NSW Treasury

Disaster Cost-Benefit Framework

TPG23-17

October 2023

Acknowledgement of Country

We acknowledge that Aboriginal and Torres Strait Islander peoples are the First Peoples and Traditional Custodians of Australia, and the oldest continuing culture in human history.

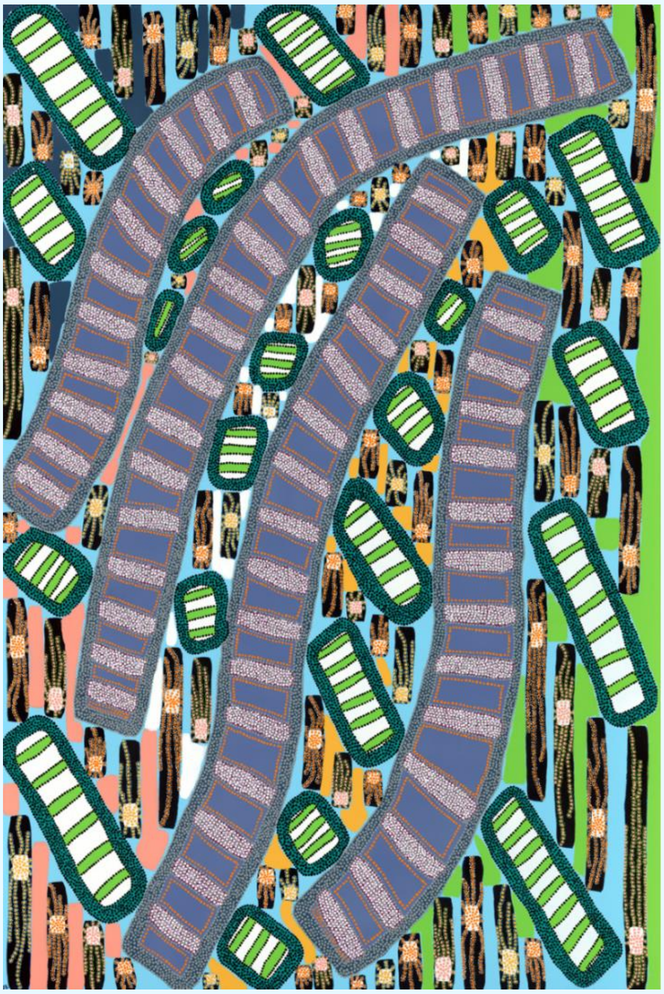
We pay respect to Elders past and present and commit to respecting the lands we walk on, and the communities we walk with.

We celebrate the deep and enduring connection of Aboriginal and Torres Strait Islander peoples to Country and acknowledge their continuing custodianship of the land, seas and sky.

We acknowledge the ongoing stewardship of Aboriginal and Torres Strait Islander peoples, and the important contribution they make to our communities and economies.

We reflect on the continuing impact of government policies and practices, and recognise our responsibility to work together with and for Aboriginal and Torres Strait Islander peoples, families and communities, towards improved economic, social and cultural outcomes.

Artwork:
Regeneration by Josie Rose



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☒ **RECOMMENDED POLICY** reflecting best practice standards.
☒ **GUIDANCE/ADDITIONAL INFORMATION** to provide clarity or explain requirements in detail.

Revision history

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Disaster Cost-Benefit Framework

Purpose

This Disaster Cost-Benefit Framework (the Framework) is a NSW Treasury Policy and Guidelines paper that sets out how to undertake disaster resilience[1] cost-benefit analysis (CBA). The Framework supplements and follows the principles and requirements of the NSW Government Guide to Cost-Benefit Analysis (TPG23-08) (CBA Guide), which applies to all NSW Government initiatives.

The Framework aims to make it easier to complete high quality and consistent disaster resilience CBAs which support decision making and well targeted investment. It identifies guiding principles to support development of initiatives[2] that support disaster resilience as well as methods, data sources and standard parameters to support their appraisal. It includes mandatory requirements and recommended guidance that should be applied as relevant and practical, depending on the size, importance, and nature of the initiative.

Overview

This Framework is primarily written for those preparing CBAs for consideration by the NSW Government. Other parties, such as local government or the non-government sector using it to inform their own decision making should consider the relevance and applicability of the guidance. It has been developed by NSW Treasury in consultation with relevant NSW Government agencies and with the assistance of expert advice.

This Framework applies to disasters resulting from natural hazards such as floods, bushfire and drought. The Framework does not apply to hazards that are solely human made, such as environmental, technological, or biological hazards (see Box 1).

> Box 1: Why not 'Natural Disaster Cost-Benefit Framework'?
>
> The term 'natural disaster' is often used to refer to harmful impacts following a natural hazard. But a growing body of academic literature shows they are more commonly the result of choices made by people. Such choices include where housing is constructed, how infrastructure is designed and the impact of humans on the environment. The phrase 'natural disaster', on the other hand, implies that disasters are the result of natural processes, and nothing can be done to reduce risk.
>
> This Framework follows the example set by the United Nations Office for Disaster Risk Reduction (UNDRR), to move away from the language of 'natural disaster'. The term 'disaster' is instead adopted in documents such as the Sendai Framework for Disaster Risk Reduction. This may help shift thinking towards how decision making can better consider and reduce disaster risk.

Natural hazards have some common features as well as variations that require different assessment methods. The following structure accounts for this:

- Establishment of key shared concepts and principles (Sections 1 and 2).
- General guidance for completing a disaster resilience CBA (Section 3).

[1] Disaster resilience includes the prevention, preparedness, response, and recovery phases of disaster management.

[2] 'Initiative' is a broad term used in this Framework that captures concepts such as program, project, policy, reform, intervention, investment, etc.

- A rapid assessment framework to support urgent initiatives (Section 4).
- Specific guidance for floods (Section 5).

A Flood CBA Tool has been developed in partnership with the Department of Planning and Environment to provide a practical and accessible application of the Framework. An accompanying technical note provides further details, a worked example, and a user manual.

Related guidance

This Framework forms part of the NSW Investment Framework, a suite of NSW Treasury policies and guidelines that support evidence informed decisions. It should be considered alongside the:

- NSW Government Guide to Cost Benefit Analysis (TPG23-08)
- NSW Government Business Case Guidelines (TPP18-06)
- Policy and Guidelines: Submission of Business Cases (TPG22-04)
- Policy and Guidelines: Evaluation (TPG22-22)
- Benefits Realisation Management Framework.

Summary of requirements

Disasters occur with a low-frequency but have high-consequences, sometimes known as 'tail events'. Accurately forecasting disasters is generally not possible. Even small changes to expected values, such as temperature and rainfall, can result in significant changes at the tail. In addition, climate change is expected to increase the risk of disasters and reduce reliability of historical observations in anticipating the severity or probability of future events.

As a result, estimates of the severity, likelihood, and frequency of disasters are sensitive to assumptions of risk, which are themselves often uncertain. Risk and uncertainty should be considered throughout a disaster resilience CBA, starting from problem definition and base case development.

For most initiative types a central estimate based on expected (average) benefit-cost-ratios is a good indicator of value. For disasters, however, relying on averages can obscure low frequency, high consequence events where mitigation can deliver large benefits.

New South Wales invests in many different types of initiatives dispersed across regions. In most cases, its variety of investments and state-wide perspective means it can take the risk neutral approach implied by using expected values. But low-frequency, high consequence events can have impacts so catastrophic that they represent a systematic or 'state significant' risk. In these cases, a more risk-averse approach, for example, investing where the expected benefit-cost-ratio is below one, may be justified. To inform these decisions, information on the benefits of protecting against low frequency, high-consequence events should be presented alongside expected values.

Early and genuine partnerships with First Nations peoples are important to ensure that their legal rights and interests, expertise and knowledge managing the natural environment, and unique needs are identified, understood and reflected throughout.

Mandatory

It is mandatory to complete a business case, including a CBA, when seeking funding for a disaster resilience initiative with an estimated cost of $10 million or higher. This requirement is set by the CBA Guide and Submission of Business Cases (TPG22-04).

When responding to a disaster decisions may need to be made quickly. There may be insufficient time to complete a business case, including a CBA, prior to funding. Where a disaster resilience initiative valued over $10 million is not supported by a business case and CBA, it is mandatory to complete an evaluation, including an ex-post CBA, within a reasonable period of time. Disaster resilience proposals not supported by a business case and CBA, must include a high-level monitoring and evaluation plan, identify resourcing for an evaluation, and identify a the party responsible ensuring the completion of the evaluation and ex-post CBA.

All disaster resilience CBAs must meet the mandatory requirements set out in the CBA Guide. Additional recommendations within this Framework represent best practice guidance. Application should be tailored to the availability of data, the size and significance of the initiative, and practical considerations such as the level of urgency.

Recommendations

Guidance for all disaster resilience CBAs

- (Section 2.3.1) Use Monte Carlo analysis to better understand and reflect uncertainty around the severity, timing and impacts of disasters.
- (Section 3.3) Combine analysis of hazard, exposure and vulnerability to quantitatively estimate disaster risk under the base case.
- (Section 3.3) Consider a variety of options that address disaster risk, including, where relevant:
  - preventing losses by avoiding the hazard
  - mitigating losses by improving preparation for events
  - mitigating losses by making communities and assets more resilient.
- (Section 3.5) Express expected yearly costs of a given natural hazard as an average annual damage.
- (Section 3.9) Describe qualitative or quantitative indicators of results under non-average conditions, such as:
  - explaining the distribution of Monte Carlo outputs with descriptive statistics such as mean, median, and variance
  - explaining the likelihood of the benefit-cost-ratio or net present value being in a certain range
  - describing the effectiveness of the initiative in terms of the severity or frequency of events that it will mitigate (e.g. the initiative will protect against hazards up to a 1-in-100 year AEP or of Category-3 severity).

Specific guidance for flood resilience CBAs

- (Section 5.1) Use a flood study to define flood behaviour and inform risk assessment within the study area as part of the base case development.
- (Section 5.1) Use Flood Risk Management (FRM) Studies and FRM Plans to inform options development and assessment.
- (Section 5.2) Where relevant, apply the Flood CBA Tool or standard quantitative parameters within the tool.

Definitions

Term	Definition
Annual exceedance probability (AEP)	The probability of a particular type of disaster of a given size or larger occurring in any twelve-month period.
Average annual damage (AAD)	The expected yearly damage cost arising from all occurrences of a given hazard.
Disaster	A serious disruption of the functioning of a community of a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources.
Disaster resilience	The ability of a system, community or society exposed to disasters to resist, absorb, accommodate to and recover from the effects of a disaster in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions.
Disaster risk reduction (DRR)	The concept and practice of reducing disaster risks through systematic efforts to analyse and manage the causal factors of disasters, including through reduced exposure to hazards, lessened vulnerability of people and property, wise management of land and the environment, and improved preparedness for adverse events.
Exposure	People, property, systems, or other elements present in hazard zones that are thereby subject to potential losses.
Hazard	A dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage.
Monte Carlo simulation	Monte Carlo analysis is a computerised simulation based on repeated random sampling from relevant probability distributions (assigned based on historical data or judgement) to produce multiple simulations.
Preliminary cost-benefit analysis	A less detailed form of CBA with principles still based on welfare economics. This may be useful in certain circumstances where a full CBA is not practical.
Preparation	Includes arrangements or plans to deal with an emergency or the effects of an emergency.
Probabilistic analysis	Probabilistic risk is the chance of something adverse occurring. Probabilistic analysis assesses the likelihood of an event(s) and it contains the idea of uncertainty because it incorporates the concept of randomness, for example, probabilistic BCRs.
Prevention	Includes the identification of hazards, the assessment of threats to life and property and the taking of measures to reduce potential loss to life or property.

Term	Definition
Quantitative risk assessment	Quantitative risk assessment provides risk information that can be used in cost-benefit analysis of risk reduction measures.
Recovery	Includes the process of returning an affected community to its proper level of functioning after an emergency.
Real options analysis	A course of action that keeps options open and delays making irreversible commitments, where benefits can be recognised when it is set against a more rigid alternative.
Response	Includes the process of combating an emergency and of providing immediate relief for persons affected by an emergency.
Risk	Risk refers to a situation where the occurrence of a future event is not known, but its probability of occurring is known or can be estimated.
Sensitivity analysis	Shows how CBA results vary with changes in assumptions.
Tail events	Low-probability high-consequence events.
Uncertainty	Uncertainty refers to a situation where the occurrence of a future event is not known, and no probability can be assigned to its occurrence.
Vulnerability	The characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard.

Other terms have been defined in the Glossary of CBA Guide.

1 Introduction

1.1 Context

The global frequency of disasters has increased five-fold over the past 50 years (WMO, 2021), primarily attributed to climate change driving extreme weather. Within Australia, New South Wales has seen a historically unprecedented spate of disasters in recent years, including bushfires and continued floods between 2019 and 2022. The 2022 East Coast Floods led to nine fatalities, damage to 14,637 homes and $4.3 billion in insured losses. The Black Summer bushfire season in 2019 to 2020 caused 26 fatalities, destroyed 2,448 homes and burnt 5.5 million hectares of land. Appendix A.6 provides further details of the impacts of disasters in New South Wales.

The economic cost of disasters to New South Wales is projected to increase due to the impacts of climate change. The 2021-22 Intergenerational Report estimated that disasters cost $5.1 billion in 2020-21, projected to rise to between $15.8 billion to $17.2 billion (real 2019-20 dollars) by 2061 (Wood, et al., 2021).

This Framework addresses a recommendation of the 2022 NSW Flood Inquiry Final Report to develop, adopt and utilise a disaster cost-benefit framework to enable a more systematic prioritisation of investment options before, during and immediately following a disaster, with an initial focus on floods. The NSW Government response to the Flood Inquiry supported this recommendation.

1.2 Key concepts

1.2.1 Disaster risk and risk reduction

Disaster risk is a combination of hazard, exposure and vulnerability[3] (Box 2).

Box 2: Key disaster risk concepts

- **Hazard**: A process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption, or environmental degradation.
- **Exposure**: People and property present in hazard zones that are thereby subject to potential losses.
- **Vulnerability**: The characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard. For example, poor design, construction, location, protection of assets, lack of public information and awareness. Vulnerability can vary significantly within a community and over time.

Source: (UNDRR, 2009)

Disaster risk reduction (UNDRR, 2009) is:

> *The concept and practice of reducing disaster risks through systematic efforts to analyse and manage the causal factors of disasters, including through reduced exposure to hazards, lessened vulnerability of people and property, wise management of land and the environment, and improved preparedness for adverse events.*

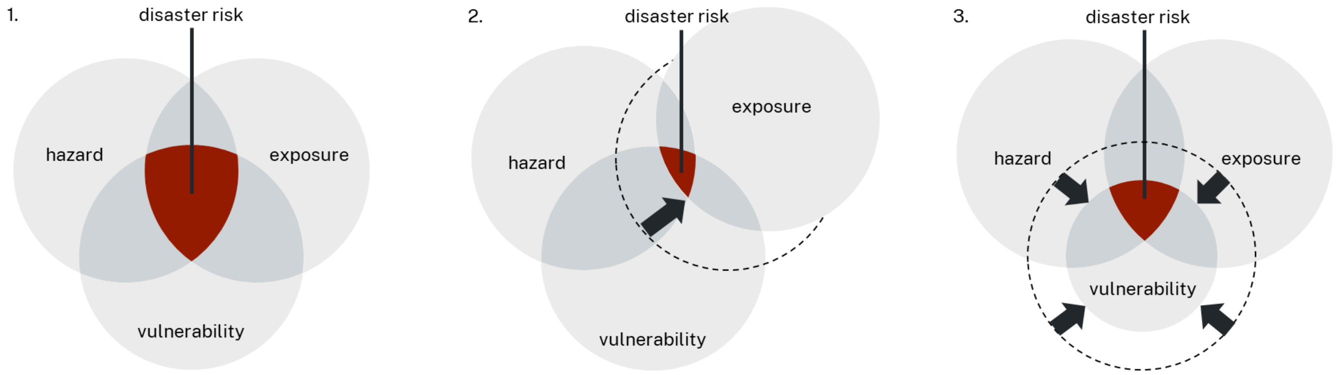
For example, flood risk reduction can include the implementation of flood monitoring and warning systems for high-risk areas, mitigation, land-use planning, reconstruction, building standards reform

[3] For more information on disaster risk, refer to https://www.preventionweb.net/understanding-disaster-risk/component-risk/disaster-risk.

and evacuation route planning. For bushfire risk, hazard reduction burns may occur ahead of the summer bushfire season, enhancing resilience and reducing disruption for an affected community.

Reduction in the area in the centre of the Venn diagram in Figure 1 provides a visual representation of disaster risk reduction. The first diagram demonstrates risk levels without any mitigation, while the second and third diagrams illustrate disaster risk reduction through reduction in exposure and vulnerability.

Figure 1: Disaster risk and its reduction



Source: NSW Treasury, adapted from (Hugenbusch & Neumann, 2016)

Residual risk is the remaining risk after mitigation measures have been implemented. For example, erecting evacuation route directional signs across a floodplain could reduce the risk of fatalities and injuries during a flood event from medium to low, leaving a lower level of residual risk.

Disaster risk reduction lowers future impacts and costs, increasing the value of resilient infrastructure and a safe environment. CBA should quantify and consider *initial risk minus residual risk* (i.e. the incremental change that would not otherwise occur).

1.2.2 Disaster resilience

Disaster resilience (UNDRR, 2009) is:

> *The ability of a system, community or society exposed to disasters to resist, absorb, accommodate to and recover from the effects of a disaster in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions.*

Resilience is determined by the degree to which the community has the necessary resources and is capable of organising itself both prior to and during times of need. The phases of disaster emergency management – prevention, preparedness, response, and recovery – each offer practical opportunities to enhance disaster resilience.

Resilience is a prominent concept in climate change adaptation, disaster risk management, and sustainable development. It can be defined, understood, and measured in many ways, and looks different in different communities. In this Framework, disaster risk reduction is treated as a contributor to disaster resilience. Relevant initiatives are referred to as 'disaster resilience initiatives', with core elements defined in Box 3.

Box 3: Core elements of disaster resilience

- **Context**: Resilience of what – such as a social group, socio-economic or political system, environmental context or institution.
- **Disturbance**: Resilience to what – shocks (weather-related and geophysical events) or stresses (long-term trends like urbanisation and climate change).
- **Capacity to respond**: Depends on the magnitude of the shock or stress, sensitivity to a given shock or stress and how well a system can adapt, take advantage of opportunities, and cope with transformation.
- **Reaction**: A range of responses are possible, such as rebuilding a community with disaster resilient materials, where capacities are enhanced, exposures are reduced, and the system is more able to deal with future shocks and stresses.

Source: (UK Department for International Development, 2011)

In this Framework, disaster resilience covers the four phases of the emergency management cycle (Table 1).

Table 1: Emergency management cycle

Phase	Description	Time-frame	Examples
Prevention	Identification of hazards, the assessment of threats to life, property and the environment, and the taking of measures to reduce potential loss to life or property.	Months or years	• Hazard reduction burning • Constructing sea walls • Land use planning
Preparedness	Arrangements or plans to deal with an emergency or the effects of an emergency.	Months or years	• Ensuring fire safety plans are enacted routinely • Educating and sharing information
Response	Process of combating an emergency and of providing immediate relief for people affected by an emergency.	Hours, days or weeks	• Government emergency response and agency response (e.g. search, rescue and firefighting) • Financial arrangements that allow an appropriate and timely response • Temporary accommodation
Recovery	Process of returning an affected community to its proper level of functioning after an emergency.	Months or years	• Repair, or reconstruction, of physical infrastructure • Buyback or relocation • Physical and mental health support

Source: (NSW Parliamentary Counsel's Office, 1989)

1.3 Cost-benefit analysis and disaster resilience

1.3.1 What is cost-benefit analysis?

CBA estimates the economic, social, environmental, and cultural costs and benefits of an initiative and expresses them in monetary terms. Not to be confused with financial analysis which looks at the monetary returns from an investment, CBA is a more holistic assessment of a proposal. It involves putting a monetary value on non-market items such as green space, public amenity, and leisure time.

It measures costs and benefits relative to a 'base case' and places different types of costs and benefits on a common monetary scale (where possible). CBA assesses whether the benefits of a proposal or initiative are likely to exceed the costs, and which option among a range of options is expected to result in the highest net social benefit, as measured using Net Present Value (NPV) and the Benefit-Cost Ratio (BCR).

CBA should draw on the best available evidence and make all assumptions and data limitations clear. It is not always practical to monetise every category of benefits and costs. Significant costs and benefits that cannot be valued should be presented alongside monetised costs and benefits to provide a holistic view.

1.3.2 Limitations of cost-benefit analysis

CBA is valuable at all stages of policy or project development. It improves transparency and enables systematic discussions of the advantages and disadvantages of different initiatives. Application of CBA principles or completion of a preliminary CBA is valuable, even when conducting a full CBA is not possible.

CBA should be undertaken and considered within context. Key considerations for disaster resilience include:

- complexity and uncertainty around climate change
- expectations of the society around the response of government to disasters
- the stage of the analysis and decision making process, for example more detailed analysis is needed to prioritise major investments
- timing, including whether a decision is:
  — for a specific event-based decision leading into a disaster associated with preparedness, response and relief
  — for short term recovery or response measures
  — for longer term strategic or system wide initiatives.
- whether the initiative is focussed on prevention, preparedness, response or recovery
- stakeholder impacts and views
- the size and significance of an initiative
- available resources, data and capability.

There are limitations and challenges when CBA is applied to disaster resilience initiatives. Table 2 summarises key challenges and how this Framework helps address them.

Table 2: Key challenges in preparing CBA for disaster resilience initiatives

Challenge	Description	How this Framework addresses the challenge?	Section
Decision context	CBA not undertaken and considered within context.	• Decision context acknowledged and discussed	1.3.2
Rapid decision making	Rapid decision making is often expected following a disaster event.	• Rapid assessment • Flood CBA tool	4
Risk and uncertainty	The frequency and severity of future natural hazards is not known with certainty.	• Probabilistic assessment • Monte Carlo simulation	2.1
Impact of climate change			
Complexity	Disasters can have significantly different impacts on various communities, cohorts, and stakeholders.	• Distributional analysis	3.8
Indirect and intangible benefits	Challenges of forecasting and valuing indirect and intangible benefits.	• Standard parameters • Flood CBA tool	5.2
Learnings from previous decisions	A lack of information on learnings from previous resilience investment decisions. For example, databanks are not updated regularly given the urgency of disaster-response initiatives.	• Ex-post evaluation	2.1, 3.10
First Nations perspectives knowledge and interests	Ensuring that the interests, perspectives and knowledge of First Nations peoples and communities are accurately reflected in CBA.	• Guidance to work in genuine partnerships with First Nations people and communities	2.4

2 Guiding principles

Key points:

- CBAs must be completed for all disaster resilience initiatives valued over $10 million. Where, due to emergency circumstances, a CBA is unable to be completed prior to funding, proposals must include a high-level monitoring and evaluation plan (including an ex-post CBA), resourcing to complete an evaluation, and identify an accountable party and timeframe in which to complete the evaluation.
- Disasters occur with a low frequency but have significant consequences, making their likelihood, severity, and timing impossible to accurately predict. Climate change is expected to increase this uncertainty and make risk assessment more vulnerable to error.
- As disaster resilience CBAs are dependent on estimates of the severity, likelihood and frequency of disasters, their results can be sensitive to the distribution of risk, and uncertainty.
- Risk and uncertainty and the likely impacts of climate change should be explicitly considered throughout a disaster resilience CBA.
- Early and genuine partnerships with First Nations peoples should ensure that their:
  - legal rights, interests and unique needs are identified accurately and reflected
  - expertise and knowledge concerning management of the natural environment is understood and considered.

2.1 When are CBAs required for disaster resilience initiatives?

All NSW Government business cases with an estimated total cost over $10 million must be supported by a CBA. This requirement is set by the CBA Guide. The $10 million threshold is set by the Policy and Guidelines: Submission of Business Cases (TPG22-04).

The CBA Guide sets out mandatory features of a CBA, including a clear problem definition, and assessment of a base case and at least two realistic options. This Framework does not alter these requirements, but recognises that their application may look different for disaster initiatives:

- For a disaster mitigation initiative, such as building a levee to protect a town from possible future floods, the Framework should be applied to complete a CBA to inform a funding decision.
- For urgent response and recovery initiatives, a CBA is still required, but it may not be possible to complete prior to a funding decision. In these cases, an evaluation must be completed, including an ex-post CBA to provide evidence for future initiatives.
- A rapid assessment framework (Section 4) may also be applied to support prioritisation of options in urgent situations, although it does not replace the requirement to complete a CBA.

Encouraging development of more robust evidence that can support disaster resilience initiatives is a key objective of this Framework. For example, in the aftermath of a disaster, the government may provide concessional loans or transport subsidies to primary producers and other businesses. An ex-post CBA could include analysis of who received this assistance, and the benefits delivered, which can inform future design and targeting of assistance.

Ex-post CBAs follow the same general steps and principles as ex-ante CBAs, with some adjustments, including incorporation of actual data (where available). Further guidance is available in the Ex-Post Cost-Benefit Analysis Technical Note.

