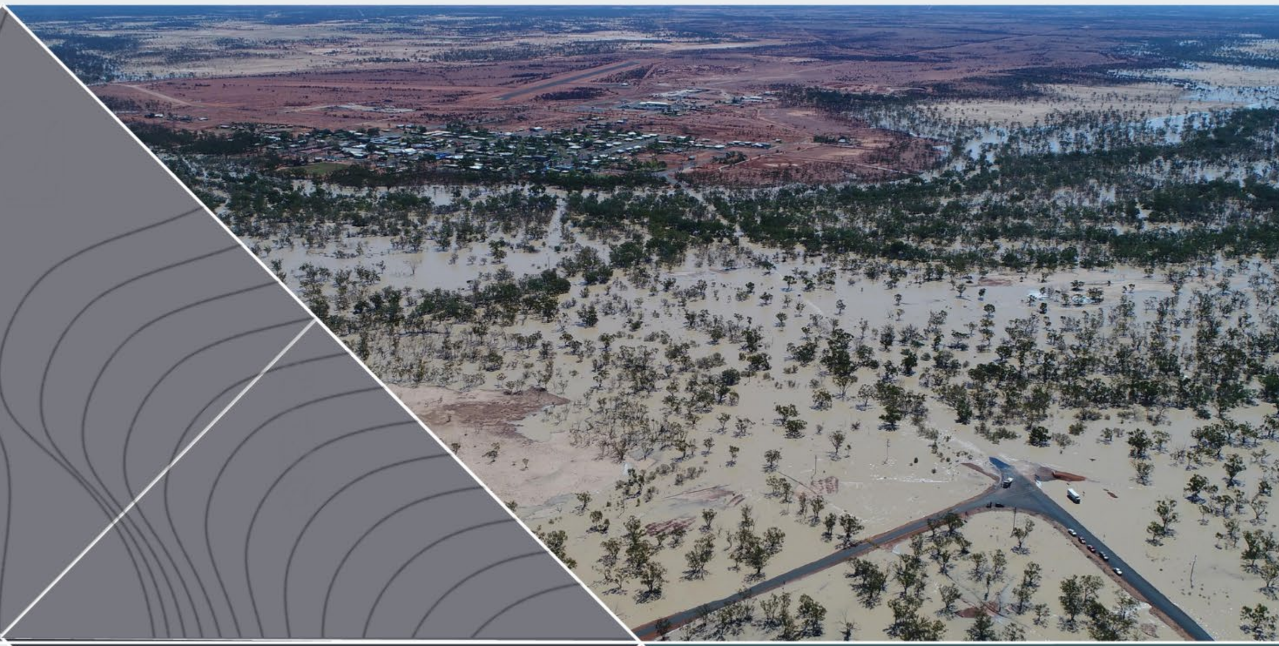
Economic Assessment Framework of

Flood Risk Management Projects



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Acknowledgements

This **Economic Assessment Framework of Flood Risk Management Projects** has been delivered as an initiative of the Brisbane River Strategic Floodplain Management Plan implementation. This is a resource for flood risk practitioners, state and local governments to help improve the robustness and consistency of economic assessments supporting decision-making and investment in flood risk management and intervention throughout Queensland.

This Framework was developed by the Brisbane River Strategic Plan Economic Assessment Working Group, which included the following members:

- Queensland – Ella Harrison (Chair and co-author), Andy Wyer, Queensland Reconstruction Authority
- New South Wales – Duncan McLuckie, Angela Toniato, Department of Planning, Industry and Environment
- Victoria – Mike Edwards, Department of Environment Land, Water and Planning
- Research community – Andrea Keating, RMIT University
- Private practice – Jim Binney, NCEconomics (co-author), Mark Babister, WMAwater, Rhys Thomson, RHELM.

The Framework has also been reviewed by key stakeholders and end users. The working group wishes to thank all those involved in the development of this document.

Disclaimer

The guidance, methods and approaches discussed in this document are based on current best practice and research available at the time of development. This is expected to be a continually improving and developing field. Users of this Framework are strongly advised to satisfy themselves that the methods employed are appropriate and fit for purpose for the specifics of the project.

Definitions

Terms shown in *italics* throughout this document are defined below

Term	Definition applied in this Framework
Disaster resilient communities	Communities are disaster resilient when (1) they understand the potential disaster risk they face; (2) they work together to better manage the disaster risk; (3) they seek new opportunities to reduce disaster risk; and (4) they continuously improve how we prepare for, respond to and recover from disasters.
Multi-criteria assessment	Multi-criteria assessment is a decision-making tool used to evaluate problems when one is faced with several different alternatives and expectations and wants to find the best solutions with regard to different and often conflicting objectives.
Return on investment	Return on investment is a financial metric that is widely used to measure the probability of gaining a return from an investment. It is a ratio that compares the gain or loss from an investment relative to its cost. It is as useful in evaluating the potential return from a stand- alone investment as it is in comparing returns from several investments.
Net present value	Net present value (NPV) is the present (current day) value of the benefits and costs incorporated into the economic analysis.

Contents

Explanatory summary

Queenslanders are no strangers to flooding – it is one of our greatest natural disaster risks. The impacts of flooding are widespread with individuals, communities, businesses and the environment potentially impacted, both directly and indirectly.

Some impacts of flooding are easier to measure and mitigate against than others. We know that investing in flood risk mitigation is key to minimising the need for, and cost of recovery.

The Queensland Government is committed to strengthening disaster resilience so that our communities are better equipped to deal with the inevitable challenges we face from floods and other natural disasters.

What is the problem to be addressed?

To effectively invest in flood risk mitigation, it is important to be able to quantify all the types of damages resulting from floods, and fairly compare a wide range of possible options, from community awareness and education activities to building more resilient homes, to ensure targeted investment provides the greatest return.

To date, there has been an absence of state or national guidance on such assessments, leading to a wide variety of approaches, methodologies, data and results. This has potentially impeded the necessary investment in flood mitigation.

How does this Framework help?

This Framework has been developed to bridge that gap and is a first for Queensland. It identifies methods to quantify both the tangible costs – physical damage to property, assets, as well as impacts to businesses and community disruption – and the intangible costs – such as impacts on mental health, loss of life, injury and environmental damage.

This Framework was developed based on defensible methods, applicable to the Queensland landscape, extending the economic framework elements established previously by government to include a wider range of damage categories as well as providing methods for assessing a broader array of mitigation options, including community awareness and resilience, disaster management and resilient building designs.

> Queensland incurred 60 per cent of the national economic cost of natural disasters over the past decade.
>
> This cost is estimated at $11 billion per year, including $7 billion in flood-related costs.*
>
> If unmanaged, the impacts of climate change and population growth are likely to further exacerbate flood risk in Queensland.

* Source: http://australianbusinessroundtable.com.au/assets/documents/ABR_building-resilience-in-our-states-and-territories.pdf

How can this Framework be applied to projects?

This Framework outlines various methodologies to quantify damage caused by flooding or the benefits of implementing flood risk mitigation activities. The methodologies are used in support of economic assessment processes and are underpinned by guiding principles (outlined in Section 3).

The principles ensure that any economic assessment is proportionate to the project, and that all impacts are qualified, and where possible quantified. The principles also point to the need to determine the most relevant variables through the economic assessment and to capture the full benefits of potential options.

Further, the Framework describes a five-stage process for undertaking economic assessment for flood risk management (outlined in Section 4) and provides tools to undertake that economic assessment, underpinned by the guiding principles mentioned above (refer Figure 1).

