of:

- Operating Licence conditions (regulated by IPART) which focus on customer impacts; and
- Environment Protection Licence conditions (regulated by the EPA), such as the number of 'wet weather' overflows, which focuses on impacts on the environment.

The redesign of its wastewater network to manage inundation risks would require extensive studies by Hunter Water, in collaboration with the EPA. The results below should be considered preliminary and would require extensive work by Hunter Water. This would also need to be undertaken with any upgrades to the road networks to minimise disruption. This is why is it paramount for planning to commence at the earliest opportunity.

61 Further information should be collected from the different infrastructure service providers to gain a more detailed understanding of the probability of service disruptions due to inundation events and the options to manage this risk.

Sewer pump stations

Figure 7.12 presents the location of the sewer pump stations within the Precincts.

7.12 Sewer pumping station locations

Data source: Hunter Water Corporation.

The ground levels of the sewer pump stations and the AEP event (in 2020) that exceeds ground levels are presented in Table 7.13.

7.13 Sewer Pumping station characteristics

ID	Sewer Asset	Ground Level mAHD	Precinct	AEP (%), 2020
25	PUMP STATION, SWANSEA HEADS 1 (SWANS 15)	7.663	10	>PMF
12	PUMP STATION, BLACKSMITHS 3	1.526	15	0.5
4	PUMP STATION, SWANSEA 4	1.299	20	0.5
17	PUMP STATION, SWANSEA 3A	1.826	20	0.05
23	PUMP STATION, SWANSEA 1	2.262	20	>PMF
2	PUMP STATION, SWANSEA 2	1.519	25	0.2
6	PUMP STATION, SWANSEA 6	0.962	25	10
7	PUMP STATION, SWANSEA 5	1.358	25	0.5
8	PUMP STATION, SWANSEA 7	0.899	30	10
11	PUMP STATION, BLACKSMITHS 2	0.93	30	10
14	PUMP STATION, PELICAN 2 (BLACKSMITHS 5)	1.371	30	0.5
13	PUMP STATION, PELICAN 1 (BLACKSMITHS 1)	1.771	40	0.1
24	PUMP STATION, BLACKSMITHS 4	1.647	40	0.2

ID	Sewer Asset	Ground Level mAHD	Precinct	AEP (%), 2020
3	PUMP STATION, SWANSEA 11	1.007	LakeA	10
5	PUMP STATION, SWANSEA 10	1.084	LakeA	5
9	PUMP STATION, SWANSEA 9	1.161	LakeA	5
10	PUMP STATION, SWANSEA 8	0.78	LakeA	18.13
15	PUMP STATION, SWANSEA 16	10.731	LakeA	>PMF
16	PUMP STATION, SWANSEA 12	1.294	LakeA	2

Source: Hunter Water Corporation, Salients Consulting.

The table indicates that the sewer pumping stations are located on land that provides sufficient protection from inundation in all but the more infrequent AEP events (18.13% AEP or less frequent). However, assuming that the floor level of the pump stations are around 0.5m above ground level, then it would require an event of 0.05% AEP to inundate the floor levels.[62]

Further, *Hunter Water and Sewer Design Manual* (section 4.2.3) states that

> Where a pumping station is sited in a flood prone area the switchgear must in all cases be located above flood level. For small to medium pumping stations the finished surface of the top of the wet well roof slab should be placed 0.3 metres above 100 year flood level. The base of the electrical switchboard cabinet shall be mounted a minimum of 0.6 metres above 100 year flood level.

This suggests that there are minimal impacts on sewer pump stations of the inundation events in 2020. The inundation risks are expected to change over time. Therefore, further work would be required to understand the inundation risks would impact these assets in in the future.

Sewer mains

Table 7.14 provides an indication of the length of sewer mains at different ground levels. The ground levels of the sewer mains were calculated based on estimating the 3 closest residential properties to the relevant segment of sewer main.

62 This assumption was based on general discussions with a consulting engineer who suggested that this was a general approach adopted, although a detailed investigation of these assets should be undertaken at a later stage to understand the extent of inundation risks faced

7.14 Length of sewer mains at different ground levels

Length sewer mains	10	15	20	25	30	40	LakeA	Total
.	m	m	m	m	m	m	m	m
<1	-	-	-	-	206	141	2 771	3 117
1 to 1.2	-	92	484	889	1 527	772	5 166	8 930
1.2 to 1.4	-	636	1 714	2 871	435	446	3 174	9277
1.4 to 1.6	-	1 347	2 641	4 283	1 732	553	259	10 816
1.6 to 1.8	-	3 670	2 139	2 674	1 482	1 364	845	12 175
1.8 to 2	-	2 591	448	584	594	1 116	-	5 334
2 to 2.2	-	711	410	36	200	1 134	109	2 601
2.2 to 2.4	-	582	215	23	192	257	-	1 268
2.4 to 2.6	-	241	630	21	397	293	-	1 583
2.6 to 2.8	-	136	189	62	140	132	-	658
2.8 to 3	-	158	361	42	-	484	-	1 045
3 to 5	275	290	1,459	42	-	513	278	2 857
5 to 10	342	130	713	64	-	-	1 912	3 160
10 to 20	56	467	-	353	-	-	1 159	2 036
Total	**673**	**11 051**	**11 403**	**11 944**	**6 907**	**7 205**	**15 672**	**64 856**

Source: Hunter Water Corporation, CIE estimate of elevation.

For the purpose of our analysis, we assume that the sewer pipes are constructed 1.0m below the ground level. The depth of the sewer pipes will vary between locations however, this provides an average estimate. We also assume that the relaying of the sewer pipes will commence once the inundation level exceeds the sewer main depth 6 times a year (as at 2050). This results in 44,373m of sewer mains to be re-laid over the next 30 years.

We assume that the mains are progressively re-laid over the next 30 years, resulting in 1,479m of pipe per year and 58 properties per year being reconnected. We assume that a pressure sewer system would be installed to replace the existing gravity fed sewer system. The cost of relaying pipes for the system is around $100/m. The cost of connecting the systems to the properties is around $10,700 per property. In aggregate, it is expected to cost around $0.77m per annum or $9.5m in PV terms over the next 30 years.

The benefit of adopting this strategy is challenging to estimate. A detailed study would be required to understand the extent of service disruption to properties, as well as potential environmental impacts from wet weather overflow events from the sewers.

However, as an indication of the potential quantum of benefits, we draw on a survey conducted by Sydney Water Corporation to inform their 2020 submission to IPART.[63]

63 See page 256 https://www.ipart.nsw.gov.au/files/sharedassets/website/shared-files/pricing-reviews-water-services-metro-water-prices-for-sydney-water-corporation-from-1-july-2020/legislative-requirements-prices-for-sydney-water-corporation-from-1-july-2020/appendices-customer-engagement.pdf

The study indicates that each household in Sydney Water's area of operation would be Willing to Pay $2.40 per year for a 0.1% reduction in the chance of experiencing 3 sewer overflows events per year. Applying it to the 2,691 households in the case study area, this equates to a Willingness to Pay of $139,372 per year for a 0.1% reduction in the chance of experiencing 3 sewer overflow events per year. Over a 30 year period this equates to $1.7m in PV terms.

8 Options analysis – wetlands

This chapter discusses the options to make changes that would allow the wetlands to move landward with SLR and increasing depth of inundation that is expected over time. Rather than a formal CBA, we have presented a range of information that will guide whether or not the options are likely to deliver a net benefit (i.e. benefits minus costs) to the community.

Overview of options

Council has identified a range of options to manage the landward progression of coastal wetlands which is expected with SLR as landward locations are subjected to more frequent inundation. The existing wetlands are identified in the spatial datasets for coastal wetlands mapped in NSW for the purpose of the *State Environmental Planning Policy (Coastal Management) 2018*.[64] Coastal Wetlands are identified as plant communities dominated by any of the following six vegetation types: mangroves, salt marshes, melaleuca forests, casuarina forests, sedgelands, brackish and freshwater swamps, wet meadows.

There are three separate options that have been identified. The options are designed to allow the wetlands to continue to move landward:

- on 'environmental land' around Pelican Inlet (option RA4)
- into coastal use area, with land acquisition (option RA5)

Another option (RA6) seeks to limit the landward movement of the identified wetlands, but to offset these losses with wetland reservation elsewhere around the lake.

Locations identified include Coon Island, Galgabba Point, Pelican Inlet and Black Neds Bay.

Potential for landward expansion of wetlands

The currently low-lying salt marshes which are temporarily inundated as the tides rise and fall. With SLR in the future, these marshes may be permanently inundated which would lead to the loss of wetlands in the region.

The extent to which the wetlands will naturally progress landward will depend on a range of factors such as the gradient and elevation of the land where the wetlands could migrate. There may also be existing barriers such as roads or buildings which currently limit the landward migration of the wetland.

64 https://www.planningportal.nsw.gov.au/opendata/dataset/state-environmental-planning-policy-coastal-management-2018

The existing wetlands on the seaward side may change in nature with more frequent inundation and eventually permanent inundation. However, the wetland on the seaward side is not 'lost'. From this perspective, the options considered here will *expand* the size of the existing wetlands.

