Reaping the rewards of resilience

Insurance Council of Australia

February 2022

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18 February 2022

Andrew Hall
Chief Executive Officer
Insurance Council of Australia
Sydney NSW 2000

Dear Andrew

Reaping the rewards of resilience

Finity is pleased to provide the attached report on a resilience investment program for Australia, as agreed in our engagement letter dated 17 January 2022.

We very much appreciate the opportunity to work with you on this important issue. We remain available to answer any questions you may have on our report.

Yours sincerely

Sharanjit Paddam MA MSciTech FIA FIAA

Reaping the rewards of resilience

Appendices

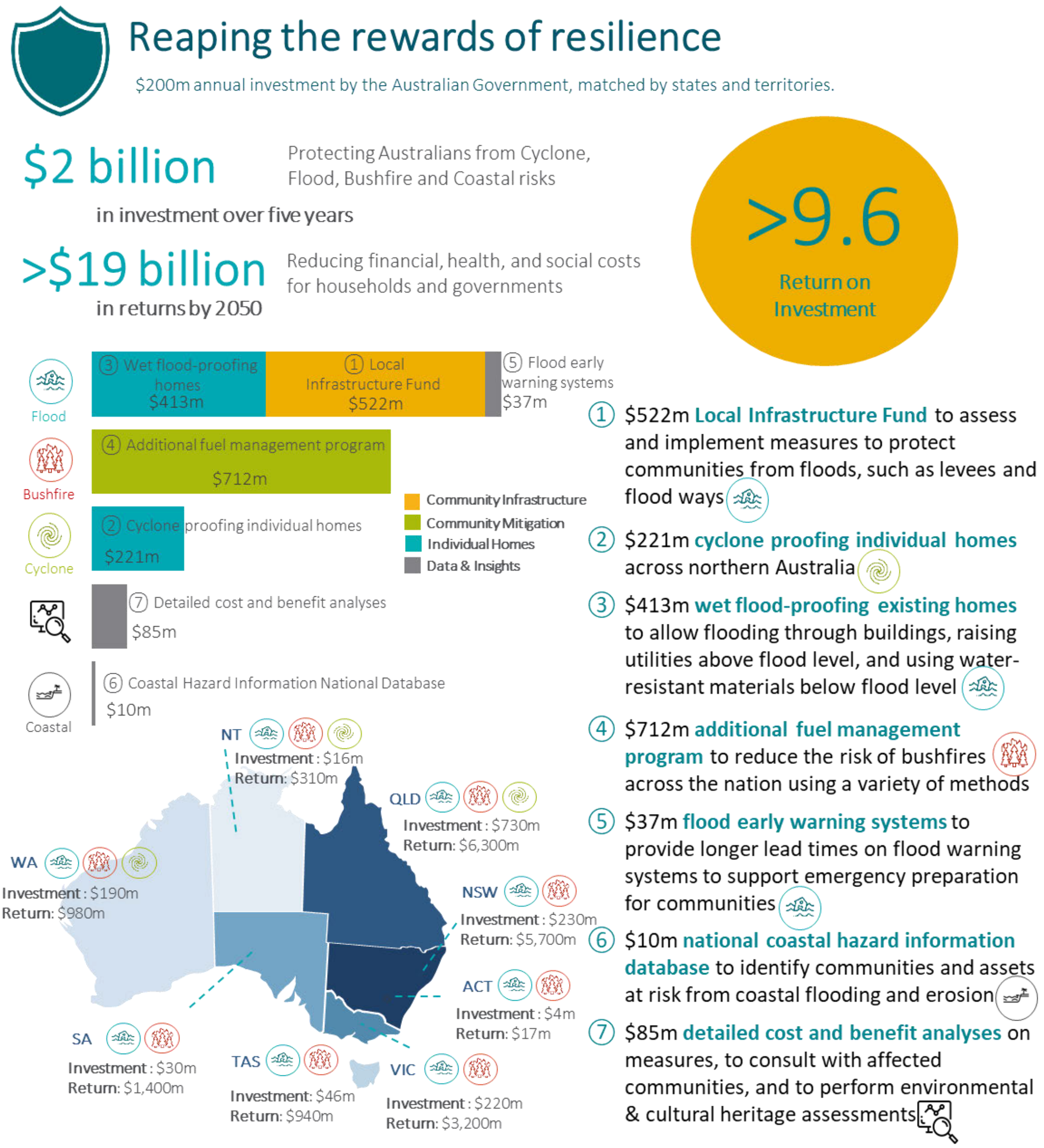
Glossary

Term	Description
AAL	Annual average loss
ABR	Australian Business Roundtable for Disaster Resilience and Safer Communities
BCR	Benefit to Cost ratio (Section 2.2)
BNHCRC	Bushfire and Natural Hazards Cooperative Research Centre
DAE	Deloitte Access Economics
ICA	Insurance Council of Australia
IPCC	Intergovernmental Panel on Climate Change (Section 3.2.4)
JRC	Joint Research Centre
LGA	Local Government Association
RCNNDA	Royal Commission into National Natural Disaster Arrangements
RCP	Representative Concentration Pathway (Section 3.2.4)
ROI	Return on Investment (Section 2.2)

1 Summary

Extreme weather events are putting Australian homes, communities and livelihoods under pressure and increasing the financial risk to Australian governments. Investing in resilience protects Australian households, can improve access to affordable insurance coverage, and reduces the risk to taxpayers of providing direct financial assistance. Resilience is a win for households, a win for business, and a win for governments.

In order to reap these rewards, we have researched potential resilience measures and proven historical experience, and propose a five-year $2b investment program commencing in 2022, with $200 million annual investment by the Australian Government and matching contributions from states and territories. As well as saving lives and reducing physical and mental injuries, this program is expected to reduce financial, health and social costs to the Australian Government and Australian households by at least $19 billion by 2050 – a return on investment exceeding 9.6. Our work is subject to the limitations and uncertainties discussed in Section 4.



2 Proposed resilience program

2.1 The call for resilience

Extreme weather events are putting Australian homes, communities and livelihoods under pressure and increasing the financial risk to the Australian Government.

Multiple stakeholders have called out the value of investing in resilience measures to better protect Australian households and communities from the impacts of extreme weather. In 2014 the Productivity Commission performed a detailed review of Natural Disaster Funding Arrangements and found that expenditure on resilience measures across all levels of government is likely to be below the optimal level. It also found that governments overinvest in post-disaster reconstruction and underinvest in resilience measures that would limit the impact of natural disasters in the first place. It recommended that Federal Government post-disaster support to state and territory governments should be reduced, and support for resilience measures increased. Specifically, it recommended that the Federal Government should gradually increase the amount of annual funding it provides for pre-disaster resilience measures to $200 million, which should also be matched by funding from states and territories.

While the Australian Government did not pursue these recommendations[1], in 2020 the Royal Commission into National Natural Disaster Arrangements[2] emphasised the importance of long-term disaster risk reduction, and recommended that the Australian Government should establish a standing entity that will enhance national natural disaster resilience and recovery, focused on long-term disaster risk reduction. In 2020, the Australian Government announced[3] that it would establish a new resilience, relief and recovery agency to coordinate and align Australia's national capability to build resilience, better prepare for natural disasters, and recover from all hazards. The National Recovery and Resilience Agency was established in 2021, bringing together existing and new funding for resilience measures.

The Australian Business Roundtable for Disaster Resilience and Safer Communities (ABR) has commissioned a number of reports from Deloitte Access Economics (DAE) that have considered the economic and social benefits of resilience measures. DAE estimated[4] the current cost of natural disasters to the Australian economy at $38 billion per annum, and forecast an increase to between $73 billion and $94 billion per annum by 2060, depending on future emissions.

A proven example of the rewards from investing in resilience was the construction of a flood levee in **Roma, Queensland** in 2013. Prior to the commencement of the levee, Suncorp, a major insurer in the area, had withdrawn insurance coverage for Roma following significant losses over a number of years. If the situation had continued, and householders had not been able to obtain insurance coverage, the Australian Government would likely have had to provide increased direct financial assistance to households. Instead, Suncorp insured Roma again, with premium reductions between 30% to 80%.