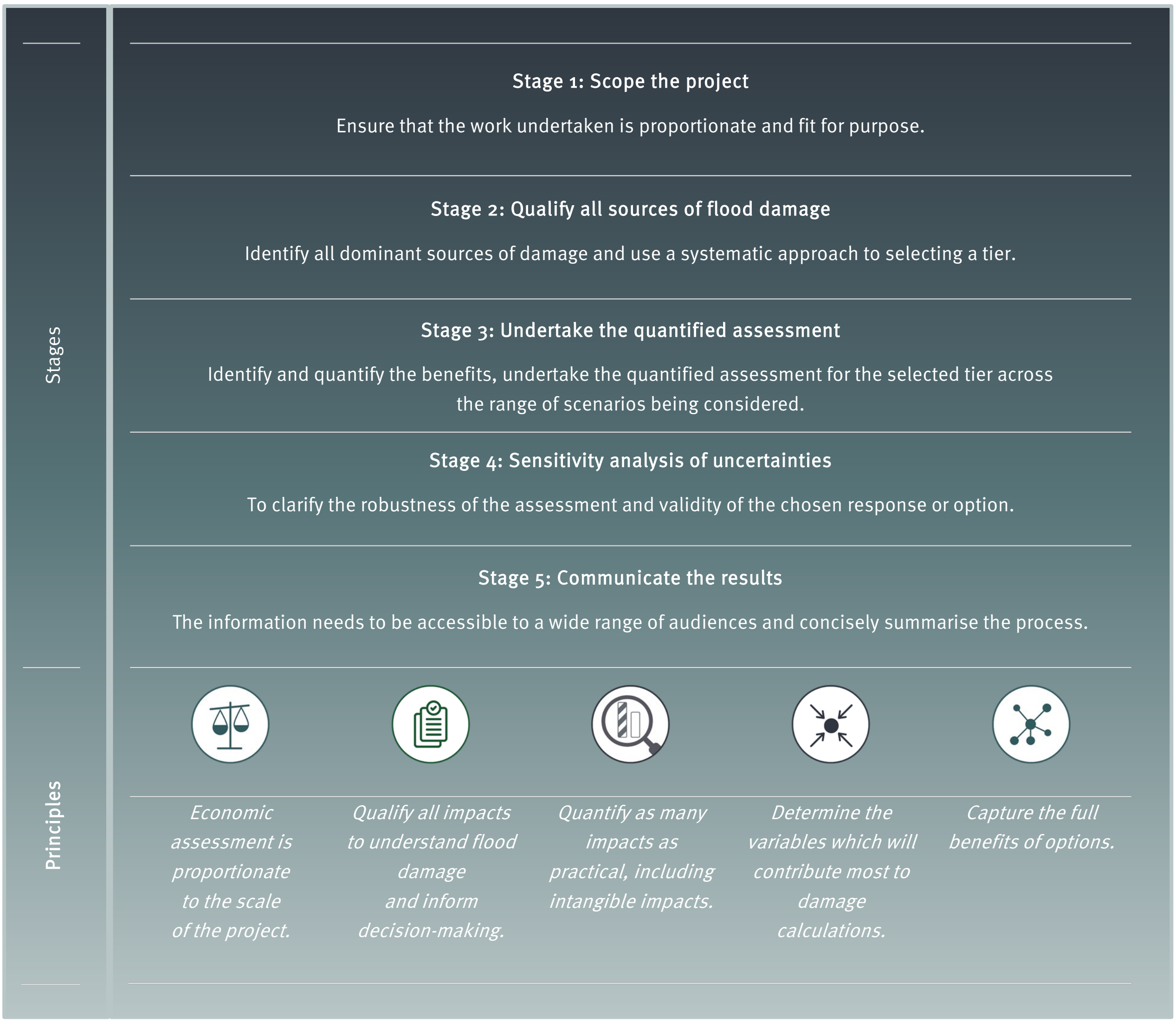
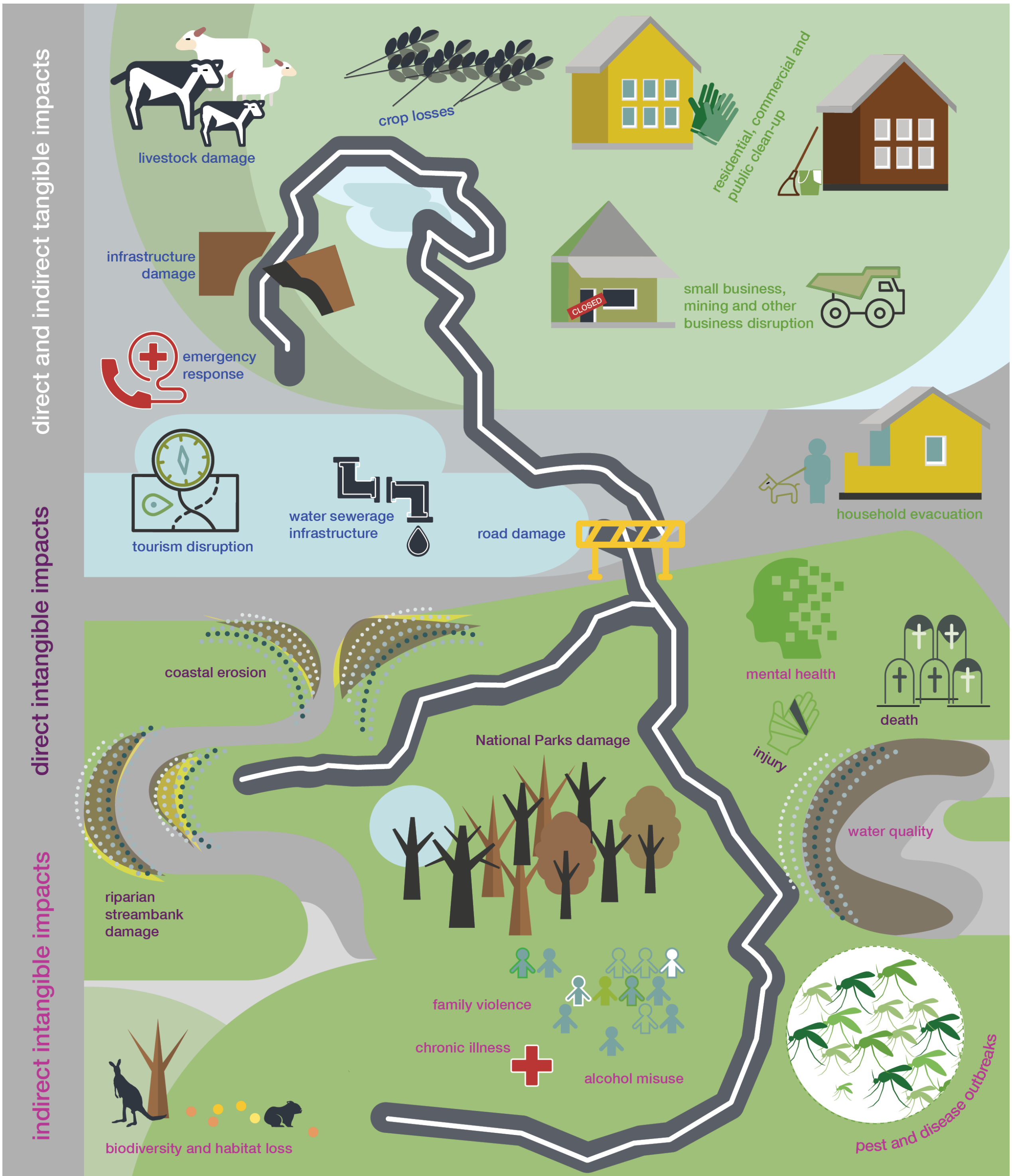


Figure 1: Stages for economic assessment underpinned by guiding principles

By following this approach and utilising the guidance material within, practitioners have access to the level of detail necessary to undertake economic assessment of the various impacts of flooding, ensuring consideration is given to the full range of mitigation options.

This is a key tool for local and state governments, which provides a comprehensive framework to undertake consistent and comparable economic assessments. This Framework can be used by practitioners to undertake economic assessments, as well as by governments to support decision-making, with the knowledge that assessments have been undertaken objectively and consistently.



PROPERTY MODIFICATION MEASURES
Flood proofing/building control
House raising | House purchase
Land use planning/zoning

FLOOD MODIFICATION MEASURES
Dams | Detention basins | Levees
Floodways | Floodgates
(Backflow Prevention Valves)
Temporary Flood Barriers
Landscape management

RESPONSE MODIFICATION MEASURES
Flood prediction and warning
Flood access and evacuation
Emergency response
Flood-awareness, education
and readiness

1. Introduction and overview

1.1. Policy context

In Queensland flooding is one of our greatest natural disaster risks. The Queensland Government is committed to strengthening disaster resilience so our communities are better equipped to deal with the increasing prevalence of natural disasters, such as flooding.

The **Queensland Strategy for Disaster Resilience** (2017) aligns strongly with the **National Strategy for Disaster Resilience** (2011) to build *disaster resilient communities* across Australia.

Two of the priority outcomes for achieving more *disaster resilient communities* identified within the **National Strategy for Disaster Resilience** are:

- using consistent methodologies and frameworks in relevant impact assessments
- costs and benefits associated with hazard management informing risk reduction activities.

Within this, governments at all levels have a responsibility to identify and implement strategies to manage disaster risks. The **National Strategy for Disaster Resilience** recognises that consistent information on the costs and benefits of risk management options, which considers the full impacts on the social, built, economic and natural environments, is required to support this.

Australia's **National Disaster Risk Reduction Framework** (2018) guides national, whole-of-society efforts to proactively reduce disaster risk in order to minimise the loss and suffering caused by disasters. It is designed to leverage the work and progress made across all sectors since the release of the **National Strategy for Disaster Resilience** to better understand and reduce disaster risks, improve resilience, and bolster the capability and capacity of communities to withstand natural hazards.

Traditionally economic assessments for flood management projects in Australia, have focused on the tangible damage of flooding, particularly to property. Other impacts of flooding, such as environmental or social impacts, are typically considered qualitatively or assessed through a *multi-criteria assessment*. To date the absence of state or national guidance on undertaking such assessments has also led to a wide variety of approaches, methodologies, data and results. This creates an unnecessary layer of complexity when seeking to compare and prioritise projects within states and across Australia. It can also lead to the underestimation of the *return on investment* resulting from flood risk management projects, due to the incomplete capture of benefits.

This **Economic Assessment Framework of Flood Risk Management Projects** (herein 'the Framework') is a key step towards consistent, comparable and complete economic assessments as a tool to support increased investment in risk mitigation and *disaster resilient communities*.

1.2. Developing the Framework

This Framework has been developed by a working group, which included membership from three state governments, as well as researchers and private flood practitioners. Consultation occurred across relevant Queensland state and local government agencies in developing the Framework.

A substantial literature review was undertaken to inform the development of the Framework. This not only looked at current national and international practice on flood economic assessments, but also looked to identify emerging practice in methods to assess some of the previously unquantified impacts. From this, a comprehensive framework was developed based on defensible methods, applicable to the Queensland landscape.

1.3. Purpose and scope

This Framework will improve the robustness and consistency of economic assessments supporting decision-making and investment in flood risk management intervention. The Framework builds on the **Queensland Disaster Resilience and Mitigation Investment Framework** (2019), which provides high-level guidance on effective investment decision-making and prioritisation to support disaster resilience and mitigation across Queensland.

The Framework establishes the recommended approach for undertaking economic assessments for projects which may, at some stage, seek state government funding. It has been developed in support of the **Queensland Framework for Flood Risk Management** (QRA, 2021), and is also consistent with the national **Handbook 7: Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia** (AIDR, 2017). It has been developed specifically for application in Queensland, though may also be appropriate in other states and territories. However, as other jurisdictions have specific guidance relating to economic assessments of projects, practitioners should seek agreement to its use from the relevant lead agency prior to application outside of Queensland.

Economic assessments can be used to support issue identification, decision-making and evaluation activities. The Framework has been developed to support a range of potential uses including:

- baseline cost estimates, to understand the potential damage caused by flooding in areas
- options assessment, to inform option assessment through the form of cost–benefit analysis (CBA)
- pre-feasibility assessments, to support the development of preferred options and determine the viability
- measuring outcomes, as a tool to track the outcomes delivered through intervention.

There are several policy/program/project cycles that are used across Australia. Many of these include an economic assessment as part of the decision-making process. This Framework has been developed for use early in the policy/program/project cycle to give a high-level assessment of the overall approach, and expected benefits and costs, as shown in Figure 2 below. It is important to note that economic assessments can be used at multiple stages within many of the project cycles, depending on the decisions to be made and the degree of rigour required, reflecting the interactive nature of project cycles.

FRAMEWORK	APPLIED	STAGE/ GATE								
		Initiate	Plan		Procure		Deliver	Operate	Benefits / Close	
Project Decision Framework (PDF)	Local/ State (Qld)	Stage 1: concept selection stage	Stage 2: pre-feasibility stage	Stage 3: feasibility stage	Stage 4: planning stage		Stage 5: delivery stage	Stage 6: operate and maintain stage		Stage 7: abandon stage
Project Assessment Framework (PAF)	State (Qld)	Stage 1: strategic assessment of service requirement	Stage 2: preliminary evaluation	Stage 3: business case development	Stage 4: supply strategy development	Stage 5: source supplier/s	Stage 6: establish service capability	Stage 7: deliver service	Stage 8: benefits realisation	
Infrastructure Investor Assurance Framework (IIAF)	State (NSW)	Needs confirmation: Gate 0 go / no go	Needs analysis: Gate 1 strategic options	Investment decision: Gate 2 business case	Procure: Gate 3 readiness for market	Procure: Gate 4 tender evaluation	Deliver and initial operation: Gate 5 readiness for service		Benefits realisation: Gate 6 benefits realisation	
Infrastructure Australia Assurance Framework (IAAF)	National	Stage 1: problem identification and prioritisation	Stage 2: initiative identification and options development	Stage 3: business case development	Stage 4: business case assessment		Stage 5: post-completion review			
Queensland Government's Business Case Development Framework	State (Qld)	Stage 1: strategic assessment	Stage 2: options analysis	Stage 3: detailed business case						

Preliminary Cost Benefit Analysis may be undertaken per guidelines

Cost Benefit Analysis to be undertaken per guidelines

Cost Benefit Analysis potentially informs decision making

Figure 2: Potential application of the Framework within policy/program/project cycles

Using a CBA framework to underpin analysis is fundamental to all of the policy/program/project cycles outlined in this document. The key differentiator is not necessarily whether a CBA should be undertaken, but how rigorous and comprehensive the CBA should be. This guideline therefore outlines a three-tiered system of assessments based on the requirements of decision-makers, data availability and quality, with Tier 1 being the least rigorous. These assessments progressively require more detail, more data, more complex analysis and greater resources (skills and financial resources). This is outlined in Section 4.2.1.