Options to support landward expansion of options

In order to allow this expansion, the options allow the wetlands to progress on to land which is currently used for other uses (e.g. land zoned RE1). It may also require the removal of physical barriers which impede the landward migration of the wetlands. From this perspective, the options involve a trade-off between the:

- benefits received from allowing the wetlands to migrate landward
- costs associated with preventing the current use of the land to continue, as well as any costs associated with removing physical barriers that would allow the migration to occur.

In regards to the timing of benefits/costs, the costs will largely be incurred upfront. For example, in order to allow the natural landward progression of the wetlands, the existing uses would need to cease *immediately* so as to enable the progression to occur. The wetlands, on the other hand, will take time to migrate and establish. Therefore, the benefits, may only start to arise after several years into the future.

Option RA5: Wetlands to move landward into coastal use area, with land acquisition.

There are three sub-options considered.

- The first is at Coon Island which would allow the southern migration of wetlands on to the land currently used for the holiday park (zoned RE1). This would only be adopted if the holiday park was relocated.
- The second is at Galgabba Point where the wetland (zoned E2) would be allowed to migrate to a small block of land that is currently zoned for RE1.
- The third is at Pelican Inlet where the wetland to the east of the Pelican Inlet would be allowed to migrate to several areas current zoned RE1 (excluding Aitcheson Reserve).

Coon Island

8.1 Wetland migration, Coon Island

Data source: Lake Macquarie Council

For the wetland migration at Coon Island, the adjoining boundary with the Swansea Holiday Park is an internal road for the park which varies in elevation from 1.27m on the north-west corner to 1.35m on the south-east corner, with high points of 1.54m in the central points. On average the road height is around 1.41m.

In comparison, the ground level where the wetland is currently established is around 0.5m AHD. This would suggest that for the migration to occur, the road would need to be removed and the land lowered. Alternatively, if the inundation levels are expected to be significant, then the wetland could establish at the high points.

Based on the current levels of the existing wetlands (0.5m AHD), the site is impacted by the 1 EY event in 2020. By 2050, 1 EY event is expected to reach 0.73m AHD. This is still below the 1.41m AHD of the road which is currently restricting the landward migration of the wetland. Inundation levels for Precinct 40 are shown in Table 8.2 and Chart B.4 in Appendix B.

Further work would be required to understand the extent to which the existing road barrier would limit the landward migration of the wetland. It is unknown whether the wetland could be established if inundation events occur less than once per year. Alternatively, the landward migration may require the removal of the existing road barrier and associated infrastructure.

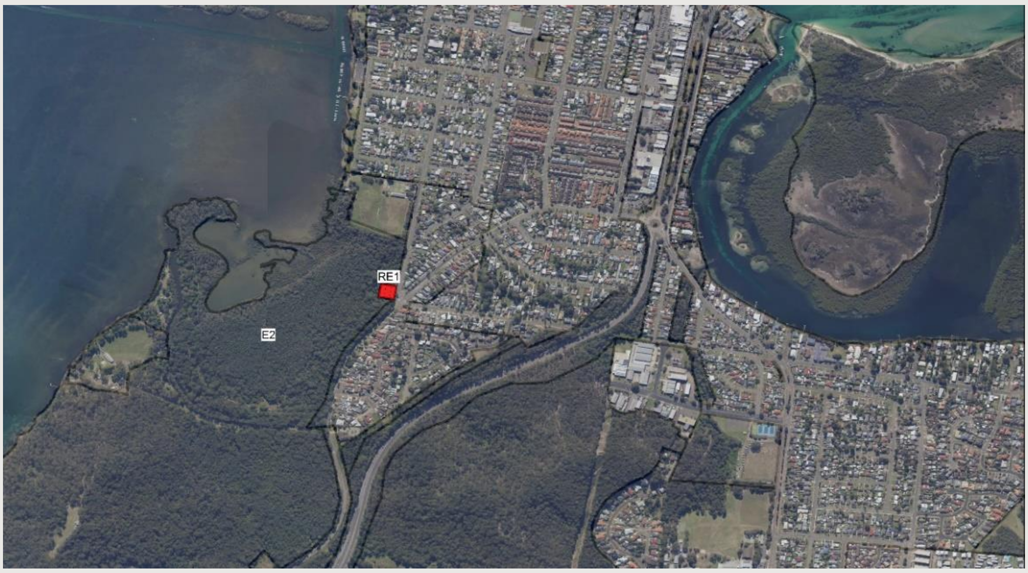
8.2 Inundation levels, Precinct 40

EY	AEP	2020	2050
times per annum	%	mAHD	mAHD
6	99.75	0.38	0.58
4	98.17	0.41	0.62
3	95.02	0.44	0.65
2	86.47	0.48	0.69
1	63.21	0.52	0.73
0.5	39.35	0.63	0.82
0.2	18.13	0.77	0.95
0.11	10.00	0.87	1.06
0.05	5.00	0.99	1.17
0.02	2.00	1.15	1.32
0.01	1.00	1.27	1.44
0.005	0.50	1.39	1.55
0.002	0.20	1.55	1.70
0.001	0.10	1.67	1.81
0.0005	0.05	1.79	1.93
0.0002	0.02	1.97	2.05
	PMF	2.51	2.83

Source: Salients Consulting.

Galgabba Point

8.3 Wetland migration, Galgabba Point



Data source: Lake Macquarie Council.

For the wetland at Galgabba Point, the option seeks to allow the migration into 3 separate lots (zoned RE1), the land area of each lot being around 696sqm. These lots are at elevation of around 1.697m AHD. Based on the inundation levels presented in Table 8.4, the RE1 zoned land would be inundated around 0.001 times per year in 2020, rising to around 0.002 times per year in 2050.

8.4 Inundation levels, Precinct LakeA

EY	AEP	2020	Yr 2050
times per annum	%	mAHD	mAHD
6	99.75	0.36	0.56
4	98.17	0.40	0.61
3	95.02	0.42	0.64
2	86.47	0.46	0.68
1	63.21	0.51	0.73
0.5	39.35	0.63	0.82
0.2	18.13	0.78	0.96
0.11	10.00	0.89	1.07
0.05	5.00	1.02	1.19
0.02	2.00	1.18	1.35
0.01	1.00	1.30	1.47
0.005	0.50	1.42	1.58
0.002	0.20	1.59	1.74
0.001	0.10	1.71	1.85
0.0005	0.05	1.83	1.96
0.0002	0.02	2.00	2.08
	PMF	2.54	2.86

Source: Salients Consulting.

Based on the elevation data and inundation levels projected in 2020 and 2050, it is not clear that the wetlands would be able to migrate to lands which are infrequently inundated. If this is the case, the option would not deliver any benefits, although there would be a cost associated with locking the land from alternative uses based on the zoning.

Pelican Inlet

8.5 Wetland migration, Pelican Inlet

Data source: Lake Macquarie City Council.

For the wetland at Pelican Inlet, the option seeks to allow the migration on to the RE1 zoned land to the north with a land area of around 47,520sqm. This land is generally around 1m AHD or less. The land is located in Precinct 40 (similar to Coon Island). Based on the inundation levels presented in Table 8.2, the RE1 zoned land would be inundated around 0.05 times per year in 2020, rising to around 0.2 times per year in 2050.

It is not clear whether the wetlands could establish in the area with relatively infrequent inundation. Further, some works would be required on the RE1 zoned land to remove structures to allow for landward migration. If this approach was adopted consideration could also be given to changing the slope of the land to promote wetlands establishment.

Black Neds Bay wetland

8.6 Wetland migration, Black Neds Bay

Data source: Lake Macquarie City Council.

For the wetland at Black Neds Bay, the option seeks to allow the migration on to the RE1 zoned land at two separate locations. The RE1 zoned land to the north is around 3,334sqm in area and the RE1 zoned land to the south around 7,839sqm. This land is generally around 1m AHD. The land is located in Precinct 20. Based on the inundation levels presented in Table 8.7, the RE1 zoned land would be inundated around 0.05 times per year in 2020, rising to around 0.5 times per year in 2050.

It is not clear whether the wetlands could establish in the area with relatively infrequent inundation. Further, some works would be required on the RE1 zoned land to remove structures to allow for landward migration. If this approach was adopted, consideration could also be given to changing the slope of the land to promote wetlands establishment.

8.7 Inundation levels, Precinct 20

EY	AEP	Yr 2020	Yr 2050
times per annum	%	mAHD	mAHD
6	99.75	0.65	0.84
4	98.17	0.69	0.88
3	95.02	0.71	0.90
2	86.47	0.74	0.93
1	63.21	0.77	0.96
0.5	39.35	0.82	1.02
0.2	18.13	0.88	1.09
0.11	10.00	0.94	1.14
0.05	5.00	1.01	1.21
0.02	2.00	1.11	1.31
0.01	1.00	1.20	1.39
0.005	0.50	1.29	1.48
0.002	0.20	1.42	1.61
0.001	0.10	1.54	1.72
0.0005	0.05	1.67	1.87
0.0002	0.02	1.89	2.05
	PMF	2.11	2.43

Source: Salients Consulting.