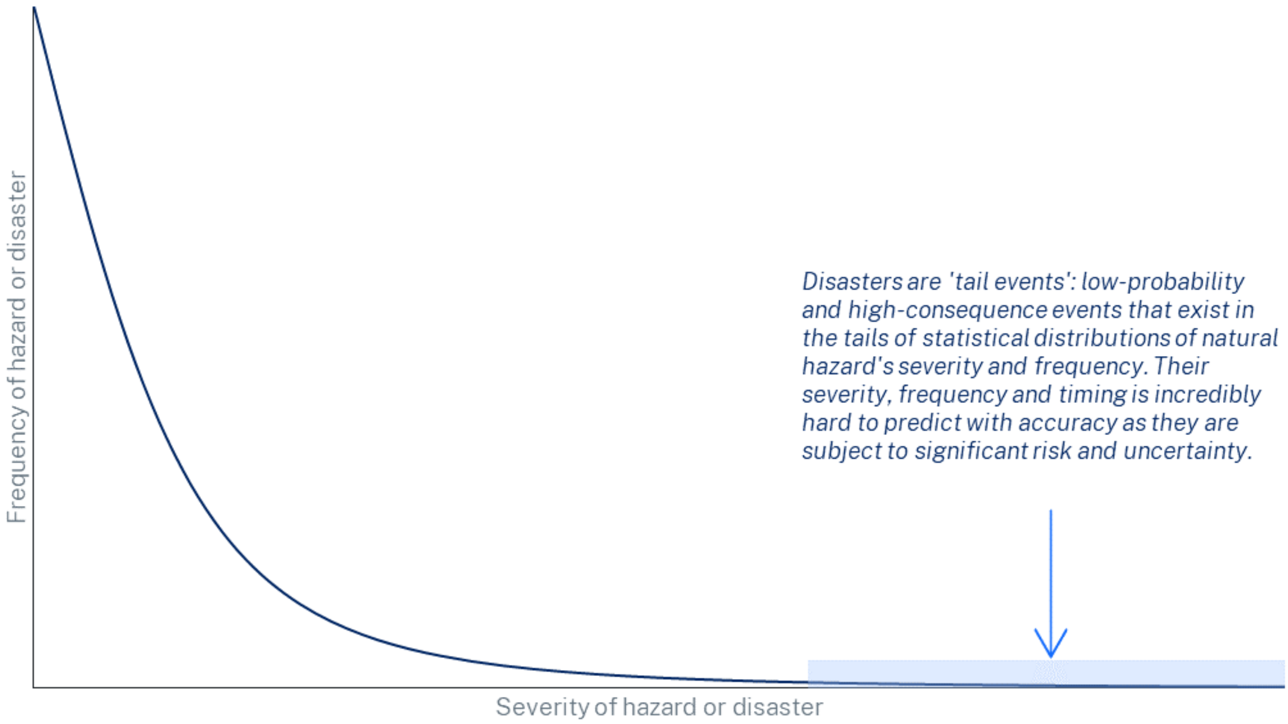
Where no ex-ante CBA has been completed to support an initiative valued over $10 million, funding proposals must, consistent with Policy and Guidelines: Evaluation (TPG22-22):

- provide a monitoring and evaluation plan, including an ex-post CBA
- identify the required resources to conduct monitoring and evaluation
- identify the party responsible for monitoring and completing the evaluation
- commit to completing the evaluation within a reasonable timeframe (for example, within 24 months of the initiative being delivered, however a longer timeframe may be appropriate for some initiatives).

2.2 Disaster resilience CBAs are sensitive to assumptions around risk and uncertainty

Disasters are low-frequency, high-consequence events, sometimes known as 'tail events.' Figure 2 visualises this concept, showing a typical power law that natural disasters follow, with a small number of low-frequency events making up the bulk of impacts (represented by the shaded area). For example, the 2011 Tohoku (Japan) earthquake lasted only six minutes but caused US$220 billion in damages.

Figure 2: Natural hazards follow power laws where disasters are low-probability high-consequence events



Note: this represents a stylised version of a power law that is seen for natural hazards such as earthquakes, floods, and bushfires.

Source: NSW Treasury

The frequency, severity and timing of tail events are impossible to accurately predict as natural hazards are determined by a complex set of interactions and interdependencies. Moreover, small changes in expected values — such as temperature or rainfall — can create significant changes in tail events. Moreover, climate change is reducing reliability of historical data and contributing to more tail events (see Section 2.2.1).

This means disaster resilience CBAs are sensitive to estimates of, and assumptions about, the frequency, severity, and timing of natural hazards. They are also sensitive to assumptions around changes in climate over time. Even small variations can change a BCR by several orders of magnitude (Box 4).

Box 4: How tail events make CBAs sensitive to risk and uncertainty

- **Timing**: CBA requires discounting of the value of future benefits to their present value to enable comparison of costs and benefits occurring at different time periods. Given the long lifespan of some investments, this makes CBA results sensitive to assumptions about when natural hazards occur.
  - For example, if a flood mitigation initiative aims to protect against a 1-in-100-year event at a cost of 10 per cent of the total damage (if the event occurs) it could have a BCR of 10 if the flood event occurs in year one, but 1 if the same event occurs in year 47.
- **Frequency**: If the likelihood of a natural hazard increases from a 1-in-200-year event to a 1-in-100-year event, this could cause the BCR of a related initiative to double.
- **Severity**: If a flood wall with an estimated BCR of 10 is built to withstand recorded historical highs of flood events, an event that is only 15 per cent above observed historical maximums could cause the entire area to flood and the BCR to drop towards zero (or become negative).

2.2.1 Climate change exacerbates disaster risk and uncertainty

A connection between climate change and natural hazards is well established in Australia and internationally.[4] Climate change leads to changes in weather parameters, including the frequency, severity, and spatial extent of natural hazards (Lawrence, et al., 2022).

Climate driven natural hazards are projected to become more frequent and intense in Australia (Commonwealth of Australia, 2020a), creating more frequent and severe tail events. In New South Wales specifically, the NSW and Australian Regional Climate Modelling project (NARClim) projects (DPE, 2022):

- increased rainfall in summer and autumn
- decreased rainfall in spring, and winter
- increased average severe fire weather in summer and spring
- increased frequency and severity of disasters.

Climate change itself is hard to predict due to uncertainty around its drivers and impacts. Changes in demographics, preferences, and technology are also hard to predict (Stern, et al., 2021). Even small changes in average climate can have significant impacts on the frequency and severity of disasters (see Box 5). This compounds the inherent uncertainty in natural hazards.

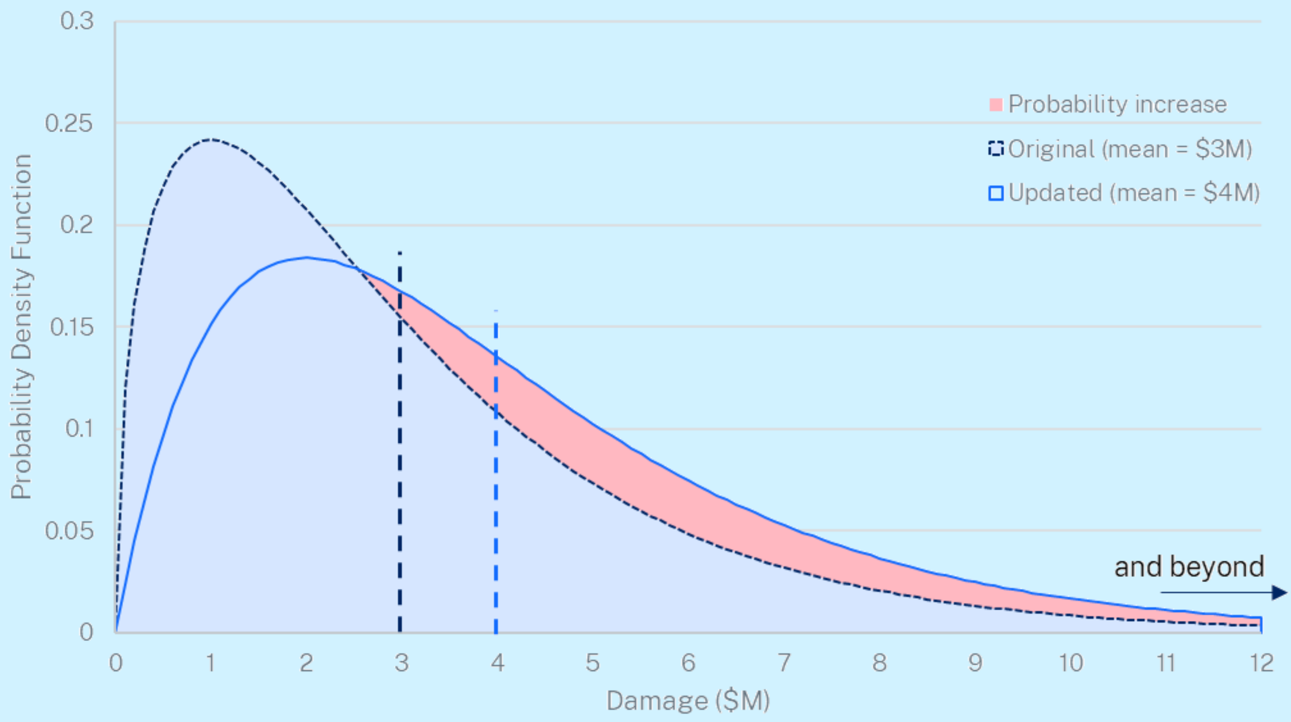
To account for this, consistent data sources should inform base case development (Section 3.3) and Monte Carlo analysis should be used (Section 2.3.1).

[4] For example, it has been recognised by the Intergovernmental Panel on Climate Change (IPCC) (Lawrence, et al., 2022) and the Royal Commission into National Natural Disaster Arrangements (Commonwealth of Australia, 2020a).

Box 5: How small changes can have large impacts on tail events

Figure 3 illustrates the forecast damage to a township under one scenario with a mean (expected) value of $3 million and another scenario with a mean value of $4 million. The shift could be attributed to various factors, including climate change. The pink shaded area represents an increase in probability of damage due to changes in the frequency and severity of disasters. A shift in expected value of $1 million leads to the probability of damages equalling $10 million doubling, and the probability of damage at $23 million increasing threefold.

Figure 3: Distribution shift in forecast disaster damage, increasing the probability of tail events



Source: NSW Treasury

2.2.2 Failing to account for risk and uncertainty can lead to misspecification

Misspecification of a CBA means that it relies on estimates or assumptions that cause its results to deviate from reality in a meaningful way. This can result in CBAs that do not provide an accurate evidentiary basis to inform decision making. Two sources of misspecification for disaster resilience CBAs include (see Figure 4):

1. Failing to recognise how the severity and frequency of tail events differ from everyday events. In this case, focussing on the most probable outcomes without giving sufficient emphasis to events that are far less likely but generate the bulk of negative consequences. Probabilistic CBAs can be a very effective tool in these circumstances if they can use the statistical distributions that accurately represent the underlying phenomena (Figure 4.a).
2. Being unable to accurately predict the frequency, severity, or timing of tail events. Uncertainty should be modelled to the extent possible, acknowledged, and made transparent to decision makers. Supplementary sensitivity testing, such as modelling an event 50 per cent higher than the most severe event can also provide complementary information (Figure 4.b). This can illustrate the consequences of misspecification.

Figure 4: Sources of misspecification

Figure 4.a: Failing to understand the impact of extreme events

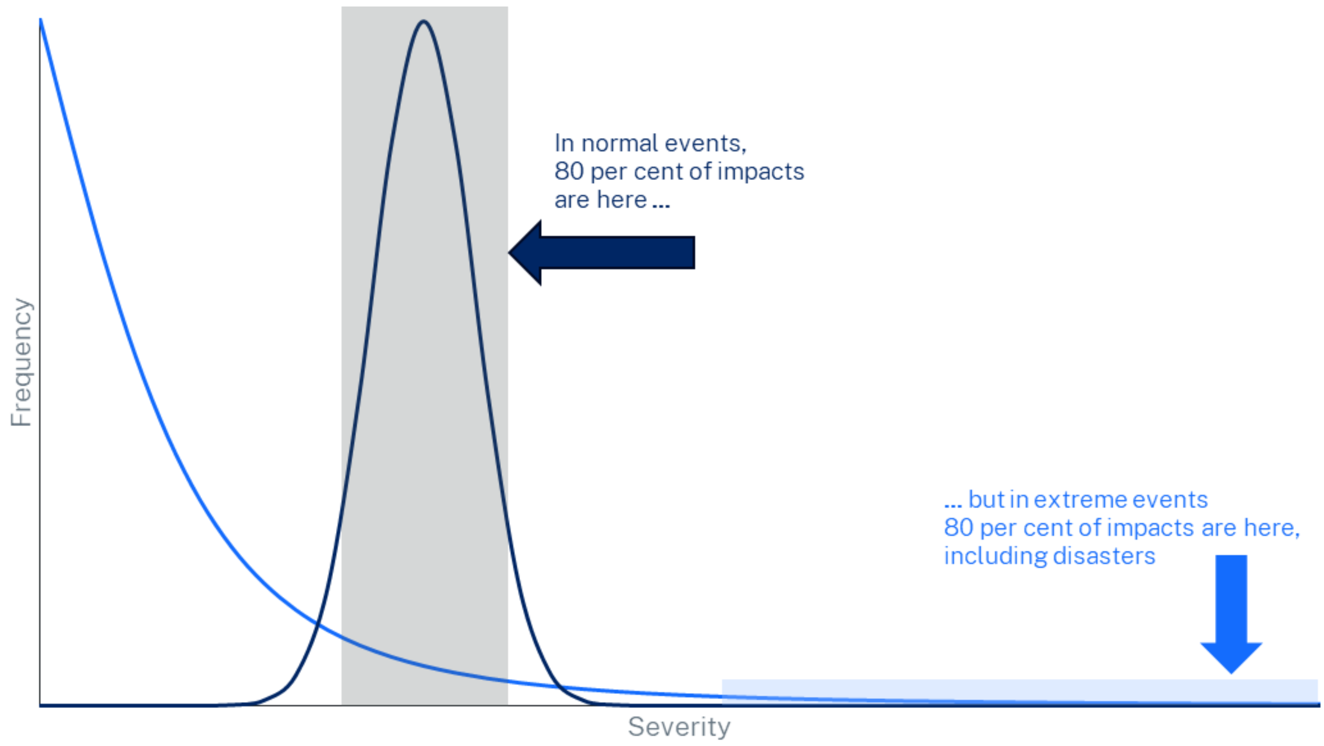
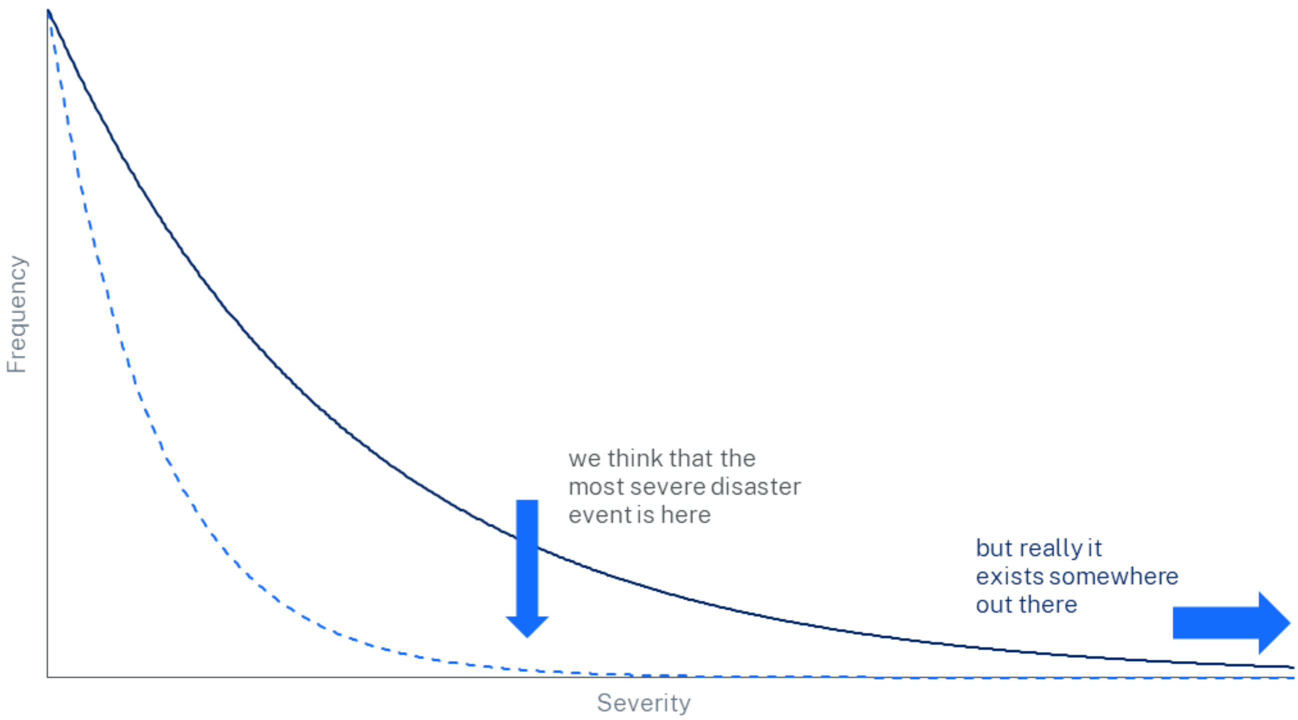


Figure 4.b: Failing to accurately estimate impacts

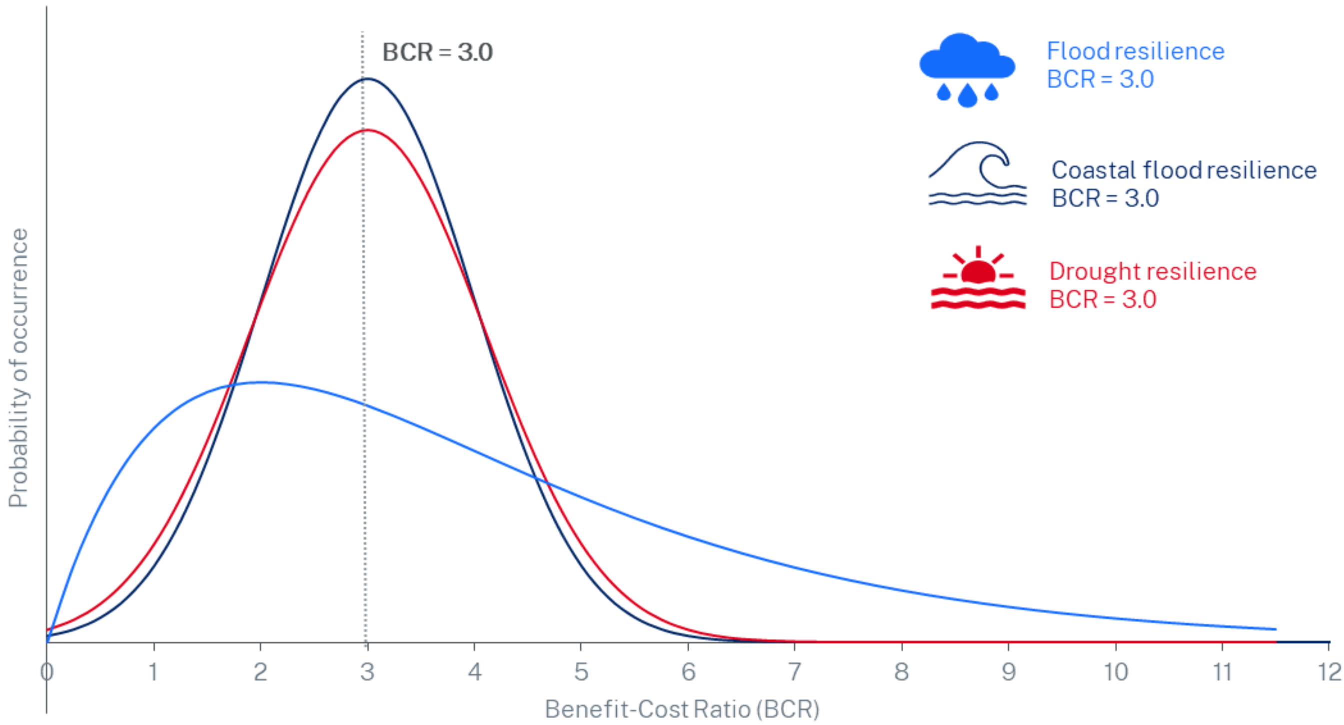


Source: NSW Treasury

2.3 Probabilistic cost-benefit analysis

Probabilistic CBAs can help decision makers understand the risk and uncertainty[5] inherent in any initiative. They estimate the full range of expected outcomes of an initiative and weight each (possible) outcome with the probability that it is estimated (or assumed) to occur. This approach produces distributions of all possible (or expected) estimates rather than only presenting the average expected outcome (as in Figure 5).

Figure 5: Initiatives with similar expected value but different range of expected outcomes



Source: Adapted from CBA Guide, Figure A4.1, (NSW Treasury, 2023a)

Probabilistic CBA is valuable because projects with very similar average expected outcomes can have a range of projected outcomes that vary significantly – representing different exposure to risk and uncertainty. Figure 5 shows a hypothetical example where three disaster resilience initiatives have the same BCR but different exposures to risk and uncertainty. The flood resilience initiative has larger potential upside than the other two initiatives, but also more potential downside. In this example:

- The flood resilience initiative might be a levee that primarily protects against 1-in-100-year events and has a low BCR most of the time because these events are rare. This is offset by very large payoffs if a severe flood occurs.
- In contrast, the drought resilience initiative might be a desalination plant that provides benefits in the event of water shortages that occur around 1-in-10 years. It has a narrower BCR range than the flood resilience initiative because while it only mitigates a small amount of drought impact, it does so relatively frequently.

The distribution of possible BCRs can help inform decisions where risk tolerance for extreme events is a factor. For example, an initiative that reliably provides modest benefits may have the same expected value as an initiative that offers large benefits when an extreme event occurs but

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[5] For more information on the concepts of risk and uncertainty, refer to Appendix 4.1 of https://www.treasury.nsw.gov.au/finance-resource/guidelines-cost-benefit-analysis.

otherwise offers little. A community may however be more willing to tolerate frequent minor damage, but seek to protect itself from the risk of an extreme event.

Vulnerability to rare events that happen at the same time can also be tested using probabilistic CBAs. This can inform an understanding of how a group of complementary initiatives would perform under these extreme events.

2.3.1 Monte Carlo analysis

Recommendation:

Use Monte Carlo analysis to better understand and reflect risk and uncertainty in the severity, timing and impacts of disasters.

Key parameters for a CBA each have their own probability distribution. Monte Carlo analysis uses repeated random sampling from each of the relevant probability distributions (that may be based on historical data or judgement) to generate multiple simulations. These simulations define the combined frequency distribution for certain interdependent outcomes. This allows an understanding of risk and uncertainty to be developed from a combination of varying assumptions and probability distributions. Monte Carlo analysis may be applied after calculation of average annual damage, during sensitivity testing, or in early stages of developing a base case and options.

For example, the distributions for the frequency of a possible natural hazard event in a location, the intensity of the event, and the distribution for the range of possible costs for a given intensity event could be combined. This would give an overall distribution for the range of possible costs. Any number of parameters can be used, including scenarios where risks are varied individually, sequentially or simultaneously. Box 6 illustrates a Monte Carlo analysis in flood risk management.

Box 6: The role of Monte Carlo simulations in flood risk management

Flood risk management is subject to significant uncertainty regarding the number, timing and size of flood events. This creates significant uncertainty regarding the damage-reduction benefits of flood risk interventions.

Analysts can use historical records and hydrological modelling to estimate the probability of a flood of a given severity occurring in any year, even though individual floods are unpredictable events. Timing drives net benefits in a CBA as discounting means even very severe floods have a low present value cost if they occur very far in the future.

Monte Carlo simulation is a way to process these probabilities and estimate the likelihood of different levels of flood damage over a 100-year period. Thousands of different possible combinations of flood scenarios are randomly generated from a flood probability distribution, and the flood damage costs calculated for each. This allows for the probability distribution for flood damage costs to be derived.

For example, a town might have a 5 per cent chance each year of experiencing a flood causing $1 million damage, a 1 per cent chance each year of experiencing damage of $10 million and a 0.1 per cent chance of experiencing damage of $20 million. A Monte Carlo simulation can create thousands of simulations for possible outcomes over the next 100 years. These simulations can show the expected value and probability distribution of benefits where an initiative mitigates flood damage (Figure 12).

Monte Carlo analysis can be used to generate probability distributions for the NPV and BCR. Drawing on these distributions, it is possible to present an ‘expected BCR’ based on the probability-weighted average amount of damage avoided, and the probability that the BCR falls within a certain range (above 1, for example). Importantly, it enables modelling of how various policy interventions alter the likelihood of different levels of damage – in other words, modelling of the damage-reduction benefits.