In 2022, as part of research commissioned by the Minderoo Foundation, DAE estimated[5] that by adapting now, Australia could avoid $380 billion in worsening annual economic costs from climate change, of which $120 billion relates to resilience measures to reduce the impact of extreme events on the economy.

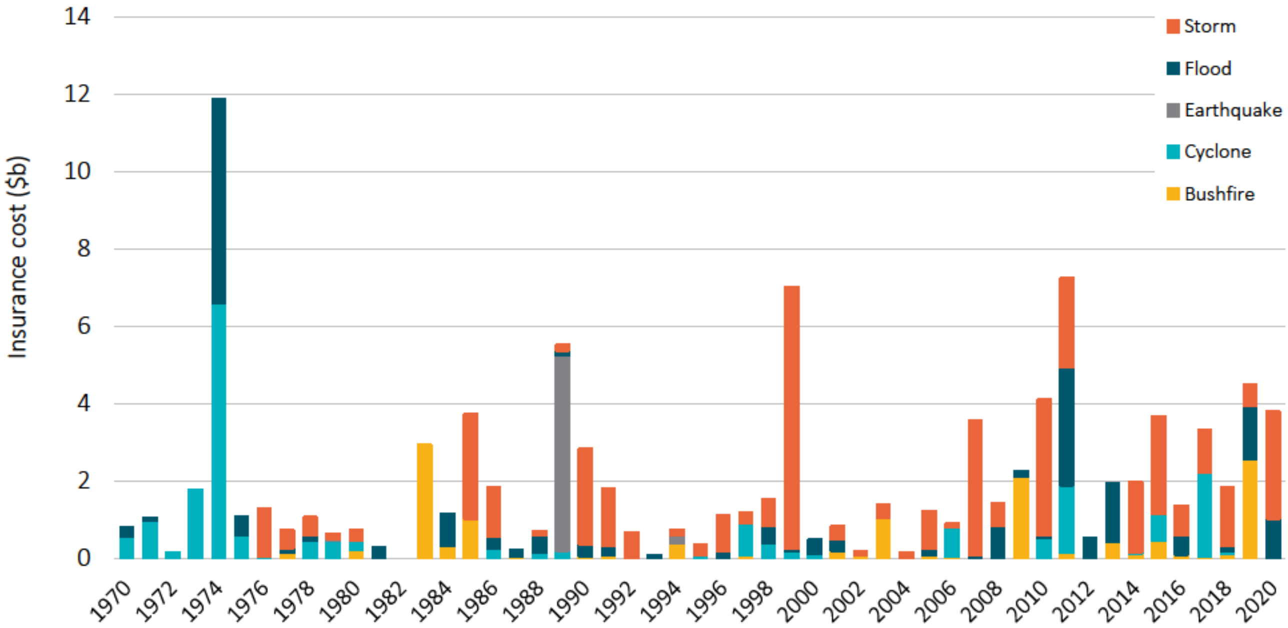
[1] (Australian Government, 2016)
[2] (RCNNDA, 2020)
[3] (Australian Government, 2020)
[4] (Deloitte Access Economics, 2021)
[5] (Deloitte Access Economics, 2022)

2.2 Scope of assessment

As requested by the ICA, we have considered a range of resilience measures to better protect Australian households and communities from the impacts of extreme weather, the investment required for those measures, and the returns as avoided costs for households and the Australian Government. We have not considered measures that are primarily the responsibility of state and territory governments, noting however that many of the program measures are likely to be delivered by the states and territories, even if funded by the Australian government. We have also excluded investments and returns for business and commercial enterprises.

For this assessment, we have looked at resilience measures applicable to bushfire, flood and cyclones. These perils were collectively responsible for over 50% of insured losses between 1970 and 2020 (insured loss estimated at $53 billion)[6]. These figures exclude non-insured losses, and historical insurance coverage often excluded flood losses, and so very likely understate the actual losses due to these perils.

Figure 2.1 Insured losses by peril between 1970 and 2020[7]



[6] (ICA, 2022)
[7] Costs inflated to 2022. From (ICA, 2022).

Table 2.1 Included and excluded components of investments and returns

	Included	Excluded
Investment	◦ Direct project expenditure (construction or modification costs) for resilience measures for residential property ◦ Hazard mapping or other additional data gathering initiatives ◦ Funding for detailed assessment of resilience project costs and benefits	◦ Changes to the National Building Code, and land use and planning frameworks (state responsibility) ◦ Increased business expenses to comply with rules and regulations (business expense)
Returns (avoided costs)	◦ Damage to residential property (both insured and uninsured properties) ◦ Damage to health, including fatalities and injury ◦ Damage to community, including family violence, mental health costs and chronic disease	◦ Damage to commercial property or public assets and infrastructure (primarily state owned) ◦ Business disruption ◦ Disruption of public utility services such as water, sewerage, electricity, telecommunications (state and territory responsibility) ◦ Increased travel and congestion costs including disruption to transport networks ◦ Damage to environmental, cultural and heritage assets ◦ Emergency response, clean-up, evacuation and temporary housing ◦ Damage to other social assets, including through unemployment, crime and disruption to education

In this report we use the following definitions:

- **Investment** is the present value at the start of 2022 of the investment across the five years of the proposed program.
- **Returns** is the present value at the start of 2022 of the avoided property damage, health and social costs from 2022 to 2050.
- Both **Investment** and **Returns** include the components described in Table 2.1, and are based on the assumptions in Section 3, including a real discount rate of 2% p.a. and an allowance for climate change.
- **ROI** is the ratio of Returns to Investment, rounded to two significant figures, where Returns and Investments are as above. We use ROI to report the results of our analysis throughout this report.
- **BCR** is the ratio of **benefits** to **costs**, where benefits and costs may be calculated using different assumptions – i.e. do not have the same components, real discount rate or period of measurement, etc. BCRs come from the sources we have researched as part of preparing this report.

We have focused on the significant items driving financial costs for households and expenditure by the Australian Government. These form a subset of the full economic costs. Our estimates are likely to underestimate the overall returns compared to a full economic analysis. However, our bottom up approach allows us to consider the investments required to achieve those returns.

This report should be read in conjunction with the reliances and limitations set out in Section 4. These are important and must be read, to put our analysis and this report in its proper context.

2.3 The resilience program

We propose a five-year program of resilience measures commencing in 2022, totalling $2 billion in investment, with a $200 million annual investment by the Australian Government and matching contributions from states and territories. Under our analysis, the program is expected to reduce financial, health and social costs to the Australian Government and Australian households by at least $19 billion by 2050 – a return on investment (ROI) exceeding 9.6. Table 2.2 summarises the proposed measures, with details provided in Section 2.4.