9 Distributional Analysis

The distributional analysis is typically conducted to understand which parties are the beneficiaries of particular actions, the quantum of benefits and which parties bear the costs of the actions. This can also assist with the development of funding models to support the implementation of selected options. The potential beneficiaries of the actions are summarised in Table 9.1 below.

9.1 Potential beneficiaries of selected options

Option	Description	Beneficiaries
Options to raise and fill land and built assets		
AC1	Raise and fill residential areas (house sites and yards)	Beneficiaries are largely the owners of the homes whose properties will experience a higher level of protection. Council may also benefit from higher property values, but this may be negated in the context of a rate cap.
AC2	Raise transport infrastructure (over and above gradual raising of roads through maintenance)	If the roads are linked to the property raising, then the individual property owners would also be a key beneficiary. However, there are also likely to be benefits to other users of the roads where it reduces disruption costs. There may also be benefits from reduced future maintenance costs.
AC3	Raise other infrastructure (power, water, sewer, stormwater, telecommunications)	This option would reduce the disruption to properties if the assets are inundated. Therefore, the property owners would be the key beneficiaries. There would also be some benefit to asset owners through lower ongoing maintenance costs.
AC4	Raise and fill education land (schools)	The students and carers of the students are the key beneficiaries by reducing disruption and travel time if an alternative school is required.
AC5	Raise and fill public recreation land such as foreshore reserves and playing fields	This includes both including active and passive recreation: sporting facilities and public open space. The beneficiaries will be those who use these grounds, parks, reserves.
AC7	Raise and fill commercial land in the Central Business District (CBD)	The owners of the CBD properties will be the main beneficiaries. Local residents as well as employees will also be beneficiaries of this.
Swansea Holiday Park and Wetland/Environmental Options		
AC6	Raise and fill Swansea Holiday Park	The beneficiaries will largely be the visitors (local and outside the region) who use the facility, as well as the owners of the facilities.
AC6B	Relocate Swansea Holiday Park	The beneficiaries will largely be the visitors (local and outside the region) who use the facility, as well as the owners of the facilities.
RA4	Allow wetlands to move landward on 'environmental land' around Pelican Inlet and other suitable areas	The beneficiaries are expected to be the wider community who value the wetlands.

Option	Description	Beneficiaries
RA5	Allow wetlands to move landward into coastal use area, with land acquisition	
RA6	Offset losses of wetlands with wetland reservation elsewhere around the lake	
Channel and Foreshore Protection Works		
CP4	Inundation protection works (or a levee) inside Black Ned's Bay	Property owners that receive protection from the levee are likely to be the key beneficiaries
Staged raising of Ungala Road		
CP8A/CP14	Staged Raising of Ungala Road, first near the boat ramp	Beneficiaries include the users of the road that face reduced disruption, as well as some property owners who may face lower inundation risks as a result of the road raising.

Source: CIE.

As noted earlier, the analysis conducted demonstrates that none of the subset of options analysed resulted in a positive BCR on the basis of the available data and assumptions presented in the model. That is, the options result in net costs to society where the costs outweigh the benefits. This, in part, reflects the relatively low risk to properties and assets in the study area in the short to medium term. This risk will increase over time with anticipated SLRs. Therefore, the actions may become economically viable at some future point in time. However, implementing the actions immediately cannot be justified on the grounds of an economic assessment. Having said this, the sensitivity analysis conducted shows that options can become economically viable if the risks are greater than modelled. This highlights the importance of continuing to monitor risks and to update the modelling where new information on inundation risks becomes available.

Therefore, if the actions were implemented now, the quantum of benefits is not large and would be substantially outweighed by the cost of undertaking the actions. Therefore, the key question for the distributional analysis will be how each of the options are funded. These could be funded by the direct beneficiaries of particular mitigation actions (e.g. the household, the road user, the wider community). This could include benefits beyond the property boundary.

Any actions on recreational land, road upgrades and the wetland expansion could be funded through general council revenue. This, in part, reflects the challenges of identifying who are the users of these facilities. Further work would be required to establish the key beneficiaries of actions.

Funding of utility assets (e.g. upgrading wastewater mains or the electricity distribution network) would be subject to the funding approaches adopted by the utilities. Ausgrid and Hunter Water Corporation, for example, are regulated utilities (by the Australian Energy Regulator and IPART, respectively). The utilities are required to meet defined service obligations and these would be the primary drivers of their decisions to upgrade assets in the Lake Macquarie region. These would be subject to the periodic price reviews however, we would anticipate that any upgrades of assets to a region would be funded through the utilities' whole customer base.

10 Findings and Recommendations

The CBA results show that most of the options requiring significant structural intervention are not cost effective to implement now. That is, the current levels of risks and damage are not sufficiently large to warrant taking the identified action *immediately* from an economic assessment standpoint.

Over the longer term, the modelling demonstrates that the level of risk and damage increases substantially after 2050. This may reflect a 'tipping point' has been reached such that the inundation levels for the frequent events become higher than existing floor levels. The projects could become viable at a future point in time as the inundation risks increase (due to SLR), therefore, there is value in delaying the decisions regarding the options to implement. This is also important where new technologies become available to manage the different risks.

While the findings above do not support the immediate implementation of the options, it is important that this is not interpreted as encouraging Council to 'do nothing'. Rather, the results imply that there is time to conduct further robust planning to ensure that the future actions provide the best 'value for money' for the community.

Given this, the following recommendations should be considered by Council.

Continued monitoring of inundation risks

As noted earlier, the conclusions of the CBA reflect the inundation risks modelled by Salients, in consultation with the University of Queensland and Flood Focus Consulting. The inundation modelling utilises statistical modelling based on recorded history. While this modelling was based on the best information currently available these risks are not known with certainty. In particular, there is uncertainty regarding how climate change could impact on the inundation risks, including in the short to medium term.

Given this, it is important that there is ongoing monitoring of the inundation levels to understand whether any changes in the risks would alter the results of the CBA. Sensitivity analysis conducted for some of the options provides a guide on how changes in inundation risks can change the CBA results and conclusions.[65] If new information changes the risks in line with the sensitivity analysis, then there may be merit in implementing (in the short term) some of the options considered.

65 This included options AC1 (raise and fill residential areas (house sites and yards)), AC7 (raise and fill commercial land in the CBD) and CP4 (storm surge protection works). Sensitivity analysis tested included where inundation levels are 0.2m AHD higher than those predicted by the statistical model.

Continued planning of actions

There is significant value in having time to undertake robust planning in advance of a 'crisis'. Therefore, given that the inundation risks are not imminent Council should take this opportunity to continue developing strategies to manage inundation risks.

Some actions that could be undertaken include:

- The CBA was based on the available elevation data (e.g. ground levels, property floor levels, roads, sewer main depths). Further data collection could be undertaken to help refine the analysis at a later stage. If there are significant changes to the elevation data, then additional analysis should be undertaken to test the extent of changes in inundation risk. If there are significant changes to inundation risks then additional economic analysis should be conducted to evaluate the options.
- Gathering additional information on the costs of the different actions should also be undertaken. The CBA was based on the best available information within the scope of the project. Further site-specific investigations may change some of the cost assumptions adopted in the CBA.
- Additional information is required to understand the extent of use of the different recreation areas.
- In regards to the wetlands, specific studies could also be undertaken to understand the value that the community places in expanding the wetlands. It would also be useful to gain further scientific information on the frequency of inundation required for wetlands to establish and how quickly wetlands could establish.
- Investigation of other actions should also be undertaken to understand whether there are 'better' actions than those considered in the CBA. This may arise where, for example, there are technological advancements which reduce the costs of managing inundation risks.
- For all options, Council should consider when approvals should be sought from relevant authorities, and agreements in principle from property owners affected (including where access to a property is required for construction works).

Interlinkages between the different actions

There are significant interlinkages between property damage and damage to other assets (e.g. roads, electricity, water etc). For example, raising roads would be dependent on the raising of residential properties (or commercial properties). Likewise, any upgrading on sewer/water mains should be interlinked with any road raising.

In the options modelled, the property raisings are not triggered in the immediate future, reflecting the relatively low levels of risk currently faced by the properties. If the property raisings aren't triggered then raising roads could have detrimental impacts on some locations (e.g. by causing pooling of water). Given this, it would be prudent to develop risk management strategies on a 'region by region' basis, covering all the assets. This will involve first understanding the inundation risks to each of the assets and then developing strategies that result in an 'optimised' staging/sequencing of works to manage risks in that region.

Given that different assets are owned by different service providers (e.g. Hunter Water Corporation, Department of Education) this will further complicate the coordination/sequencing of options to manage inundation risk. It will be important to work closely with these authorities to understand the risks to the different properties/assets and potential solutions to manage the risks. This will ensure alignment with the capital works programs of the different asset owners.