Monte Carlo analysis only provides an accurate distribution for outcomes to the extent that the assumptions and data underpinning the analysis are realistic. In practice uncertainty and data limitations may lead to challenges in arriving at accurate distributions. Research, findings from similar projects, and expert opinion should inform its use.

2.3.2 Other methods

Risk and uncertainty in disaster resilience CBA can arise from a range of sources such as assumptions or estimates[6] of a natural hazard, or interdependencies between initiatives or hazard events.

A range of strategies can make risks and uncertainties clearer to decision makers, including:

- rating the quality of the data used to estimate impacts
- making clear the size of contingency allowances in cost estimates
- identifying variables that are subject to high levels of uncertainty
- sensitivity analyses and simulations (such as Monte Carlo simulation)
- scenario planning[7] to test climate change scenarios.

Strategies may also be employed to reduce the consequences of uncertainty. For example, pilots, staged implementation, or adaptive management. Real options analysis may also be employed to allow the scope and timing of initiatives to change as risks and uncertainties become clearer. Further details are provided in the CBA Guide Appendix 4.

2.4 Risk neutrality

CBA uses a risk neutral approach. Risk preferences, however, can differ across communities and individuals. For a risk neutral individual, costs are equal to the expected cost of a disaster. For a risk averse individual, however, costs are greater than the expected cost of a disaster.

The risk neutral approach of CBA may not reflect the risk preferences of society (Hudson & Botzen, 2019). It would typically be expected that people do have some level of risk aversion.

The difference in cost between risk neutral and risk averse individuals can vary greatly depending on the level of risk aversion, the amount of expected damage, and the probability of damage occurring (see Box 7).

Box 7: Differing attitudes to risk and the cost of floods

A flood mitigation CBA undertook analysis of varying risk preferences as a sensitivity analysis to the main estimate. Risk adjusted cost was calculated as the cost, in dollars, that would lead to equal utility as the cost of flooding. The difference between the risk adjusted cost of risk neutral and risk averse individuals was modelled under a range of parameters:

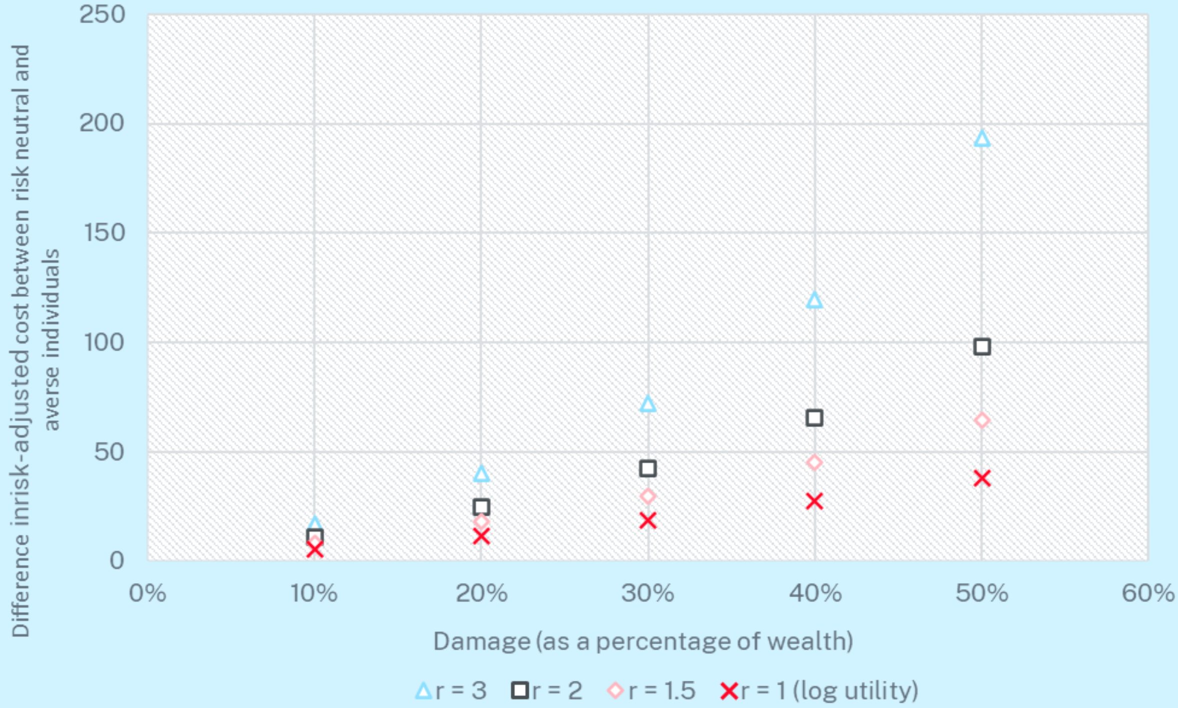
- probability of loss (either 1 per cent or 0.1 per cent)
- amount of damage (between 10 and 90 per cent of total wealth)
- relative risk aversion coefficient (between 1 and 3).

Figure 6 illustrates the results, demonstrating that the difference in risk adjusted cost is higher the greater the level of risk aversion and where potential losses represent a large portion of an individual's wealth. In short, this suggests that risk preferences will have the greatest impact on expected benefits where an initiative mitigates against low-frequency, high-consequence events.

[6] A proponent might assume maximum flood levels based on historical levels, or use modelling techniques to estimate the likelihood of disasters based on various parameters. There will be uncertainty in both cases.

[7] Scenario planning is a planning method that examines scenarios that represents a different possible state of the world, as opposed to a prediction or best guess.

Figure 6 Percentage difference between risk adjusted cost for risk neutral and risk averse individuals, 1 per cent chance of flood damage



Source: Analysis provided by the Centre for International Economics

Insurance is one mechanism that limits the impacts of individual risk aversion. Government action should be mindful that it does not erode incentives to purchase insurance (see Section 3.3.3 for discussion on moral hazard).

It is possible to use willingness-to-pay (WTP) to estimate risk preferences; individuals with a higher WTP to avoid disaster impacts generally have higher risk aversion. For these individuals the WTP to avoid disaster impacts would be higher than the expected cost of the disaster. WTP estimates, however, require time, resources and capability to complete and also depend on whether the individuals have accurate information about the likelihood and consequences of disasters.

Expected damage cost estimates and their risk neutral approach are preferred by this Framework. It is generally appropriate for the State to take a risk neutral perspective, which reflects the community at large, and the many investments it makes across different regions.

Recent events, however, such as the East Coast Floods and Black Summer bushfires demonstrate the outsized and long-lasting costs that low-frequency, high-consequence events can have, that are not mitigated by insurance or government intervention. These events have catastrophic impacts on individual communities and large impacts on the State, i.e. they could be considered as 'State significant' risks. In these cases, sensitivity analysis could be included of benefits under different risk aversion scenarios.

2.5 Early and genuine partnerships with First Nations peoples

First Nations peoples have been custodians of the Australian land for tens of thousands of years, managing the land, waters, and seas in a sustainable manner through a suite of traditional land management techniques that are intrinsically linked to culture and its practice within community.

This understanding is often highly attuned to the local circumstances and the unique natural features of an area.

A growing body of evidence demonstrates that 'cultural burning' and complementary land management techniques can de-risk a landscape from bushfires: ensuring that small naturally occurring fires do not become large-scale wildfires, while improving soil quality, biodiversity, and resilience to drought and other natural disasters.

The benefits offered by First Nations perspectives and knowledge may not be reflected accurately in an initiative unless:

- The legal rights and interests of First Nations people and communities are adequately understood, recognised, articulated, and respected throughout the development of an initiative.
  - This may require additional consultation and knowledge of land rights and related legislation, including Aboriginal Cultural Heritage and Native Title.
  - For example, Native Title can sometimes provide traditional owners with a set of non-exclusive rights, like the right to conduct cultural and land management activities and which require governments to consult before making changes to land and water use.
- First Nations people and communities are included in early stages of an initiative where they can make a significant contribution to better understanding the problem or opportunity being addressed, and the options available to address them.

Consultations that develop partnerships at the local and community level can produce information that can improve the nature of an initiative. It is important that these partnerships:

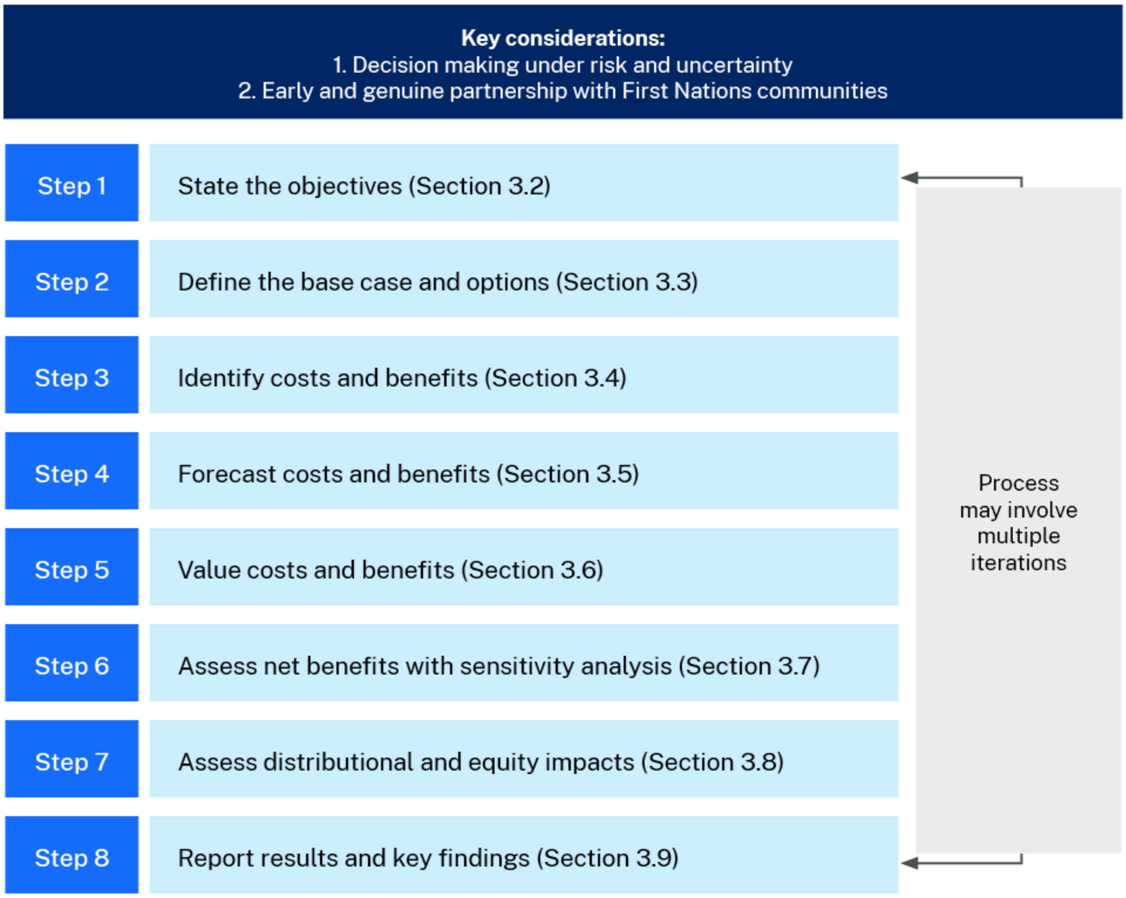
- Acknowledge First Nations culture and knowledge as an asset that:
  - First Nations people and communities own – including the collection and use of their information
  - can improve the understanding of the problem (or opportunity) an initiative is addressing, as well as develop high-quality options.
- Work to identify and understand the First Nations legal rights and interests that may be impacted by an initiative.
- Work to identify and understand the benefits that can accrue to First Nations people and communities – such as the unique spiritual significance of place.
- Highlight any barriers to the use of First Nations knowledge and expertise and options to overcome them. For example, regulatory barriers that determine when and how cultural burning can take place.

3 Completing a disaster resilience cost-benefit analysis

3.1 Overview

Figure 7 identifies the key steps to develop and present CBAs of disaster resilience initiatives aligned with the CBA Guide. The steps are presented as sequential, however, CBAs may involve multiple iterations depending on initial findings and as better information becomes available. For example, the base case and options may require reassessment as better information becomes available.

Figure 7: Steps for conducting a CBA of disaster resilience initiatives



Source: Adapted from CBA Guide (NSW Treasury, 2023)

3.2 Step 1: State the objectives

The immediate objectives of a disaster resilience CBA could include:

- reduced likelihood of future disasters
- reduced severity and impacts of future disasters
- increased coping and adaptive capacity to disaster risks
- reduced recovery time from disasters
- reduced recovery costs of disasters.

The longer-term objectives of a disaster resilience CBA could include:

- safety of community
- preserving infrastructure
- ensuring continuity of service provision
- improving social equity
- promoting economic development
- identifying and protecting where possible, culturally significant areas, items and landscapes
- preserving environmental values.

Objectives should be stated clearly in terms of welfare outcomes rather than specific outputs. For example, following a hailstorm, an objective could be to promote safety of the community rather than specific outputs such as delivering a certain amount of disaster assistance.

Objectives should reflect input from subject matter experts and early engagement and partnerships with impacted communities, including First Nations peoples where appropriate (Section 2.4).

As stated in Section 3.1, CBAs may involve multiple iterations and objectives may require reassessment as better information becomes available.

3.3 Step 2: Define the base case and develop options

3.3.1 Natural hazard risk assessment method

Recommendation:

Combine analysis of hazard, exposure and vulnerability to quantitatively estimate disaster risk under the base case.

Natural hazard risk assessment can be carried out in several ways and for different purposes. The most common methods include:

- quantitative risk assessment (see subsection below)
- event tree analysis
- risk matrix approach
- indicator-based approach.

Appendix B: Disaster risk assessment techniques provides further details of these methods.

Quantitative risk assessment

Quantitative risk assessment provides risk information that can be used in cost-benefit analysis. A full natural hazard risk assessment for the study area[8] should establish the baseline risk faced by the exposed population, assets, and the environment.

Therefore, the three steps that are required to estimate the disaster risk for the study area include the assessment of:

1. hazards
2. exposure
3. vulnerability.

[8] Previous disaster risk assessment might already exist for the study area; depending on the scale of the initiative, proponent might use previous study where appropriate.

Assessment of hazards

Hazard assessment determines the types and scales of hazards that can impact an area. It provides an estimate of the type and nature, intensity and potential frequency of hazards. A common estimate of the probability of a hazard occurring is the recurrency period, which is an estimate of the expected time between similar events. Hazards may become more, or sometimes less, frequent as a result of changing weather patterns due to climate change. Climate change modelling (where available) or the NSW Common Planning assumptions (Table 3) should form part of hazard assessment.

Assessment of exposure

Exposure assessment builds on hazard assessment by identifying the people and assets (both human created assets and natural assets) that are subject to loss when each hazard and disaster type occurs. Data relevant for the study area includes:

- number, type, age, size and location of physical assets
- number of households and their characteristics (including social-economic status, wealth and income)
- past growth in physical assets
- population growth rate.

Assessment of vulnerability

Vulnerability assessment identifies the characteristics that make people or assets vulnerable to a given set of hazards and exposure. The vulnerability model directly relates the amount of damage or functionality expected to the level of hazard (or intensity) experienced. The variability associated with these models is often expressed in statistical (e.g. standard deviations) or probabilistic terms.

Understanding exposure and vulnerability can assist with assessing initiatives and prioritising interventions. For example, when doing a risk analysis of heat waves:

- exposure assessment would identify the number of people living in an area where a heatwave is expected to occur
- vulnerability assessment would identify that people living in areas where there are urban heating effects would be more vulnerable, and that the elderly, especially those without air conditioning, would be more vulnerable to death or injury
- prioritising provision of cooling devices to elderly people rather than the entire population with an exposure could enhance efficiency of intervention.

Capacity should also be considered when analysing vulnerability (i.e. the combination of the strengths, attributes and resources within a community to respond to different types of disasters).

Risk analysis

As outlined in Section 1.2, risk analysis combines the concepts of hazard, exposure, and vulnerability. Figure 2 illustrates the typical relationship between exceedance probability (the probably of a certain threshold being exceeded) and damage, whereby damage is concentrated for low-probability disasters (such as a 1-in-1,000 AEP flood). The exceedance probability multiplied by the damage gives a measure of natural hazard risk.

Box 8 illustrates the elements of risk analysis in the context of an urban area.

Box 8: Example of risk analysis

A proponent is considering the risk analysis of an urban area and seeks to describe the risk by identifying relevant hazards, exposures, and vulnerabilities.

- Hazard: Due to its geography, the area is unlikely to be affected by riverine floods or bushfires. It is, however, subject to occasional severe storms. Specific hazards arising from this include lightning, hail, damaging wind, and flash flooding.
- Exposure: The region is a typical residential area, with predominantly low-density housing, although recently there has been a rapid increase in high-density developments fuelled by population growth. There is also a variety of retail and commercial developments such as shopping centres, small office blocks, and entertainment venue, as well as some light industrial activity. The area has exposure to storm damage because a severe storm could result in injury, damage to dwellings and other property, and economic damage from disruption to trade. While exposure to lightning is modest, the people and assets in the area are potentially exposed to damage in the event of heavy hail, strong winds, and flash flooding. Ground-floors of buildings are particularly exposed to flash flooding.
- Vulnerability: New high-density developments in the area have been built to standards designed to resist storm damage and have low vulnerability. However, older buildings remain vulnerable, due to the nature of structural and roofing materials. A lack of covered parking also increases the vulnerability of vehicles to hail damage. Retail and entertainment venues are mainly located at ground level and are more vulnerable to flooding, but the impacts are moderated for premises that are designed for commercial use and efficient industrial-scale cleaning, rather than residential use.

Defining the base case

A realistic base case must be defined to act as a comparator to the initiative options. The NSW Common Planning Assumptions are the agreed information assets which should be used when preparing business cases that rely on projections. They include expected impact of climate change on rainfall, heatwaves, cold days, and sea level rises. This information should be applied when developing a disaster resilience base case to ensure quality, consistency and comparability across initiatives. Other resources set out in Table 3 may supplement the Common Planning Assumptions on a case-by-case basis.

Table 3: Assumptions used to guide the base case

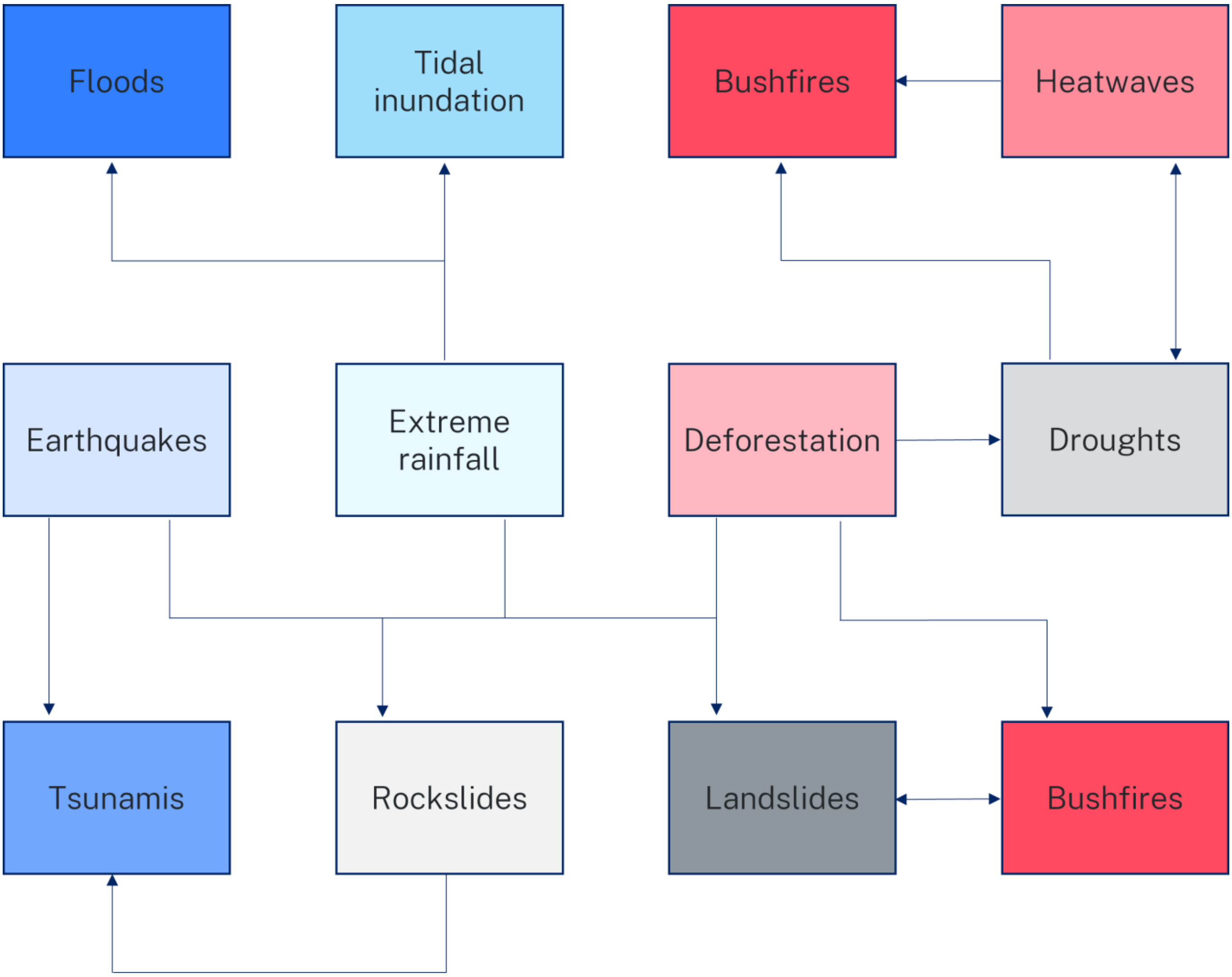
Source	Applicable Hazards	Use
NSW Common Planning Assumptions – Climate and natural resources	All	NSW Common Planning Assumptions provide consistent evidence to prepare proposals, business cases and strategies that rely on certain projections. The resource accounts for the impact of climate change in its projection and impacts of disasters.
Strategic guide to planning for natural hazards	All	The Strategic guide to planning for natural hazards resource kit provides a comprehensive list of hyperlinked sources for data associated with natural hazards, as well as management guidance, risk assessment guidance and emergency management.

Source	Applicable Hazards	Use
Climate Change in Australia – Projection Tools	All	Climate Change in Australia is a project led by CSIRO. It provides tools, varying in complexity, that provide the likelihood of different climate scenarios occurring in the future. The tools are useful for all climate scenarios, and for different regions and time horizons.
Australian Exposure Information Platform (AEIP)	• Floods • Bushfires • Heatwaves • Coastal Hazards	The AEIP allow users to identify what the exposure is within an area.
NSW Flood Data Portal	Floods	The NSW Flood Data Portal primarily provides flood data from projects under the NSW Floodplain Management Program. Local councils remain the primary source of flood information for their service areas. The Australian Flood Risk Information Portal (AFRIP) holds a subset of information on the NSW Flood Data Portal.
Australian Rainfall and Runoff (ARR)	Floods	The ARR is a national guideline document, data and software suite that can be used for the estimation of design flood characteristics in Australia. The ARR Data Hub and ARR Guidebook supports the ARR.

3.3.2 Multi-hazard risk assessment

Many natural hazards are linked. Earthquakes can create tsunamis, rainfall extremes associated with high winds can lead to floods and landslides, droughts can create conditions for bushfire. Analysing the risk associated with hazards occurring either simultaneously or subsequently is difficult. Figure 8 provides a sample of hazards and their possible interactions.

Figure 8: A sample of relationships between hazards.



Note: the colours in Figure 8 *represent different hazards and are not indicative of any other characteristics or linkages.*
Source: NSW Treasury, based on (CDEMA, 2021)

Independent events

Where hazards are independent (in causes and effects), the total associated damage can be calculated by summation. For example, an earthquake and a storm-related flood can have separate triggering mechanisms. The losses from each event can be added, and the associated risk(s) separately analysed. A specific hazard may, however, lead to causal chain of events. For example, an earthquake could lead to landslides, which can alter topography and result in localised flooding.

Compounding events

Hazards originating from the same trigger are known as a compounding event(s). The probability of each hazard is the same, as both are linked to the probability of the triggering mechanism occurring (CDEMA, 2021). For compounding events, hazard and consequence modelling across the potentially affected area should be undertaken simultaneously, due to the interaction of processes and overlap of hazard footprints.

Where coupled hazards have a causal relationship from one to the other, for example a storm followed by a flood, the combined overall risk will be equal to, or exceed, the sum of the individual risk associated with each hazard.

Double-counting should be avoided due to the interaction of multiple hazards on a particular area. This is primarily dictated by the nature of the coupled events, along with their chronological order, detailed using the following examples:

- If a bushfire destroys vegetation and is followed by a flood, the land degradation, landslide risk and water quality effects of the flood will be potentially worse (than the 'sum of the parts').
- If riverine flooding destroys properties and is closely followed by a landslide, the direct damage from the landslide will not increase the overall damage for properties already destroyed by flooding. However, indirect impacts from the overall compounding event can still be attributed to the landslide. Alternatively, the properties might be damaged by a flood but recoverable, whereas a landslide may destroy the property.