Figure 2.2 Investment and ROI on resilience measures

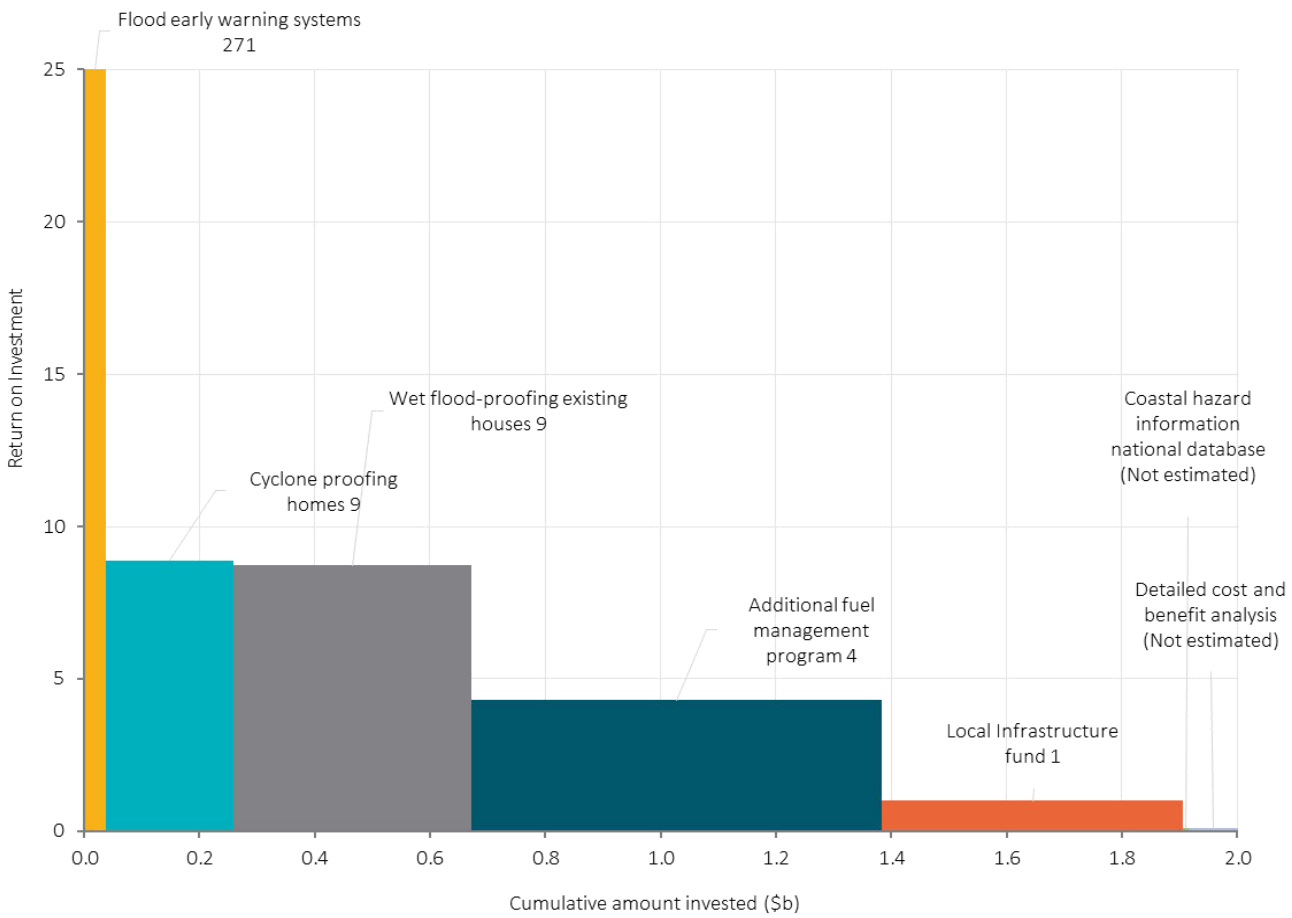


Table 2.2 Summary of proposed program[8]

Resilience measure	Description	Basis of assessment	Investment ($m)	Returns ($m)	ROI
① Local Infrastructure Fund	New fund to assess and implement measures to protect communities from floods, such as levees and flood ways in flood prone areas across Australia	Examples including Roma, St George, Grafton[9] Conservatively assumed ROI of >1	522	>522	>1

[8] See end of Section 2.2 for definitions of Investment, Returns, and ROI
[9] (Urbis, 2014)

Resilience measure	Description	Basis of assessment	Investment ($m)	Returns ($m)	ROI
② Cyclone proofing homes	Additional funding and extension of the Queensland Household Resilience Program across QLD, NT and WA, to retrofit homes for cyclone protection	Urbis study of costs and benefits[10]	221	1,964	8.9
③ Wet flood-proofing existing homes	Allow flooding through buildings to reduce damage to homes, raising utilities above flood level, and using water-resistant materials below the flood level, in flood prone areas across Australia	BNHCRC review of US experience[11]	413	3,602	8.7
④ Additional fuel management program	Funding for states and territories to increase fuel management programs using a range of measures including prescribed burning, mechanical removal, and remote sensing systems, in order to reduce the risk of bushfires across the nation	State and territory prescribed burning targets BNHCRC DAE review of costs and benefits[12]	712	3,065	4.3
⑤ Flood early warning systems	Improving flood early warning systems (Flood Watch) to provide longer lead times of 10-15 days, to support decision-making, drive enhanced monitoring, and initiate emergency preparedness for communities in flood prone areas across Australia	JRC evaluation of the European Flood Alert System[13]	37	10,141	271
⑥ National coastal hazard information database	Creation of a national database to identify communities and assets at risk from actions of the sea	Baird Australia report for ICA[14]	10	Not estimated	Not estimated
⑦ Detailed cost and benefit analysis	Detailed cost and benefit analyses on measures within this program, to consult with affected communities including indigenous communities, and to perform environmental and cultural heritage assessments	Finity estimate	85	Not estimated	Not estimated
Total			2,000	>19,294	>9.6

The program allows for a spread of investment across Australia (Figure 2.3), protecting our most vulnerable communities against floods, cyclones and bushfire, and assessing the vulnerability of communities to actions of the sea (Figure 2.4). It combines a balance of community infrastructure measures, community mitigation measures, measures that protect individual homes, and measures on data and insights (Table 2.3 and Figure 2.5).

[10] (Urbis, 2015)
[11] (BNHCRC, 2021)
[12] (Deloitte Access Economics, Scoping Study on a Cost Benefit Analysis of Bushfire Mitigation - Australian Forest Products Association, 2014)
[13] (Joint Research Centre, 2015)
[14] (ICA, 2021)

Figure 2.3 Investment and return by state and territory[15]