Funding options

There is considerable cost, lead time and further investigations to be undertaken in respect to serval options under the CBA and implementation of any/all the LAP options. Consideration should be given to the approaches to funding the actions and whether the costs should be borne only by the beneficiaries of the actions or the wider community. The staging and sequencing of options could be undertaken to spread the costs of over several years. Council could also consider establishing a pooled fund to minimise 'spikes' in funds required in any particular year.

Implications for the LAP

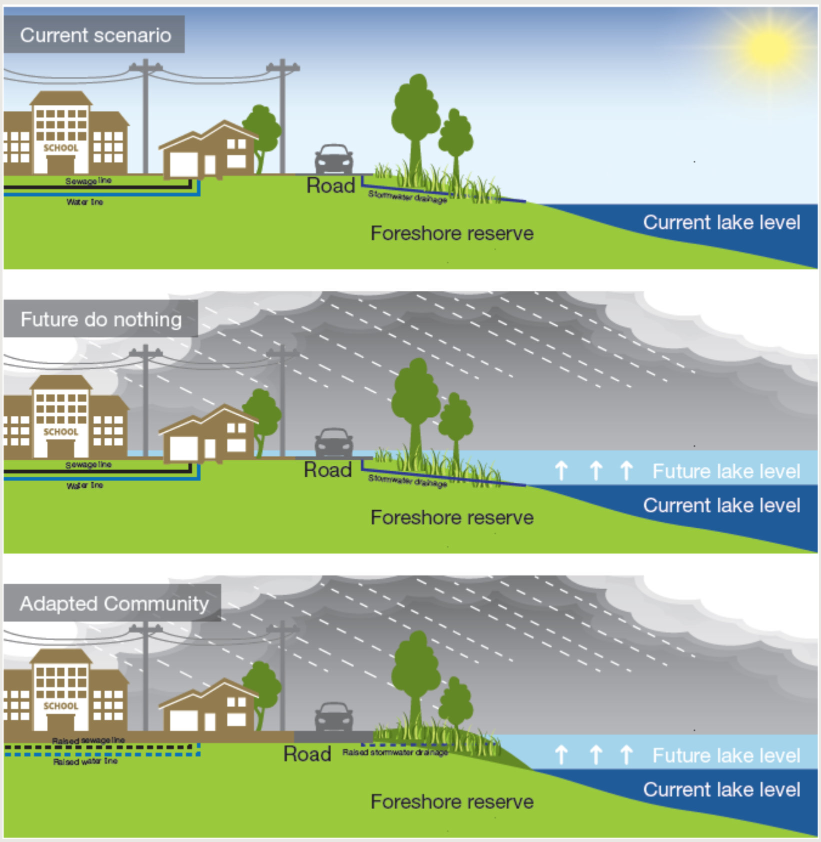
This CBA is one of a number of tools used to assess a limited number of options developed from the MCA, and it is highlighted that there are other options, drivers and considerations for discussion in the upcoming LAP. While the CBA results conclude that there are no specific actions that need to be incorporated into the LAP immediately, there are a range of other actions evaluated as part of the MCA that will be incorporated into the upcoming LAP.

Appendix A: Option graphics and description provided to the broader Lake Macquarie community

Raise and Fill Land and Built Assets

This set of illustrations shows adaptation options to raise and fill educational land, residential land, infrastructure (roads), and other infrastructure (including sewer, water, power and stormwater drainage lines). It also includes the raise and fill of public recreational land, such as foreshores and playing fields, to maintain access. This diagram does not represent a specific location, but shows the overall raise and fill concept.

10.1 Raise and Fill Land and Built Assets illustration

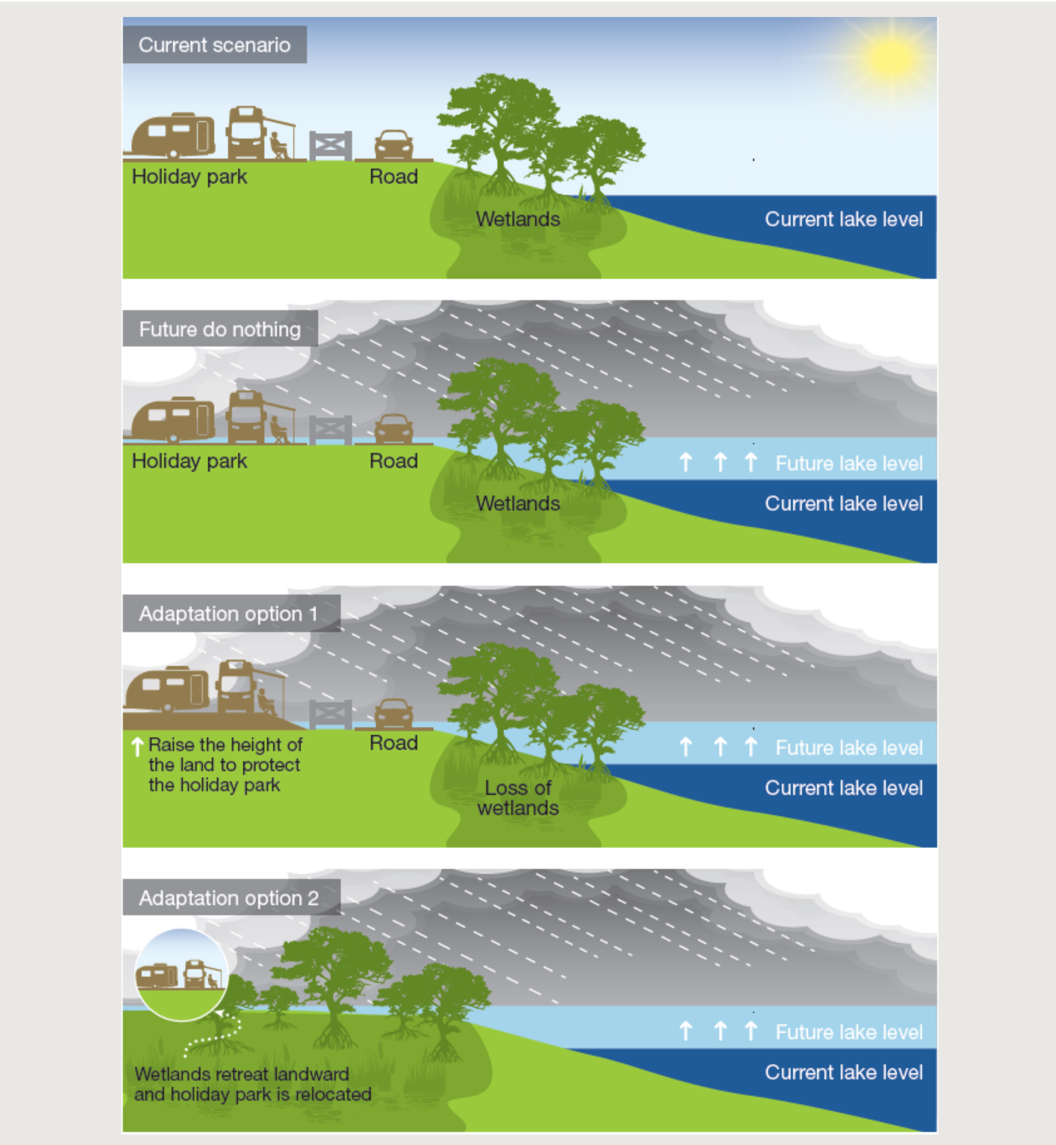


Data source: Lake Macquarie City Council 2020, *Options guide for the cost benefit analysis: Pelican, Blacksmiths, Swansea and Surrounds*, https://shape.lakemac.com.au/37415/widgets/210625/documents/167956

Holiday park and wetlands

This set of illustrations show multiple possibilities to adapt both the Swansea Holiday Park and wetland areas in the study area. For example, at Coon Island, if both the holiday park and wetlands are inundated, one adaptation option would be to raise the holiday park. The wetlands would be lost and offset with the development of protected wetland reserves elsewhere around the lake. Alternatively, another adaptation option is to relocate the holiday park elsewhere to allow the wetlands to move landward. The consideration of these wetland options applies to other locations in the study area.