For further guidance, the joint probability of coastal inundation and riverine flooding is explored in Floodplain Risk Management Guideline – Modelling the Interaction of Catchment Flooding and Oceanic Inundation in Coastal Waterways (OEH, 2015).

Alteration of conditions

In certain situations, one hazard can significantly alter the terrain conditions of a particular area leading to a second hazard, without directly being the trigger mechanism (Kappes, et al., 2012). Best practice is to update the risk assessment subsequent to the occurrence of a hazard event, taking into account how updated physical conditions may impact the likelihood and consequences of future hazards.

Cascading events

Hazards can also form part of a chain of events (i.e. cascading events also known as domino events), where each subsequent event is influenced by the previous event. This is known as the domino effect and can be difficult to quantify in terms of the attribution of damage and risk to each respective hazard event. Event tree analysis is useful for analysing cascading events, their probabilities, and displaying the links between each hazard and their respective consequences.

3.3.3 Option development

Recommendation:

Consider a variety of options that address disaster risk, including where relevant:

- preventing losses by avoiding the hazard
- mitigating losses by improving preparation for events
- mitigating losses by making communities and structures more resilient.

CBA should canvas a diverse range of options to address the objectives. Generally, disaster risk can be mitigated by reducing: the likelihood of an event occurring, the exposure of people or property to losses, or the vulnerability of an area to the damaging effects of an event. Development of options should draw on stakeholder consultation and technical expertise. This could include natural hazard experts, climate change specialists, infrastructure specialists, urban planners, First Nations groups and business case practitioners.

Options may aim to reduce the impact of natural hazards through capital investments, including:

- mitigating the frequency or scale of events, for example constructing a flood mitigation levee in a riverine area, or the erection of a seawall to stop strong ocean storms and tidal events
- modifying the exposure of communities, for example, raising the floor levels of houses in areas that are more frequently affected by flooding, relocating to lower risk areas or changing the land use
- improving the response of the community when a disaster occurs, for example through improved warning systems or signals.

Regulatory options may also increase disaster resilience. For example, planning changes may prevent construction in disaster-prone areas, or changes to building regulation can require properties with higher resilience to be constructed. The costs and benefits of regulatory options should be identified and assessed in accordance with the *NSW Government Guide to Better Regulation TPG19-01*.

Financial options may not directly alter the losses associated with an event but may assist to alter the distribution of costs or transferring risk to where it can be borne more cheaply. Financial options can:

- reduce the cost of, or reward, actions that mitigate risks (such as through subsidy or concessions)
- reduce the costs associated with a specific event (such as by spreading or pooling risks)
- compensate people who have been adversely impacted by an event (such as by subsidising repairs or providing assistance for relocation)
- seek contributions from a group to fund a project that benefits an area.

Identification and mitigation of moral hazard

Moral hazard is where a person has an incentive to take a higher exposure to risk, because they do not bear the full costs of that risk. In the disaster context, a person may not take prudent steps to avoid disaster risk because they believe the government will cover some of their costs should a disaster occur. This can lead to reduced incentives to make a property more flood resilient, to insure assets, or to locate property and valuables away from disaster-prone areas.

Moral hazard will, in general, increase the costs or decrease the benefits of current and future initiatives. This is most obvious in the context of financial subsidies and incentives where a payment reduces the need for a person to mitigate their own risks, but also applies more broadly. For example, building government-funded infrastructure to protect an area from disasters may set a precedent that encourages more people to locate in similar areas.

Moral hazard is common for disaster resilience initiatives and should be considered when developing options. It can be mitigated, for example, by seeking a financial contribution from beneficiaries, or by targeting benefits towards people who took reasonable precautions. Other government policies may also mitigate moral hazard. For example, planning or regulatory controls may reduce moral hazard from disaster compensation payments by requiring resilient building design or limiting the capacity for someone to build in risky areas.

Where significant moral hazard issues are unable to be mitigated, they should be clearly identified and incorporated into the analysis. For example, this could include reflecting an expected decrease in benefits of an initiative from moral hazard.

Other practical considerations

Preventative measures often require significant expenditures to mitigate against losses that may occur far in the future, whereas response measures react to an urgent and pressing community need. To counter this, an evidence-informed approach should be taken to options development and selection. Each project and location will be different, however as a guide consideration should include:

- avoiding the hazard, for example by locating development in areas with less vulnerability to extreme weather events
- preparedness measures, such as early warning systems and information campaigns
- mitigating the impacts of disasters through increased resilience, including where possible to multiple disasters
- considering whether disaster risk could be managed through private insurance markets.

Box 9: Example of bushfire risks and mitigation strategies

A township and surrounding areas are exposed to bushfire risks, which are expected to increase in intensity and severity. The cost of bushfires in the area arises from the overlap between the risk of bushfires occurring, the location of the community relative to the bushfires, and the vulnerability of the community in the area in the event of a bushfire. A range of options could reduce disaster risk:

- Clearing a larger area of land to reduce the likelihood of fires reaching people or property.
- Improved vegetation management, for example controlled burning of built-up fuel load, drawing on insights from First Nations land management techniques.
- Moving the township to a more easily protected location and shifting land use towards agricultural uses that can recover more quickly from fires. The demolition and stranding of buildings and infrastructure would, however, immediately crystallise asset losses.
- Providing subsidies to homeowners to make dwellings more fire resilient, reducing the risk of property damage and injury.
- Improving early warning systems and evacuation routes to ensure that people can make an informed decision to leave or stay and defend properties. This would provide relatively modest protection to buildings and other assets but could be effective in preventing injuries where hazards are more severe.

3.3.4 Packaged options

Combining two or more options into a package of measures may be more effective. This is commonly the case when structural and non-structural options[9] are combined, or when options are complementary. By definition, complementary options together provide benefits greater than the sum of the individual options. Examples of packaged options include:

- for coastal hazards: building a seawall and installing early warning systems
- for bushfires: mechanically removing Australian Cypress complemented by fuel reduction burning within the hardwood areas.

3.3.5 Logic model

Logic models describe the causal links between an initiative's identified need, inputs, activities, outputs, outcomes and benefits. The CBA Guide suggests using a logic model as part of the development process of an initiative.

The Policy and Guidelines: Evaluation (TPG22-22) provides further guidance on developing a logic model.

3.3.6 Monte Carlo analysis

Monte Carlo analysis is recommended as part of the base case and option development (Section 2.3.1 and *Technical Note: Flood CBA Tool*).

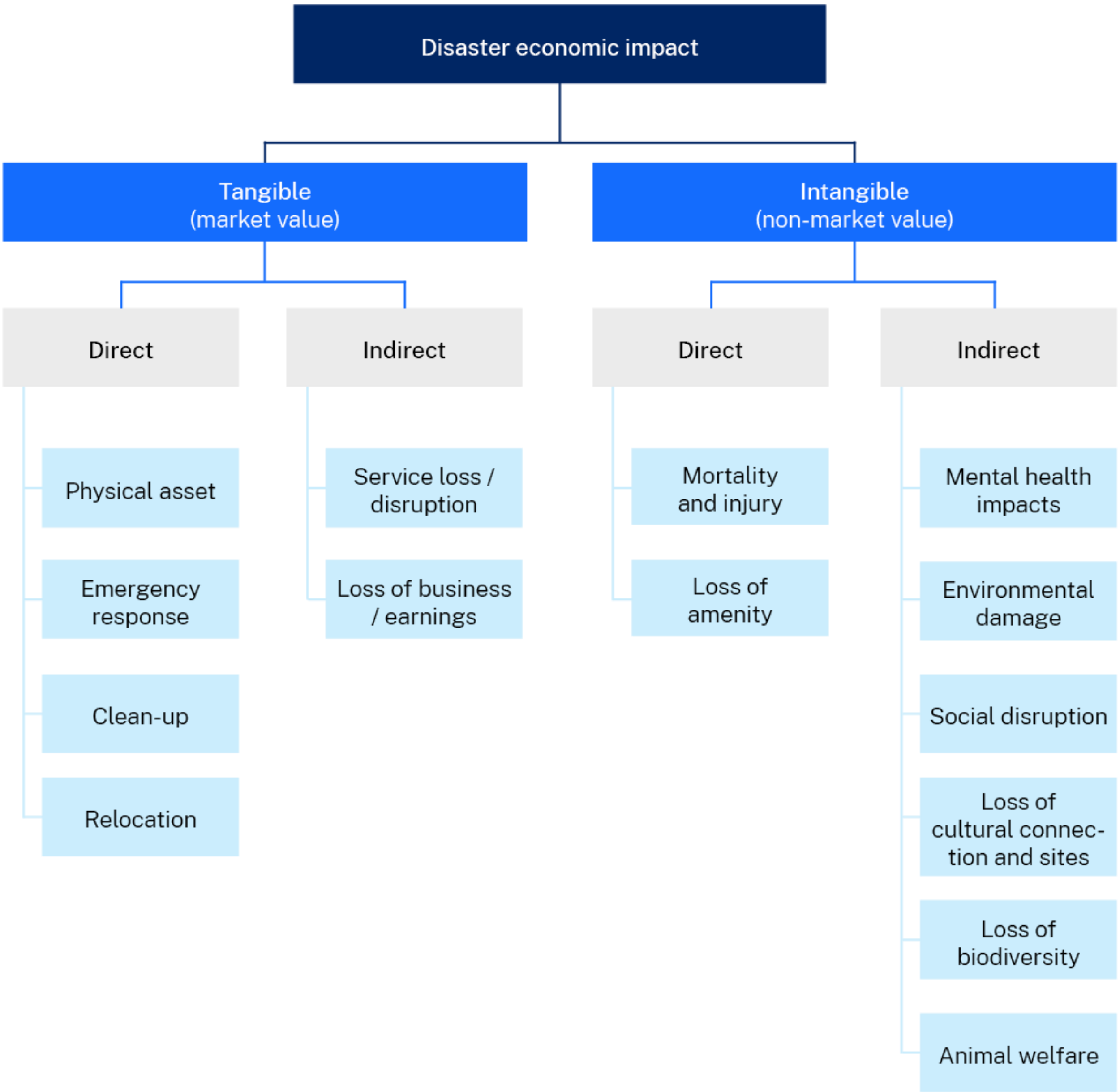
[9] Structural measures are physical constructions that are targeted at reducing the direct adverse effects of natural hazards (e.g. levees or earthquake resistant buildings). Non-structural measures include early warning systems, land use planning, knowledge building and transfer, capacity building and codes or standards.

3.4 Step 3: Identifying and categorising costs and benefits

3.4.1 Common benefit categories

Benefits are a measure of the value of the outcomes attributable to the initiative to the NSW community (the reference group).[10] Many, but not all, benefit categories may be valued in monetary terms. Benefits can be broadly categorised[11] into tangible or intangible and direct or indirect. Figure 9 provides an overview and further examples.

Figure 9: Categories of disaster economic impacts[12]



Source: NSW Treasury

[10] The Framework focuses on the costs and benefits of disaster to the NSW community (the referent group), irrespective of the origin of the natural hazard. Where local level, cross-border, or national analysis is required by decision makers it should be presented separately from impacts on New South Wales.

[11] There may be overlap between some categories for some benefits (e.g. mental health impacts can be direct and indirect).

[12] For more information on definitions and examples of direct and indirect impacts, refer to Section 2.3 of https://www.treasury.nsw.gov.au/finance-resource/guidelines-cost-benefit-analysis.

Tangible impacts have observable market values. For example, the damage and destruction to infrastructure and other physical assets can be valued in terms of being the replacement cost net of physical depreciation (wear and tear). Intangible impacts do not have observable values, but non-market valuation methods may be applied. Examples include mental health impacts, disruption of livelihoods and community connections, connection to cultural sites, or loss of environmental amenity.

3.4.2 Common cost categories

Table 4 presents typical cost types for disaster resilience initiatives.

Table 4: Cost types and examples

Cost Type	Cost Sub-type	Examples
Direct Costs	*Capital Costs*	• New assets or asset replacement • Infrastructure refurbishment • Major repairs • ICT capital costs • Change in land value resulting from change in use
	Recurrent Costs	• Agency salaries and labour-on costs • Accommodation and expenses • Operating costs (e.g. program, training, communication, and evaluation) • Infrastructure ongoing repair and maintenance costs • ICT running costs
	Regulatory Costs	• Compliance costs • Costs to government to administer the regulation
	Ancillary costs	Transaction costs.
	Land Acquisition Costs	• Solicitor fees Note that the purchase price of land is generally a transfer payment with no impact on the NPV of the project.
Indirect Costs	*Negative Externalities*	• Disruption costs • Environmental costs (e.g. effects of raising of a levee on riverine areas, upstream dam impacts, erosion) • Cultural costs (e.g. damage to sites of cultural significance) • Social costs (e.g. reduction in amenity – for instance, using a sports oval as a detention basin can destroy its turf and take considerable time to repair and regrow. This would mean the playing field could not be used until the grass re-grew – resulting on a loss of amenity to the local community)

Financial arrangements and transfer payments

Economic costs and benefits associated with various interventions accrue to individuals, businesses, government and communities are treated equally, so long as the parties are located within New

South Wales (referent group). Where the program involves a financial transaction – for example payments to affected households and businesses – the payment of funds does not, of itself, bring any net benefit to the community. It is a just transfer from one party to another. The payment will, however, generate an economic benefit it is more useful in the hands of the payee than the payer. The CBA should therefore examine what outcomes are achieved because of the payment. For example, more businesses may be able to avoid bankruptcy, communities may be able to recover more rapidly, resulting in better health, and education, outcomes over the medium term.

Because cost-benefit analysis is a whole economy assessment it includes costs and benefits beyond just the fiscal impacts to government. It encompasses contributions from both government and private entities. For example, a CBA for a program that gives households a subsidy to modify their property should include both the government and private contributions to the achieve the desired outcome in the denominator and the net benefits associated with making those modifications on the numerator.

An incentive that is aimed at encouraging a behaviour that the recipient is already incentivised to do, or doing, is in substance a transfer payment. Such payments impose a cost on the government and an offsetting benefit to the recipient, without any resulting behavioural change, or net benefit to the community. For example, property owners who are aware of disaster risks are likely to factor them into the price and usage of the property. These owners are already fully incentivised to mitigate risks because they face the full property damage costs of failing to do so.

Additional benefits may exist where the transfer payment addresses a market failure and these should be identified. For instance:

- Incentivising actions may lead to reductions in costs borne by parties other than those who receive the incentives (such as through avoided costs to government in providing healthcare, or emergency services to those affected by disasters).
- Aligning incentives may lead to more efficient decision making (such as where a government initiative requires contributions from beneficiaries of the initiative).
- Subsidising private benefits may reduce costs that have not been fully priced in (such as where there is a demonstrated gap between perceived and actual disaster risk).

3.4.3 Qualitative impacts

Quantification is not always possible or practical. In these cases, material impacts should be described qualitatively and be presented alongside quantitative CBA results.

3.5 Step 4: Forecast all quantifiable benefits and costs

3.5.1 Forecasting costs

Total cost of an option should be calculated using the estimated volume impacts and the unit price of each respective input. Distinction between estimated volume impacts and the dollar value per unit of volume should be made clear. For example:

- For capital estimates such as constructing a levee, this would be the quantities of land, labour, materials and equipment consumed in the construction process. Total forecast cost is, however, sensitive to project design and technology, which may change as the project matures, or with the physical conditions encountered.
- Disruption costs, such as relocation costs, will vary depending on the number of residents affected and the chosen relocation option. The types of accommodation, or different relocation areas, may impose different costs, despite accommodating the same number of residents.

A dollar value per unit should reflect the contribution to overall project cost. For example, the cost of soil for an earth levee per metre can be obtained from technical experts and corroborated against similar projects. Where market values are not readily observable non-market methods, such as revealed preference, stated preference, or benefit transfer may need to be required.

3.5.2 Forecasting benefits

Forecast benefits (primarily avoided and reduced losses and damages) depend on:

- the likelihood of a disaster occurring and its severity
- the expected damage should a disaster occur
- the effectiveness of any mitigation strategies implemented.

Annual exceedance probability (AEP) should be used to assess the likelihood of a disaster occurring. AEP estimates the probability of a particular type of disaster, equal to or larger than a given magnitude, occurring in any year. AEP can be applied to all types of disasters. Average recurrence interval (ARI) is an alternative way of expressing AEP.

Disaster risk cannot be entirely mitigated. An acceptable level of risk, representing tolerance depending on social, economic, political, cultural and technical conditions[13] should be defined by the appropriate authority or governing body (Table 5). Acceptable risk is also used to assess and define the structural and non-structural measures that are needed to reduce harm to a tolerated level, according to codes or 'accepted practice' that are based on known probabilities of hazards and other factors (United Nations General Assembly, 2016).

Table 5: Examples of acceptable risk for disasters

Disaster	Example of acceptable risk
Flood	A 'flood planning level' is implemented by local councils by location. This governs the minimum habitable floor level for each property within its jurisdiction.
Bushfire	Properties within a bushfire prone area are designed to a specific Bushfire Attack Level (BAL) rating, which ranges from low to flame zone. Properties in the vicinity of bushfire prone land are often designed to Bushfire Attack Level 12.5, defined as the withstanding of the fire risk from embers.[14]

Average annual damage (AAD) estimates the expected yearly damage cost[15] arising from all occurrences of a given natural hazard. AAD streamlines the calculation of expected damage and enables a like-for-like comparison between different risk mitigation options.

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

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

Recommendation:

Express expected yearly costs of a given natural hazard as an average annual damage.

Risk, as represented by the loss-frequency function, is quantified in terms of AAD in Table 6. In this example, damages due to the 1-in-10, 20, 50, 100 and 200-AEP events, along with the PMF[16]

[13] As defined in the Sendai Framework.

[14] For more information on acceptable risk of bushfire, refer to https://www.rfs.nsw.gov.au/plan-and-prepare/building-in-a-bush-fire-area/planning-for-bush-fire-protection.

[15] That is, the 'expected value' weighted by a probability. Clearly this value should **not** be interpreted as the value that is most likely to occur. This is analogous to the rolling of a dice. While this has an expected value of 3.5, we are clearly never going to see a dice show this value.

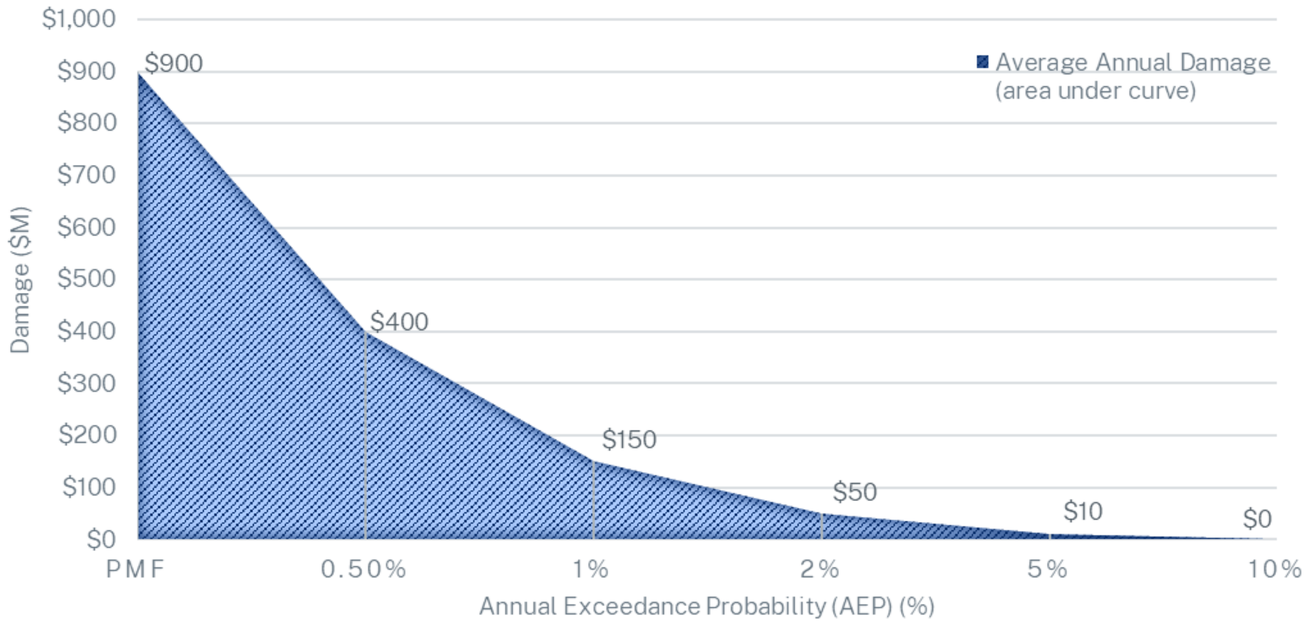
[16] For more information on PMF, refer to https://www.environment.nsw.gov.au/-/media/OEH/Corporate-Site/Documents/Water/Floodplains/flood-risk-management-manual-220060.pdf.

(Probable Maximum Disaster, 0.001 per cent AEP), are estimated. For instance, the 1 per cent AEP event is estimated to lead to damages of $150 million. The last column shows the result of the area under the curve between each point estimate (calculated using the trapezoidal rule); the sum of all these products is the expected annual loss (i.e. AAD). This is denoted as the area under the damage–probability curve (Figure 10[17]).

Table 6: AAD calculation example

AEP	ARI (1 in X years)	Damage ($M)	Contribution to AAD ($M)
0.001%	PMF (~100,000)	$900	$3.24
0.5%	200	$400	$1.38
1%	100	$150	$1.00
2%	50	$50	$0.90
5%	20	$10	$0.25
10%	10	$0	-
		Average annual damage (AAD)	$6.77

Figure 10: AAD calculation example – area under the curve



Source: NSW Treasury

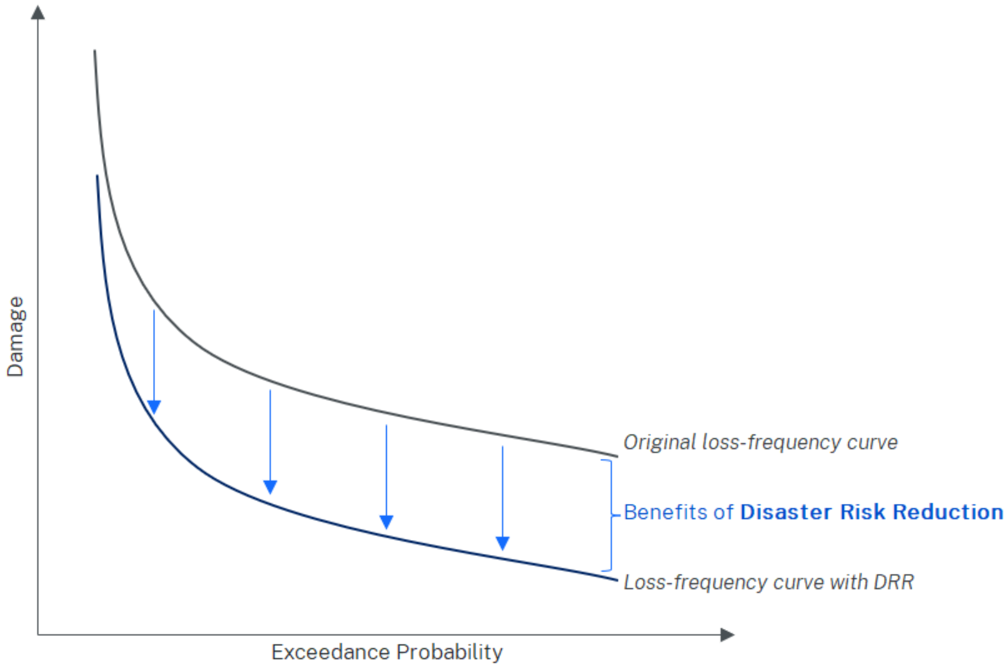
The area under the curve (i.e. the sum of all damages weighted by its probabilities) represents the expected annual value of damages for a given natural hazard within the study area. This provides an annual number that can be used for CBA purposes.

Theoretically, values for a substantial number of points on the curve would be needed for accuracy. In practice, as in this example, only several values will be available. Uncertainty of these calculations should be acknowledged (Section 2.1).

[17] X-axis not to scale for illustrative purposes.

Figure 11 shows disaster risk reduction benefits being greater where exceedance probability of a disaster event is higher. This is generally the case because smaller events are easier to mitigate and more common than larger events. The effectiveness of common mitigation strategies are often well-known, whereas others may need further investigation and evidence building. This includes how benefits may diminish over time (e.g. the effectiveness of raised housing reduces if lower storeys are filled over time).

Figure 11: Reduction in the damage-probability curve



Source: NSW Treasury

Bias

Unchecked bias[18], such as optimism bias relating to the success of interventions, can overstate benefits and understate costs, impacting the reliability of CBA estimates. An 'outside view' of the analysis, for example, through independent peer review, can help counter bias.

3.6 Step 5: Value costs and benefits

Some benefits are not easily quantifiable due to a lack of information, or the time and expense involved in collecting the necessary data. Decisions about whether to quantify these benefits should balance the materiality of the likely quantified amount, versus the effort required to quantify, and the significance of the benefit to the case for investment.