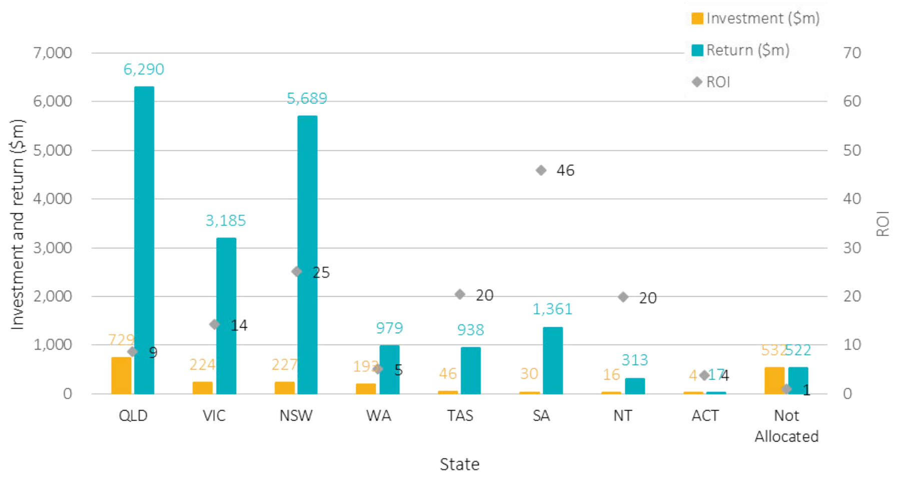


Figure 2.4 Investment and return by peril

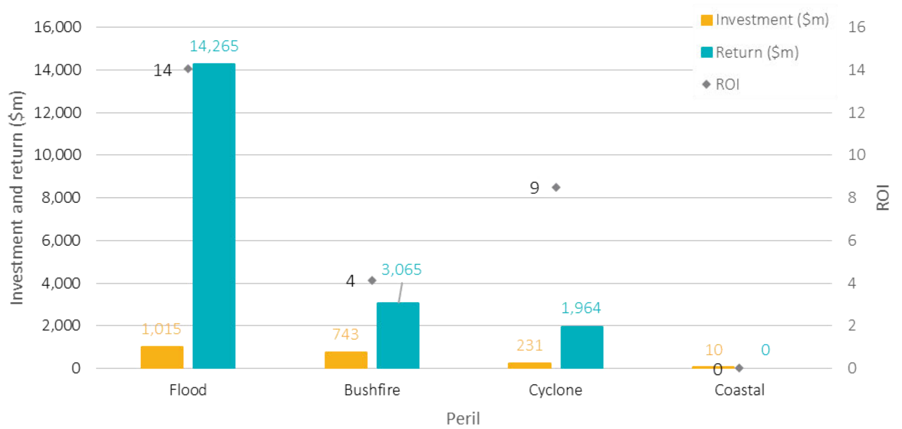
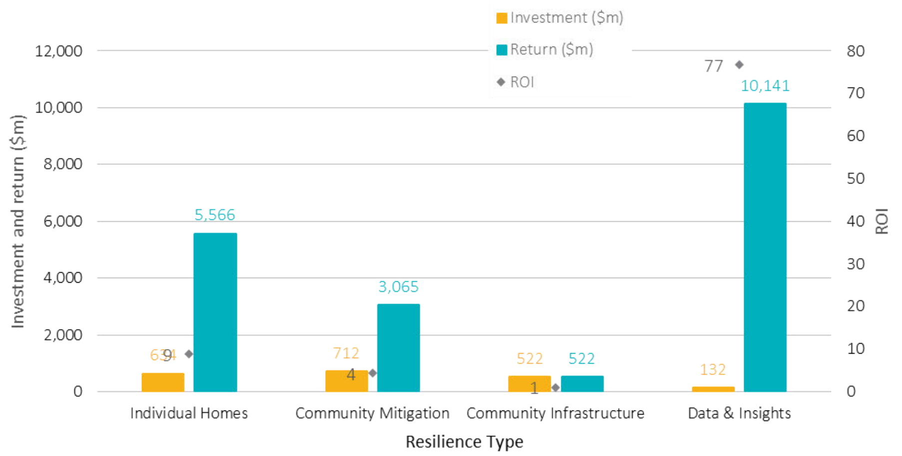


Figure 2.5 Investment and return by type of resilience measure



[15] The Local Infrastructure Fund and National coastal hazard information database resilience measures have not been allocated to states and territories as the investment required in each jurisdiction will depend on the location of potential levees or coastal assets and communities considered under each resilience measure.

Table 2.3 Investment and return by type of resilience measure

Type of measure	Resilience measures	Investment ($m)	Return ($m)	ROI
Protecting individual homes	◦ Cyclone proofing homes ◦ Wet flood-proofing existing homes	634	5,566	8.8
Community infrastructure	◦ Local Infrastructure Fund	522	>522	>1
Community mitigation	◦ Additional fuel management program	712	3,065	4.3
Data & insights	◦ Flood early warning systems ◦ National coastal hazard information database ◦ Detailed cost and benefit analysis	132	10,141	77
Total		2,000	>19,294	>9.6

Our assessment makes some key assumptions, such as using a real discount rate of 2% and the impact of climate change, and uses a range of studies to assess the avoided damages to property, health and social costs. Sections 2.4 and 3 provide details of the measures considered and our assumptions.

Designing this program to prioritise ROI and ensure a variety of resilience measures with a broad geographic spread required us to exclude a range of additional resilience measures, such as community awareness programs. These measures still provide considerable value to communities and governments, but fell outside of the scope of this analysis. These are discussed in Appendix A (resilience measures assessed but not included in program) and Section 2.5 (resilience measures not considered in our assessment).

2.4 The resilience measures

2.4.1 Local Infrastructure Fund

Table 2.4 Benefit to cost ratios of flood levees in Australia[16]

Levee name and location	BCR	Estimated financial benefit (2014 dollars)
Roma levee (Roma, Queensland)	4.9	◦ Household assets: $18.4 million ◦ Business assets and stocks: $7.6 million ◦ Public infrastructure: $4.5 million ◦ Productivity losses: $10.9 million ◦ Better insurance coverage $39.7 million
St George levee (St George, South West Queensland)	5.4	◦ Household assets: $7.6 million ◦ Business assets and stocks: $20.8 million ◦ Public infrastructure: $5.3 million ◦ Productivity losses: $29 million ◦ Better insurance coverage $11.4 million
Grafton flood levee (Clarence Valley, NSW)	2.2	◦ Household assets: $41.6 million ◦ Business assets and stocks: $3.8 million ◦ Public infrastructure: $2.3 million ◦ Productivity losses: $5.4 million ◦ Better insurance coverage $12.6 million

Floods are the one of the most expensive type of natural disaster in Australia, with insured losses estimated at $20 billion (2022 values) between 1970 and 2020 [17,18]. While property level measures can reduce the damage to individual houses, public infrastructure measures such as levees or flood ways offer wider community level protection, minimising disruptions to people and the economy. For example, the Roma flood levee was estimated as not only being able to deliver $18.4 million in protective benefits for households, but an additional $62.7 million in benefits for business assets and stocks, public infrastructure, economic productivity and better insurance coverage[16]. Other levees have also shown similar extents of protective benefits outside of households as shown in Table 2.4.

Despite this, large-scale infrastructure projects for flood protection can be overlooked in communities due to their high upfront costs, as well as concerns about the precise location of the infrastructure and its local impact. It is on this basis that the Local Infrastructure Fund of $522 million has been allocated to the program. The fund should be largely targeted at flood mitigation projects such as levees and flood ways which could prove economically viable when assessed to account for the wider community benefit and avoided public costs. Flood prone LGAs for consideration by the Local Infrastructure Fund could include:

- Lismore
- Shepparton
- Narrabri
- Innisfail
- Rockhampton
- Tweed Heads South
- Dalby
- Seymour
- Mackay

[16] (Urbis, 2014)
[17] Loss estimates are based on historical insurance coverage, which often excluded flood cover. Under current policy conditions, losses for flood would be greater.
[18] (ICA, 2022)

We note that the Australian Government provided $50m in 2021 for the National Flood Mitigation Infrastructure Program[19]. The proposed Local Infrastructure Fund would be in addition to this existing funding.

2.4.2 Cyclone proofing homes

The Queensland Household Resilience program[20] has shown that retrofitting for cyclone exposed homes is an inexpensive means to provide homeowners with tangible protection against cyclones.

This measure adopts low to medium cost methods to retrofit homes in high cyclone prone areas, limiting wind and water related damage. It includes the strengthening of roller doors, the installation of window coverings, and retrofits to the roofing system using an over batten system, which involves securing the roof by connecting a beam on the top of a roof to the house foundations. The investment and returns have been modelled using work by Urbis in 2015[21].

The selected option for window protection was the low-cost option $1,660 (2015 values) which was identified to be the most viable option in the Urbis (2015) study. This option assumes the home owner strengthens roller doors through aftermarket bracing ($300) (2015 values), and installs plywood window coverings on their windows prior to a cyclone to reduce wind and water ingress through damaged windows $1,360 (2015 values). The labour involved in this option is assumed to be conducted by the homeowner themselves.

The assumed retrofit for the roofing system (for pre-1980 housing only) is the over batten system ($12,000 (2015 values). While this option has a lower cost benefit ratio over the lower cost strapping option ($3000 (2015 values)), it was selected due to the strapping option assuming the owner is replacing the roof already and therefore the measure would only be cost effective in any substantive roof renovation[21].

The table below shows our assumptions for the cost of the program, based on the analysis performed by Urbis[21]. We have assumed that the program will cover approximately 44,200 upgrades (approximately 8,800 homes a year), which is 2.7% of high-risk homes and 1.1% of all homes and require $221 million in funding. This funding represents a ten-fold increase to the QLD Household Resilience Program[22] which received funding of $21.25m, and upgraded 1,693 homes[23]. Within these 44,200 homes, we have assumed that 25% will implement the roofing upgrade and window protection measures, with the remaining 75% implementing window protection only.

The 22% reduction in Annual Average Losses (AALs) estimated for this measure is in line with premium reductions reported from the roll out of the Queensland Household Resilience program which reached a maximum premium reduction of 25%, and 8.2% on average[24].