As a general guide:

- Tier 1 and 2 level assessments should be sufficient for pre-feasibility, preliminary evaluations, smaller project proposals or funding applications, and the initial identification of options assessments.
- Tier 3 level assessments are likely to be required for very large projects, policies or programs that require changes to regulatory instruments, or controversial policies or projects that have major distributional impacts across stakeholder groups.

In some cases, there are specific requirements. For example, under the Queensland Government's **Business Case Development Framework**, a detailed business case would include a rigorous CBA for projects with a capital investment exceeding $100 million.

Decision-making on management of natural disasters generally lies in the public sector, as the scale and scope of management actions typically benefit the broader community. Management measures to limit the impacts of natural hazards on the community need to be considered from a range of perspectives, all of which can influence decision-making. These can include the practicality and feasibility of the option (both to implement and to manage long term), community attitude and acceptance of the solution, social and cultural impacts of the solution, environmental impacts, the potential to gain funding from external sources to support implementation of local solutions, and economic assessment.

Economic assessments are one of the tools used to support decision-making, but should not be relied on exclusively as they are seldom able to capture the full range of considerations. However, when done well, they are a powerful tool for highlighting the impacts of flooding, as well as the benefits and costs from interventions. Furthermore, they use an approach consistent with the assessment of other public investments (e.g. infrastructure), ensuring the relative merits of flood management interventions are considered on an equal basis.

This Framework is not a prescriptive standard. However, it encapsulates current best practice and provides pragmatic and robust approaches to economic assessments, and will be applicable to many situations. Importantly, this Framework builds on and is complementary to other analytical approaches, tasks and consultation undertaken for flood management activities.

It is intended that this Framework becomes a living document, with periodic revision to include new development, approaches and data, as well as feedback from users of the Framework.

2. Key concepts in this Framework

2.1. Economic assessment versus financial assessment

Economic assessment quantifies in monetary terms the social costs and benefits of activities. In the case of flood risk management, this could be the impacts of floods occurring, or the consequences of intervention. Economic assessment focuses on the society as a whole and is a broad appraisal that includes consideration of market (e.g. priced) values such as damage to houses, and non-market values such as the loss of recreational amenity values.

In contrast, financial assessment views investment decisions from the perspective of an organisation, entity or individual. It assesses the viability of a project based on the direct effects on the cash flow. It considers whether the organisation's projected income base will be sufficient to cover expenditures and whether the financial return is sufficient to make the investment affordable (or commercially viable or profitable).

This Framework is based on economic principles of valuation and assessment.

2.2. Damage and losses

The definition and use of 'damage' and 'loss' vary depending on the situation to which they are applied. In the context of economic assessment, 'damage' is a broader concept that includes both the tangible and intangible impacts, whereas 'loss' is commonly understood as the monetised outcome of direct or indirect damage. Losses are always evaluated in monetary terms, whereas damage may also be quantified using other metrics or methods.

2.3. Flood risk management in Australia

This Framework has been developed in support of wider flood risk management processes in Queensland specifically, however it may also be relevant to other states in Australia.[1] These processes are documented within the **Queensland Framework for Flood Risk Management**, and the national **Handbook 7: Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia (Handbook 7)**.

> **Flood behaviour**
>
> For a particular floodplain, flood behaviour can be studied and the likely location, type and scale of effects for a range of floods can be determined within reasonable accuracy to inform its management. With floods, it is not a matter of if, but when, the flood will occur. Understanding flood behaviour, including potential alterations due to changes in climate or catchment development, enables us to assess the likely impact of flooding on the community and examine options to manage the risk.
>
> Flood behaviour depends upon a range of factors, including the source of flooding, catchment and floodplain location, size, shape, topography, vegetation, underground geological features and development. Key components to adequately understanding flood behaviour include understanding the probability of flooding, flow conveyance and storage functions of the floodplain, and the variation in the drivers and degree of flood hazard within the floodplain.

An understanding of flood likelihood and behaviour is a key input into economic assessments for flood risk management. This extract, from **Handbook 7**, describes what is meant by 'flood behaviour', with further detail included within the relevant sections of the handbook.

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[1] Practitioners are advised to seek agreement to its use from the relevant lead agency prior to application outside of Queensland.

2.4. Types of flood damage

The economic assessment of floods focuses on the quantification of the damage caused by a range of flood events. This damage can be defined as either tangible or intangible. Tangible damage is that for which a monetary value can be easily assigned, while intangible damage is that to which a monetary value cannot easily be attributed.

Damage can be further categorised as either direct or indirect. Direct damage is caused by the direct interaction with the floodwaters, causing damage or disruption. Indirect damage is the flow-on effects from the flood events, such as loss of economic activity and wages, traffic disruption, and loss of individual and community welfare. Some common categories of flood damage are provided in Table 1 below.

Table 1: Categories of flood damage

Direct tangible damage	Indirect tangible damage	Intangible damage
Losses incurred as a result of the disaster event that have a market value	*Any tangible flow-on effects, not directly caused by the natural disaster but arise as a consequence of the damage and destruction*	*Direct and indirect damage that cannot be easily priced*
• Property: – residential – commercial – industrial – public assets – community infrastructure – vulnerable facilities • Transport (damage to assets): – roads, rail, bridges – airports, train stations – passenger transport – active transport facilities along ports • Agriculture • Motor vehicles	• Emergency costs • Alternative accommodation • Clean-up and rehabilitation • Business disruption • Disruption of public services and services to the community • Transport disruptions and indirect costs (travel time, delays, vehicle operating costs)	• Mortality (loss of Life) • Morbidity (injury, stress and mental health, other flood-related health impacts) • Environmental values • Cultural, heritage, social and recreational values

2.5. Average annual damage

Depending on its size (or severity), each flood will cause a different amount of flood damage to a flood-prone area. In many years there may be no damage, in some years there will be minor damage (caused by small, relatively frequent flood events), and in some years there will be major damage (caused by large, rare flood events).

Average annual damage (AAD) is the average damage per year that would occur in a nominated area over a very long period of time. It is the probability-weighted expected damage that is estimated to occur in a given year under multiple flood magnitudes. It can be understood using the standard risk equation:

$$Risk = Expected\ average\ annual\ damage\ = \sum_{i=1}^{n} (Consequence_i \times Likelihood_i)$$

Where: i is the hazard event, n is the number of hazard events, consequence is the damage or loss from a hazard event, and likelihood is the probability of a hazard event occurring.

If the damage associated with various annual events is plotted against their probability of occurrence, the AAD is equal to the area under the consequence–probability curve. AAD provides a basis for comparing the economic effectiveness of different management measures against floods of all sizes (i.e. their ability to reduce the AAD). This is shown in Figure 3 below where the blue line shows the baseline consequence–probability curve and the grey line shows the consequence-probability curve after management measures are implemented. It is the difference in the areas under the curves (change in AAD) that represents the benefits of the management actions (i.e. benefits are typically a reduction in future costs or an avoided cost). This can then be compared to the costs of implementing the management actions.

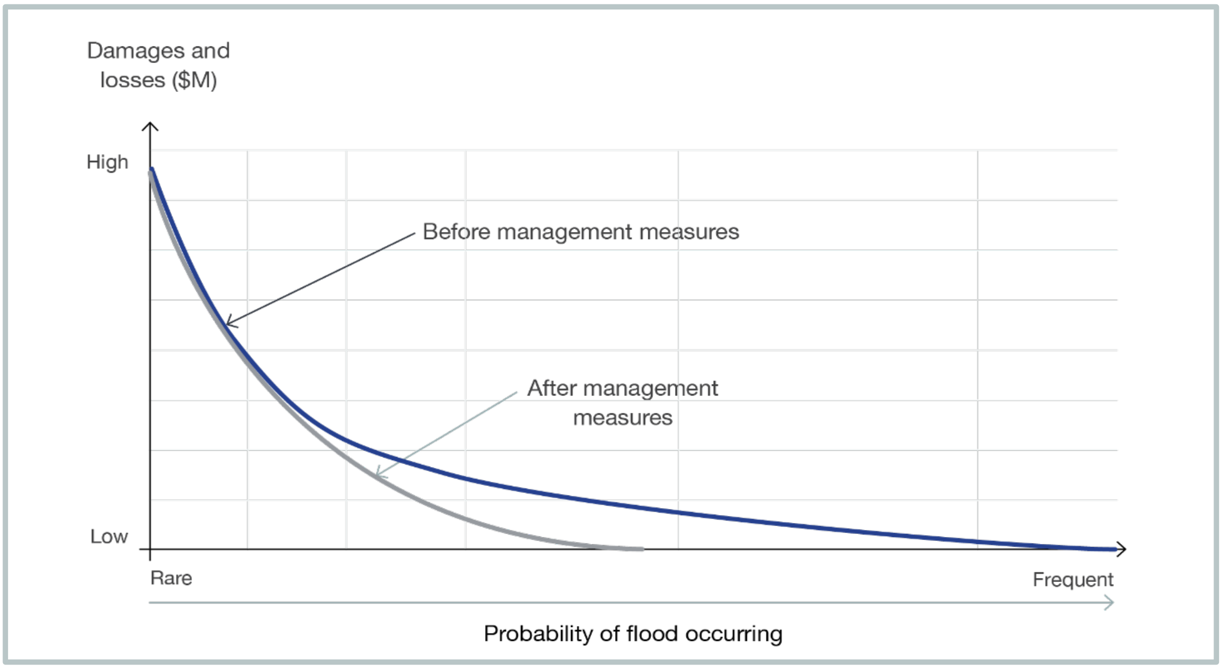

Figure 3: Consequence–probability curve – before and after management measures

AAD is the best practice approach for understanding potential economic impacts of flood hazards and for economic analysis of flood risk adaptation options. It is consistent with the framework used by insurance companies to value risk (to underpin insurance premiums), and is used widely by the United Nations and the World Bank.

3. Principles of economic assessment in floodplain risk management

Economic assessments can be used in the consideration of floodplain risk management activities. They seek to quantify the damage caused by flooding and the benefits resulting from option implementation, and guide the decision-making processes in determining which options should be considered further or prioritised for implementation.