3.6.1 Valuing tangible benefits

Table 7 provides an overview of the valuation principle and data sources of tangible values.

[18] For more information on bias, refer to https://www.treasury.nsw.gov.au/finance-resource/guidelines-cost-benefit-analysis.

Table 7: Valuation principles and data sources of tangible values

Typical impact category	Valuation principles and methods	Examples of data sources
Direct		
Residential building (structure and contents)	Market value of the existing house structure and content (not including the land value, but including any costs required to rectify damage to the land).	• Adjusted insurance claims • Size of property (Council data or aerial imagery) • Stage-damage curve (*Technical Note: Flood CBA Tool*)
Commercial and industrial building (structure and contents)	Market value of the existing building structure and content (not including the land value, but including any costs required to rectify the land).	
Public building (structure and contents)	Market value of the existing building structure and content (not including the land value, but including any cost required to rectify the land).	
Motor vehicle	Market value.	• Adjusted insurance claims • Average cost of a written off vehicle due to flooding[19]
Infrastructure and utility	Cost of restoration (and opportunities for betterment).	• Government data • Utility company data
Road, bridge and railway	Cost of restoration (and opportunities for betterment).	Government data.
Land and waterways	• Costs of removing sediment and repairing land erosion • Cost of bush regeneration • Cost of removing debris and anthropogenic waste from waterways • Loss of land to the sea, loss of land to landslip and even loss of land to major flood event (where river changes location)	Survey.
Agriculture (crops and livestock)	Losses of gross margins (the sale price of produce lost less production and transport costs).	• Survey • ABS Value of Agricultural Commodities Produced

[19] For more information, refer to Section 3.4.4 of https://www.environment.nsw.gov.au/research-and-publications/publications-search/flood-risk-management-measures.

Typical impact category	Valuation principles and methods	Examples of data sources
Clean-up (residential and non-residential)	Cost of materials plus opportunity cost of labour (Section 1.2.6 of the *Technical Note: Flood CBA Tool* for one method of calculating this).	Survey.
Government emergency response costs	• Cost of materials plus opportunity cost of labour • Opportunity cost of volunteer labour[20] • Use qualitative assessment if required (further research is required to develop standard parameters)	• Government data • Survey of volunteer organisations (very large or significant initiatives only)
Indirect		
Business disruption and loss	Loss of operating profits of disaster affected businesses less any gains in operating profits of firms that are not disaster affected.	• Local industry structure • Survey of local businesses (turnover and margins)
Loss of public services and utilities	• School days lost (partially offset by remote learning days) • Loss of parent working days (partially offset by remote working days) • Sum of the repair costs for capital replacement and for resuming operations • Use qualitative assessment if required	• School data • Service provider data
Relocation and alternative accommodation	• Moving cost (equivalent accommodation) • Moving cost plus rent differences (inferior accommodation) • Moving cost plus overall fall in housing market rental values (no accommodation resulting in more crowded housing) • Use qualitative assessment if required (incremental impacts likely to be small)	Stated preference survey (very large or significant initiatives only).
Transport	• Increased vehicle operating cost • Value of time for delayed people and freight	See TfNSW Economic Parameter Values for guidance.

[20] Using the opportunity cost of labour should be limited to the context and supported by strong evidence. Using it outside of that context creates risks and is likely to be inaccurate. One way to estimate this is using the Average Weekly Earnings ABS data. The *full-time adult average weekly ordinary time earnings* in November 2022 and dividing by the number of working hours in a week.

Government emergency response costs[21]

During and following a disaster, governments may incur a wide of range of emergency response costs, such as search, rescue and evaluation, providing shelter and food, repairing infrastructure and clean-up. Volunteers participate in many of the above activities as well. Extreme events may also draw military, Commonwealth Government, interstate, and overseas support.

Treatment of Commonwealth Government funding

Where Commonwealth funds are received for an initiative:

- If funding ***would have been received by New South Wales regardless of whether the initiative proceeds,*** for example for an alternative initiative, it should be treated as a cost, as with NSW Government funding. This is because the funds have an opportunity cost equal to the full value of the funds.
- If funding ***will only be received if the initiative proceeds,*** the value of the funds can offset against the cost of the initiative. In this case, the Commonwealth funds carry no opportunity cost. For transparency purposes, the CBA Guide recommends a sensitivity test to treat Commonwealth funding as New South Wales state funding, in order to understand the difference in results from a state and national perspective.

Alternative accommodation and relocation costs

Damage to residential buildings forces households to seek alternative accommodation during and following a disaster. Not all costs of alternative accommodation are an aggregate economic cost. Like business disruptions, the loss of rental income for a landlord (or imputed rent for a homeowner) is likely to be partially offset by gains to other landlords.[22] If rental values increase after a disaster due to a reduction in available housing supply, the increased rents would also be a transfer from the household to the landlord, rather than an incremental increase. Care should be taken to avoid double counting these impacts, however they may be included in a CBA to help illustrate the flow of costs and benefits between groups.

If a household were to find alternative accommodation that provided equal utility, the welfare impact would be limited to the cost of relocating and the inconvenience of living without one's belongings. Households staying temporarily with friends or family likely also create welfare impacts due to crowding and inconvenience, however, these will be difficult to quantify.

3.6.2 Valuing intangible benefits

Intangible impacts can be valued using non-market methods, such as revealed and stated preference (see Table 8 for an overview and Appendix A2.2 of the CBA Guide for further details about non-market valuation methods). Benefit transfer draws valuations from existing studies to provide proxy values (see also benefit transfer checklist in Appendix 2 of the CBA Guide). The Value Tool for Natural Hazards guidelines (BNHCRC) (Department of Industry, Science, Energy and Resources, 2019) provides a range of peer-reviewed, non-market value estimates related to natural hazard management.

[21] For more information on government emergency response costs, refer to:

- https://www.disasterassist.gov.au/disaster-arrangements/disaster-recovery-funding-arrangements. The Disaster Recovery Funding Arrangements categorises Commonwealth assistance into four categories (A-D).
- https://www.nsw.gov.au/sites/default/files/2022-02/nsw-disaster-assistance-guidelines-dag-2021.pdf. The NSW Disaster Assistance Guidelines outlines a range of post-disaster assistance measures targeted to five groups.

[22] The extent of this offset will likely determine on the availability of unused or underutilised property. There will likely be an overall reduction in aggregate rents paid within the economy.

Table 8: Valuation methods of intangible values

Typical impact category	Valuation methods
Direct	
Mortality and injury	Value of statistical life: $5.3 million per fatality (2022 dollars) (Commonwealth Department of the Prime Minister and Cabinet, 2022).
Loss of amenity	• Contingent valuation (stated preference survey) • Travel cost • Hedonic pricing • Benefit transfer • Qualitative assessment (if impractical to quantify)
Environmental damage	• Often not quantified or assessed qualitatively • Contingent valuation (stated preference survey) or benefits transfer could be considered as relevant
Loss of cultural connection and sites	• Contingent valuation (stated preference survey) • Travel cost • Benefit transfer • Qualitative assessment (if impractical to quantify)
Indirect	
Mental health[23]	• Value of statistical life • Clinical measure • Healthcare usage • Productivity loss
Social disruption	• Contingent valuation (stated preference survey) • Benefit transfer • Qualitative assessment (if impractical to quantify)

3.7 Step 6: Assess net benefit with sensitivity analysis

3.7.1 The central estimate and discount rate

A central estimate of BCR and NPV[24] should be produced using the:

- central real social discount rate set in the CBA Guide (i.e. 5 per cent)
- New South Wales referent group

[23] For information on methodologies that may be applied to flood resilience initiatives and adapted for other hazard types, refer to Section 1.2.6 of *Technical Note: Flood CBA Tool*.

[24] For more information on the detailed formular of BCR and NPV, refer to Appendix 7 of https://www.treasury.nsw.gov.au/finance-resource/guidelines-cost-benefit-analysis.

- proponent's central estimates of costs and benefits.

3.7.2 Sensitivity analysis

Sensitivity analysis should show the impacts changes in key assumptions on inputs on the NPV and BCR of each option. A realistic range of values for variables that would most significantly impact the outcome should be tested. Examples of sensitivity analyses include:

- **risks**: low and high estimates of population growth
- **assumptions**: slow and fast uptake of a new service
- **parameters**: low and high estimates from the willingness-to-pay survey informing a benefit valuation
- **discount rate**: sensitivity tests at 3 and 7 per cent, per annum.

Single parameter testing, where a variable is tested holding all others constant, is typically undertaken. Where key variables may be correlated sensitivity analysis can also be run on key variables moving at the same time, e.g. a worst- or best-case scenario.

Monte Carlo simulation (probabilistic analysis) should be considered (Section 2.3.1).

Reporting in ranges

Where benefits transfer for a willingness-to-pay (WTP) study has been conducted the full range of results should be reported and subject to sensitivity testing. This includes upper-bound and lower-bound estimates alongside a measure of central tendency (the median, mean, or mode). The upper-bound and lower-bound estimates can be described using the standard deviation. This provides richer information than a single point estimate.

3.8 Step 7: Assess distributional and equity impacts

3.8.1 Distributional analysis

Disasters can have disproportional effects on vulnerable groups. For example, the IMF (2023) found disproportional impacts on less educated, women, ethnic minorities and the young. Distributional analysis should supplement CBA to provide decision makers with information about what groups (e.g. geographic, gender, First Nations, socio-economic, government, businesses, and households) in the community experience the gains and losses.

The UK MCM Handbook uses a vulnerability analysis that assesses the likely impact of floods on households (Penning-Roswell, et al., 2013). Indicators such as number of residents, dwelling type, and approximate proportions of households in each social group are used to infer vulnerability. Vulnerability analysis of this nature may help inform distributional analysis.

3.9 Step 8: Report results and key findings

Recommendation:

Highlight the continuing possibility of extreme events using graphics and narrative, by:

- supplementing the reported mean, median, and variance with a Monte Carlo analysis showing their distribution
- explaining the likelihood of the BCR or NPV being in a certain range
- describing the effectiveness of the initiative in terms of the severity or frequency of events that it will mitigate (e.g. the initiative will protect against hazards up to a 1-in-100 year AEP or of Category-3 severity).

Core reporting to decision makers will often be based on average outcomes that do not adequately communicate the full extent of their uncertainty. A more complete picture requires information on the distribution of expected outcomes. Example statements include:

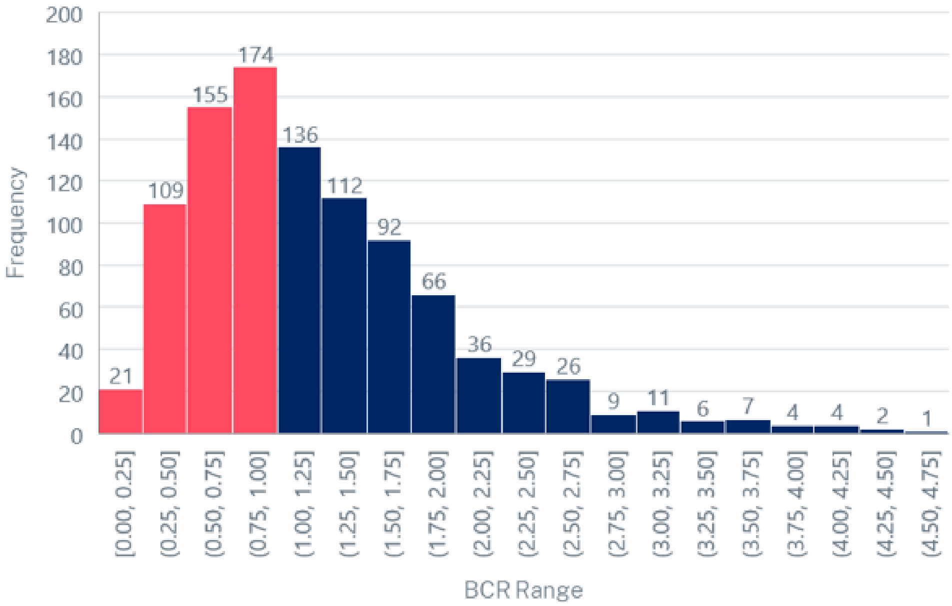
- The initiative will protect against disaster hazards up to a 1-in-500 AEP.
- The initiative will protect against disasters up to a Category-3 severity.
- The initiative has a central (expected value) BCR of 1, but a 30 per cent chance of the BCR exceeding 2, and a 10 per cent chance of the BCR exceeding 3.

Information relating to the severity of impacts, as opposed to frequency, may also be useful where the frequency is unverifiable. For example, highlighting that initiatives can produce protection against events of category three bushfires, or floods at 3-metres above the river level and below. These can be accompanied by estimates of the frequency of such events. For example, ‘this initiative would eliminate losses for floods events up to three-metres above the river level, which we currently estimate to be 1-in-200 year (0.5 per cent AEP) events’.

As established in Section 2.2.2, initiatives with similar BCRs can have different distributions of expected outcomes. The extent of upside or downside risk is of particular interest, given peoples’ tendency towards ‘loss aversion’ – the propensity to weigh losses more heavily than equivalent foregone gains. To provide greater visibility, information on the distribution of benefits, BCR or NPV can be summarised into standard statistical outputs such as:

- a table of descriptive statistics such as minimum, maximum, mean, median, standard deviation
- a histogram illustrating the distribution of values around the central estimate (Figure 12).

Figure 12: Results of a Monte Carlo simulation (histogram and table summary)



BCR Distribution Statistics	
% BCR > 1	54.70%
%BCR < 1	45.30%
Minimum	0.00
Maximum	4.65
Range	4.65
Median	1.08
Mean	1.24
Standard Deviation	0.76

Source: NSW Treasury

The content of Figure 12 could be described in simple statements that convey key concepts to readers. For example:

- *Describing the relationship between uncertainty and BCR estimates*: The BCR of this proposal is subject to substantial uncertainty regarding the timing, frequency and severity of flooding. Based on historical trends this proposal is expected deliver no net benefit. Analysis shows, however, that in 37 per cent of scenarios – where there is significant flooding – the investment could be expected to have a net benefit.
- *Description of the range of results*: Sensitivity analysis suggests that there is a 99 per cent probability that the BCR will be between 0.15 and 4.25.
- *Description of BCR distribution*: The proposal has a BCR of 1.25. But sensitivity analysis suggests that:

— There is an 87 per cent chance that the BCR will be greater than 0.5

— There is a 54 per cent chance that the BCR will be greater than 1

— There is a 14 per cent chance that the BCR will be greater than 2

— There is a 4 per cent chance that the BCR will be greater than 3

- *Placing results within context of the type of disaster (numbers below are illustrative only)*: This proposal is expected to substantially reduce the losses arising from flood events of up to 3 metres above river level, which are estimated to be a 1-in-100-year event. It will produce net social benefits if flooding of this severity occurs at any point in the appraisal period, or if there is a flood of over 1 metre (or 1-in-20-year event) within the next 20 years.

The potential effect of risk aversion on benefits can be informative where an initiative mitigates state significant risks. In these cases, risk aversion can result in people receiving some benefit in addition to the quantified value of avoided damages. A presentation of results may include reference or analysis of this potential upside.

3.10 Establish evaluation and monitoring plan

The Policy and Guidelines: Evaluation (TPG22-22) requires initiatives resourced by the NSW Government to be regularly examined to ensure they are achieving intended outcomes. Monitoring and evaluation planning should be undertaken early in initiative design. A high-level monitoring and evaluation plan is required for all submissions seeking investment of $10 million or above. Ex-post CBAs are recommended for all types of initiatives valued $50 million and higher and for pilot initiatives.

For disaster resilience initiative proposals valued over $10 million that are not supported by an ex-ante CBA, completion of an ex-post CBA is mandatory. Proposals must include planning, resourcing and an accountable party to complete an evaluation, including an ex-post CBA, within a reasonable timeframe (see Section 2.1).

Disasters happen irregularly, and monitoring and evaluating a disaster initiative may be substantially different from evaluating a standard project with regular annual costs and benefits. For example, monitoring of contextual risks is an important consideration. This would involve assessing the degree to which the initiatives have reduced contextual risks by reducing exposure and vulnerabilities, or by strengthening communities' capacities to absorb or adapt to hazards.

Monitoring and evaluation should include measures and indicators to monitor performance of the initiative, even without a disaster occurring during the assessment period. In this case, a process evaluation can be undertaken to examine the implementation and delivery of the initiative, with particular focus on its inputs, activities, and outputs.

4 Rapid assessment framework

4.1 Overview

Response and recovery initiatives are often subject to rapid approval as governments seek to provide timely support to affected communities. In such cases, a rapid assessment can provide a 'second best' process to assess options. Rapid assessment is transparent and logical and may be all that is possible where urgency is high and data not readily available.

A rapid assessment involves the four steps set out below. The assessment process should be applied flexibly and adapted according to the problem at hand.

- **Step 1:** Qualitatively assess the suitability of each measure against the principles outlined in Table 9 (below). Identify the objective, benefits, implementation requirements, outcome timeframe (immediate effect, medium term effect, long term effect), risks and disadvantages.
- **Step 2:** For initiatives assessed as likely to be suitable, using existing information conduct a preliminary CBA to estimate the likely costs and benefits with a preliminary CBA.[25]
- **Step 3:** Assign a suitability ranking to each initiative based on the qualitative and quantitative assessment in Steps 1 and 2 (Table 10 and Table 12).
- **Step 4:** Develop a monitoring regime to collect data for evaluation to and inform future initiatives. See Evaluation Workbook 2: Monitoring and Evaluation Framework for further details.

This rapid assessment can assist with practical analysis in urgent situations but does not substitute the need to complete a business case, including a CBA. Where proposals are not supported by a business case they must include planning, resourcing and an accountable party to complete an evaluation, including an ex-post CBA, within a reasonable timeframe (Section 2.1).

4.2 Application

Table 9: Government assistance principles

Principle	Criteria
1. Basic safety net	• Assists relief and recovery of households and businesses who have been severely affected as a direct result of the disaster and who are unable to recover on their own • Is the scope of the proposed measure proportionate to the impact of the disaster? • Is eligibility and assessment criteria clearly defined and robust? Is the basis for inclusion or exclusion of certain classes of households or businesses principles based? • Are there similarly affected communities not covered that could successfully seek inclusion?

[25] For more information on preliminary CBA, refer to Appendix A8.1 of https://www.treasury.nsw.gov.au/finance-resource/guidelines-cost-benefit-analysis.

Principle	Criteria
2. Complementary	• Complement (rather than substitute) the responsibilities of individuals, other government jurisdictions, insurers and asset owners • Does the initiative align with other NSW Government priorities?
3. Value for money	Value for money for taxpayer funds, balanced with speed of rollout.
4. Effectiveness	• Are there clear causal links between inputs, activities, and intended outputs, outcomes and benefits? • Is the initiative likely to achieve the desired objectives and outcomes? • Have unintended impacts been considered?
5. Promote long term resilience	Promote preparedness for future disasters.
6. Support short- and longer-term economic recovery	• Mitigate the risk of broader shocks to the economy (including the risk of recession) • Help to restore an economy by maintaining or building of capital (including human capital) so that it can return to its long-run growth trajectory
7. Deliverable	The initiative can be implemented by the responsible agency in a timely manner, substantially from using existing processes and governance arrangements.
8. Social equity	• Consider the distributional impacts of an initiative and ensure that no group or cohort is disproportionately advantaged or disadvantaged • Identify the extent to which the initiative results in winners and losers and look to address inequities. This information may influence who contributes to paying for the works and the need for compensatory measures to offset or reduce negative effects • Have the eligibility criteria been set in a way that will be seen by the community to be fair?

Table 10: Rapid qualitative assessment definitions[26]

Not suitable	Unlikely to be suitable	Potentially suitable	Likely to be suitable	Suitable
• Does not provide safety net • Duplicates other initiatives • More appropriately delivered by another level of government • Is highly costly or offers low value for money • Effectiveness of such programs has been found to be marginal or limited • Does not promote long term resilience • Does not support short- and longer-term economic recovery • Cannot be implemented without significant preparation, planning and coordination • Results in significant social inequities	• Unlikely to provide safety net • Likely to duplicate other initiatives • Could be delivered by another level of government • Such programs are usually highly costly or offer limited value for money • Effectiveness of such programs have been found to be mixed • Unlikely to support long term resilience • Unlikely to support short- and longer-term economic recovery • Cannot be implemented without significant preparation, planning and coordination • Results in some social inequities	• Can provide safety net • Potentially duplicates other initiatives • Cost can largely be controlled, and has potential to deliver value for money • Well planned, fit-for-purpose and well executed programs can be effective • Potentially promotes long term resilience • Potentially supports short-term and longer-term economic recovery • Opportunity to implement without significant preparation, planning and coordination	• Likely to provide safety net • Likely to complement other initiatives • Appropriately delivered by NSW Government • Unlikely to be excessively costly or can provide value for money • Such programs have often been effective • Likely to promote and support long term resilience • Likely to support short-term and longer-term economic recovery • Can be implemented without significant preparation, planning and coordination • Improves social inequities	• Provides basic safety net • Complements other initiatives • Most appropriately delivered by NSW Government • Such programs are generally low cost and provide significant value for money • Such programs are almost always effective • Promotes and supports long term resilience • Supports short-term and longer-term economic recovery • Can be implemented easily • Significantly improves social inequities

[26] This table aims to assist proponents to think through the principles logically for their proposed initiative It does not mean an initiative has to meet all principles to be considered, noting some principles might not be applicable for a specific initiative.

Table 11: Indicative comparison between detailed and preliminary CBA for disaster resilience initiatives

CBA Element and Section	Detailed CBA	Preliminary CBA
Decision making under uncertainty (Chapter 2)	• Detailed consideration of risk and uncertainty • Monte Carlo analysis is recommended	High level consideration of risk and uncertainty.
State the objectives – 3.2	Immediate and long-term objectives developed with community consultation where practical.	Consider as part of the government assistance principles in Table 9.
Define base case and develop options – 3.3	• Incorporate data specific to the study area where possible • Range of options modelled	• Base case: use existing data (e.g. historical flood study) • Short list of options modelled
Identify, forecast and value costs and benefits – 3.4	• All material costs and benefits included • Average annual damage modelling used where appropriate	• Focuses on the most material costs and benefits, applying simplified assumptions and standard value parameters where available • A quantitative risk assessment (e.g. average annual damage approach) required to quantify benefits relating to reduced future disaster risk • For flood initiatives, apply the Flood CBA tool
Assess net benefits with sensitivity analysis – 3.7	Standard and project-specific sensitivity testing of the key drivers of risk and uncertainty.	Standard sensitivity testing (e.g. discount rate, variation of total costs/ benefits by a certain percentage).
Assess distributional and equity impacts – 3.8	Standard and project-specific distribution analysis (e.g. age, gender, socio-economic variables, location).	Distributional impact considered qualitatively.
Report results and key findings – 3.9	Standard CBA key metrics reporting and additional reporting to reflect risk and uncertainty (e.g. Monte Carlo results).	Standard CBA key metrics reporting (i.e. BCR and NPV).

Table 12: Rapid assessment template

Initiative example	Intended outcomes and benefits	Potential risks	Net social benefit and BCR	Suitability rating
• Explain the initiative or proposal • What is the problem being solved? Be as specific as possible	• What are the objectives? Are there other options to meet the objectives? • How does the initiative assist affect individuals or businesses in New South Wales? • Does it complement other existing initiatives? • What evidence can be provided to support likely effectiveness? For example, were previous similar programs found to be effective? • How does the initiative support long term resilience • How does the initiative support short-term and longer-term economic recovery? • How will the program be implemented? • Are there winners and losers from the initiative? How is social inequity addressed?	• What are the financial and implementation risks? • How can the risks be managed? • Who will manage these risks?	Preliminary CBA conducted to calculate BCR and NPV based on valuing incremental costs (upfront and ongoing) and benefits to New South Wales consumers (users), labour, business, government or the broader community*. *Broader community (indirect impacts) comprises positive or negative spillover including environmental and social impacts **and** businesses in related markets (**but** excludes multiplier effects).	Suitable if intended benefits are likely to be achieved and risks can be managed, **and** BCR >1 (Table 10). **Note:** • BCR>1 indicates potentially suitable, likely to be suitable and suitable • BCR<1 indicates not suitable or unlikely to be suitable

5 Flood resilience guidance

5.1 Flood concepts

Before commencing a flood resilience CBA, it is important to understand and analyse flood size, severity, and risk.[27]

Flood size

A flood occurs when water exceeds the ordinary limits of a watercourse. Floods can be described in many ways, such as volume, rate of rise, flow velocity, duration, and area of extent. Small floods occur more regularly and are generally less costly than larger floods.

Floods generally occur independently, so one flood event does not change the probability of a subsequent one. Historic data is generally used to predict flood events. There is, however, only limited data available on extreme flood events; estimates rely on extrapolations and are therefore more uncertain. Climate change further reduces what we can confidently infer from the limited historical data (Section 2.2.1).