[19] Media Release dated 10 May 2021 from the Minister for Agriculture, Drought and Emergency Management
[20] (Queensland Government, 2020)
[21] (Urbis, 2015)
[22] (Queensland Government, 2020)
[23] (Queensland Government, 2019)
[24] (Queensland Government, 2019)

Works	Assumption	Assumed (2022 values)	Reference (2015 values)	Notes
Opening protection for windows and doors	Cost per house ($)	1,862	1,660	Reference values adjusted for inflation
	BCR	2.41	1.2 – 3.9	Average of reference value
Roof and strapping upgrade using an over batten system for pre-1980 housing	Cost per house ($)	13,462	12,000	Reference values adjusted for inflation
	BCR	2.02	1.1 – 3.3	Average of reference value
	Proportion of housing stock pre-1980	25%		Based on Finity approximation across NT, QLD, and WA
	AAL reduction	22%		Calculated to meet assumed BCRs

2.4.3 Wet flood-proofing homes

This measure involves raising utilities and other important contents above the expected flood level and selecting materials to protect building components below the flood level. Floodwater is allowed to enter the building to equalise hydrostatic pressure such that the risk of building failure is reduced. The modelled benefits and costs of this upgrade have been estimated using work by the BNHCRC[25] researching US examples supported by other research reviewing measure effectiveness.

Wet flood-proofing reduces losses from floods, but some damage can remain for extended floods, and clean up and cosmetic repairs are usually necessary. However, the measure is cheaper, faster and easier to implement for existing homes, and can allow for rapid recovery for affected communities.

Consistent with the BHNCRC analysis, we have applied the measure to the estimated number of brick veneer homes within the top 0.1% of high-risk homes.

Assumption	Assumed (2022 values)	Reference (2019 values)	Notes
Cost per household ($)	17,071	16,450	Cost ranges between 15,500 to 17,400 [25]
AAL reduction	50%	50%	Wet flood proofing can minimise damage up to 50% [26,27,28]
Average proportion of brick veneer houses (national)	57%		Finity assessment

[25] (BNHCRC, 2021)
[26] (Attems, 2019)
[27] (Alabbad, 2022)
[28] (International Commission for the Protection of the Rhine, 2002)

2.4.4 Additional fuel management

This measure provides additional funding for fuel management, including prescribed burning, other techniques[29] and satellite imagery and other remote sensing systems[30] to monitor fuel loads across the nation.

Fuel management methods

Prescribed burning entails the controlled burning of vegetation in a predetermined area under specified weather conditions and is one of the most common bushfire reduction techniques adopted across Australian. Prescribed burning has been shown to materially reduce or limit the intensity and spread of bushfires.

However, prescribed burning can result in negative environmental and health costs, such as increased respiratory issues caused by reduced air quality. If the burning is not planned and managed appropriately, the fire can potentially escape. These issues may result in some community reluctance for the adoption of the measure, and close community engagement is required. In 2020, the Royal Commission into National Natural Disaster Arrangements (RCNNDA) noted there would be clear benefit in improving public knowledge and understanding of fuel management techniques[31]. Further, studies have indicated there could be added benefit to integrating the knowledge of traditional Indigenous burning practices to improve hazard management around prescribed burning[32,].

The potential increase of prescribed burning may become limited, firstly because prescribed burning is restricted to public land, and secondly climate change is projected to lengthen the fire season and so reduce the periods of time when conditions are suitable for prescribed burning[33]. This measure therefore includes the use of other fuel management techniques, which have been found to be effective under a range of circumstances[34]. Such an example of an area is the Blue Mountains whereby the bush urban interface areas can be difficult to burn at low intensities. As a result, mechanical treatments are required along this interface to thin out shrubs and reduce near surface and elevated fuels[35].

[29] (BNHCRC, 2021a) considers a range of alternate fuel management methods, including forest thinning, scrub rolling/brush-cutting, mulching, mowing/slashing, fire breaks and strategic access, parkland clearing, pile burning, chipping, herbicide and grazing.

[30] An example of this is the adaptive analytical bushfire likelihood (AABL) tool which uses remotely sensed earth observations to provide information on the landscape (vegetation, soil moisture, climate variables) to map fuel loads and bushfire risks, enabling authorities to better target fuel reduction (SmartSat, n.d.)

[31] (RCNNDA, 2020)

[32] (Bardsley, 2019) (Eriksen, 2014) Investments in education and community consultation related to this measure have been included within the detailed cost and benefit analysis measure discussed in Section 2.4.6

[33] (Clarke, 2019) and (RCNNDA, 2020)

[34] (BNHCRC, 2021a)

[35] (AFAC, 2014)

Table 2.5 Prescribed burning targets and assumed reduction in AAL for states and territories

State	Total vegetation area (kha)	Target area burnt (kha)	Target area burnt (%)	Target risk reduction[36]	Assumed AAL reduction of existing program	Assumed AAL reduction from additional funding
QLD[37]	14,200	710	5% [38]	NA	25%	15%
VIC[39]	8,200 [40]	275	3%	70%[41]	30%	20%
WA[42]	18,000 [43]	200	1%[44]	NA	25%	15%
NSW[45]	2,187 [46]	135	6%	35% [47]	30%	20%
TAS[48]	3,350 [49]	74	2%	NA	25%	15%
SA[50]	NA	9	NA	NA	25%	15%
ACT[51]	NA	7	NA	35% [52]	30%	20%
NT	NA	NA	NA	NA	25%	15%
Total		1,335				

Investment

The estimated investment under this measure is 78% of the cost of achieving all existing prescribed burning regime targets for the states and territories, as set out in Table 2.5. Fuel management requirements are expected to increase five-fold by 2050 due to climate change[53], which over five years is an increase of approximately 78%.

Fuel management costs

Prescribed burning costs per hectare are based on DAE's analysis[54] for the Australian Forest Products Association, adjusted for inflation. Other fuel management methods have a wide range of cost estimates[55], with some measures such as grazing being much lower (US$25/hectare), and others such as park clearing being much more expensive ($8,000/hectare). We have assumed that on average costs will be similar to prescribed burning.

[36] Ratio of Residual Risk (after risk mitigation) to Inherent Risk (before risk mitigation)
[37] (DES, 2020)
[38] (RCNNDA, 2020)
[39] (Victorian Auditor-General's Office, 2020)
[40] (DELWP, 2019)
[41] Statewide target to maintain bushfire risk at, or below, 70 % of Victoria's maximum bushfire risk. (DELWP, 2018)
[42] (RCNNDA, 2020)
[43] (Department of Biodiverstiy, n.d)
[44] WA seeks to maintain 45% of the fuel in the broader landscape managed at less than 6 years old to see significant reductions in the extent of bushfires (RCNNDA, 2020)
[45] (RCNNDA, 2020)
[46] (Forestry Corporation, n.d)
[47] (Environment Planning and Sustainable Development Directorate, 2020)
[48] (State Fire Management Council, 2014)
[49] (Tasmanian Government, 2018)
[50] (Premier of South Australia, 2021)
[51] (ACT Emergency Services Agency, 2019)
[52] (Environment Planning and Sustainable Development Directorate, 2020)
[53] (Bradstock, 2012)
[54] (Deloitte Access Economics, Scoping Study on a Cost Benefit Analysis of Bushfire Mitigation - Australian Forest Products Association, 2014)
[55] (BNHCRC, 2021a)

Assumption	Assumed (2022 values)	Reference[56] (2014 values)	Notes
Total target area burned under existing regime	1,334 kha	N/A	From Table 2.5
Cost of fuel management $/hectare	134	115	Prescribed burning costs from reference adjusted for inflation
Additional funding as a ratio to funding for existing regime	78%	83%	Approximately five years of increases based on 500% increase over 30 years to 2050[57].
AAL reduction for additional funding	15% to 20%	50%	See commentary below

AAL reduction

The effectiveness of fuel reduction varies widely between regions due to the location of homes and natural vegetation[58]. While DAE[54] indicates a 5% prescribed burning regime could halve the total cost of bushfires, Lindenmayer et al.[59] suggests a 10% regime would be required to halve the risk to people and property.. Other studies[60] suggest prescribed burning needs to be between 8-10% per annum for any significant risk reduction to be achieved.