10.2 Holiday park and wetlands illustration

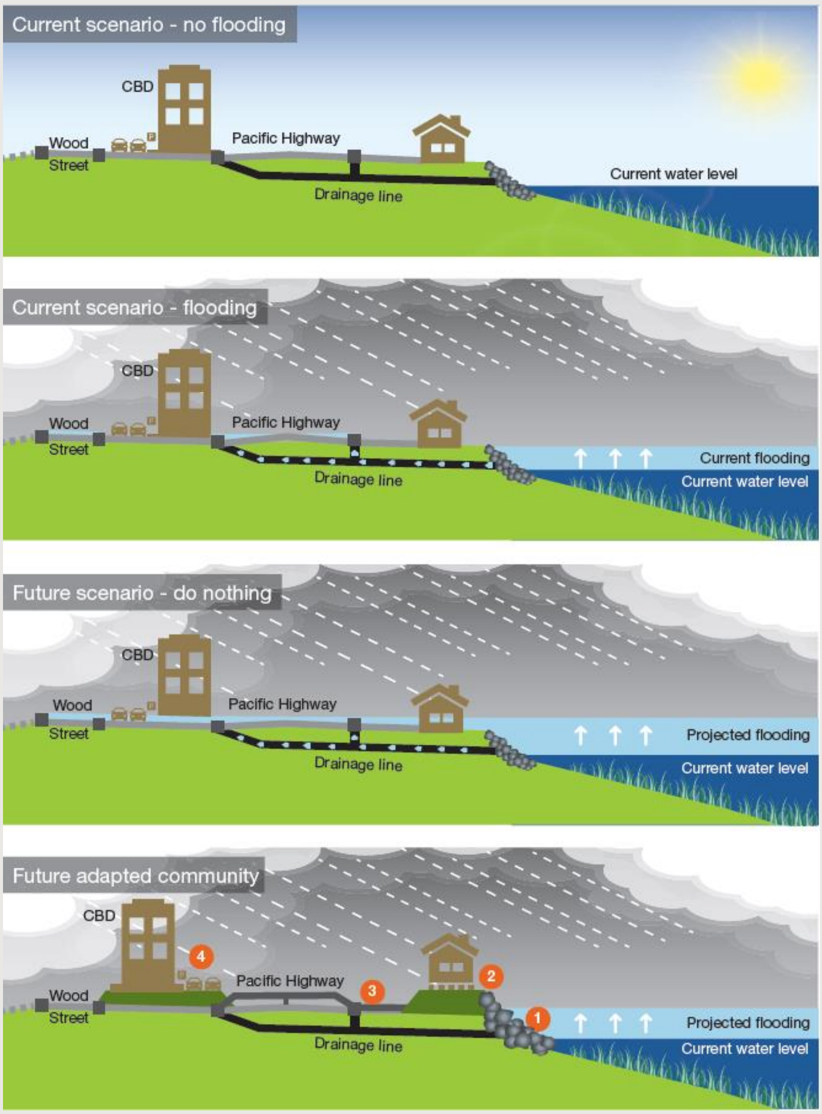


Data source: Lake Macquarie City Council 2020, *Options guide for the cost benefit analysis: Pelican, Blacksmiths, Swansea and Surrounds*, https://shape.lakemac.com.au/37415/widgets/210625/documents/167956

Channel and Foreshore protection works

This series of options considers the protection of Swansea's economic centre (CBD). It is a four-staged process to raise the CBD over time. At present, under normal conditions no flooding occurs. However, during high tide, or high intensity storms, flooding does take place across sections of the Pacific Highway, the CBD, and along Wood Street. As water levels rise and storm intensity and duration increase, flooding will become more severe eventually inundating the CBD and Pacific Highway, as shown. The first stage of the suite of options is to raise the exiting revetments along Black Neds Bay (1), followed by the raise and fill of residential land of properties adjacent to the Bay and some sections of recreational land (2). The major arterial roads connecting to the Pacific Highway will then need to be raised (3). Finally, Swansea CBD and car park will then be prepared to be raised and filled (4).

10.3 Channel and Foreshore protection works illustrations



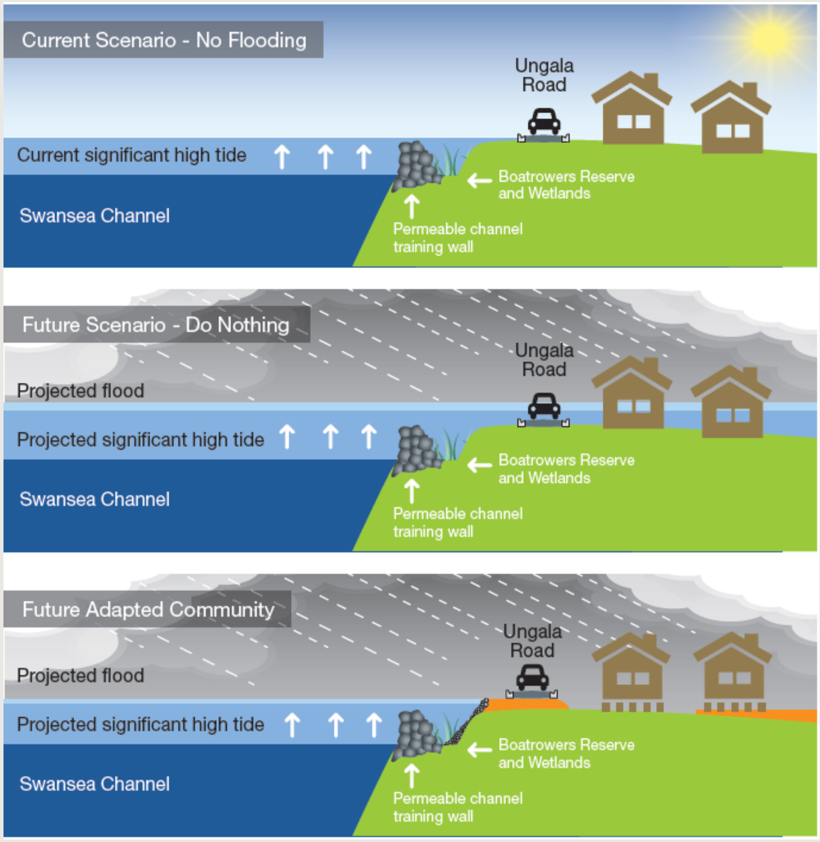
Data source: Lake Macquarie City Council 2020, *Options guide for the cost benefit analysis: Pelican, Blacksmiths, Swansea and Surrounds*, https://shape.lakemac.com.au/37415/widgets/210625/documents/167956

Raise and fill of Ungala Road

This illustration series considers specifically raising Ungala Road and varies from the raise and fill of other infrastructure. It will also be a staged process with sections of

Ungala Road that currently experience inundation raised first. The boat ramp, car park and residential land would also need to be raised to prevent water pooling.

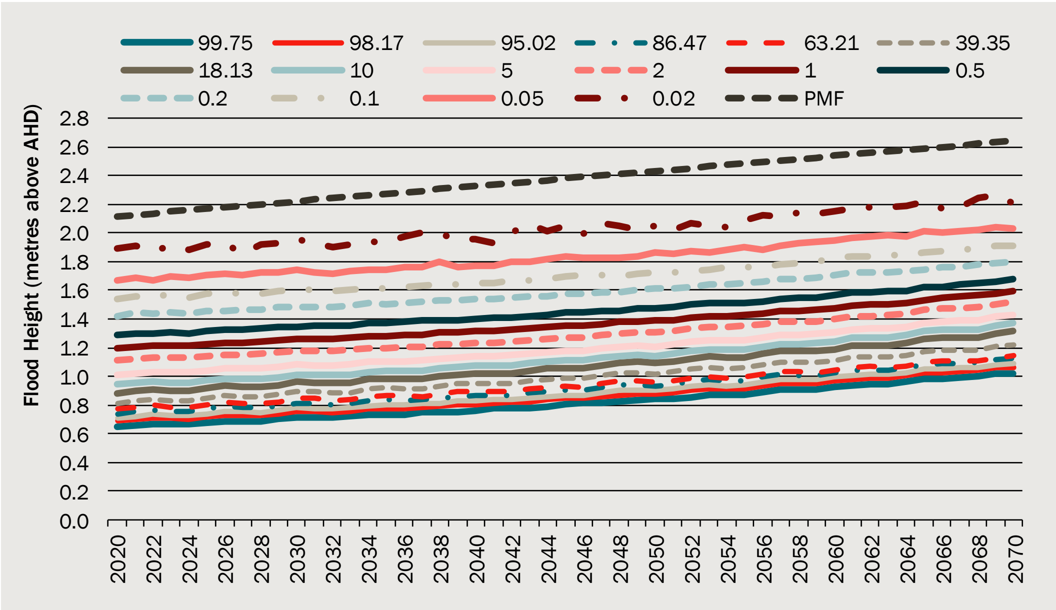
10.4 Raise and fill of Ungala Road illustrations



Data source: Lake Macquarie City Council 2020, *Options guide for the cost benefit analysis: Pelican, Blacksmiths, Swansea and Surrounds*, https://shape.lakemac.com.au/37415/widgets/210625/documents/167956