In this Framework, flood size is the probability of that flood occurring in any one year or annual exceedance probability (AEP). For example, the term '1 in 100 AEP flood' refers to a flood that has a 1:100 (or 1 per cent) chance of occurring or being exceeded in any given year. Expressed another way, it means that a person living to 80 years of age has more than a 55 per cent[28] chance of experiencing this type of flood during their lifetime. The probable maximum flood (PMF) is defined as the largest flood that could conceivably occur at a particular location.[29] Flood planning levels (FPLs) for typical residential development in New South Wales generally start with the 1 per cent AEP flood (NSW Department of Planning and Environment, 2023a).

Flood severity

Flood height and associated depths are one measure of potential flood severity. The height of floodwaters is measured as flood level, which is metres above the Australian Height Datum (AHD). They can also be measured as flood depth, which is the height of floodwaters above ground level.

Other severity measures include:

- **Flood volume**: total amount of water in the flood, which relates to both height and duration.
- **The rate of rise**: floods that rise quickly (e.g. flash floods) provide less warning time for evacuation.
- **Flow velocity**: faster flowing water causes greater risk to life, higher risk of erosion and greater damage to infrastructure. This is amplified when combined with increased depth.
- **Flood duration**: floods that have a longer duration (i.e. longer time to recede) can have greater disruption impacts to transport, business, and personal networks.
- **Flood area**: the greater the area affected by a flood, the greater its impacts.

Flood risk

Floods are the second most deadly disaster in Australia after heatwaves (Haynes, et al., 2017). Flood risk is a combination of the probability of an event happening and the consequences (impact) of its

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[27] For a one-page summary on floods, refer to Appendix A.1: Floods.

[28] Calculation: $1 - 0.99^{80} = 55.2\%$.

[29] For more information on PMF, refer to https://www.environment.nsw.gov.au/research-and-publications/publications-search/flood-risk-management-manual.

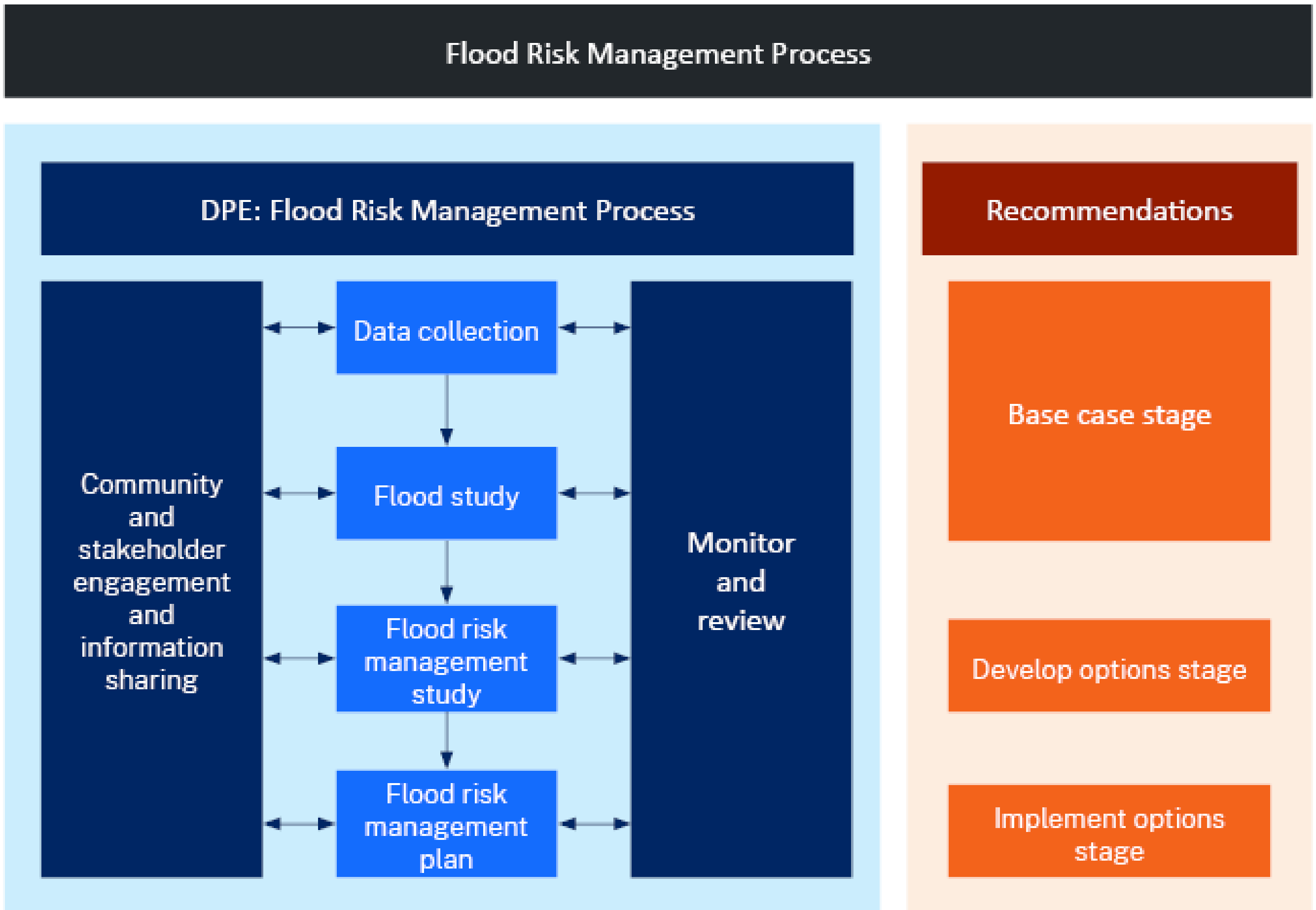
occurrence. Flood risk is dependent on there being a source of flooding, such as a watercourse, a route for the flood water, and something that is affected by the flood, such as housing or people.

The consequences of a flood depend on exposure and vulnerability. Every flood is different. People, businesses, assets, and environment should be considered in totality. In place where there are lower populations, there is often more damage to the natural environment (e.g. erosion, landslip, water quality, cultural heritage). The rise, peak, and duration of a flood can all influence the consequences.

The Department of Planning and Environment's (DPE) Flood Risk Management Manual (2023) sets principles and processes, as well as roles and responsibilities of flood risk management (FRM) in New South Wales. Management of flood risks aims to provide:

- an understanding of the full range of flood behaviour and the associated flood risk (direct and indirect) to the community and how these may change over time
- the opportunity to consider whether current FRM measures are adequate
- advice on managing flood risk through FRM measures suited to community needs.

Figure 13: Flood risk management process



Source: NSW Treasury, based on DPE, 2022

5.2 Flood CBA Tool

A Flood CBA Tool has been developed to make assessment of flood mitigation initiatives faster and easier. It may be used to:

- calculate AAD based on a series of standard parameters
- estimate risk-to-life, mental health, clean-up costs and indirect commercial costs
- undertake a sensitivity analysis and Monte Carlo analysis.

Technical Note: Flood CBA Tool supplements this section and includes an overview of the Flood CBA Tool, a worked example, and a user manual. Box 10 summarises an example application of the Flood CBA Tool.

Box 10: Case study – Flood CBA Tool

A township in New South Wales is seeking to undertake flood mitigation. Four options are under consideration: a levee, house raising, a warning system, and an agricultural levee extension. The Flood CBA Tool was used to calculate the AAD for the base case of $2.5 million and the four project options (Figure 14: Case study – AAD calculation for the base case and all options). Calculated CBA results are displayed in Table 13.

Figure 14: Case study – AAD calculation for the base case and all options

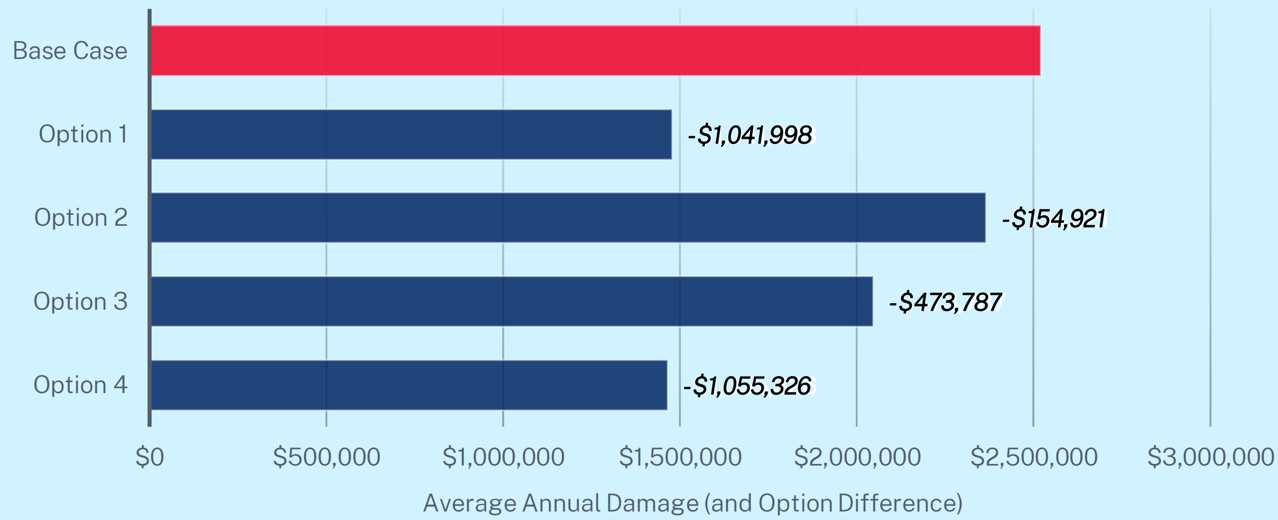


Table 13: Case study – CBA result

Option	PV Costs	PV Benefits	NPV	BCR
1. Levee	$3,209,764	$15,523,261	$12,313,497	4.8
2. House raising	$1,708,333	$2,268,116	$559,783	1.3
3. Warning system	$6,383,492	$6,936,444	$552,952	1.1
4. Agriculture levee extension	$8,360,289	$16,155,575	$7,795,286	1.9

The Monte Carlo method (1,000 simulations) was also applied to each option, in order to determine the probability of feasibility:

- Option 1: 77 per cent of simulations have a positive NPV, which is indicative of project feasibility
- Option 2: 47 per cent of simulations have a positive NPV, which indicates that the project is not economically feasible
- Option 3: 35.7 per cent of simulations have a positive NPV, which indicates that the project is not economically feasible
- Option 4: 63.5 per cent of simulations have a positive NPV, which is indicative of project feasibility.

Option 1 (levee) had the highest BCR as well as the highest probability of feasibility, followed by Option 4 (agricultural levee extension). Option 2 (house raising) and Option 3 (warning system) had positive BCRs, however probability of feasibility suggests the options have a lower than 50 per cent chance of delivering a net benefit, highlighting the importance of considering BCR results alongside results of Monte Carlo analysis.

Section 2 of the *Technical Note: Flood CBA Tool* provides further details of this worked example.

Source: Summary of detailed case study from Section 2 of the *Technical Note: Flood CBA Tool*.

5.3 Flood resilience CBA considerations

5.3.1 Define base case and develop options

Defining a base case and developing options for a flood resilience initiative follows a process of data collection, flood study, flood risk management study (FRM study) and flood risk management plan (FRM plan). This involves the analysis of flood hazard, exposure, and vulnerability of the study area.

Flood study

Recommendation:

Use a flood study to define flood behaviour and inform risk assessment within the study area as part of the base case development.

A flood study should inform assessment of flood risks and provide the basis for forecasting effects of proposed flood resilience initiatives. Flood studies require specialised technical expertise and may involve examining catchment hydrology, floodplain hydraulics and post-processing of model information (mapping products) over a wide range of flood levels (NSW Department of Planning and Environment, 2023a). Flood studies are often commissioned by local councils.

A flood study aims to define flood behaviour in sufficient detail to support the understanding and management of flood risk. It is a comprehensive technical investigation that looks at the variation of flood levels over time, the extent and velocity for flood events of various severities and impacts of climate change.

Flood Risk Management Study and Plan[30]

Recommendation:

Conduct Flood Risk Management (FRM) Studies to support FRM Plans to inform options development and assessment.

A FRM Study aims to identify, quantify, and weigh the relevant risks to the community and the potential for different options to manage these risks, considering any negative impacts they may create (NSW Department of Planning and Environment, 2023a). It provides a basis for assessing options against a range of performance criteria related to their effectiveness, efficiency, practicality, feasibility, and community and environmental impacts. In most cases these investigations aim to provide recommendations for a range of measures that together mitigate flood risks. The recommendations of the FRM Study would inform an FRM plan.

5.3.2 Options development

Table 14 provides potential flood resilience options that may be considered as part of an FRM Study.

[30] For more information and details on the Floor Risk Manage Study and Plan, refer to https://www.environment.nsw.gov.au/research-and-publications/publications-search/flood-risk-management-manual.

Table 14: Flood resilience option types and examples

Option Types	Examples
Flood modification measures	• Flood mitigation dams • Levees • Waterway or floodplain modifications • Stormwater runoff and drainage systems • Other catchment management
Property modification measures	• Landfilling[31] • Flood proofing • House raising • Property purchase or relocation schemes
Response modification measures	• Evacuation route upgrades • Flood warnings • Flood education and community engagement programs
Regulatory options	• Land use planning or revised land use zoning • Building standard reforms
Finance options	• Temporary financial support for affected businesses and households

Flood mitigation measures should not be a catalyst for additional residential development. For example, raising a levee around a town to reduce flood risk for existing residents may protect development within but additional development may increase aggregate exposure to the remaining risks that the levee does not protect against.

5.3.3 Quantifiable benefits

Quantifiable benefits for a flood resilience initiative are set out in Table 15, accompanied by a summary of default values used within the Flood CBA Tool. These are subject to available data sources, broader research, expert opinion, and literature.

[31] Established with appropriate planning and support to deal with waste (i.e. opportunity to reuse or recycle flood affected waste).

Table 15: Benefit types and examples

Type: Example[32]	Description and potential quantification approach	Default Parameters used within the *Flood CBA Tool*[33]
Direct Tangible: Avoided residential property and content damages (structural, internal and external)	Avoided property damage costs due to external and internal flooding. Data is needed on the ground and floor level of each property for accurate measurement as internal flooding causes most damage. Stage-Damage Curves calculate the amount of damage that is incurred for a property, using inputs such as land use type, building types, and flood characteristics such as depth and velocity.	Property sizes (floor area, per m^2): • Detached dwelling (single and double storey): 90 (small), 180 (medium), 240 (large), 220 (default) • Unit or apartment: 100 • Townhouse: 160 Structural replacement value (per m^2): • Detached dwelling (single storey): $2,280 • Detached dwelling (double storey): $2,620 • Unit: $2,730 • Townhouse: $2,620 Contents value for residential properties (per m^2): $550. External damage for residential properties (if ground flood depth exceeds 0.3 metres): $17,000 Damage downscale for units and townhouses: 30% Section 1.2.2 of *Technical Note: Flood CBA Tool* provides residential damage curve default values.

32 There may be overlap between some categories for some benefits (e.g. mental health impacts can be direct and indirect). This is a non-exhaustive list of recommended parameters to quantify, as appropriate.

33 For more information and details of how these values are estimated and the application of these values in flood resilience initiative CBAs, refer to *Technical Note: Flood CBA Tool*. These parameters may be applied to other flood resilience CBAs as appropriate.

Type: Example[32]	Description and potential quantification approach	Default Parameters used within the *Flood CBA Tool*[33]
Direct Tangible: Avoided commercial and industrial property and content damages	Commercial property damage depends on use. For instance, an electronics retailer would be expected to incur higher damages than a grocer. *MM01* provides a practical approach categorising commercial property damage based on commercial use. The stage damage curve for commercial property is based on the square metreage of each property, which can be sourced from the local council. Data on the ground and floor levels of each property is also needed to determine when flooding overtops the external and internal components of the structure.	Property sizes (floor area, per m^2), non-residential buildings: • Average (default): 418 • Low-to-medium value: 186 • Medium-to-high value: 650 • School: 17,000 • Hospital: 28,000 • Other public (government) buildings: 2,200 Section 1.2.3 of *Technical Note: Flood CBA Tool* provides commercial damage curve default values.
Direct Tangible: Avoided public infrastructure property and content damages	Public assets and infrastructure include high value assets such as bridges, roads, railways, and utility infrastructure (e.g. sewerage system, transmission lines and underground cabling). Valuing infrastructure damage can be challenging. One approach is to apply an uplift to residential damages. Practitioners may also estimate the total replacement value of the asset and account for the AEP level at which the asset is inundated. Assets may fall into multiple AEP levels depending on the scale and nature of the asset, as well as the land that it encompasses. Additional detail may be needed to apportion asset replacement values across each AEP level. Geoscience Australia has developed the National Exposure Information System (NEXIS) dataset to capture exposure information for physical infrastructure assets and populations. Future improvements to the dataset will aim to provide replacement values for infrastructure assets at the local government level (Geoscience Australia, 2022).	Infrastructure damage uplift of total residential damage: 10% (drops to 5% if road damage is considered). External damage, road repair cost (per m^2): $5.65. Section 1.2.4 of *Technical Note: Flood CBA Tool* provides public buildings stage-damage curve default values.

Type: Example [32]	Description and potential quantification approach	Default Parameters used within the *Flood CBA Tool* [33]
Direct Tangible: Avoided transport damage (roads, railways, train stations, bridges)	Transport infrastructure is vulnerable to flood damage, particularly when inundated for prolonged periods (Bureau of Transport Economics, 2001). Direct impacts include the cost of reconstruction and removing debris (The World Bank, 2016) as well as damage to the underlying structures (Tao & Mallick, 2020). Semi-rural and rural roads tend to be less resilient to flood damage, as they typically use more cost-effective materials.	External damage, road repair cost (per m^2): $5.65. Section 1.2.4 of *Technical Note: Flood CBA Tool* provides further guidance.
Direct Tangible: Avoided vehicle damages	Flood water can compromise a vehicle's structural and electrical integrity leading to them being written off. Both commercial and private use vehicles should be considered.	May be included as a bespoke element.
Direct Tangible: Avoided agricultural losses (crops and livestock)	Loss of crops and livestock will depend on the type of crop and the nature and duration of the flooding event. The season can also be relevant, as a crop has a higher value prior to harvest than when just planted. Under extended conditions of inundation, fungal and bacterial pathogens can further impact the crop, including through soil borne diseases. An agricultural profile of the study area is required. The Australian Exposure Information Platform provides a summary of agriculture commodities by region. Other damage may include on-farm infrastructure and equipment, fences (external and internal), access roads, motors, tractors and sheds.	Agriculture commodity (expected annual output per ha, per year): • Broadacre crops: $996 • Hay: $1,584 • Nurseries, cut flowers or cultivated turf: $141,552 • Fruit and nuts (excl. grapes): $21,216 • Grapes: $10,274 • Vegetables: $47,115 • Total crops (overall figure): $1,223 • Livestock: $180 Crop damage may be estimated based on duration of waterlogging (Section 1.2.5 of *Technical Note: Flood CBA Tool*). Other damage may be included as a bespoke element.

Type: Example[32]	Description and potential quantification approach	Default Parameters used within the *Flood CBA Tool*[33]
Direct Tangible: Avoided emergency services costs	Reduction in emergency service costs, such as evacuations, rescues and supply of essential goods and services represent avoided costs to government (Section 3.6.1).	Emergency management costs may be included, when supported by robust data.
Direct Tangible: Avoided clean-up costs	Clean-up costs relate to the time (opportunity cost of labour) and materials involved in cleaning up a property (residential or commercial). Estimated costs should reflect the extent of expected damage (e.g. ground floor flooding only).[34]	Residential clean-up if affect by over-floor flooding (per property): $4,500. Non-residential clean-up cost and loss of trading: 30% of direct damage.
Direct Intangible: Avoided mortality and injury	Floods have recorded one of the highest instances of fatalities, injuries and morbidities, among disasters in Australia (Commonwealth of Australia, 2020a). Cost estimates should include the likely injury and loss of life. One method is the UK DEFRA Wallingford method, which estimates the potential reduction in risk to life associated with changes to flood behaviour (such as flood hazard: H1-H6[35]). The method can be used to estimate losses across a study area but should not be used to estimate risk to life at the property scale.	Value of statistical life (Commonwealth Department of the Prime Minister and Cabinet, 2022) 2022 dollars: • Fatality: $5.3 million. • Injury: $52,962 (based on a reduction weightage).
Direct Intangible: Avoided environmental damages	Floods may lead to changes in environmental resources or environmental deterioration (Meyer, et al., 2013). Floods may also have regenerative effects on the environment, for example by redistribution of topsoil. These impacts are seen as part of a natural cycle of events are generally not included in CBA. Where environmental damage causes disruption to human and business activity not counted elsewhere in the framework, it may be considered under other cost categories (Bureau of Transport Economics, 2001).	N/A

[34] For more information on safety and health costs, refer to https://www.nsw.gov.au/floods/recovery/clean-up-advice.

[35] For more information on flood hazard, refer to Figure 6 in https://knowledge.aidr.org.au/media/3518/adr-guideline-7-3.pdf.

Type: Example [32]	Description and potential quantification approach	Default Parameters used within the *Flood CBA Tool* [33]
Indirect Tangible: Avoided business activity interruptions and loss of production	Lost production and forgone profit (difference between the price that a producer would have received and the marginal cost of production) due to business disruption. Lost production does not include damaged inputs or inventory, as these would have already been accounted for in commercial property and contents damage. Displacement should be considered as some lost production may be picked up by a non-flood affected business (e.g. revenue lost by a supermarket in a flood zone may be offset by increased revenue to another supermarket. Some businesses may benefit, particularly if their goods or services are related to flood recovery.	Non-residential indirect costs, comprising of clean-up costs and loss of trading: 30% of direct damages.
Indirect Tangible: Avoided service losses (damage to infrastructure and telecommunication networks)	Traffic delays may be quantified based on increased operating costs from additional fuel and wear and tear and travel time costs for road users. See TfNSW Economic Parameter Values for guidance Disruption of school services due to school closures could be measured by number of school days lost. This may, however, be partially offset by remote learning. Some parents may be forced to take time off work, resulting in loss of earnings and value of output associated with workdays, however this may be partially offset by increased remote working or other workers being asked to take on more hours. Disruption to school services and other public utilities should be discussed qualitatively if quantification not possible.	N/A
Indirect Tangible: Avoided accommodation and relocation costs	Costs such as lost rental income should be treated as a transfer. (Section 3.6.1) Cost of relocating and associated inconvenience should be discussed qualitatively if quantification not possible.	Relocation cost (per week): $0

Type: Example [32]	Description and potential quantification approach	Default Parameters used within the *Flood CBA Tool* [33]
Indirect Intangible: Avoided stress, mental health and other health related impacts	Impacts may be estimated based on the cost of treatment, cost of work absenteeism and presenteeism and estimated increased prevalence due to floods. Longer displacements and higher levels of direct damage are associated with greater mental health impacts than brief displacements (Shih, 2022). Further details are provided in *Technical Note: Flood CBA Tool*.	Mental health impacts based on food level, cost per household (2022 dollars): • <30cm: $5,331 • 30 to 100cm: $8,586 • >100cm: $11,651
Indirect Intangible: Avoided loss of social and cultural values	Loss of cultural heritage can be difficult to quantify (Bubeck, et al., 2017). Estimation methods depend on the specific scenario and damages. Potential for negative unintended consequences should be considered.	May be included as a bespoke element, based on benefits transfer or stated preference surveys.

5.3.4 Sensitivity analysis

Table 16 provides examples of common sensitivity tests for flood resilience initiatives.

Table 16: Examples of common sensitivity tests for flood resilience initiatives

Sensitivity category	Examples (non-exhaustive list) [36]
Developments	• No new developments in the floodplain • Moderate levels of developments in the floodplain • Development to continue at a set rate
Discount rates (p.a.)	3 per cent and 7 per cent (5 per cent p.a. being the central discount rate).
Residential damages	If guided by evidence-based assumptions, other methods of quantifying residential damages. Otherwise, the following parameters and assumptions can be varied: • Property replacement value • Average value of contents • External damage value • Clean-up costs
Flood levels	List damages associated with each flood level as opposed to an expected value.
Representation Concentration Pathways (RCP) or	• RCP: 1.9 to 7 • SSP: 1 to 5

[36] The examples provide high level guidance on sensitivity category and should be tailored to the context of the initiative. This should be guided by research and evidence or at minimal by the reasonableness check.

Sensitivity category	Examples (non-exhaustive list)[36]
Shared Socio-Economic Pathways (SSP) emission scenarios[37]	
Timing of climate scenarios	Near-term, short-term, and long-term timing of impacts.
Critical infrastructure damage[38]	• Electricity damage estimates • Water plant damage estimates • Telecommunications damage estimates
Fatality differences	Low, medium, and high estimation curves.
Evacuation responses	Varying percentages of evacuation possibilities e.g. 20–100 per cent in 20 percentage point increments.
Cost variances	Low, medium, and high-cost estimates for the initiative (guided by P50, P90 etc.).
Benefit variances and sensitivity testing	Low, medium, and high estimates (guided by expected values).

[37] For more information on RCP and SSP refer to https://www.ipcc.ch/report/ar6/wg2/chapter/annex-ii/

[38] Critical infrastructure is defined as the assets, systems and networks required to maintain the security, health and safety and economic prosperity of New South Wales. These are underpinned by the organisation and people that support them.