For the existing state and territories regimes, and given the variability across studies and regions, we have assumed a conservative estimate of a 25% AAL reduction where the burning regime targets 5% or more of burned area, or where this information was not available. Where a risk reduction target was used by a state or territory, the AAL reduction was assumed to be equal to the target risk reduction.

For the AAL reduction under the additional funding, we have conservatively allowed for some reduction in effectiveness and estimate this for each state and territory as 10% lower than our estimate of the AAL reduction under the existing regime.

2.4.5 Flood Early Warning Systems

This measure involves upgrading the flood awareness system (Flood watch) to provide longer lead times (e.g. 10-15 days) as opposed to 3-5 days lead time. This skill upgrade would look to be similar to the European Flood Alert System (EFAS) which produces probabilistic hydrological forecasts through the incorporation of medium range weather forecasts. Earlier forecasts can support decision making, drive enhanced monitoring in the coming days and allow for the initiation of any mitigation or emergency preparedness measures.

The modelled benefits and costs of this upgrade has been estimated using an evaluation of EFAS[61]. The EFAS was developed by the European Commission and is able to forecast floods up to 10 days in advance across Europe. The benefits of the EFAS system have been estimated to provide a return in the order of 400 Euros for every Euro invested (over 20 years using a 5% discount rate)[62]. Costs and benefits however are ultimately based on the course of action taken by authorities upon receiving the warning. In Australia, a lower benefit to cost

[56] (Deloitte Access Economics, Scoping Study on a Cost Benefit Analysis of Bushfire Mitigation - Australian Forest Products Association, 2014)
[57] (Bradstock, 2012)
[58] (Penman, 2020)
[59] (Lindenmayer, 2021)
[60] (Burrows, 2019)
[61] (Joint Research Centre, 2015)
[62] (Pappenberger, 2015)

ratio of 6 has been reported for investment in early urban flood warning systems[63]. Similarly, a case study evaluating the BCR of an Early Warning System providing 14-20 hours of lead time in Flanders, Belgium found BCRs to range between 0.5 to 5.2 under various loss reduction scenarios[64].

The table below summarises the assumptions used in the calculation of the ROI for this measure. As costs have been based on the development of EFAS in Europe, to account for Australia's larger landmass, the costs have been scaled by land size. Costs provided by state and territory have been determined by their total AAL relative to the National AAL.

Assumption	Assumed (2022 values)	Reference[65] (2012 values)	Notes
Land size scaling factor	1.82	N/A	Scaling factor to represent difference in land areas of Australia compared to Europe
Cost of operational and fundamental research	$71m	€20m	The reference value is based on a 10-year program. Assumed value has been adjusted for currency, inflation, program length and the land size scaling factor
Annual costs thereafter	$6m	€1.8m	The reference value is based on a 10-year program. Reference cost includes running cost of the system including operational development. Assumed value has been adjusted for currency, inflation, program length and the land size scaling factor
Reduction in natural disaster costs	16%	0.36% to 32.85%	Reduction in damage can be up to 32.85%, which Includes the combined impact of avoided damage by warning dependent flood defences (32%), watercourse capacity maintenance (0.9%) and community level defences (0.36%) [66]. We have adopted the average of this range at 16%

2.4.6 National Coastal Hazard Information Database

As sea levels rise, Australia's exposure to coastal hazards will increasingly render exposed properties uninhabitable. Coastal areas will increasingly be at risk of actions of the sea such as tidal inundation, coastal and estuarine inundation, coastal erosion, shoreline recession, and in some cases tsunamis. The 2021 ICA report *Climate Change Impact Series: Actions of the Sea*[67] highlighted this risk and Baird Australia estimated that a $30 billion investment over the next 50 years was needed to mitigate against these coastal hazards.

This measure seeks to fulfil a key recommendation of the ICA report to create a National Coastal Hazard Information Database. The database, similar to the existing National Flood Information Database, would seek to collate available local government coastal hazard information into central location and make it publicly available. It would also include an understanding of exposure to coastal hazards in a worst-case scenario[68] and consider sea level rise post 2100. This would provide a national view of coastal hazard risks both now and into the future, allowing for better planning and assessment of coastal resilience measures.

2.4.7 Detailed cost benefit analysis

The data used in the calculation of ROIs for each measure in this assessment has been based on existing literature and industry reports. In reality, we recognise that the ROI of each measure may differ across

[63] (UNISDR, 2003)
[64] (The World Bank, 2021)
[65] (Joint Research Centre, 2015)
[66] (Pappenberger, 2015)
[67] (ICA, 2021)
[68] Above 1% annual exceedance probability

individual regions and be subject to other considerations such as existing mitigation measures in place, community acceptance, and environmental and heritage assessments that need to be undertaken prior to implementation. As such, the program includes $85 million in funding towards conducting an in-depth assessment of proposed measures and their suitability of implementation at a local level. This funding also includes detailed environmental and cultural heritage assessments, and in-depth consultation with affected communities, including indigenous Australians.

2.5 Measures not assessed

Due to the design and scope of this assessment we have excluded some resilience measures for consideration in the proposed program. However, we recommend that these are considered further, as they have the potential to substantially improve the resilience of Australian households to extreme weather events.

2.5.1 Building codes and land use planning

We excluded resilience measures on the adoption of stronger building codes and land use planning. This is because state and local governments rather than the Federal government having the primary responsibility over land use planning and building regulations within their jurisdictions[69].

2.5.2 Nature-based solutions

Nature-based solutions can be effective in reducing the impacts of natural hazards (e.g. flooding and storm surge) while providing additional ecosystem and ecosystem benefits. While nature-based solutions have been shown to produce ROI's greater than 1[70], they have been excluded from this assessment due to the scope of the assessment not being able to capture the full benefit of the measure (i.e. we exclude the wider financial and non-financial benefit of nature's contribution to people and economy). Given the complexity in measuring the benefit of such measures, we recommend that nature-based solutions are considered in a more detailed analysis in future work.

2.5.3 Climate resilient home retrofits

A 2020 report by Edge Environment[71] for the ICA noted the benefits of retrofitting homes[72] to increase their resilience to bushfire and flood. The study identified BCRs over 1 for both the building and retrofitting of existing homes to be 'climate ready' (see table below), providing evidence for the potential high returns on climate-resilient homes. As the study area was confined to South Australia however, additional work is required to confirm similar returns can be obtained elsewhere should the program be rolled out on a national level. Given the promising findings of this study, we recommend that this measure is investigated further for national applicability.

Table 2.6 Benefit to cost ratios of building new or retrofitting existing homes to be climate ready[71]

Scenario	BCR[73]
Building new 'climate ready homes'	2.59
Immediate retrofit of existing homes to be climate ready	1.02 and 3.31
Staggered retrofitting of homes to be climate ready[74]	1.95 to 93.3.

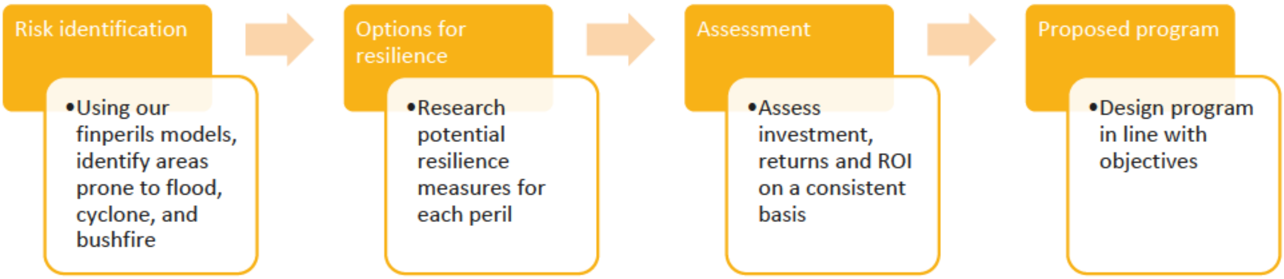
69 (Productivity Comission, 2014)
70 (The World Bank, 2021)
71 (Edge Environment, 2020)
72 through the inclusion of climate resilient materials for in building elements
73 Assuming a 7% discount rate
74 Building elements were only replaced at the end of their life

3 Methods and assumptions

3.1 Approach

Our overall approach is summarised in Figure 3.1. Using our finperils models, we identified local areas exposed to high bushfire, flood, or cyclone risk. Through a review of existing industry reports, scientific studies, and any existing feasibility assessments, we selected eighteen resilience measures based on their historically proven or robust expectations of benefits from adoption. Each measure was evaluated for the potential avoided costs from extreme weather events to 2050, using a real discount rate of 2% and allowing for climate change, giving ROIs for each measure. The detailed outcomes of this assessment can be found in Appendix A.