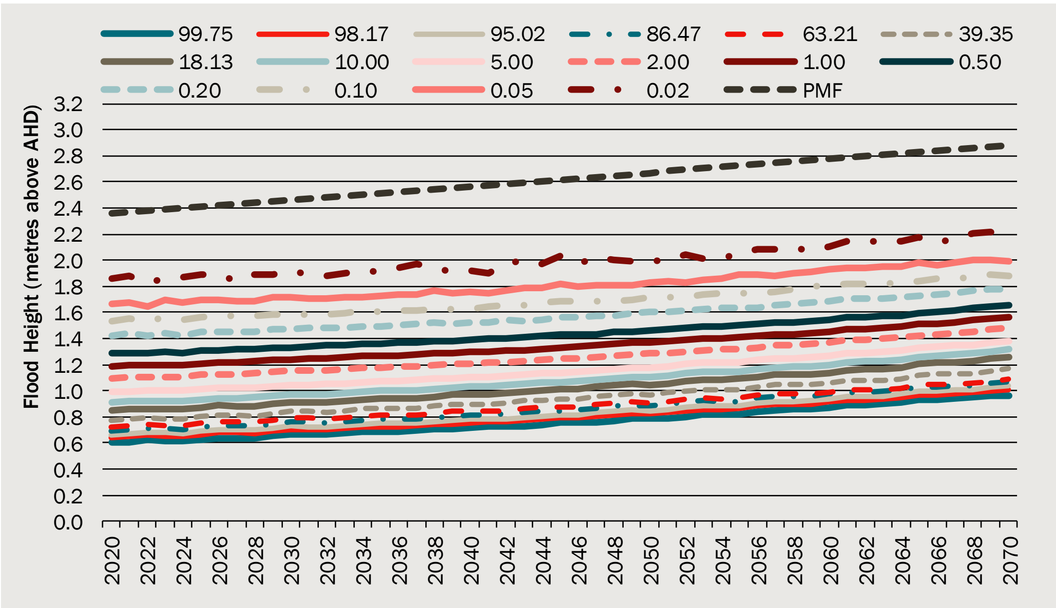
Appendix B: Inundation water level heights

10.5 Inundation water level heights - Precinct 20



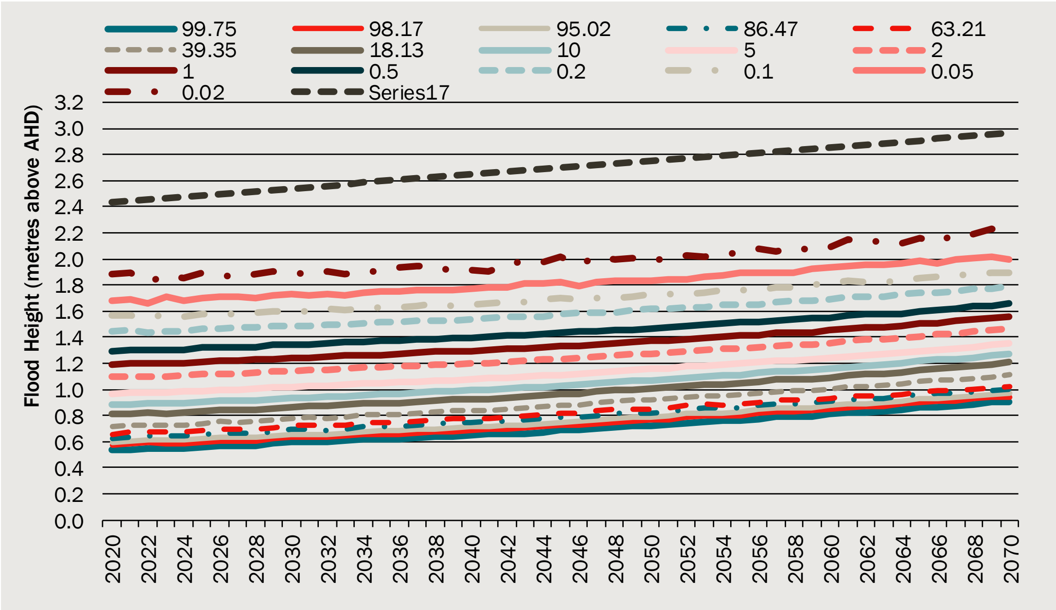
Data source: Salients et. al 2020.

10.6 Inundation water level heights - Precinct 25



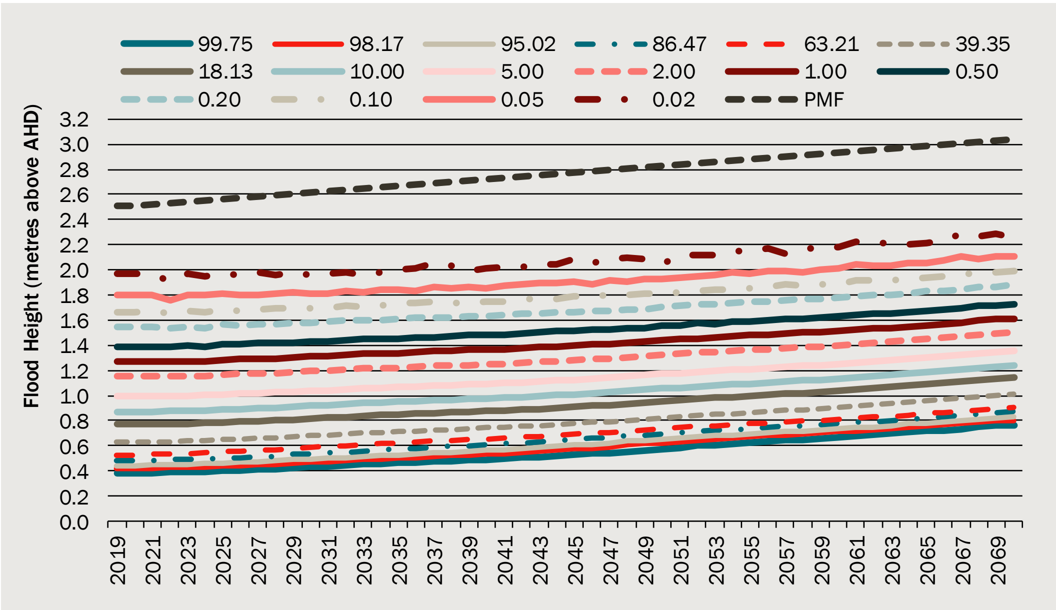
Data source: Salients et. al 2020.

10.7 Inundation water level heights - Precinct 30



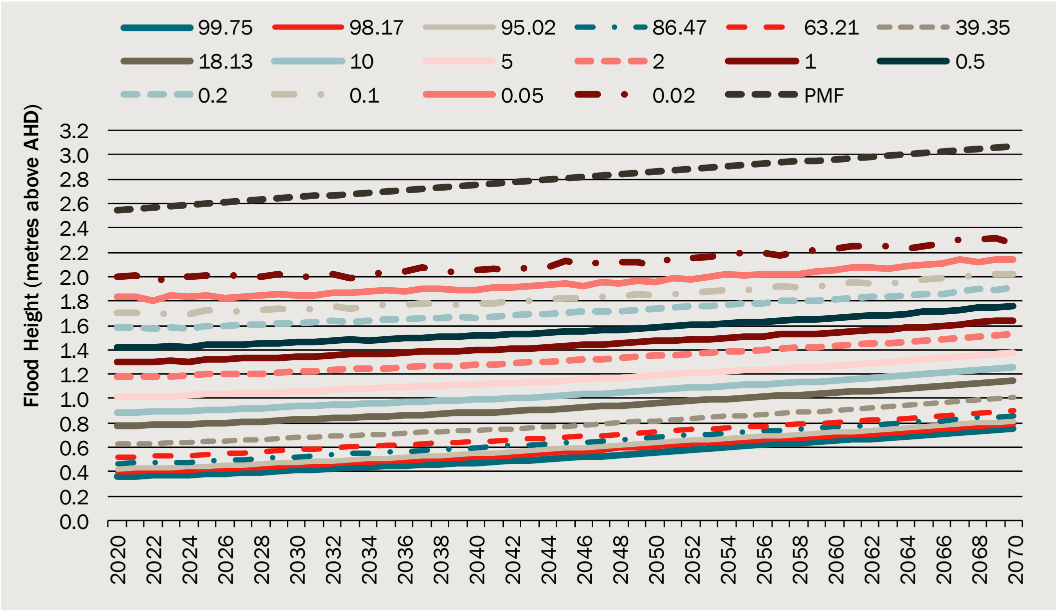
Data source: Salients et. al 2020.

10.8 Inundation water level heights - Precinct 40



Data source: Salients et. al 2020.

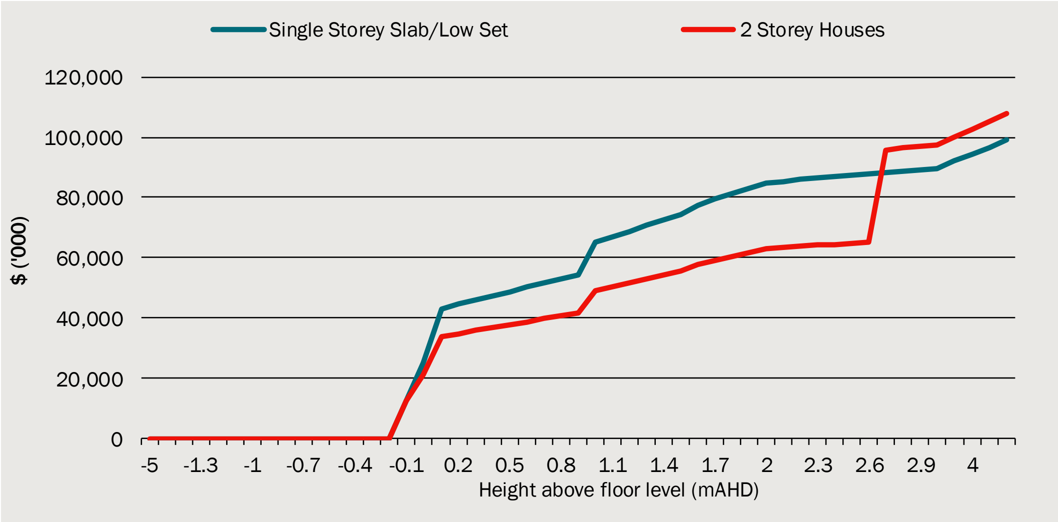
10.9 Inundation water level heights - Lake Area



Data source: Salients et. al 2020.