The economic analysis should not be undertaken in isolation from other activities that are typical of floodplain risk management assessments, such as mapping, assessments of flood behaviour, identification of assets at risk, and consultation. These other activities provide the bulk of the data required to identify and parameterise the impacts for inclusion in the economic assessment. The economic analysis should be properly informed by and integrated with other analysis.

The following principles should guide all economic assessments being undertaking as part of floodplain management studies, assessment and appraisal.

Figure 4: Guiding principles of economic assessments

3.1. Proportionate assessments

Economic assessments are undertaken to support decision-making. They are just one of the tools used to support option analysis and prioritisation. As such, the time and cost invested in undertaking the assessments need to be proportionate to the stage of the project, the scale of the issue and the scale of the investment being sought.

To support this, the Framework provides advice on three tiers of approaches, ranging in complexity, data requirements and accuracy. Through the process discussed in Section 4, users of this Framework select the appropriate tier for each parameter being quantified, based on the requirements of their project and the influence that parameter has on the overall assessment.

3.2. Qualify everything

The impacts of flooding are wide ranging and highly variable. Many are intangible and not readily quantifiable. As such, in many circumstances, it will not be practical or plausible to quantify all the impacts of flooding within the economic assessment process. However, it is important that these impacts are captured in some form, and this Framework recommends qualification of all flood impacts.

In support of this, a template is provided (see Appendix A) for considering and qualifying all potential impacts of flooding for the study area of a project. The qualification process is an important step in the Framework, but can also be used to inform other stages of the decision-making process, such as the *multi-criteria assessment*.

3.3. Quantify as much as practicable

Historically, economic assessments for flood projects have focused principally on tangible property damage. While this practice captures a significant element of flood damage, and the methodologies for capture are readily available, it is increasingly being recognised that flood impacts are far more extensive and costly. While recent practice attempts to overcome this shortfall using other tools such as *multi-criteria assessments*, the absence of valuation has inferred a zero cost, leading to the underestimation of flood impacts, and hence the benefits of intervention.

While it is recognised that not every impact can, or should, be qualified, this Framework encourages that as many are quantified as practicable within information and resource constraints for the analysis. This provides defensible, robust methodologies and data sources to quantify a diverse range of parameters, including direct and indirect tangible damage, as well as methods for approximating direct intangible costs and benefits as far as reasonably possible.

3.4. Focus on the most relevant variables

A key step to informing an economic assessment is to determine which parameters contribute the most to the damage calculations or are most likely to materially change with option implementation. It is these to which the greatest quantifying effort should be applied.

As such, this Framework provides guidance on the range of options and corresponding significant variables, as well as providing three tiers of assessment, which can be varied for each parameter being considered. For those that are identified as being significant, a higher tier (2 or 3) might be selected, which either more holistically considers the impacts, or provides a more nuanced and detailed consideration of quantification.

3.5. Capture full benefits of options

Interventions in flood risk management are not just about avoiding damage and harm. They can also enhance and catalyse economic activity, community wellbeing and vibrancy, and environmental health. As such, the practice of focusing purely on avoided damage in option assessment has again resulted in a trend to undervalue flood risk management investment. Where appropriate to the scale and stage of assessment, full benefit capture is advocated by this Framework, and tools to support this are contained within.

4. Framework stages

The Framework for undertaking economic assessment for floodplain risk management projects in Queensland involves a five-stage process:

1. Scope the project
2. Qualify all parameters
3. Undertake quantified assessment
4. Outline assumptions and undertake sensitivity analysis
5. Communicate the results

4.1. Stage 1: Scope the project

Once the need for an economic assessment has been established, the purpose, scope, scale, available data and required accuracy should be defined. This will ensure that the work undertaken is proportionate and fit for purpose. This stage should consider a broad range of factors including:

- the purpose of the assessment and what outcome is sought to be achieved
- the stage of the assessment and how the findings will be used
- the value of the project and, where applicable, the anticipated value of the options being assessed. This will determine the appropriate level of investment in undertaking the economic analysis, and the required level of certainty of the findings
- what data is currently available, and what would need to be sourced or generated. This is further discussed in Section 4.1.1
- the likely funding contributors – this Framework should be applied if public investment is likely, but is not necessary for privately funded projects and investigations
- the spatial and temporal bounds of the assessment, which should align with the purpose of the assessment. For example, economic assessments supporting local investment decisions should remain within the bounds of the local community, and the timescales should align with objectives (short, medium or long-term) and, for structural measures, the life of the infrastructure proposed
- whether wider indirect effects are significant and should be included in the assessment.

4.1.1. Data requirements

Data requirements can be broken into three categories (Figure 5) – data needed to define the flood likelihood and behaviour, data needed to understand the potential consequences, and data needed to quantify (put in dollar terms) the benefit/cost.

FLOOD LIKELIHOOD AND BEHAVIOUR DATA, FOR EXAMPLE:	CONSEQUENCE DATA, DETERMINED SPATIALLY, FOR EXAMPLE:	QUANTIFICATION DATA , FOR EXAMPLE:
• flood extents for a range of flood frequencies • flood behaviour metrics (e.g. depth, level, velocity, timing, hazard) • results from climate change or future development scenarios • observed flood behaviour from previous events.	• demographic data (e.g. census data) • assets at risk (e.g. public infrastructure, motor vehicles, building footprints and floor levels) • land use zoning.	• stage-damage curves (for building damage) • benefit transfer data (e.g. willingness to pay values) • value of statistical life • unit rates, cost estimates, asset life.

Figure 5: Categories of data requirements

4.2. Stage 2: Qualify all sources of flood damage

An initial qualification of all sources of flood damage is to be undertaken. This process will:

- identify the dominant sources of damage
- confirm existing data availability and identify where further data is required
- facilitate a systematic approach to selecting the preferred quantification methodologies (assessment tier)
- be used to inform *multi-criteria assessments* and other decision-making tools.

This stage involves a high-level consideration of all the potential sources of flood damage, their likely significance in terms of contribution to total damage or potential to change through option consideration, and the available data for use in the assessment. Appendix A provides a pro forma to guide this process.

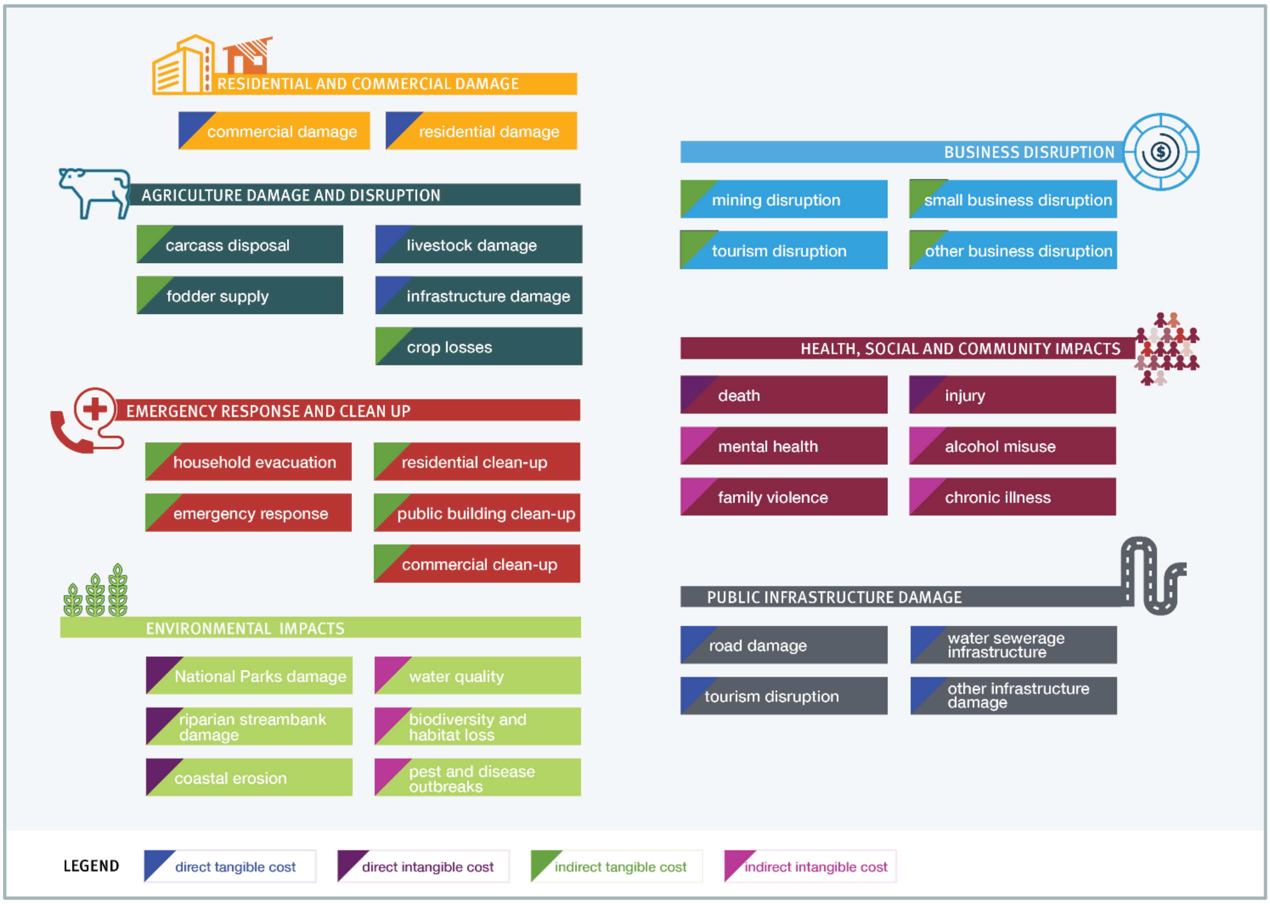

Figure 6: Framework for estimating the social and economic cost of the flood disaster

4.2.1. Select the appropriate tier

Part of this stage involves selecting the quantification method to be applied in Stage 3. For many of the damage categories, three methods or tiers are presented in this Framework (Figure 7), offering different levels of detail and accuracy.

TIER 1	• Minimum level of assessment • Relies on default values rather than study-area specific data • Allows for a 'count' of assets where changes cannot be easily quantified • Low input data requirements
TIER 2	• Relies on combination of industry-standard values and study-area specific data • Aims to capture relationship between flood event probability and potential damage • Moderate input data requirements
TIER 3	• Relies on data specific to the study-area • High degree of detail to allow for greater accuracy in the quantification of benefits/ disadvantages and comparison between preferred options • Significant time, effort and cost involved, therefore warranted only where significant investment is proposed and probable

Figure 7: Levels of assessment – details and accuracy

For each parameter that is included in the economic assessment, a tier should be selected that considers:

- available data
- available resources
- potential influence on the decision or process.