Figure 3.1 Approach



Following the calculation of ROIs for each resilience measure, the assessment considered the following key objectives when selecting measures for inclusion in the proposed 5-year resilience program:

- **Maximise return on investment**: We looked to select measures with a ROI greater than 1. Where there were a range of potential measures we selected measures with robust evidence and giving the greatest ROI.
- **Ensure broad equity between regions**: We favoured measures which could be implemented across multiple regions in Australia, and also reviewed our program to ensure a spread of programs across the nation.
- **Balance of measures used:** We looked to ensure there was a balance across (a) large scale infrastructure to protect communities, (b) improving individual homes to protect households, and (c) data and insights measures such as research and education (d) mitigation programs to protect communities
- **Budget constraint of $400 million in investment per year:** In line with the recommendations of the Productivity Commission[75].

3.2 General assumptions

3.2.1 Real discount rates

We have assumed a 2% p.a. long-term real discount rate. This rate is conservative relative to current real discount rates, and is consistent with rates used by other assessments of resilience measures, including most recently by DAE[76].

We have also undertaken a sensitivity analysis of our results to this assumption, which shows that increasing the real discount rate to 4% p.a. reduces the ROI of the proposed program from 9.6 to 6.9. Conversely reducing the real discount rate to 1% p.a. increases the ROI to 12.

[75] (Productivity Comission, 2014)
[76] (Deloitte Access Economics, 2022)

Real discount rate:	1%	**2%**	4%
Investment ($m)	2,038	**2,000**	1,930
Return ($m)	23,996	**19,294**	13,302
ROI	12	**9.6**	6.9

3.2.2 Inflation of historical investment estimates

As the primary component of the resilience measures considered was construction, we have used the ABS Construction Producer Price Index to inflate historical costs to current values in 2022.

3.2.3 Annual average losses from perils

Our analyses include estimates of the AALs for individual homes in Australia, which have been derived from our in-house finperils models for cyclones, bushfires and floods. These models are based on historical insurance data supplemented with models of the physical environment, including topographic features, weather variables such as wind speeds and levels of precipitation. We have scaled up our exposure to include uninsured properties as well as insured properties, assuming similar characteristics of uninsured properties to insured properties[77].

For each resilience measure we have then considered the impact on AAL, with returns measured as the reduction in AALs over the lifetime of the expected benefits, up to a maximum of 2050.

Our finperils models are subject to uncertainty, and actual returns may differ substantially from our estimates because of:

- Potential errors in the data underlying the model, such as data on the location and prevalent topological and meteorological data for the homes included in our models
- Incorrect assumptions being used within each model, such as assumptions regarding the vulnerability of homes to each hazard
- Differences between the models and the processes that they are approximating, such as our use of a limited number of factors within each model
- Inherent variability in the cyclone, bushfire and flood losses due to the natural variability of extreme weather

We note however, that our models have been developed over two decades, are regularly updated with new information as it becomes available, and are tested and used by insurers in Australia making up a significant portion of the home insurance market.

3.2.4 Climate change

We have included allowance for the impact of climate change consistent with models based on the Representative Concentration Pathway (RCP) 2.6, under which there is a 66% chance of global annual average temperature by 2100 increasing by less than 2°C compared to pre-industrial times[78].

There is strong scientific consensus[79] that global surface temperatures will continue to increase until at least the mid-century under a range of emissions scenarios, which will increase the frequency and intensity of extreme

[77] This is conservative as uninsured properties may be uninsured due to higher annual average losses giving higher premiums, which the householder may not be able to afford. Uninsured properties are also likely to disproportionately benefit from resilience measures, which we have not allowed for, leading to an understatement of the estimated ROIs.
[78] (ESCC, 2020)
[79] (IPCC, 2021)

weather events. However, there remains substantial uncertainty regarding the impact of climate change on the behaviour of extreme weather events at a local level, and our results may under or over-state the increases in returns we have estimated.

Limiting temperature increases to less than 2°C requires rapid transformation of the global economy to net zero emissions, which is by no means certain at this time. However, we note that if temperature rises were not constrained to 2°C, we would expect AALs to increase. Assuming that resilience measures remained effective, this would increase the estimated returns, resulting in higher ROIs.

Climate Scenario	No climate change	**RCP 2.6**
Investment ($m)	2,000	**2,000**
Return ($m)	16,250	**19,294**
ROI	8.1	**9.6**

3.2.5 Changes in population and homes

We have made no allowance for growth in population or number of homes up to 2050. This is because the returns and investments required will depend critically on where that growth takes place – inside or outside high-risk areas for extreme weather-related perils. At this time, we are not aware of projections of growth that are reliable at the level of granularity needed.

Measures such as levees can provide widespread protection for communities, and if growth occurs within these resilient areas, then returns will be higher than we have estimated, and our results are conservative. Conversely if growth takes place in high-risk areas that are not protected by the proposed resilience measures, then returns may be lower than we have estimated.

3.2.6 Health and social costs

Using our finperils models, we have estimated the size of the population benefiting from each risk measure.

Based on DAE's work for the ABR[80], we have applied death, injury, psychological injury and other social harm frequency and cost per person assumptions to estimate the AAL associated with health and social harm arising from the expected number of annual events impacting that population.

Table 3.1 Assumptions for health and social costs

Assumption	Assumed	Reference[80]
Frequency		
Death rates	0.000032%	
Physical injury rates	0.196% of population	
Proportion of injuries that are major	1/3	
Mental health issues	14.2% in the first year	
Alcohol misuse issues	10% in the first year	
Family violence issues	3% in the first year	

[80] (Deloitte Access Economics, The economic cost of the social impact of natural disasters, 2016)

Assumption	Assumed	Reference[80]
Cost per person ($)	(2022 values)	(2015 values)
Death	5,100,000[81]	
Major injuries	373,283	325,000
Minor injuries	13,323	11,600
Mental health issues	41,923	36,500
Alcohol misuse	2,297	2,000
Family violence	28,714	25,000

Based on DAE's assessment[80] of average ages and average life expectancies from the Queensland floods and Victoria Black Saturday Bushfires case studies, we have assumed that costs of psychological injury will continue for 41 years after the event.

For other social harms we have assumed that incidence rates reduce by one-third every year until 5% in the fourth year following the event. These represent the small proportion of people who do not recover and continue to experience trauma and hence have lifelong impacts.

In assessing the benefits of resilience measures we have assumed that the reduction in health and social costs will be the same as the reduction in the AAL from perils under that resilience measure.

3.2.7 Alternative programs

We have designed a five-year program of resilience measures commencing in 2022 totalling $2billion. The sensitivity analysis in this section tests how the program could be optimised given different investment amounts, for example, if total investment were to increase to $2.5billion or conversely, reduced to $1.5billion. Changing the amount of investment available allows us to add or reduce the:

- The number of resilience measures included in the program
- The amount of investment for resilience measures that have variable costs
- The amount of investment available for Local Infrastructure Fund

$1.5 billion investment program

For the $1.5 billion investment program we removed the wet flood-proofing existing homes resilience measure as it had the lowest ROI. We also reduced funding for the Local Infrastructure Fund. As a result of fewer resilience measures, the number of people and homes protected reduced, reducing the return by $3 billion to $16 billion. The program ROI increased slightly to 10.4 despite the removal of the wet flood-proofing homes resilience measure as it was offset by the reduction in Local Infrastructure Fund, which is conservatively assumed to have an ROI of 1.