6 References

AdaptNSW, 2022. *Community grants for climate change adaptation.* [Online]
Available at: https://www.climatechange.environment.nsw.gov.au/community-grants

AusAUD, 2005. *Economic Impact of Natural Disasters on Development in the Pacific; Volume 2: Economic Assessment Tools.* [Online]
Available at: http://repository.usp.ac.fj/4606/1/Economic_Assesment_Tools.pdf

Australian Department of Home Affairs, 2018. *National Disaster Risk Reduction.* [Online]
Available at: https://www.homeaffairs.gov.au/emergency/files/national-disaster-risk-reduction-framework.pdf

Australian Government, 2021. *Australia's long-term emissions reduction plan.* [Online]
Available at: https://www.dcceew.gov.au/sites/default/files/documents/australias-long-term-emissions-reduction-plan.pdf

Australian Institute for Disaster Resilience, 2019a. *Australian Emergency Management Arrangements Handbook.* [Online]
Available at: https://knowledge.aidr.org.au/resources/handbook-australian-emergency-management-arrangements/

Australian Institute for Disaster Resilience, 2019b. *Health - south-eastern Australia heatwave.* [Online]
Available at: https://knowledge.aidr.org.au/resources/health-heatwave-south-eastern-australia-2009/

Australian Institute for Disaster Resilience, 2022a. *Bushfires - Black Summer.* [Online]
Available at: https://knowledge.aidr.org.au/resources/black-summer-bushfires-nsw-2019-20/

Australian Institute for Disaster Resilience, 2022b. *East Coast Low & storm, 2016.* [Online]
Available at: https://knowledge.aidr.org.au/resources/storm-nsw-east-coast-low-storm-2016/

Australian Institute for Disaster Resilience, 2022c. *Knowledge Hub: Collections.* [Online]
Available at: https://knowledge.aidr.org.au/collections/

Australian Institute for Disaster Resilience, 2022c. *Sydney hailstorm, 1999.* [Online]
Available at: https://knowledge.aidr.org.au/resources/storm-sydney-1999/

Australian Local Government Association, 2022. *Building better roads will prevent another $3.8 billion blowout.* [Online]
Available at: https://alga.com.au/building-better-roads-will-prevent-another-3-8-billion-blowout/

Babicky, P., Seebauer, S. & Thaler, T., 2021. Make it personal: Introducing intangible outcomes and psychological sources to flood vulnerability and policy. *International Journal of Disaster Risk Reduction,* Volume 58.

Ball, J. et al., 2022a. *Australian Rainfall & Runoff (ARR).* [Online]
Available at: https://data.arr-software.org/

Ball, J. et al., 2022b. *Australian Rainfall and Runoff (ARR).* [Online]
Available at: https://arr.ga.gov.au/

Bradstock, R., 2010. A biogeographic model of fire regimes in Australia: current and future implications. *Global Ecology and Biogeography,* Issue 19, pp. 145-158.

Bubeck, P., Otto, A. & Weichselgartner, J., 2017. Societal Impacts of Floods Hazards. *Oxford Research Encyclopedia of Natural Hazard Science.*

Budina, N., Chen, L. & Nowzohour, L., 2023. *Why Some Don't Belong - The Distributional Effects of Natural Disasters.* [Online]
Available at: https://www.imf.org/en/Publications/WP/Issues/2023/01/07/Why-Some-Dont-Belong-The-Distributional-Effects-of-Natural-Disasters-527859

Bureau of Meteorology, 2023. *Understanding heatwaves.* [Online]
Available at: http://www.bom.gov.au/australia/heatwave/knowledge-centre/understanding.shtml

Bureau of Transport Economics, 2001. *Economic Costs of Natural Disasters in Australia.* [Online]
Available at: https://www.bitre.gov.au/publications/2001/report_103

CDEMA, 2021. *Multi-hazards risk.* [Online]
Available at: https://www.cdema.org/virtuallibrary/index.php/charim-hbook/methodology/5-risk-assessment/5-4-multi-hazards-risk

Climate Adapt, 2012. *Costs of Natural Hazards.* [Online]
Available at: https://climate-adapt.eea.europa.eu/en/knowledge/adaptation-information/research-projects/conhaz/index_html

Climate Council, 2019. *Sydney heatwave affects air quality.* [Online]
Available at: https://www.climatecouncil.org.au/sydney-heatwave-affects-air-quality/

Climate-KIC Australia, 2020. *Climate Measurement Standards Initiative - Summary for Executives.* [Online]
Available at: https://uploads-ssl.webflow.com/5f1bdaf710347301b0c01fd4/5f5c2f4cc0d8e1f3b153e99c_CMSI%20-%20Summary%20for%20Executives.pdf

Coates, L. et al., 2014. Exploring 167 years of vulnerability: An examination of extreme heat events in Australia 1844–2010. *Environmental Science & Policy,* 42(1), pp. 33-44.

Coates, L. et al., 2022. Heatwave fatalities in Australia, 2001–2018: An analysis of coronial records. *International Journal of Disaster Risk Reduction,* Volume 67.

Commonwealth Department of Home Affairs, 2020. *Disaster Recovery Funding Arrangements 2018.* [Online]
Available at: https://www.disasterassist.gov.au/disaster-arrangements/disaster-recovery-funding-arrangements

Commonwealth Department of the Prime Minister and Cabinet, 2022. *Best Practice Regulation Guidance Note Value of statistical life.* [Online]
Available at: https://oia.pmc.gov.au/sites/default/files/2022-09/value-statistical-life-guidance-note.pdf

Commonwealth of Australia, 2020a. *Royal Commission into National Natural Disaster Arrangements Report.* [Online]
Available at: https://naturaldisaster.royalcommission.gov.au/

Commonwealth of Australia, 2020b. *Chapter 2: Natural disaster risk.* [Online]
Available at: https://naturaldisaster.royalcommission.gov.au/publications/html-report/chapter-02

Community Research and Development Information Service, 2012. *Final Report Summary - CONHAZ (Costs of Natural Hazards).* [Online]
Available at: https://cordis.europa.eu/project/id/244159/reporting

CSIRO, 2020. *Floods - Bushland and agriculture.* [Online]
Available at: https://www.csiro.au/en/work-with-us/industries/agriculture/bushland-and-agriculture

Deloitte, 2013. *The economic cost of the social impact of natural disasters.* [Online]
Available at:
http://australianbusinessroundtable.com.au/assets/documents/Report%20-%20Social%20costs/Report%20-%20The%20economic%20cost%20of%20the%20social%20impact%20of%20natural%20disasters.pdf

Department of Industry, Science, Energy and Resources, 2019. *Value Tool for Natural Hazards.* [Online]
Available at: https://tools.bnhcrc.com.au/wtp/home

Department of Infrastructure, Planning and Natural Resources, 2005. *Floodplain Development Manual.* [Online]
Available at: https://www.environment.nsw.gov.au/-/media/OEH/Corporate-Site/Documents/Water/Floodplains/floodplain-development-manual.pdf

Environment and Climate Change Canada, 2022. *Understanding Shared Socio-economic Pathways (SSPs).* [Online]
Available at: https://climatedata.ca/resource/understanding-shared-socio-economic-pathways-ssps/

Geoscience Australia, 2022. *National Exposure Information System (NEXIS).* [Online]
Available at: https://www.ga.gov.au/scientific-topics/national-location-information/nexis

Grain Producers Australia, 2022. *Farm Biosecurity in the event of a natural disaster.* [Online]
Available at: https://grainsbiosecurity.com.au/app/uploads/2022/02/Farm-biosecurity-factsheet.pdf

Hallegatte, S. et al., 2012. Investment Decision Making Under Deep Uncertainty -- Application to Climate Change. *World Bank Policy Research Working Paper No. 6193* .

HM Treasury, 2022. *The Green Book.* [Online]
Available at: https://www.gov.uk/government/publications/the-green-book-appraisal-and-evaluation-in-central-governent/the-green-book-2020

Hori, H., 2000. *The largest hailstorm in our history: The combat agency's perspective on command & control.* [Online]
Available at: https://www.ses.nsw.gov.au/media/2541/the_largest_hailstorm_in_our_history.pdf

Hudson, P. & Botzen, W., 2019. Cost–benefit analysis of flood-zoning policies: A review of current practice. *WIREs Water.*

Hugenbusch, D. & Neumann, T., 2016. *Cost-Benefit analysis of disaster risk reduction.* [Online]
Available at: https://www.preventionweb.net/publication/cost-benefit-analysis-disaster-risk-reduction-synthesis-informed-decision-making

Infrastructure Australia, 2021. *A Pathway to Infrastructure Resilience.* [Online]
Available at: https://www.infrastructureaustralia.gov.au/publications/pathway-infrastructure-resilience-0

Infrastructure NSW, 2022. *Staying Ahead: State Infrastructure Strategy 2022-2042.* [Online]
Available at: https://www.infrastructure.nsw.gov.au/media/3503/state-infrastructure-strategy-2022-2042-full-report.pdf

Intergovernmental Panel on Climate Change, 2012. *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation.* [Online]
Available at: https://www.ipcc.ch/report/managing-the-risks-of-extreme-events-and-disasters-to-advance-climate-change-adaptation/

Intergovernmental Panel on Climate Change, 2023. *IPCC - Intergovernmental Panel on Climate Change.* [Online]
Available at: https://www.ipcc.ch/

Kappes, M. S., Keiler, M., Elverfeldt, K. v. & Glade, T., 2012. Challenges of analyzing multi-hazard risk: a review. *Natural Hazards,* pp. 1925-1958.

Keen, S., 2021. The appallingly bad neoclassical economics of climate change. *Globalizations,* pp. 1149-1177.

Kulp, S. & Strauss, B., 2019. New elevation data triple estimates of global vulnerability to sea-level rise and coastal flooding. *Nat Commun,* Issue 10.

Lawrence, J. et al., 2022. *Australiasia. In: Climate Change 2022: Impacts, Adaptation, and Vulnerability.* [Online]
Available at:
https://www.ipcc.ch/report/ar6/wg2/downloads/report/IPCC_AR6_WGII_SummaryVolume.pdf

Lenton, T. et al., 2019. Climate tipping points - too risky to bet against. *Nature,* pp. 592-595.

McGhee, R. & Semmler, E., 2023. *Bruce Highway on track to be flood resilience, but may never be flood-proof.* [Online]
Available at: https://www.abc.net.au/news/2023-01-20/bruce-highway-upgrades-flood-resilience-severe-weather/101868590

Meat & Livestock Australia, 2022. *Flood recovery.* [Online]
Available at: https://www.mla.com.au/research-and-development/dealing-with-natural-disasters/flood-recovery/

Mechler, R., 2016. Reviewing estimates of the economic efficiency of disaster risk management: opportunities and limitations of using risk-based cost–benefit analysi. *Natural Hazards,* Volume 81.

Meyer, V. et al., 2013. Review article: Assessing the costs of natural hazards - state of the art and knowledge gaps. *Natural Hazards and Eart System Sciences,* 13(1), pp. 1351-1373.

Moore, T., 2020. *Grantham reborn: Meet the little Queensland town that moved.* [Online]
Available at: https://www.brisbanetimes.com.au/national/queensland/grantham-reborn-meet-the-little-queensland-town-that-moved-20200227-p5450g.html

NSW Department of Planning and Environment, 2021a. *Coastal and estuary management grants awarded and project summaries.* [Online]
Available at: https://www.environment.nsw.gov.au/topics/water/coasts/coastal-and-estuary-grants/grants-awarded#:~:text=Coastal%20monitoring%20implementation%20%E2%80%93%20CoastSnap%20expansion%20%20,%20%20Planning%20%2020%20more%20rows%20

NSW Department of Planning and Environment, 2021b. *Fire facts.* [Online]
Available at: https://www.environment.nsw.gov.au/topics/fire/fire-facts

NSW Department of Planning and Environment, 2021c. *Planning for a more resilient NSW - A strategic guide to planning for natural hazards.* [Online]
Available at: https://www.planning.nsw.gov.au/sites/default/files/2023-03/planning-for-a-more-resilient-nsw.pdf

NSW Department of Planning and Environment, 2022a. *Climate change in NSW | Adapt NSW.* [Online]
Available at: https://www.climatechange.environment.nsw.gov.au/nsw

NSW Department of Planning and Environment, 2022b. *Climate change will exacerbate natural disasters, including flooding.* [Online]
Available at: https://www.climatechange.environment.nsw.gov.au/climate-change-will-exacerbate-natural-disasters-including-flooding

NSW Department of Planning and Environment, 2022c. *Current floodplain management grants.* [Online]
Available at: https://www.environment.nsw.gov.au/topics/water/floodplains/floodplain-management-grants/current-grants

NSW Department of Planning and Environment, 2022d. *Floodplain management grants awarded and project summaries.* [Online]
Available at: https://www.environment.nsw.gov.au/topics/water/floodplains/floodplain-management-grants/grants-awarded

NSW Department of Planning and Environment, 2022e. *NSW climate change adaptation strategy.* [Online]
Available at: https://www.climatechange.environment.nsw.gov.au/nsw-climate-change-adaptation-strategy

NSW Department of Planning and Environment, 2023a. *Flood Risk Management Manual.* [Online]
Available at: https://www.environment.nsw.gov.au/research-and-publications/publications-search/flood-risk-management-manual

NSW Government, 2022a. *Disaster Risk Reduction Fund.* [Online]
Available at: https://www.nsw.gov.au/emergencies/nsw-reconstruction-authority/disaster-risk-reduction-fund

NSW Government, 2022b. *NSW Disaster Assistance Arrangements.* [Online]
Available at: https://www.nsw.gov.au/disaster-recovery/disaster-recovery-funding-arrangements

NSW Government, 2022c. *Protection of the Environment Operations (Waste) Regulation 2014.* Sydney: NSW Government.

NSW Government, 2023a. *2022-23 Half-Yearly Review Treasurer's message.* [Online]
Available at: https://www.budget.nsw.gov.au/2022-23/half-yearly-review/factsheet/treasurers-message

NSW Government, 2023b. *Disaster Ready Fund.* [Online]
Available at: https://www.nsw.gov.au/emergency/nsw-reconstruction-authority/disaster-ready-fund

NSW Parliamentary Counsel's Office, 1989. *State Emergency and Rescue Management Act 1989 no 165.* Sydney: NSW Legislation.

NSW Police Force Emergency Management Unit, 2018. *State Heatwave Subplan.* [Online]
Available at: https://www.brewarrina.nsw.gov.au/f.ashx/SubPlan-HeatWave.pdf

NSW Rural Fire Service, 2017. *State Bush Fire Plan.* [Online]
Available at: https://www.nsw.gov.au/sites/default/files/2021-04/emergency-management-subplan-bush-fire.pdf

NSW Rural Fire Service, 2019. *Planning for Bush Fire Protection: A guide for councils, planners, fire authorities and developers.* [Online]
Available at: https://www.rfs.nsw.gov.au/__data/assets/pdf_file/0005/130667/Planning-for-Bush-Fire-Protection-2019.pdf

NSW Rural Fire Service, 2020. *Bush Fire Management Committee Handbook.* [Online]
Available at: https://www.rfs.nsw.gov.au/__data/assets/pdf_file/0004/176692/Bush-Fire-Management-Committee-Handbook-2020.pdf

NSW State Emergency Service, 2018. *New South Wales State Storm Plan.* [Online]
Available at: https://www.ses.nsw.gov.au/local-region-information/swr/flood-storm-and-tsunami-plans/

NSW Treasury, 2023a. *NSW Government Guide to Cost-Benefit Analysis.* [Online]
Available at: https://www.treasury.nsw.gov.au/finance-resource/guidelines-cost-benefit-analysis

NSW Treasury, 2023b. *Policy and Guidelines: Evaluation.* [Online]
Available at: https://www.treasury.nsw.gov.au/documents/tpg22-22-policy-and-guidelines-evaluation

NSW Treasury, 2023c. *Policy and Guidelines: Submission of Business Cases.* [Online]
Available at: https://www.treasury.nsw.gov.au/documents/tpg22-04-submission-business-cases

OECD, 2018. *Climate-resilient Infrastructure.* [Online]
Available at: https://www.oecd.org/environment/cc/policy-perspectives-climate-resilient-infrastructure.pdf

Office of Emergency Management, 2017a. *2017 State Level Emergency Risk Assessment Executive Summary.* [Online]
Available at:
https://www.opengov.nsw.gov.au/publications/19463;jsessionid=BFB8B618B927919F78E8A3D16881A7E4

Office of Emergency Management, 2017b. *Emergency Risk Management Framework.* [Online]
Available at:
https://media.opengov.nsw.gov.au/pairtree_root/ed/36/f9/a0/1c/6c/43/28/b5/98/8d/96/f4/71/14/ce/obj/ERM_framework.PDF

Office of Emergency Management, 2018a. *NSW Critical Infrastructure Resilience Strategy.* [Online]
Available at: https://www.opengov.nsw.gov.au/publications/19460

Office of Emergency Management, 2018b. *NSW State Emergency Management Plan.* [Online]
Available at: https://www.nsw.gov.au/rescue-and-emergency-management/state-emergency-management-plan-emplan

Office of Environment and Heritage, 2015. *Floodplain Risk Management Guide.* [Online]
Available at: https://www.environment.nsw.gov.au/-/media/OEH/Corporate-Site/Documents/Water/Floodplains/floodplain-risk-management-guide-190036.pdf

Office of Environment and Heritage, 2016. *Minimising the impacts of extreme heat: A guide for local government.* [Online]
Available at: https://www.climatechange.environment.nsw.gov.au/sites/default/files/2021-06/Minimising%20the%20Impacts%20of%20Extreme%20Heat%20-%20A%20guide%20for%20local%20government.pdf

Olsen, A., Zhou, Q., Linde, J. & Arnbjerg-Nielsen, K., 2015. Comparing Methods of Calculating Expected Annual Damage in Urban Pluvial Flood Risk Assessments. *Water,* 7(1), pp. 255-270.

Penning-Roswell, E. et al., 2013. *Flood and Coastal Erosion Risk Management - A Manual for Economic Appraisal.* 1st ed. London: Routledge.

Productivity Commission, 2014. *Natural Disaster Funding Arrangements: Productivity Commission Inquiry Report Volume 1.* [Online]
Available at: https://www.pc.gov.au/inquiries/completed/disaster-funding/report/disaster-funding-volume1.pdf

Productivity Commission, 2023. *Report on Government Services 2023.* [Online]
Available at: https://www.pc.gov.au/ongoing/report-on-government-services/2023/emergency-management/emergency-services

Queensland Reconstruction Authority, 2021. *Economic Assessment Framework of Flood Risk Management Projects.* [Online]
Available at: https://www.qra.qld.gov.au/sites/default/files/2021-05/economic_assessment_framework_of_flood_management_projects_2021_0.pdf

Rausand, M., 2020. *Norweigan University of Science and Technology.* [Online]
Available at: https://www.ntnu.edu/documents/624876/1277590549/chapt03-eta.pdf/6f3e1b19-4824-4812-adc8-9762d2201c22

Raymond, C., Matthews, T. & Horton, R. M., 2020. The emergence of heat and humidity too severe for human tolerance. *Science Advances,* 6(19).

Resilience NSW, 2021. *NSW Disaster Assistance Guidelines.* [Online]
Available at: https://www.nsw.gov.au/sites/default/files/2022-02/nsw-disaster-assistance-guidelines-dag-2021.pdf

Sewell, T. et al., 2016. Disaster declarations associated with bushfires, floods and storms in New South Wales, Australia between 2004 and 2014.. *Sci Rep.*

Shih, I., 2022. *Floods expose social inequities, and potential mental health epidemic in its wake.* [Online] Available at: https://www.sydney.edu.au/news-opinion/news/2022/03/23/floods-expose-social-inequities--and-potential-mental-health-epi.html

Shreve, C. & Kelman, I., 2014. Does mitigation save? Reviewing cost-benefit analyses of disaster risk reduction. *International Journal of Disaster Risk Reduction,* 10(A), pp. 213-235.

Spoon, J. et al., 2020. Anatomy of disaster recoveries: Tangible and intangible short-term recovery dynamics following the 2015 Nepal earthquakes. *International Journal of Disaster Risk Reduction,* Volume 51.

Stern, N., Stiglitz, J. E. & Taylor, C., 2021. The Economics of Immense Risk, Urgent Action and Radical Change: Towards New Approaches to the Economics of Climate Change. *National Bureau of Economic Research,* Volume 28472.

Tao, M. & Mallick, R., 2020. *Best Practice for Assessing Roadway Damages Caused by Flooding.* [Online] Available at: https://www.ltrc.lsu.edu/pdf/2020/FR_615.pdf

The World Bank, 2016. *Flood Risk in Road Networks.* [Online] Available at: https://openknowledge.worldbank.org/entities/publication/18d95c08-b7ab-57a3-a725-8b697375bfee

UK Department for International Development, 2011. *Defining Disaster Resilience: A DFID Approach Paper.* [Online] Available at: https://www.fsnnetwork.org/sites/default/files/dfid_defining_disaster_resilience.pdf

UNDRR, 2009. *2009 UNISDR terminology on disaster risk reduction.* [Online] Available at: https://www.undrr.org/publication/2009-unisdr-terminology-disaster-risk-reduction

UNDRR, 2021. *Climate and disaster resilient infrastructure: building resilience to future uncertainties and shocks,* Geneva: United Nations.

UNDRR, 2023a. *Climate action and disaster risk reduction.* [Online] Available at: https://www.undrr.org/climate-action-and-disaster-risk-reduction

UNDRR, 2023b. *Principles for resilient infrastructure.* [Online] Available at: https://www.undrr.org/publication/principles-resilient-infrastructure

UNDRR, 2023c. *The Report of the Midterm Review of the Implementation of the Sendai Framework for Disaster Risk Reduction 2015-2030.* [Online] Available at: https://www.undrr.org/publication/report-midterm-review-implementation-sendai-framework-disaster-risk-reduction-2015-2030

United Nations Framework Convention on Climate Change, 2023. *The Paris Agreement.* [Online] Available at: https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement

United Nations General Assembly, 2016. *Report of the open-ended intergovernmental expert working group on indicators and terminology relating to disaster risk reduction (A/71/644).* [Online] Available at: https://www.preventionweb.net/publication/report-open-ended-intergovernmental-expert-working-group-indicators-and-terminology

United Nations Office for Disaster Risk Reduction, 2015. *Sendai Framework for Disaster Risk Reduction 2015-2030.* [Online] Available at: https://www.undrr.org/publication/sendai-framework-disaster-risk-reduction-2015-2030

United Nations Office for Disaster Risk Reduction, 2022. *Understanding Disaster Risk.* [Online] Available at: https://www.preventionweb.net/understanding-disaster-risk/component-risk/disaster-risk

United Nations, 2023a. *The Sustainable Development Agenda.* [Online] Available at: https://www.un.org/sustainabledevelopment/development-agenda/

United Nations, 2023b. *The Paris Agreement.* [Online] Available at: https://www.un.org/en/climatechange/paris-agreement

van Westen, C., 2022. *5.5 Risk assessment methods.* [Online] Available at: https://www.cdema.org/virtuallibrary/index.php/charim-hbook/methodology/5-risk-assessment/5-5-risk-assessment-methods

Venton, C., 2010. *Cost Benefit Analysis for Community Based Climate and Disaster Risk Management.* [Online] Available at: https://www.preventionweb.net/files/14851_FinalCBASynthesisReportAugust2010.pdf

WMO, 2021. *Weather-related disasters increase over past 50 years, causing more damage but fewer deaths.* [Online]
Available at: https://public.wmo.int/en/media/press-release/weather-related-disasters-increase-over-past-50-years-causing-more-damage-fewer

Wood, N., Beauman, M. & Adams, P., 2021. *An indicative assessment of four key areas of climate risk for the 2021 NSW Intergenerational Report.* [Online]
Available at: https://www.treasury.nsw.gov.au/sites/default/files/2021-04/2021_igr_ttrp_-_an_indicative_assessment_of_four_key_areas_of_climate_risk_for_the_2021_nsw_intergenerational_report.pdf

Yumashev, D. et al., 2019. Climate policy implications of nonlinear decline of Arctic land permafrost and other cryosphere elements. *Nature Communications.*

Appendix A: Natural hazards overview

New South Wales is exposed to many natural hazards, including but not limited to floods, bushfires, heatwaves, coastal hazards, and storms. Natural hazards differ in nature and frequency. Table 17 provides an overview of the current natural hazard policy landscape.[39]

Table 17: The current natural hazard policy landscape

Global	Australia	New South Wales [40]
• The Paris Agreement (2015) is a legally binding international treaty on climate change • The 2030 Agenda for Sustainable Development (2015) has 17 goals covering sustainable development • The Intergovernmental Panel on Climate Change (IPCC) (2023) is the United Nations body for assessing the science related to climate change • The Sendai Framework for Disaster Risk Reduction 2015-2030 (2015) is an agreement that sets out objectives to prevent the creation of new risk, reduce existing risk and increase resilience	• The Australia's Long-Term Emissions Reduction Plan (2022) is a set of actions with the goal to reach net zero emissions by 2050 • The Australian Emergency Management Arrangements Handbook (2019) contains principles that guide emergency management • The National Disaster Risk Reduction Framework (2018) outlines a comprehensive approach to proactively reduce disaster risk	• The Emergency Risk Management (ERM) Framework (2017) and a State Level Emergency Risk Assessment (SLERA) (2017) addresses identified gaps and disparities across hazard management to improve access to information, enhance decision making and strengthen capability and capacity • The *Environmental Planning and Assessment Act 1979* (EPA Act) is the primary land use planning statute which includes principles to ensure high quality decision and planning outcomes • The NSW Climate Change Adaption Strategy (2022) sets out an approach to climate change adaptation. • The NSW State Emergency Management Plan (2018) (EMPLAN) provides a coordinated and comprehensive approach to emergency management • The *State Emergency and Rescue Management Act 1989* (SERM Act) relates to the comprehensive risk management of emergencies and rescues

[39] For a summary of natural hazards prevalence, impact, and outlook in Australia as well as some recent New South Wales examples, refer to Appendix A.6: Disaster prevalence, impact and outlook.