As such, varying tiers can be applied to the same project to optimise the confidence in the outputs with data, resources, time, cost and decisions being made.

4.3. Stage 3: Undertake the quantified assessment

Stage 3 involves quantifying the identified damage source using the methodology set out for the selected level of detail and accuracy (i.e. Tier 1, 2 or 3). Quantification methodologies are set out in Section 5.

Option assessments also involve quantifying the incremental costs and benefits in the range of scenarios being considered. Assessments should be compared against a 'base case' (business as usual) to ensure that the benefits reflect the incremental reduction in damage and losses.

Table 5 and Section 6 provide further guidance for option analysis.

Through this process, the distributional consequences of each option – that is, who benefits (e.g. asset owner, area, industry) and who bears the costs – should be identified.

At this stage, any additional benefits of the option beyond damage avoidance should be identified and quantified where appropriate. This is further discussed in Section 5.1.

4.4. Stage 4: Outline assumptions and limitations, undertake sensitivity analysis on parameters with high level of uncertainty

Economic assessments inherently involve assumptions, approximations and uncertainties. As such, where there is considerable uncertainty or ambiguity, or where substantial investment is required, sensitivity tests on selected parameters should be undertaken.

Sensitivity testing ultimately clarifies the robustness of the economic assessment results and can reassure decision-makers that, despite uncertainty, the chosen response or option is valid.

These tests must go beyond simple demonstration that the results change through varying the parameters. The tests should be used to understand:

- whether the assessment results would materially change if the estimated values or input parameters were varied within a credible range (e.g. range for the days of home disposition: 5 days, 10 days, 15 days)
- the robustness of the assessment parameters (e.g. how far they can vary before the decision changes)
- the influence of different parameters (e.g. whether assessment results are weighted towards a particular damage category, and whether that is reasonable and representative).

There are several ways to undertake the sensitivity analysis, ranging from simple manipulation of input parameters to determine the impact on the final assessment, through to sophisticated stochastic modelling approaches to test the impacts of multiple input variables and assumptions simultaneously through approaches such as Monte Carlo simulations.

4.5. Stage 5: Communicate the results

Reporting the analysis and results is the final stage of the assessment process. It is important the reporting highlights the assumptions and limitations, as well as clearly and concisely summarising the results of the assessment. The information needs to be accessible to non-technical audiences while also providing the necessary information to those who may require more detail.

5. Quantification methods

Flooding results in a diverse set of damage and losses, and therefore a wide range of data and valuation approaches are required. This section briefly outlines the different approaches that can be used to quantify damage and losses for inclusion within an economic assessment of flooding. The methods and data used will depend on the availability of data, the degree of robustness required to convince decision-makers, and the level of detail required for the analysis (Tier 1, 2 or 3).

Table 2, *Table* 3 and *Table* 4 provide the quantification methods for each damage category included in this Framework. Wherever possible, three options, as described in Figure 7, are provided, but for some categories, particularly indirect tangible and intangible damage, this has not been possible at this point in time. This is expected to be resolved as research and practice evolves.

Table 5 provides widely adopted methods for quantifying the costs of several flood mitigation options, with further discussion provided in Section 5.2.

Table 2: Direct tangible damage – overview of quantification methods (see Appendix D for unit values for Tier 1)

Category	Description	Quantification approach – level of detail – direct tangible		
		Tier 1	Tier 2	Tier 3
Property – residential	Damage caused to dwellings due to external and over-floor inundation. Includes all dwelling types. Treats structural, internal and external sources of damage separately.	Application of generalised stage-damage curves. Floor-level database based on gross estimated levels (desktop algorithm or gross assumptions)* if available. * Refer to Appendix C for information regarding floor-level survey methods and accuracy.	Application of generalised adopted stage-damage curves. Floor-level database based on surveyed levels (desktop algorithm, mobile laserscanning (MLS), airborne laser scanning (ALS) or traditional survey – discussed further in Appendix C).	Stage-damage curves derived for the study area specifically based on historic events orassessments from quantity surveyors. Floor-level database based on surveyed levels (desktop algorithm, MLS, ALS or traditional survey).
Property – commercial	Damage caused to business premises due to external and over-floor inundation. Building and contents treated separately.	Application of costs based on best available commercial stage-damage curves. Floor-level database based on gross estimated levels (desktop algorithm or gross assumptions).	Tier 1 plus greater consideration of typology of commercial uses and corresponding contents curves. Floor-level database based on gross estimated levels (desktop algorithm or gross assumptions).	Stage-damage curves derived for the study area specifically based on historic events orassessments from quantity surveyors For uses very susceptible to damage, greater consideration of size cost impacts may be warranted.
Property – industrial	Damage caused to industrial premises due to external and over-floor inundation.	Application of costs based on proportion of best available industrial stage-damagecurves.	Tier 1 with consideration of typology, (e.g.hazardous materials).	Stage-damage curves derived for the study area specifically based on historic events or assessments from quantity surveyors for uses very susceptible to damage, greater consideration of size cost impacts may be warranted.
Property – public assets	Buildings and facilities that do not have commercial uses but provide a service/facility to the community, including community halls, recreational facilities, parks.	Provide a count and measure of assetsaffected (by type). Identify significance (scale and or number). Obtain indicative values from council asset management systems, renewals annuity assessments or similar.	Application of factored residential state-adopted stage-damage curves by asset type andscale, for example, community halls factored against residential buildings of a similar typology (e.g. slab on ground, brick construction). Cost based on m^2/asset type, scaling of residential damage index by Rawlinson's or assetowners' detailed asset management system if available. This could also include costs such as landscaping and fences.	
Utilities	Direct damage to properties and utilities that provide critical services tothe (local and/or broader) community (electricity, water supply, sewerage, telecommunications, emergency services).	Provide a count of assets affected by type.	Apply a proportion of residential damage. WSDOS (2014) recommends critical utility damages are taken as 7.5% of residential damages, particularly for residential areas where the ratio of utility assets to the countof buildings is relatively constant.	Survey of historic damage costs to affectedproperties within study area. If significant,bespoke assessment to be undertaken in conjunction with relevant utility.

Category	Description	Quantification approach – level of detail – direct tangible		
		Tier 1	Tier 2	Tier 3
Community services infrastructure	Direct damage to properties that provide services to vulnerable occupants, such as hospitals, education and care facilities.	Provide a count of assets affected by type.	Obtain indicative values from council /State Government asset management systems, renewals annuity assessments or similar (by asset type). Estimate approximate m^2 costs and apply to approximate area of assets at risk.	Survey of historic damage costs to affected properties within Study Area. If significant,bespoke assessment to be undertaken in conjunction with relevant government agency.
Transport (roads, rail and bridges)	Direct damage caused to transport infrastructure due to inundation, scouring and erosion. Note: Where specific values are required (e.g. vehicle running costs), some transport-specific parameter values are available from the Australian Transport Assessment Planning website: www.atap.gov.au/ parameter-values/index	Apply a proportion of residential damage.The Multi-Coloured Manual (2013) recommends road damages are taken as 15.9% of residential damages.	Application of Unit Damages per Km inundated (DTMR data based on recent events). Include vehicle operation costs and travel time for major diversions. Vehicle operating costs c/km are available on the ATO website.Travel times typically based on average weekly earnings reported by the ABS. Aggregate estimates based on traffic counterdata (if available).	Determination of relationship between depth and damage, and duration and damage, applied to affected infrastructure in the Study Area. Apply relationship to known asset values. Include vehicle operation costs and travel time for major diversions. Vehicle operating costs c/km are available on the ATO website.Travel times typically based on average weekly earnings reported by the ABS. Aggregate estimates based on traffic counter data (if available). For larger projects where transport impactsare likely to be a major driver, there is additional detailed guidance provided in the Australian Transport Assessment and Planning (ATAP) Guidelines (2020).
Transport (airports, train stations, ports)	Direct damage to buildings and infrastructure at transport interchanges.	Provide a count and broad measurement (e.g. ha) of assets affected.	Bespoke based on assets and significance.	
Agriculture	Livestock, crops, pastures, fences, equipment and supporting infrastructure (such as packing sheds, milling operations and pack houses).	Measure of affected agricultural land areas (ha).	Damages to assets (e.g. fences) based onbasic unit costs from Rawlinson's (or similar). Losses based on reported gross value of production for farm type. Data is available from Qld DAF, other state agriculture departments, or industry bodies.	Tier 2 plus consideration of seasonality of floods, are gross values of losses to production (if all variable input costs already incurred) or gross margins (if variable costs can be avoided). Consider theperiod of delay until production recovers. Where possible, include estimated repair/replacement cost of infrastructure (e.g. irrigation pumps). Establish regionally specific bespoke models based on above parameters.

Category	Description	Quantification approach – level of detail – direct tangible		
		Tier 1	Tier 2	Tier 3
Motor vehicles	Vehicles are highly susceptible to flood damage, even at shallow depths (MCM): • vehicles generally written off if water enters the cabin, due to health risks from the water itself (e.g. Legionnaires disease) as well as damage to electricals • engine damage due to water entering via air intake and/or exhaust - requires total replacement (not cost effective – write off) • consideration of bow waves and local surge - damage can be caused at even shallower depths.	ABS data for average number of vehicles per household and average vehicle age, applied to residential properties in flood affected area.State-wide data available from the ABS 9309.0 - Motor Vehicle Census, Australia. State transport agencies may be prepared to provide data at a more granular spatial scale for Tier 3 assessments. Average payout for a motor vehicle write off or theft is approximately $8,500/vehicle insurancestats.com.au/coverage/motor-syndicate/		

Table 3: Indirect tangible damages

Category	Description	Quantification approach – level of detail – direct tangible		
		Tier 1	Tier 2	Tier 3
Alternative accommodation (opportunity cost of loss of use)	Where accommodation is required for the duration of the repair and recovery phase of a flood event.	Allowance per residential property based on a standard number of days multiplied by a daily rate. Obtain daily rate for short-term rental in the areas.	Tier 1 plus assess range for the number of days based on typical duration of flooding and estimated period for repairs.	Tier 2 plus modelled duration of flooding and clean-up/repair period based on probabilistic flood damages.
Business Interruption	Interruption to businesses as a result of direct inundation or community closures and potentially disruptions to supply chains and distribution chains (if materially impacted).	Multiplier of direct tangible estimates.	Multiplier of direct tangible estimates.	Local study of impacts based on local industry structure and turnover (receipts)/ margins for each industry.
Loss of earnings	Flooding of residential properties may require households to take time off work to attend to the evacuation and organising repairs. This time off work is reflected as a loss of earnings.	Apply Average Weekly earnings data (ABS) to workplaces flooded (average employees).	Tier 1 plus a degree of differentiation to reflect the local workforce (industries and professions) based on ABS census data.	
Emergency costs	Costs incurred by emergency services responding to flood events, beyond business-as-usual costs. This will vary depending on the service required, severity of flooding, and communities impacted.	Simple flat rate per household impacted.	Detailed analysis of previous floods (scale, prevalence and cost by callout type) and the development of predictive models and estimates.	
Clean-up costs	Immediate clean-up works following flood event (removal of damaged items, washing out mud and debris, sanitisation).	Apply a flat $ amount per property based in a predetermined number of hours (and costs) and an allowance for materials.	Tier 1 plus assess range for the number of days and materials required based on estimated flood depth and total area (m^2 of assets at risk).	