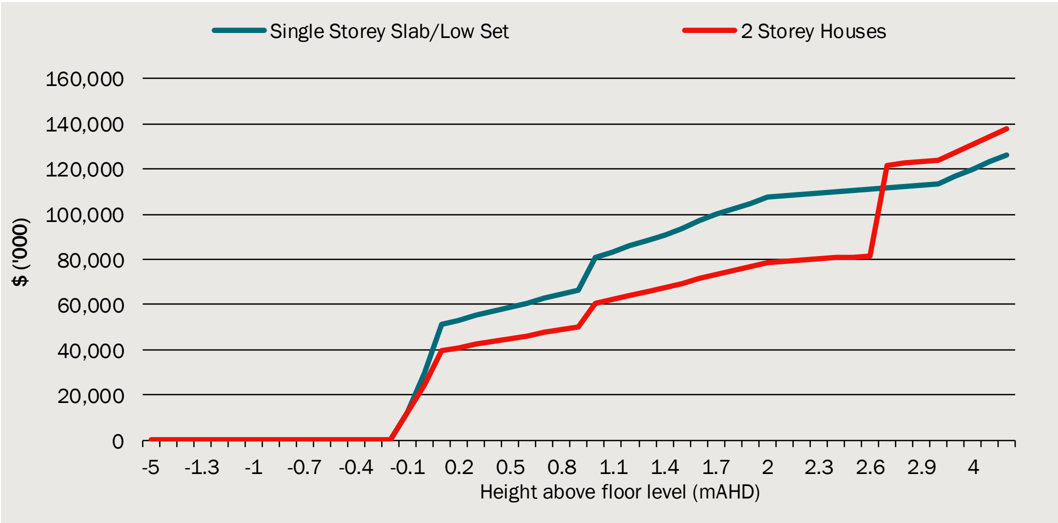
Appendix C: Stage damage curves

10.10 Inundation damage curve - 121m² residential building



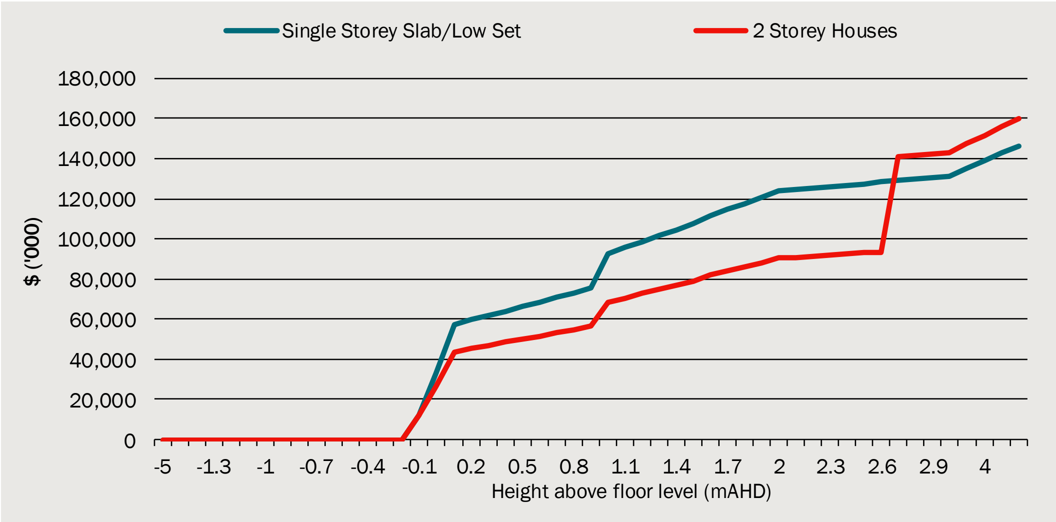
Data source: CIE.

10.11 Inundation damage curve - 164m² residential building



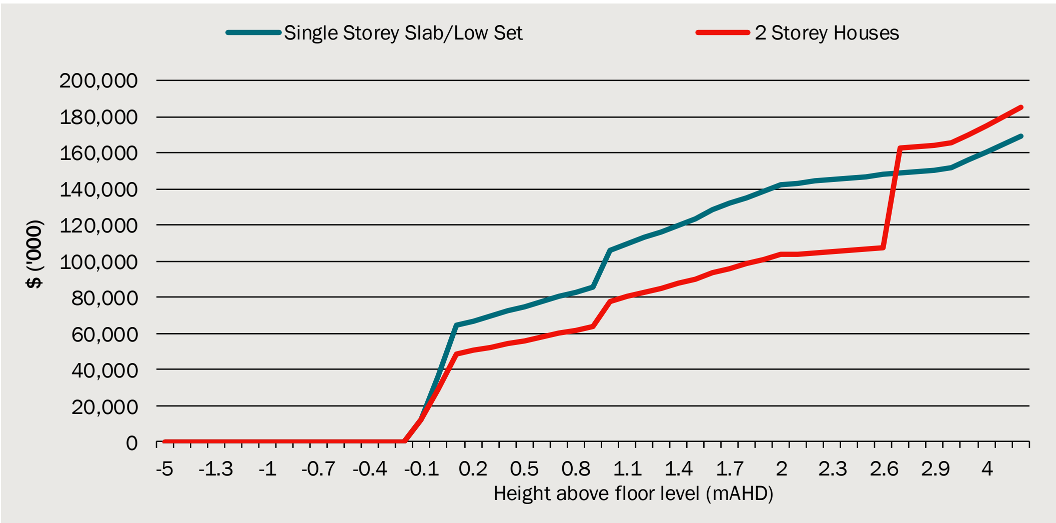
Data source: CIE.

10.12 Inundation damage curve - 195m² residential building



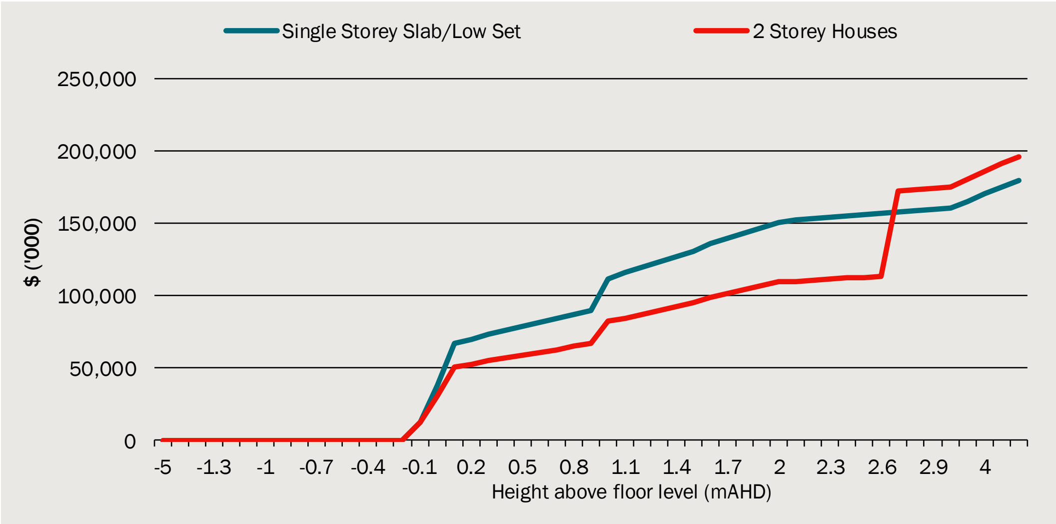
Data source: CIE.