[40] For the current disaster resilience in infrastructure planning policy landscape, refer to Section 1.2.2.

Appendix A.1: Floods

Floods and flood risks

Floods are a natural phenomenon that occurs when water covers land that is normally dry. Flood risk to communities is created through human interaction with flooding. This occurs primarily from the occupation and use of land that is affected by flooding. Three sources of flood predominate in New South Wales – riverine, overland and groundwater flooding. Floods can have a rapid or slow onset and can prevail for a period ranging from hours to weeks. While a flood that occurs with little warning or is unexpected can be referred to as a flash flood, flash floods are formally defined as flooding that peaks within six hours of the causative rain (Bureau of Meteorology (BoM)). Catchment flooding is caused by prolonged or intense rainfall such as that associated with east coast lows. In coastal waterways, catchment flooding can coincide with coastal events resulting in altered flood behaviour potentially increasing risk.

Flood concepts

Flood magnitude is typically described in terms of frequency, the annual exceedance probability (AEP) or return period. Flood behaviour (flood extents, depths, timing, and flood function) varies across the full range of flood frequencies up to and including the probable maximum flood.

Roles and responsibilities

Primary responsibility for flood risk management rests with local councils supported by the NSW Government and may vary with location and risk. The DPE Environment and Heritage Group (EHG) provides technical, policy, and financial support to local councils to assist them in understanding and managing flood risk through the Floodplain Management Program. The NSW SES is the legislated combat agency for flooding and undertakes flood emergency response planning. The NSW Reconstruction Authority (incorporating the former Resilience NSW) has specific legislative roles in prevention, preparedness adaptation and recovery including reconstruction after disasters. DPE Water has specific legislative responsibilities for managing flooding in rural areas of the Murray Darling Basin. DPE Planning provides direction for considering flooding in land use planning. The BoM supports in the role of flood warning and flood gauge operation.

The current policy landscape in New South Wales:

- The NSW Flood Prone Land Policy (2023) is the overarching policy for managing flood risk in New South Wales. The manual for flood liable land gazetted under S-733 of the *Local Government Act 1993*, currently the Flood Risk Management Manual (NSW Department of Planning and Environment, 2023a) with the associated toolkit provides guidance on policy delivery. Councils obtain a limited legal indemnity when managing flood risk consistent with the Manual.
- The State Flood Plan (2021) is a subplan of the EMPLAN. The subplan sets out the state-wide multi-agency arrangements for the emergency management of floods.
- The *NSW Reconstruction Authority Act 2022* establish and sets out the role of the Authority.
- The Planning Circular Planning System (PS 21-006) (2021) provides advice to councils on considering flooding in land-use planning.
- The NSW Government is working to implement a range of measures that address the recommendations of the Parliamentary Select Committee Inquiry and the Independent Flood Inquiry that followed the 2022 floods.
- The *State Emergency Service Act 1989* establishes the State Emergency Service and defines its functions.

Appendix A.2: Bushfires

Bushfires and bushfire risks

Bushfire is a general term used to describe an unplanned fire in vegetation. Bushfires are a natural and essential component of the Australian environment, prevalent in most landscapes that carry fuel (e.g. grasslands, forests, scrub, and heath lands). They can have significant impact on human life, property, infrastructure, environmental, economic, cultural, agricultural and community assets. A bush or grass fire can happen at any time of the year, but the risk is higher during the warmer months, when vegetation is drier.

Bushfire concepts

The occurrence of bushfires is dependent on the simultaneous presence of four 'switches'. There needs to be sufficient vegetation (fuel); it must be dry enough to burn; the weather should be favourable for the fire to spread (i.e. presence of wind and oxygen); and there needs to be an ignition source (Bradstock, 2010). Based on the NSW and Australian Regional Climate Modelling project (NARClim), climate change has increased average severe fire weather in summer and spring.

Roles and responsibilities

The NSW RFS is the lead agency for coordinated bushfire fighting and bushfire prevention with the legal frameworks that support their activities enshrined in the *Rural Fires Act 1997* (RF Act) and EMPLAN. The RFS is supported in its role by FRNSW and fire authorities including the National Parks and Wildlife Service (NPWS) and Forestry Corporation NSW. Other stakeholders include the BoM, NSW Police Force (NSWPF), NSW Ambulance Service (NSWAS), and several utility and support organisations.

The current policy landscape in New South Wales:

- The State Bushfire Plan (2017) is a subplan of the EMPLAN. The subplan describes the arrangements for the control and coordination arrangements for bush and grass fires (NSWRFS, 2017).
- Section 63 of *Rural Fires Act 1997* outlines the responsibility of landowners and occupiers to prevent the occurrence of bushfires, and to minimise the danger of the spread of a bushfire on or from any land vested in or under its control or management.
- The Planning for Bushfire Protection (2019) guide provides development standards and guidance for designing and building on bushfire prone land (NSWRFS, 2019).
- The Bushfire Management Committee Handbook (2020) is an integral part of the framework for coordinated bushfire risk assessment, mitigation, and suppression (NSWRFS, 2020).
- In 2020, the NSW Government commissioned an independent inquiry into the cause of, preparation for, and response to the 2019-20 bushfire season.

Appendix A.3: Heatwaves

Heatwaves and heatwave risks
The BoM defines heatwave as a three-day period over which the minimum and maximum temperatures are extremely high (this is compared to the average local climate and past weather at a location) (BoM, n.d.). The impact of a heatwave relates to the ability for people to adapt to high temperatures, a key influence being on how fast high temperatures cool down and stay cool overnight. Historically, heatwaves are Australia's deadliest natural hazard in terms of loss of life (Coates, et al., 2022). They are especially dangerous for vulnerable groups such as the elderly, babies, homeless people, people with certain medical conditions and pregnant or breastfeeding women. Extreme heatwaves can also cause significant damage to infrastructure due to increased demand in the system and heat impairing the operation of generators and transmission lines in particular. Transport disruptions become more frequent. Heatwaves put pressure on hospitals and emergency services. In the 2019 heatwaves, New South Wales hospitals experienced a 14 per cent rise in admissions (Climate Council, 2019). Heatwaves are categories by intensity, being: low-intensity, severe, and extreme.
Heatwave concepts (AdaptNSW)
Climate change is a key cause of more intense, more frequent, and longer lasting heatwaves. BoM defines heatwave intensity as the hottest day of the hottest heatwave of the year and the average temperature across all heatwaves, heatwave frequency as number of heatwave events each year, and heatwave duration as the length of the longest heatwave of the year.
Roles and responsibilities
There is no nominated combat agency for a heatwave emergency (EMPLAN, 2018). The relevant Emergency Operations Controller (EOCON) takes responsibility for the response to a heatwave. Bureau of Meteorology issues warnings for Severe and Extreme level heatwaves only. These warnings follow the Australian Warning System framework and will be provided at least 4 days prior to the heatwave commencement. Five action statements are included in the warning, created in consultation with health services and emergency service partners. NSW Health are a key stakeholder in heatwave events and will provide public health advice to the relevant EOCON when extreme heat events are or have the potential to create unusual health impacts. NSW Health will supply information to the Public Information Functional Area Coordinator (PIFAC), who coordinates the distribution of warnings, information, and other advice to the community. Other agencies such as Fire and Rescue NSW, NSW Rural Fire Brigades, NSW Ambulance, Energy and Utilities Functional Area, Animal and Agricultural Services Functional area will remain in a heightened level of readiness and provide information to the relevant EOCON (Heatwave Subplan, 2018).
The current policy landscape in New South Wales:
• The State Heatwave Subplan (2018) is a subplan of the EMPLAN. The subplan sets out the coordination arrangements that will apply to heatwave events, or periods of extreme heat. • Minimising the impacts of extreme heat: A guide for local government (2016) illustrates ways to manage and minimise the impacts of extreme heat for local governments.

Appendix A.4: Coastal hazards

Coastal hazards and coastal hazard risks

Coastal hazards are a term used to refer to physical phenomena, which from time to time may expose a coastal area to the risk of property damage, injury or loss of life, or environment degradation.

The *NSW Coastal Management Act 2016* (CM Act) identifies a total of seven coastal hazards: beach erosion, shoreline recession, coastal lake or watercourse entrance instability, coastal inundation, coastal cliff or slope instability, tidal inundation, erosion and inundation of foreshores caused by tidal waters and the action of waves including the interaction of those waters with catchment floodwaters.

Coastal hazards can pose significant risks to buildings and infrastructure, lead to loss of valuable social, economic, cultural and environmental assets and/or human life.

Coastal hazard concepts

The susceptibility of locations to coastal hazards naturally varies along the coast. Some locations may only be potentially exposed to a singular hazard, whereas other locations could be exposed to several. Under climate change, the extent of and risks posed by coastal hazards are expected to increase, with projected sea level rise a critical factor in the exacerbation of these hazard risks.

Roles and responsibilities

Local Government plays a central role in the management of the coast and coastal hazards. Under the CM Act, local councils prepare and implement Coastal Management Programs (CMPs), which set out the long-term strategy for management of the coastal zone in its area. The DPE Environment and Heritage Group (EHG) provides technical, policy, and financial support to local councils to assist them in developing and implementing CMPs.

In cases where land is identified within the coastal vulnerability area and beach erosion, coastal inundation or cliff instability is occurring on that land, a CMP must also include a Coastal Zone Emergency Action Subplan (CZEAS). A CZEAS outlines the roles and responsibilities of all public authorities (including the local council) in response to emergencies immediately preceding or during periods of beach erosion, coastal inundation or cliff instability, which occurs through storm activity or an extreme or irregular event.

The NSW Government has also established the NSW Coastal Council who provide independent advice on coastal issues to the Minister administering the CM Act.

The current policy landscape in New South Wales:

- The Coastal Management Manual (2018) provides mandatory requirements and guidance for the preparation, development, adoption, implementation, amendment, and review of CMPs.
- The *Coastal Management Act 2016* sets out objectives and establishes the strategic framework for managing coastal damages in New South Wales.
- The Coastal Management Framework (2018) aims to manages the coastal environment in an ecologically sustainable way, for the social, cultural, and economic well-being of the people of New South Wales.
- The State Environmental Planning Policy (Resilience and Hazards) (2021) aims to provides planning controls for development in the coastal zone and coordination on land use planning within the coastal zone.
- The NSW Coastal Design Guidelines (2003) are being updated to guide land use planning and decision making to protect the coastline and ensure better-designed developments.

Appendix A.5: Storms

Storms and storm risks
Macquarie dictionary defines storms as a combination of strong wind accompanied by heavy fall of rain, snow, hail, thunder, and lightning, or flying sand or dust. Storms in New South Wales are predominantly thunderstorms, tornadoes, tropical cyclones (including ex-tropical cyclones), mid-latitude low-pressure systems (including east coast lows), low pressure troughs, cold fronts and southerly busters and cold outbreaks. Severe thunderstorms are the most common and most damaging type of storm in New South Wales, accounting for the great bulk of damage costs (NSW SES). The BoM defines severe thunderstorms as storms that produce hailstones with a diameter of two centimetres or more, wind gust of 90km/h or greater, flash flooding, and tornadoes.
Storm concepts – Hail
Hail is a common storm hazard for New South Wales. Hail can damage the roof and windows of buildings, damage motor vehicles, injure people and damage crops. Hail risk depends on the size, wind condition, speed, and the intensity with which it falls to the ground.
Roles and responsibilities
The NSW SES is the lead agency for storm preparation and response. The NSW SES is supported in its role by NSW RFS. Other stakeholders include BoM, NSWAS, Department of Education, NSWPF, NSWRFS, OEM, NSW NPWS, NSW Marine Rescue, Housing NSW, Surf Life Service NSW, and several utility and support organisations.
The current policy landscape in New South Wales:
• The State Storm Plan (2018) is a subplan of the EMPLAN. The subplan sets out the state-wide multi-agency arrangements for the emergency management of floods and storms. • Part 2, Section 9 of the *Emergency Service Levy Act 2017* defines that all hail damage insurance policies are liable for paying the emergency service levy. • The *State Emergency Service Act 1989* establishes the State Emergency Service and define its functions.

Appendix A.6: Disaster prevalence, impact and outlook

Table 18 gives an overview of the most common and impactful disasters in Australia with New South Wales specific examples.

Table 18: Disaster overview in Australia and New South Wales

Disaster	Prevalence and Impact (Australia wide)	Outlook (Australia wide) Source: (Commonwealth of Australia, 2020a)	New South Wales Example
Floods Source: (Commonwealth of Australia, 2020a)	• 1,911 (fatalities 1900-2015) • ~$5b (insured losses 2010-2020)	By 2090, the Australian sea level is projected to rise by between 26 and 82 cm.[41] Flooding of low lying coastal and tidal areas with increased regularity and increase rainfall events are projected to increase in intensity.	East Coast Floods, New South Wales, 2022 (NSW Flood Inquiry) Date: February and March 2022 Where: Coastal catchments along the north and mid-east coast of New South Wales What: Floods occurred along the east coast of New South Wales due to an intense and slow-moving low-pressure weather system. The worst damage occurred in the Northern Rivers and the township of Lismore. These floods led to nine fatalities and $4.3 billion in insured losses. Significant additional losses occurred to public infrastructure such as roads and facilities. Over 14,637 homes were damaged across the state with 5,303 uninhabitable. In the Lismore LGA 1,400 residences sustained major damage.
Bushfires Source: (Commonwealth of Australia, 2020a)	• 974 (fatalities 1900-2015) • ~$3b (insured losses 2010-2020)	There has been an increase in the frequency and severity of fire weather since 1950 in southern and eastern Australia, and this trend is projected to continue.	Black Summer bushfires, New South Wales, 2019-20 (2022) Date: 2019-20 Where: New South Wales What: The bushfire season in 2019 to 2020 caused 2,448 homes to be destroyed, 5.5 million hectares of land to be burnt and 26 fatalities. This was due to dry conditions, high average temperatures, and low moisture levels across the state. Estimated losses were $1.88 billion.

[41] IPCC AR6 states that RCP4.5 5%-95% = 277-745mm and RCP8.5 5%-95% = 418-965mm.

Disaster	Prevalence and Impact (Australia wide)	Outlook (Australia wide) Source: (Commonwealth of Australia, 2020a)	New South Wales Example
Heatwaves Source: (Coates, et al., 2014)	• 4,555 (fatalities 1900-2015) • Not reported (insured losses 2010-2020)	Hot days, warm spells and heatwaves are all projected to occur more often and with increased intensity. Extreme hot days that now occur every 20 years are expected to occur every two to five years by 2050.	Heatwave, South-Eastern Australia 2009 (2019) Date: late January 2009 – early February 2009 Where: south-eastern Australia What: Prolonged high temperature (maximum temperatures were 12-15 degrees Celsius above normal temperatures. This caused 374 excess deaths over what would be expected for that time of the year. The elderly were the most affected. 43 degrees Celsius for 3 consecutive days and a peak of 45.1 degrees Celsius was reached. 500,000 homes and business were left without electricity. 1,300 trains were cancelled as rails buckled and air-conditioning failed.
Coastal Damages Source: (Australian Institute for Disaster Resilience, 2022c)	• Not reported (fatalities 1900-2015) • Not reported (insured losses 2010-2020)	By 2090, the Australian sea level is projected to rise by between 26 and 82 cm.	East Coast Low and storm, New South Wales (2016) Date: 4-6 June 2016 Where: Entire coast of New South Wales. Key affected areas included the Northern and Southern coastal regions, Sydney Northern Beaches and Southwest metropolitan region. What: Storm and East Coast Low, which is an intense low-pressure system that forms close to the coast. This caused coastal erosion affecting 600 properties (leaking roofs, wind damage and minor coastal inundation), 130 businesses and caused two fatalities. There were over 11,000 requests for assistance to NSW SES. Insurance Council of Australia estimated the 2016 direct damage cost to be $304m.

Disaster	Prevalence and Impact (Australia wide)	Outlook (Australia wide) Source: (Commonwealth of Australia, 2020a)	New South Wales Example
Storms Source: (Commonwealth of Australia, 2020a)	• 3 (fatalities 1900-2015) • ~$6b (insured losses 2010-2020) • Not reported (average annual cost between 1967 and 1999)	*Not discussed*	Sydney hailstorm, New South Wales 1999 (2022) Sydney hailstorm, New South Wales 1999 (2022) Date: 14 April 1999 Where: Sydney's inner and eastern suburbs. 85 suburbs, the worst-affected areas were Kensington, Kingsford, Botany, Mascot, Randwick, and Paddington. What: Common season is September to March. Hail size of cricket balls at more than 200 km/h. Fire & Rescue NSW reported more than 2,000 emergency calls within the first five hours of the event. The event affected 100,000 people, many injured and attended hospitals and one fatality. Insurance Council of Australia estimated the 1999 direct damage cost to be $1.7 billion.

Appendix B: Disaster risk assessment techniques

Disaster risk assessment for natural hazard risk can be carried out at varying scales and for different purposes. The most common methods (which are not exclusive) include:

- quantitative risk assessment
- event tree analysis
- risk matrix approach
- indicator-based approach.

Appendix B.1: Quantitative risk assessment

Refer to Section 3.3.1 for the assessment of hazards, exposure and vulnerability.

Appendix B.2: Event tree analysis

Event tree analysis (also known as decision tree analysis) is a useful technique to consider possible decision points and quantify the value of any associated feasible real options in cost-benefit analysis. This procedure facilitates the analysis of sequential risks compounding over time.

This technique is detailed in Appendix 4.4 of the CBA Guide.

Appendix B.3: Risk matrix approach

Risk can be defined as the likelihood of the occurrence of a particular event, multiplied by the consequence or outcome of that event occurring. A qualitative risk matrix can be applied to estimate the impact of a risk associated with an event (Table 19). In this method, risks are typically assessed using professional judgement and expert opinion, in the absence of data.

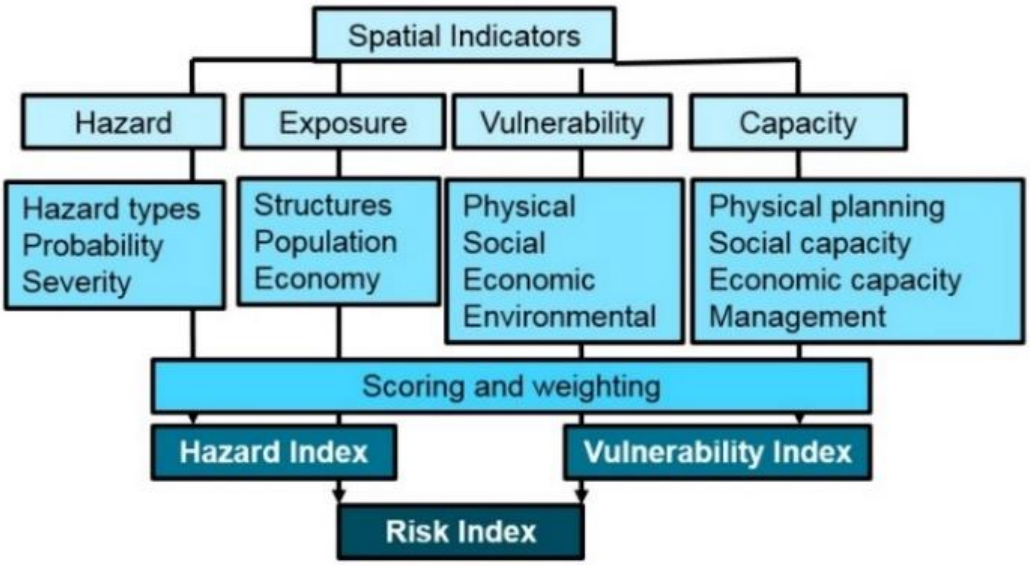
Table 19: Sample risk matrix

Likelihood	Consequence				
	Insignificant	Minor	Moderate	Major	Catastrophic
Likely	*Low*	*Medium*	*High*	*Extreme*	*Extreme*
Unlikely	*Low*	*Low*	*Medium*	*High*	*Extreme*
Rare	*Very low*	*Low*	*Medium*	*High*	*High*
Extremely Rare	*Very low*	*Very low*	*Low*	*Medium*	*High*

Appendix B.4: Indicator-based approach

An indicator-based approach is a semi-quantitative method used to assess risk, based on various elements (indicators), which are given a percentage weighting. This approach is recommended when there is a lack of data, and a quantitative risk assessment cannot be undertaken. Each respective element is assigned a percentage weighting (based on subjective judgement), allowing the calculation of a risk index. This facilitates the comparison between different locations, subject to the choice of weights, and can be applied to a CBA. An example layout (without weightings) is displayed in Figure 15.

Figure 15: Indicator-based approach



Source: (van Westen, 2022)

Appendix B.5: Summary

The advantages and disadvantages of each method are outlined in Table 20. Across all four methods, the assessment of some study areas may be difficult, depending on their nature and the data available.

Table 20: Methods of risk mapping – advantages and disadvantages (van Westen, 2022)

Method	Advantages	Disadvantages
Quantitative risk assessment	The quantitative risk output is compatible with cost-benefit analysis.	• Extensive data required • Quantifying probability, hazard intensity and vulnerability can be difficult
Event tree analysis	• Sequential events can be modelled • Strongly suited for cascading events	• Difficult to assess and assign probabilities due to data constraints • Spatial implementation can be challenging, depending on the types of disasters involved
Risk matrix approach	• Predominantly qualitative, and does not require large amounts of data • Good basis for comparing risk reduction measures	In most cases, it cannot be directly used in a CBA as this method is not quantitative.
Indicator-based approach	A holistic approach that considers all aspects of a risk assessment.	The impact of a disaster is not calculated, and the method relies on subjective weights for the components and elements.

Appendix C: Can natural hazards have benefits?

There is a significant body of theoretical and empirical evidence showing that natural hazards can have benefits. These benefits result largely from the adaptations to the disaster, where something that was limiting productivity is replaced, or part of the natural environment's cycle of renewal. Positive impacts generally come in three areas.

- **Environmental benefits**: Can occur when natural hazards add resilience to ecosystems.
- **Economics benefits** : Productivity improvements due to responses to the disaster replacing infrastructure or technologies that are either inefficient or ineffective, or results in better allocation of land use.
- **Social and institutional benefits**: Created by changes made to meet the immediate challenge of the disaster or recovery from it, such as increases in volunteerism or institutional reforms.

Appendix C.1: Environmental benefits

Natural hazards, such as rain and floods have regenerative impacts on natural ecosystems. Floods redistribute nutrients and topsoil, volcanic eruptions create new land and fertile soils, and bushfires eliminate weeds, disease, and insects while promoting new growth.

Many of these environmental benefits occur independent of a disaster resilience initiative. For example, floods of certain intensity cannot be prevented, but initiatives can redirect or slow their flow: meaning that the redistribution of nutrients from flooding still occurs, but to different timelines, intensity, and location. There are, however, cases where disaster resilience initiatives can prevent environmental benefits. For example, in the case of damns that prevent floodplains from forming, nutrients redistribution, and the resulting benefits for biodiversity may be lost.

Appendix C.2: Economic benefits

Empirical and theoretical evidence highlights that it is common for areas that experience disasters to emerge with higher levels of income and productivity. The opportunity cost of funds required to rebuild, such as schools or hospitals not built elsewhere, also need to be considered. Positive impacts in one area can come at the expense of another region.

While some types of disasters, such as floods and earthquakes, are associated with improvements in long-term growth, others, such as long droughts, are associated with permanent declines in growth. Where disasters are linked to increases in long-term economic growth, a key driver may be removing or replacing outdated or ineffective infrastructure and catalysing economic transitions to higher value, more resilient activities.

Appendix C.3 Social and institutional benefits

Natural hazards can result in changes to social arrangements and institutions – both formal and informal – often because responding to the disaster allows groups to coordinate to a new set of arrangements that have previously been too difficult or costly. The Fukushima disasters of 2011 provide several examples. These include increases in social cohesion and trust from increased volunteerism, including cases where retired engineers volunteered to replace younger workers in radiation-exposed areas. After the Fukushima disaster, there were also regulatory changes to make production safer, including the adoption of protocols to avoid the construction of power plants in areas that could be impacted by Tsunamis.

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