Table 4: Intangible damages (direct and indirect) – refer Appendix B for further discussions on methods

Category	Description	Quantification approach – level of detail – direct tangible		
		Tier 1	Tier 2	Tier 3
Mortality	Loss of life as a direct result of a flood.	Value of a statistical life (VSL) is currently around $4.65 million (2020 dollars).		
Morbidity	Injury, stress and mental health, other health related impacts.	Available revealed or stated preference studies to avoid or reduce flood related health impacts (per household per year). Applied as an annual cost, regardless of over-floor flood affectation.		Revealed or stated preference to avoid or reduce flood related health impacts (per household per year). Applied as an annual cost, regardless of over-floor flood affectation.
Environ-mental	Values relating to biodiversity and ecology, e.g. water quality, erosion/accretion, amenity.	Qualitative description.	Benefit –transfer if appropriate data is available. (NB this will require specialist advice)	Revealed or stated preference studies. (NB this will require specialist advice)
Cultural/ heritage/ recreational	Values relating to society's personal attachment to 'things' (e.g. monuments, landmarks, environmental assets) can be lost or reduced as a result of flood damage.	Qualitative description.	Benefit –transfer if appropriate data is available. (NB this will require specialist advice)	Revealed or stated preference studies. (NB this will require specialist advice)

Table 5: Cost quantification methods. (See Section 6 for further detail)

Category	Description	Quantification approach – level of detail – direct tangible		
		Tier 1	Tier 2	Tier 3
Structural Mitigation	Physical measures, such as levees, flood gates and dams, which seek to alter the flood behaviour.	Unit rate method for construction costs (see Section 5.2).	Concept design and quantities, gross assumptions regarding operational and maintenance costs.	Preliminary / detailed design, consideration of life of assets, incorporation of operational and maintenance costs benchmarked from other projects.
Voluntary House Raising	Voluntary programs which raise eligible properties so that the lowest habitable floor is flood free to the designed event.	Unit rate per eligible property. Costs are dependent on location and property type In lieu of local data, test viability under the following costs assumptions.		
Voluntary House Purchase	Voluntary programs where eligible properties are purchased typically by the state or local council, and the land reused for non-occupied purposes (e.g. parks, open space, stock grazing).	Median property value by suburb (realestate.com.au data, or RP data). Include an allowance for removal costs and other relevant transaction costs.	Valuation by specific property using on- line estimation tools realestate.com.au. Include an allowance for removal costs and other relevant transaction costs.	Property valuation survey and formal valuations by a registered valuer. Include an allowance for removal costs and other relevant transaction costs.
Refer to Section 6 for discussion on approaches for other mitigation options				

5.1. Other co-benefits and co-investment opportunities created from flood initiatives

Many flood policies, plans and projects can result in other co-benefits or opportunities beyond flood mitigation. Where possible, these should be identified, scoped and incorporated into the economic assessment.

For example, some flood mitigation actions such as revegetating catchments could improve the natural environment, amenity and potential recreation opportunities in addition to flood risk mitigation. Where practical, these co-benefits should be valued for incorporation into the economic assessment. Where realising these co-benefits is contingent on another action (e.g. another level of government establishing a walking track in the revegetated area), the costs of that action should also be included.

Where a co-benefit is identified, there may be opportunities for co-investment on the flood intervention, recognising benefits accruing to multiple entities. While this should not influence the decision on whether the project proceeds or not, the valuation of co-benefits identified can form a basis for negotiating co-investment.

5.2. Cost estimation methods

Common sources of unit data include **Rawlinsons Construction Cost Guide** and other industry standards. There are several frameworks available nationally and internationally with regard to cost estimation for engineering projects. Like the tiered approach provided in this Framework, they are based on varying degrees of complexity and accuracy, with corresponding input costs and time requirements.

Table 6 summarises three of the most widely adopted systems.

Table 6: Cost estimation frameworks

AACE Class Estimates (US)	ANSI Standard Classification (US)	Association of Cost Engineers (UK)	Typical use/ end purpose
Class 5	Order of magnitude estimate (-30/+50)	Order of magnitude (-30/+30)	Concept screening
Class 4	Budget estimate (-15/+30)	Study estimate (-20/+20)	Study or feasibility
Class 3	Budget estimate (-15/+30)	Budget estimate (-10/+10)	Budget, authorisation or control
Class 2	Definitive estimate (-5/+15)	Definitive estimate (-5/+5)	Control or bid
Class 1	Definitive estimate (-5/+15)	Definitive estimate (-5/+5)	Check estimate or bid

Cost estimates undertaken to support the economic assessments discussed in this Framework would most commonly be based on order of magnitude/Class 5 estimates (or better if available). Estimates of this kind typically use unit-price approaches based on available historical cost information, which may include previous bids, cost curves, catalogues, detailed analyses, vendor quotations or regression analysis. Costs are calculated for labour, equipment, materials and, where appropriate, subcontracts, based on the design information that is available to the project. Quantities are derived either from unit quantities for similar structures where data is available, or through allocating reasonable allowances for specific items, which would include the final structure itself as well as allowances for waste, error, breakage.

Contingencies are then added to cost estimates to allow for the inherent uncertainties. A basic principle is that the amount of contingency always becomes lower as project knowledge and level of development increases. For the order of magnitude estimates, contingencies generally vary between 20% and 50%. It is prudent to seek some expert advice when determining what contingencies might be most appropriate.

For more complex assessments (e.g. Tier 3), probabilistic approaches such as Monte Carlo simulations could be used. However, it should be noted that the skills required to undertake these assessment are significant.

5.3. Discounting

A key concept underpinning economic analysis of projects that have long lives is the time value of money – $1 in a year is worth less than $1 today. Within an economic assessment, the time value of money is expressed through the process of discounting. The process of discounting enables the direct comparison of benefits and costs that accrue in different time periods. Discounting gives greater weight to initial costs and benefits, and less weight to those in the future, based on societal preferences.

Discount rates not including inflation should be used in economic appraisals (called real discount rates), with all input costs and benefits presented in present value dollars. State Treasury Guidance on discount rates should be used in economic assessment for flood risk management projects. However, as part of the robustness assessment, influence of the chosen value on the resulting decisions should be undertaken through sensitivity assessment on the chosen rate, and a consistent discount rate should be used for assessing all options.

There is no universally (or in many cases, even nationally) accepted approach to and justification for discounting; yet all major economies require discounting as part of economic assessment. In Australia, at the federal level, Prime Minister and Cabinet and the Office of Best Practice Regulation recommend a constant central rate of 7%, which is the same as the NSW and Queensland Treasuries. Often rates of 4% and 10% are used as the ranges for sensitivity analysis. An overview of recommended rates is shown in the table below.

Table 7: Social discount rate recommendations

Organisation	Low rate	Central rate	High rate
Queensland Government (Building Queensland (2020))	4%	7%	10%
Office of Best Practice Regulation (2016)	3%	7%	10%
Estimates of social discount rate		6.5%	
Productivity Commission (2010)	3%	8%	10%
Queensland Treasury (2015)	Case by case basis		

Harrison (2010) suggests that if sensitivity testing of the discount rate substantially changes the feasibility of the action (e.g. from a positive *net present value* (NPV) to a negative NPV), then the discount rate should be interrogated more closely.

5.4. Time period for the analysis

It is well-accepted that the evaluation period of an economic assessment should take a long-term outlook, aligning with sector investments and demands. 'Long-term' is not specifically defined, but 30 years is a typical period for an analysis. Analyses should not typically exceed 30 years unless robust information is available to value benefits and costs into the longer term (European Commission, 2014; Building Queensland, 2016). Because the economic life of assets varies, and an asset may need replacing once or more over a 30-year period, or alternatively, still have utility past 30 years (commonly known as 'residual value'), analysis should include asset replacement/refurbishment or residual values where applicable. For projects that involve climate change, a longer period for the assessment is sometimes taken (e.g. 50 years). This effectively means that some long-term impacts are more likely to influence the findings from the analysis.

Where an asset needs to be replaced at least once in the time period used for the economic assessment, the replacement cost of that asset should be included at the time in which that cost is incurred. When considering the residual value of an asset, a standard accounting depreciation method should be used to determine the remaining value of that asset, and then that value should be included as a negative cost (or benefit) in the final year of the analysis (e.g. in year 30) (European Commission, 2014).

6. Damage parameters in option assessments

Flood mitigation measures can generally be classified into three categories, as shown below.

FLOOD MODIFICATION MEASURES modify the physical behaviour of a flood including depth, velocity and redirection of flow paths. Typical measures include flood mitigation dams, retarding basins, channel improvements, levees or defined floodways. Pit and pipe improvement and even pumps may be considered where practical.

PROPERTY MODIFICATION MEASURES modify existing properties, and land use and development controls for future new development or redevelopment. This is generally accomplished through such means as flood proofing, house raising or sealing entrances, strategic planning such as land use zoning, building regulations such as flood-related development controls, or voluntary purchase/voluntary house raising.

RESPONSE MODIFICATION MEASURES modify the response of the community to flood hazard by educating flood-affected property owners about the nature of flooding so that they can make better informed decisions. Examples of such measures include provision of flood warning, emergency services, and improved awareness and education of the community.

Each of the above options will have a different influence on the flood damage. Table 8 provides a generalisation of the most relevant damage categories for each broad option type. The table is provided to assist in identifying the key parameters likely to change in an economic assessment of options.