10.13 Inundation damage curve - 230m² residential building



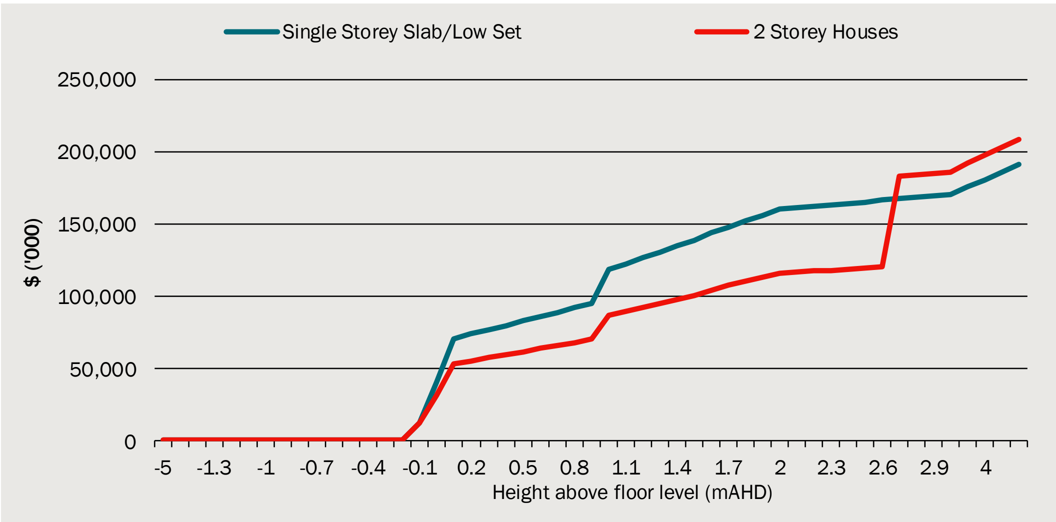
Data source: CIE.

10.14 Inundation damage curve - 246m² residential building



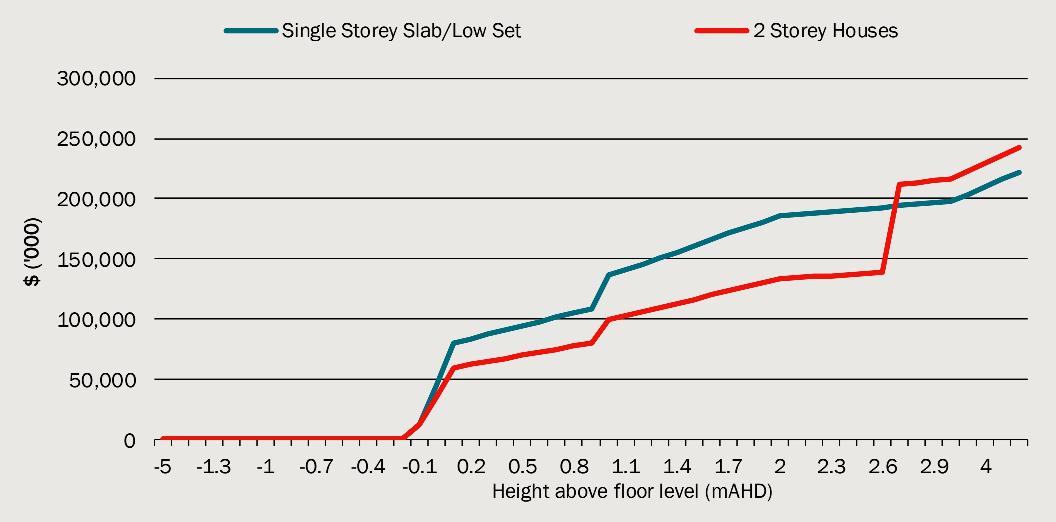
Data source: CIE

10.15 Inundation damage curve - 264m² residential building



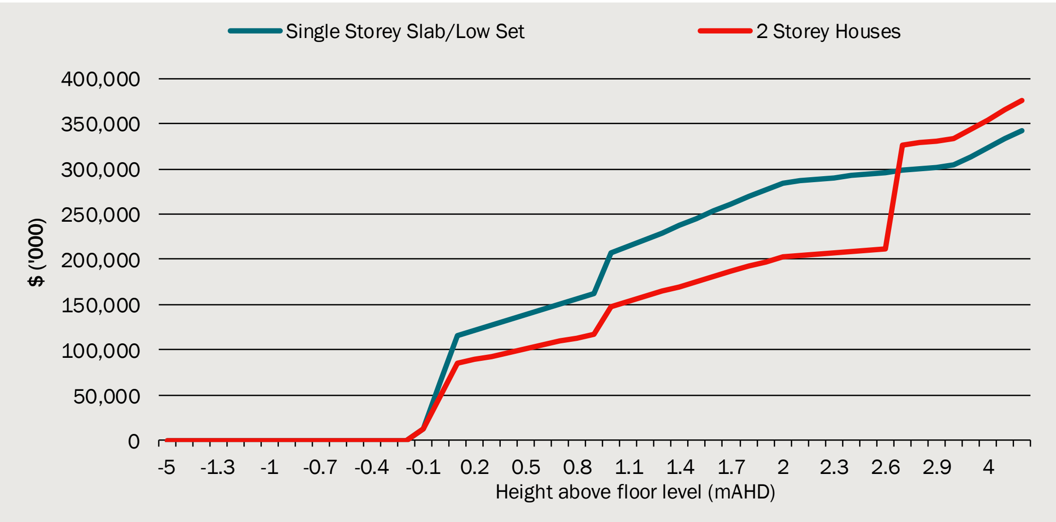
Data source: CIE

10.16 Inundation damage curve - 312m² residential building



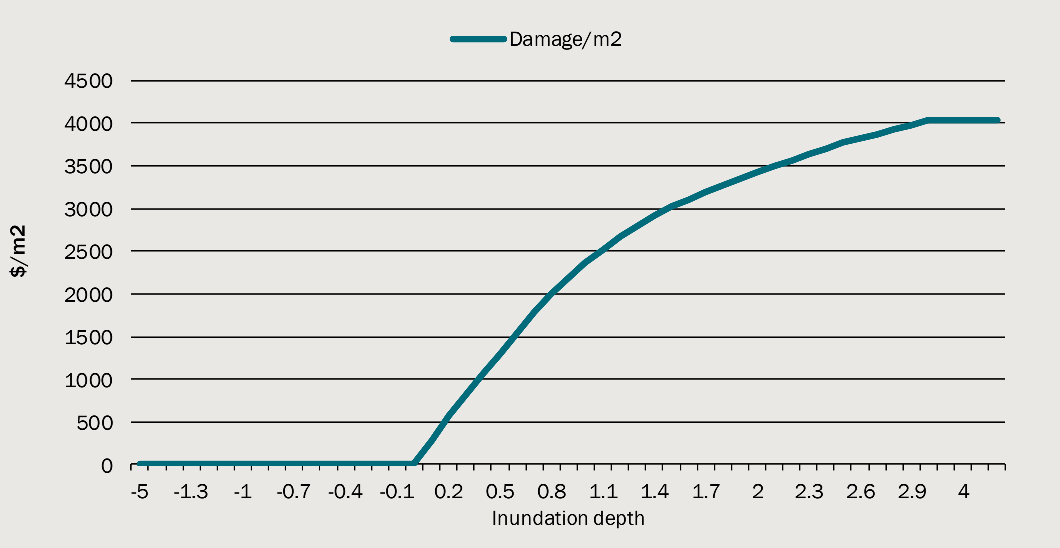
Data source: CIE.

10.17 Inundation damage curve - 500m² residential building



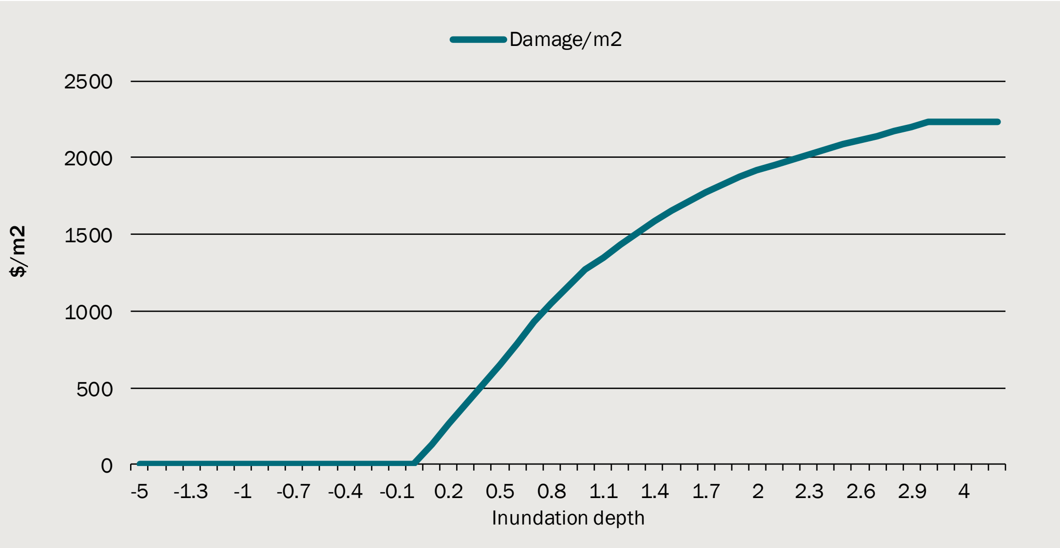
Data source: CIE.

10.18 Education building inundation stage damage curve



Data source: Data source: Molino Stewart; CIE.

10.19 Commercial building inundation stage damage curve



Note: Applied to non-accommodation buildings within the holiday park.

Data source: Data source: Molino Stewart; CIE.

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