$2.5 billion investment program

For the $2.5billion program, we first decreased the investment for Cyclone Proofing Homes from $221m to $115m, allowing more diversity in the resilience measures that protects homes against cyclones. We then added new resilience measures to the program, prioritising the ones with higher ROIs:

- Cyclone community awareness campaign ($169m), ROI 10

[81] (Department of the Prime Minister and Cabinet, 2021)

- Inspections of homes at risk of cyclones ($57m), ROI 53
- Establishing coastal wetlands ($379m), ROI 19

Further details of these additional resilience measures can be found in Appendix A.

Resilience measure	Baseline ROI	$1.5 billion program Investment ($m)	**$2 billion program Investment ($m)**	$2.5 billion program Investment ($m)
Local Infrastructure Fund	>1	435	**522**	522
Wet flood-proofing existing homes	8.7	0	**413**	413
Cyclone proofing homes	8.9	221	**221**	115
Establishing coastal wetlands	30		**0**	379
Cyclone community awareness campaign	10		**0**	169
Inspections of homes at risk of cyclones	53		**0**	57
Remaining measures		844	**844**	844
Investment ($m)		1,500	**2,000**	2,500
Return ($m)		15,604	**19,294**	30,525
ROI		10	**9.6**	12

4 Reliances and Limitations

4.1 Use of this report

This report is solely for the use of ICA for the purpose stated in Section 2.2. It is not intended, or necessarily suitable, for any other purpose. This report should only be relied on by ICA for the purpose for which it is intended. Any third party receiving this report or accessing information derived from the report should not rely on it, and this report is not a substitute for their own investigations and due diligence. We accept no liability to third parties relying on this report.

Please read the report in full. If you only read part of the report, you may miss something of critical importance. If anything in the report is unclear, please contact us. We are always pleased to answer your questions.

4.2 Reliances and limitations

Our work has relied on detailed analyses performed by others, as discussed within each measure. While we have carefully selected references we believe to be reliable, and considered each assumption for reasonableness, we have not performed a detailed review of each reference. Any errors within those references will translate to errors in our results.

4.2.1 Detailed cost and benefit analysis required

By relying on desk-top research of existing published works on resilience measures, our results are therefore subject to significant uncertainty. Each of these measures will require detailed investigation, and investment and return costs will need to be rigorously assessed and reviewed before any implementation. We have included funding within the program for this detailed costs and benefits assessment.

4.2.2 Uncertainty in our analyses

Our estimates are subject to uncertainty due to uncertainty associated with our assumptions, the information used and future circumstances. We have tested the sensitivity of our results to changes in some assumptions as discussed in Section 3.2, but these are not exhaustive, they have not tested the maximum or minimum range of possible values for the assumptions we have used, and they have not tested combinations of changes in assumptions.

Our investment and returns estimates for each resilience measures is based on top-down benchmarking against similar resilience measures in the past and publicly available research. Our estimates are not a substitute for detailed bottom-up assessment by suitably qualified experts on each resilience project. Our estimates will therefore be approximate and should not be relied on for final decision making.

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A Summary of resilience measure options

Resilience measure	Description	Type of measure	Perils addressed	Region addressed	Investment ($m)	Return ($m)	ROI	Population benefiting
Included in program								
Local Infrastructure Fund	New fund to assess and implement measures to protect communities from floods, such as levees and flood ways	Community infrastructure	Flood	Not allocated	522	522	>1.0	N/A
Cyclone proofing homes	Additional funding and extension of the Queensland Household Resilience Program across QLD, NT and WA, to retrofit homes for cyclone protection	Individual homes	Cyclone	WA, QLD, NT	221	1,964	8.9	65,208
Wet flood-proofing existing houses	Allow flooding through buildings to reduce damage from pressure on the building, raising utilities above flood level, and using water-resistant materials below the flood level	Individual homes	Flood	Flood prone regions	413	3,602	8.7	37,812
Additional fuel management program	Funding for states and territories to increase fuel management programs using a range of measures including prescribed burning, mechanical removal, and remote sensing systems, in order to reduce the risk of bushfires across the nation	Community Mitigation	Bushfire	Bushfire prone regions	712	3,065	4.3	2,779,822
Flood early warning systems	Improving flood early warning systems (Flood Watch) to provide longer lead times of 10-15 days, to support decision-making, drive enhanced monitoring, and initiate emergency preparedness for communities.	Data & Insights	Flood	Flood prone regions	37	19,141	270	663,370
Coastal hazard information national database	Creation of a database to identify communities and assets at risk from actions of the sea	Data & Insights	Flood	Not allocated	10	-	-	N/A
Detailed cost and benefit analysis	Detailed cost and benefit analyses on measures within this program, to consult with affected communities including indigenous communities, and to perform environmental and cultural heritage assessments	Data & Insights	All perils	All regions exposed to perils	856	-	-	N/A
Not included in program								
Cyclone community awareness campaign	Community awareness campaign for educating the public on the adoption of cyclone damage prevention measures. Targets low cost mitigation options such as dismantling shade cloth awnings, unblocking gutters, limiting unfixed objects in gardens and preventing minor water ingress.	Community education	Cyclone	WA, QLD, NT	169	Additional work required to validate the likely take up of this program by households		

Resilience measure	Description	Type of measure	Perils addressed	Region addressed	Investment ($m)	Return ($m)	ROI	Population benefiting
Inspections of homes at risk of cyclones	Formal inspection program to rate resilience of individual properties to cyclones, and to recommend resilience measures	Individual homes	Cyclone	WA, QLD, NT	57	Additional work required to validate the likely take up of this program by households, and whether grants can be included for households to implement recommendations		
Improved Cyclone detection	Research to improve the accuracy of atmospheric models used to forecast cyclones	Data & Insights	Cyclone	WA, QLD, NT	83	Benefits unclear as willing to pay used as proxy for returns		
Underground Power lines	Sink power lines below ground to reduce risk of bushfires	Community infrastructure	Bushfire	VIC	46,077	Potentially significant benefits for state and community, but not valued in our framework, resulting in low ROI		
Community fireguard program	Adoption of the Victorian Community Fireguard Program in other states, where fire authority facilitators train small community groups in bushfire behaviour, personal preparedness and response strategies	Community education	Bushfire	Bushfire prone regions	1,190	Lower ROI compared to additional fuel management program		
Raising height of Wivenhoe Dam	Raise Wivenhoe Dam height by 1.5m to increase the available flood mitigation storage, install a second emergency spillway, and optimise flood operations.	Community infrastructure	Flood	Brisbane floodplain	612	Potentially significant benefits for state and community, but not valued in our framework, resulting in low ROI		
Raising homes in high risk flood zones	Raise the floor height of individual properties in high-risk flood zones by 3m	Individual homes	Flood	Flood prone regions	991	Lower ROI compared to other measures such as wet flood-proofing		
Relocating homes in high risk flood zones	Relocate homes in high risk flood zones to low risk areas through land swaps and other programs	Individual homes	Flood	Flood prone regions	2,295	Lower ROI when compared to other flood measures (e.g. wet flood-proofing). ROI highly dependent on local conditions.		

Resilience measure	Description	Type of measure	Perils addressed	Region addressed	Investment ($m)	Return ($m)	ROI	Population benefiting
Temporary flood barriers in high risk flood zones	Install temporary flood barriers around high risk flood zones	Community infrastructure	Flood	Flood prone regions	372	Lower ROI when compared to other flood measures (e.g. wet flood-proofing). ROI highly dependent on local conditions.		
Establishing coastal wetlands	Establish coastal wetlands along the coast to absorb storm surges and slow winds.	Community infrastructure	Cyclone	QLD	187	More work required on Australian coastline to understand feasibility, cost and benefits. In addition, our framework didn't account for value of biodiversity.		