Table 8: Relevant damage categories for each broad option type

	DIRECT TANGIBLE					INDIRECT TANGIBLE					DIRECT / INDIRECT INTANGIBLE			
	Property (Residential, Commercial, Industrial, Public Assets, Critical Infrastructure)	Vulnerable Facilities	Transport (Roads, Rail, Bridges, Airports, Train Stations)	Agriculture	Motor Vehicles	Alternate Accommodation	Loss of Earning	Business Interruption	Emergency Costs	Clean-up Costs	Mortality (Loss of life as a directresult of a flood)	Morbidity (Injury, stress and mental health, other health related impacts)	Environmental	Cultural / Heritage / Recreational
FLOOD MODIFICATION MEASURES														
Dams	P	P	P	S	S	P	P	P	P	P	P	P	P	P
Detention basins	P	P	S	S	S	S	S	S	S	S	S	S	S	S
Levees	P	P	P	P	S	P	P	P	S	S	P	P	S	S
Floodways	P	P	P	S	S	S	S	S	S	S	S	S	P	P
Floodgates (Backflow Prevention Valves)	S	S	P	S	S	S	S	S	S	S	S	S	S	S
Temporary Flood Barriers	P	P	S	S	S	S		P	S	S	S	S		
Landscape management	S	S	S	P				S			S	S	P	P
PROPERTY MODIFICATION MEASURES														
Flood proofing / building control	P	P	S		S	P	S	P		P	S	P		S
House raising	P					P	S		P	P	S	S		S
House purchase	P				S	P	S	P	P	P	P	P		S
Land use planning / zoning	P	P	P	P	S	P	P	P	P	P	P	P	P	P
RESPONSE MODIFICATION MEASURES														
Flood prediction and warning	S	S		S	S			S	P	S	P	P		
Flood access and evacuation			S		S				S		P	P		
Emergency response									S		P	P		
Flood-awareness, education and readiness	S	S			S			S	S		P	P		

P: Primary impact (which can be positive or negative)

S: Secondary impact (which can be positive or negative)

(blank): No or very low impact (which can be positive or negative)

Economic assessments can theoretically be used to analyse land-use planning, building controls, emergency response measures and community awareness programs, though they are rarely undertaken. It is presumed this is due to the difficulties in identifying and quantifying the benefits, and particularly the costs, which can be less apparent than those arising from other interventions.

The following sections provide guidance on methods to quantify the benefits of these interventions. This then provides an understanding of the magnitude of costs that would result in a favourable assessment (i.e. costs would need to be less than benefits). While not definitive, it can be used to provide greater certainty in qualitative assessments.

Table 9 identifies the primary beneficiaries of the full range of intervention methods. The benefits (avoided impacts) should be quantified using the appropriate methodology contained in Section 5.

The following sections provide further high-level discussion on each measure. It also includes a brief discussion on cost quantification methods that could be employed if a more detailed analysis of the measure was warranted.

6.1. Land-use planning

Discussion

Development of land may occur in a previously undeveloped (greenfield) setting, or through redevelopment or intensification of existing developed (brownfield) land. Risk-based land-use planning can be key to creating flood resilient communities. Appropriate policies can manage development of flood-prone areas, as well as introduce flood resilient building codes, revert built areas to natural landscapes, align appropriate land uses with the existing flood hazard, and raise public awareness. In doing so, it has the potential to lower the vulnerability (remove vulnerable people or properties from areas that flood), limit the exposure (locate development out of areas with high probability of flooding), or change the hazard ('making room for the river'). Although limiting flood risk is the primary aim, land-use planning and zoning can also have other benefits such as improving the local environment.

The main cost resulting from risk-based land-use planning is the 'loss' of development opportunity and potential economic benefits arising from a particular land use, as well as the actual costs associated with drafting and adopting land-use planning artefacts. A high-level overview of the primary potential benefits and costs are tabled below (Table 9).

Table 9: Potential benefits and costs – land-use planning

	Benefits	Costs
Economic	• Avoid annual expected damage to property due to lower exposure, less valuable assets located in the area, lower vulnerability • Avoid flood losses due to business disruption • Avoid indirect and intangible impacts	• Potential loss of development opportunity, lost income/loss of employment (this is the difference between the proposed use and the current use) • Indirect economic impacts (e.g. business losses) • Administrative/enforcement costs
Societal	• Prevent human welfare impacts: • dislocation of population, community disruption, fatalities and injuries, indirect health impacts • Improve awareness and risk perception • Reconnect Traditional owners with country	• Unequal distribution of impacts • Loss or damage of artefacts, heritage features and properties that are important to the community
Environmental	• Newly developed or maintained ecosystem services due to change land- use patterns (e.g. recreational uses, landscapes, habitat and biodiversity)	• Nil

Cost quantification

A practical approach to valuing the suboptimal use of land is to take the difference in the price of the original land-use type and the price of the alternative land-use type (capital cost), plus annual costs of the use of the land (average agriculture revenues, business venues, rental). Alternatively, costs may be inferred from the land value premium attributable to the planning change.

6.2. Building control/resilient design

Discussion

In parts of the floodplain where the risk to life from flooding is minimal, impacts on built form can be mitigated through design and construction methods. The opportunity for built form to assist in mitigating the impacts of flooding is increasingly being recognised, including the advancement of methods in wet-proofing. In doing so, the time spent away from properties following a flood can be minimised, and the costs and time associated with clean-up and repair can be significantly reduced, if not eliminated.

The costs associated with resilient design vary based on the property type, whether it is implemented through retrofit or new build, and the characteristics of the flooding needing to be addressed. Recent projects in the Brisbane River floodplain have shown that even when costs may be greater than ‘traditional’ cost methods, they are quickly exceeded by the benefits.

Table 10: Potential benefits and costs – building control

	Benefits	Costs
Economic	• Reduce building damage costs • Reduce clean-up costs • Reduce alternative accommodation costs as buildings are quickly re-inhabitable following the receding of waters	• Resilient principles may have a higher cost than ‘traditional’ construction methods (only the cost premium should be included in the analysis)
Societal	• Reduce intangible impacts including mental health	• Nil
Environmental	• Nil	• Nil

Cost quantification

Quantify the increment costs of flood resilient building methods by cost comparison with ‘traditional’ methods. Actual quotes can be obtained, alternatively, building off two recent projects (Brisbane City Council Flood Resilient Homes Program, and the work undertaken as part of the Brisbane River Strategic Floodplain Management Plan) as a starting point.

6.3. Emergency response

Discussion

The public costs for emergency services during and after a flood event can be substantial, but are not often quantified in an analysis. Where data is available, the costs of increased emergency services activity when compared to typical activity provides a reasonable estimate of the costs associated with flooding. Flood risk management options have the potential to reduce this future cost. It is important to include these costs where possible, as ignoring the costs, or the associated benefits of mitigating these costs, can lead to suboptimal decision-making.

Table 11: Potential benefits and costs – emergency response

	Benefits	Costs
Economic	• Reduce damage and losses, particularly intangible (e.g. productivity)	• Personnel, equipment and time
Societal	• Reduce human health impacts (e.g. loss of life, injury, stress) • Provide intangible benefits (e.g. sense of support/security)	• Potential health and safety impacts on emergency personnel
Environmental	• Nil	• Nil

Cost quantification

Actual event costs can be obtained from local grant expenditure and emergency responders reporting, which can be used to generate costs per impacted property or resident. Alternatively, several recent studies have calculated costs as percentage of overall damage, which could be used in the absence of local data.

Recent examples include **The Social and Economic Cost of the North and Far North Queensland Monsoon Trough** (Deloitte, 2019), which calculated that costs for emergency response and clean up came to $109 million for that event (representing approximately 2% of total social and economic costs). This comprised $59 million in emergency responses, and $49.9 million in clean up and evacuation costs. Other international estimates have been higher – 4% (US), 5% (Germany) and 10% of total costs (UK) have been found.

6.4. Community awareness and resilience

Discussion

A flood-aware community is better able to prepare for, respond to and recover from flood events. Community awareness and resilience programs seek to achieve a behavioural change in the community that leads to reduced damage from flooding, both intangible and tangible. However, it can be difficult to quantify the extent of these reductions, especially as they will vary with each flood, even for the same community. Traditional economic assessments have tried to include an allowance for the benefits of flood awareness through differentiating between 'potential' and 'actual' flood damage.

Table 12: Potential benefits and costs – community awareness

	Benefits	Costs
Economic	• Reduce damage, particularly intangible, but also to property as communities prepare themselves for flooding	• Development and ongoing implementation costs (note: awareness programs need to be sustained, repeated regularly and adapted to changing community profiles)
Societal	• Reduce human health impacts (e.g. loss of life, injury, stress) • Provide intangible benefits (e.g. sense of support/security)	• Nil
Environmental	• Nil	• Nil

Cost quantification

Costs to implement activities such as campaigns, stalls, newsletters and community events can be used as a guide for implementation and assume to occur on an annual basis. Alternatively, costs could be viewed as a lack of benefit, in a method similar to generating 'actual' and 'potential' costs.

Causal relationships between community awareness programs and flood risk mitigation are difficult to quantify, but community awareness programs can be relatively effective. Where the cost of an awareness program is known (e.g. $10,000), and the potential damages that *could* be mitigated through behavioural change are also able to be estimated (e.g. $100,000), then the relative behaviour change required to achieve a positive benefit–cost ratio can be calculated (i.e. a 10% behaviour change would be required to achieve parity in this example). Rates of behaviour change evaluated through other similar programs can then be used to estimate the economic viability.

7. Economic assessment as a tool for decision-making

Two key economic assessment approaches are most appropriate for decision-making:

- Cost-benefit analysis (CBA), which assesses the long-term benefits and costs, all in monetary terms. This approach is more appropriate for larger and more complex assessments, or where competing options provide significantly different scopes of benefits (e.g. one option provides flood mitigation only, while the other provides flood mitigation and recreational amenity benefits)
- Cost-effectiveness analysis (CEA), where benefits are expressed in physical terms (e.g. number of houses protected), while the costs are the life cycle costs of the option.

Each approach has accepted decision rules that provide robust, transparent and repeatable metrics to inform decision-makers. Importantly, both approaches are common in infrastructure investment analysis, policy-making and regulatory impact assessments, and are commonly understood by decision-makers.

7.1. Cost–benefit analysis

CBA is a comprehensive approach that identifies and values as many relevant benefit streams and costs as possible. In the case of flood management:

- benefits are future damage and losses mitigated that are attributable to the option being assessed
- costs are the life cycle costs of implementing the option.

Projects should also be assessed against a base case ('business as usual' or 'do nothing differently' case) to ensure the analysis only considers the benefits and costs attributable to the proposed intervention (policy, program or project). The base case is described in part of Section 7.1.1. CBA has a significant advantage over other approaches as it enables comparisons of projects with different types of benefit streams and values. CBA has two key decision rules for the assessment and comparison of options:

- the NPV – a present value (all values discounted to present day terms) of the benefits less the present value of the costs. For an option to be economically viable, the NPV must be >$0 (i.e. benefits exceed costs). The option with the highest NPV provides the greatest net social benefit
- the benefit–cost ratio (BCR) – the ratio of the present value of benefit over the present value of costs. For a project to be viable, the BCR must be >1. The project with the highest BCR is considered superior, except when comparing mutually exclusive options in which case the NPV should be used. The BCR is very useful for comparing options with vastly different budgets. Furthermore, the BCR is also very useful for prioritising multiple options, particularly where there is a budget constraint[2]
- the incremental benefit–cost ratio (IBCR) – an approach that is sometimes used when comparing two options. The IBCR calculates the increase in benefit from additional augmentations to the selected option (e.g. additional height to a flood levee). This indicator can be extremely useful during options analysis.

The general procedure for the CBA is shown in the figure below. Much of the information and data required to conduct the CBA will be drawn from other assessments (e.g. probabilistic damage assessments, option cost estimates).

[2] For comparing mutually exclusive options for the same initiative, the use of BCRs can provide misleading findings where projects are of a different scale. Rather, where there are two mutually exclusive options that deliver the same outcome, it may be more appropriate to compare them using a CEA framework (see section 7.2).

Step 1: Define the problem, government rationale and objective/s

1.1 Explain the purpose of the economic evaluation by describing the problem(s).

1.2 Assess whether the market can solve the problem and, if not, explain the rationale for government intervention.

1.3 Outline the primary flood management objective/s of government intervention.

Step 2: Determine the base case and identify options

2.1 Determine the base case

2.2 Identify options with clear explanations of how they would achieve the benefits (objective/s) and address the problems.

Step 3: Identify costs and benefits for the different options

3.1 Identify all costs and benefits, including market impacts and non-market impacts.

3.2 Determine data and resources required to value the identified costs and benefits.

Step 4: Quantify and monetise costs and benefits

4.1 Quantify and monetise the costs and benefits.

4.2 Use the valuation techniques, appropriate default values, and other guidance recommended in this guideline.

Step 5: Discount costs and benefits back to present values

5.1 Adopt the appropriate real discount rate as advised in the relevant guidelines.

5.2 Ensure only real prices are used to ensure consistency with the use of a real discount.

5.3 Determine the appropriate evaluation period.

Step 6: Aggregate costs and benefits

6.1 Calculate NPV and BCR for each option.

6.2 Use NPV and BCR to help rank the options.

Step 7: Assess risk and uncertainty

7.1 Identify risk and uncertainty with the options analysed using scenario/sensitivity analysis.

7.2 Analyse and discuss how the above analyses may affect the feasibility and ranking of the options.

Step 8: Assess distributional impacts

8.1 Identify the impacts on different groups in society that are likely to be affected by the different options.

Step 9: Assess results and determine a preferred option

9.1 Analyse overall results including the NPV and BCR, distributional impacts, scenario/sensitivity analysis.

9.2 Recommend the final preferred option(s).

9.3 Present findings and a recommendation in the full business case.

Figure 8: General process for a CBA

7.1.1. Steps of a cost-benefit analysis

The steps to undertake the CBA are outlined in more detail below.

Step 1: Define the problem, government rationale and objective/s

This step sets the scene for the CBA and will primarily draw on the analysis undertaken to date, such as flood risk assessments. This provides the rationale for the proposed flood intervention. It is always worthwhile considering whether a low-cost or market approach could be used to solve or incentivise self-resilience by entities that may be impacted by flood risk. For example, could the provision of better information on flood risks (e.g. an SMS warning system) result in homeowners self-mitigating the consequences of flood events by moving furniture and other chattels out of the flood zone when a flood event occurred?

Step 2: Determine the base case and identify options

The base case is essentially an expression of the likely future risks if nothing is done differently to what is already proposed (the blue line in Figure 1). What is expected to happen if nothing is done differently to the existing interventions (e.g. planning policies, investments) and what are the estimated risks, benefits and costs? It is against this base case that any identified options are assessed. It is important to note that options are not necessarily mutually exclusive and that there may be synergies or interdependencies between options. When identifying and scoping the options, their performance should be considered against the base case. Document the expected changes from the base case incremental to each option, and the assumptions underpinning these expected changes.

Step 3: Identify costs and benefits for the different options

A structured process should be undertaken to identify costs (capital and operational) and benefits for the different options. Costs are typically the financial costs of implementing the flood intervention (plan/policy/project).

The benefits are typically the reduction in future flood damage and losses that can be attributed to the intervention. Typical costs that could be reduced are outlined in Section 5.2 of this document.

Because flood interventions involve benefits and costs across long time periods, it is important to consider the temporal aspects of key benefits and costs. This is also the underlying rational for undertaking CBA over long time periods (e.g. 30 years).

Step 4: Quantify and monetise costs and benefits

There are several different types of benefits and costs that need to be incorporated into a CBA. These are outlined in Section 5 and Section 6 of this report. Note that not all benefits and costs will necessarily be quantifiable. Furthermore, all sources of information and assumptions should be clearly stated. Examples of unit values for some benefits are also provided in Appendix D.

Step 5: Discount costs and benefits back to present values

Typically, a CBA is undertaken using a spreadsheet. All future benefits and costs should be discounted to present value terms to enable credible comparisons of the options over longer timeframes. This process is outlined in Section 5.3 of this document.

Step 6: Aggregate costs and benefits

The present value (discounted) benefits should be aggregated and compared to the present value of the aggregated costs, and the NPV and BCR should be calculated. This provides the key metrics to assess and compare options. See section below on interpreting the aggregated costs and benefits.

Step 7: Assess risk and uncertainty

There will always be variability in the input data used for a CBA and uncertainty underpinning key assumptions. Therefore, it is important to undertake sensitivity analysis to test how sensitive your results are to change in input data used or assumptions made. This is outlined in section 4.4 of this document.

Step 8: Assess distributional impacts

It is also worthwhile considering the distributional impacts of each option (Who benefits and how? Who pays the costs and how?). It is worthwhile assessing the distribution of these benefits and costs as this provides insight into issues such as stakeholder acceptance of an option, and identifies any opportunities for co-investment by other parties.

Step 9: Assess results and determine a preferred option

In this final step, the results are assessed, interpreted and communicated to decision-makers or investors. The communication of the results should outline the process used for the analysis, key data and information used, key assumptions made, and any gaps and deficiencies in the analysis. Where not all benefits and costs are quantified, it is prudent to qualitatively describe any benefits and costs not incorporated into the CBA calculations.

It is important to note that a CBA does not make the decision – it informs the decision. Most senior decision-makers will be familiar with concept of CBAs and business cases.

7.1.2. Interpreting the results of a cost-benefit analysis

When interpreting the results of a CBA, it is important to consider the key decision rules (NPV and BCR). Table 13 below shows the results of a hypothetical CBA and the different insights for decision-makers. Consider the below example – when considering BCRs alone, the rank of projects would be Project B, Project A and Project C. However, when considering the net benefits achieved by the project, Project C would be ranked highest overall – delivering more than seven times the benefits of Project B.

Table 13: Cost-benefit analysis example

Project	Costs (present value)	Benefits (present value)	BCR	NPV
Project A	$10,000	$30,000	3.0	$20,000
Project B	$5,000	$16,000	3.2	$9,000
Project C	$100,000	$170,000	1.7	$70,000

7.2. Cost-effectiveness analysis

CEA compares the costs of different options with the same or similar outputs. CEA is similar to CBA, except that there is no need to value benefits in monetary terms. Rather, benefits are measured in physical measurements (e.g. reductions in houses at risk). CEA is most appropriate for:

- comparing and ranking large projects with primarily a single benefit stream
- initial comparison of conventional costs where projects may 'stack up' without consideration of a broader assessment of benefits.

CEA is an analytical tool commonly used in infrastructure analysis. There are typically three components to a CEA:

- ***Assess efficacy*** – for each option, an assessment of efficacy is undertaken (e.g. the count of residences that would be protected for each option) based on previous modelling and efficacy outlined in previous investigations (e.g. exposure mapping). This draws heavily on typical flood modelling approaches and other relevant studies.
- ***Assess life cycle costs*** – for each option, an assessment of life cycle costs must be undertaken. This includes relevant establishment and capital costs (including opportunity costs of land foregone where necessary/possible), annual operation and maintenance costs, and any relevant renewal/refurbishment costs. Discounted cashflow analysis is then commonly used to ensure all options are assessed in a consistent economic framework. A 30-year timeframe for the analysis is usually used.
- ***Calculate cost-effectiveness and compare options*** – using this approach enables a relative comparison of cost-effectiveness for different options (e.g. $/residence protected) and greater insight into the variability in costs across multiple options. Once the cost-effectiveness of individual options has been determined, they can be ranked based on their cost-effectiveness. To maximise benefits from available financial resources, options are progressively selected until the available budget is exhausted, or a specific target is achieved.

7.3. Common pitfalls of a cost-benefit analysis

There are several pitfalls associated with undertaking a CBA of flood policies and projects. These are briefly outlined below, including options to reduce the risk of this occurring.

- **With and without analysis** – it is important to ensure the estimation of benefits and costs for the proposed policy or project is compared to what would have happened without the policy or project (i.e. the incremental benefit or cost). For example, if the cost of building a home is \$2,000 m^2, but the cost of building a flood-resilient home is \$2,200 m^2, the cost of the flood investment to be incorporated into the CBA is \$200 m^2. When undertaking a CBA, it is worthwhile establishing a simple table of benefits and costs with and without the project to help identify and scope the incremental benefits and costs.
- **Narrow scope** of benefits and costs considered – a CBA considers benefits and costs from a societal perspective. This includes tangible and intangible benefits and costs, many of which will be non-market in nature (i.e. there is not a market value for the benefit or cost). As outlined in Section 3.5, the scope of the assessment should capture as many benefits and costs as practicable. Section 5, Section 6 and Appendix D of this Framework discuss the full scope of values that could be included in a flood CBA, and provide unit values that should be appropriate for a simple Tier 1 assessment. Where formal quantification is not undertaken, the benefits and costs should be qualitatively identified, scoped and outlined in the CBA report.

- **Avoiding double counting** – it is important to avoid double counting benefits. For example, if a flood levee was established that resulted in lower flood risk, it would be reasonable to expect house insurance premiums to decline (an annual benefit to the householder) and house values to increase (capitalising the annual benefit). Within a CBA, these benefits should only be counted once. It is worthwhile always checking the logic and calculations to avoid double counting.
- **Forecasting and estimation bias** – it is important to avoid forecasting and estimation bias through inadvertently overstating benefits or understating costs, or through the use of overly optimistic assumptions. These potential biases can be reduced through transparent and full disclosure of data sources and assumptions made.

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APPENDIX A. Flood damages qualification form

Project name	Insert name of project
Objective	Purpose of the economic assessment

Direct tangible

Damage category	Description	Relative magnitude of costs	Assumptions, uncertainties and constraints for quantification	To be quantified and chosen methodology
Property: Residential	*Where possible, quantify the number by flood extent based on best available information*	*Low/ Medium/ High/ Unknown*	*List key assumptions, uncertainties and constraints if quantification were to occur*	*Flag if intended for quantification (Y/N) and select tier of methodology (Tier 1 – Tier 3)*
Commercial	*Where possible, quantify the number by flood extent based on best available information*	*Low/ Medium/ High/ Unknown*	*List key assumptions, uncertainties and constraints if quantification were to occur*	*Flag if intended for quantification (Y/N) and select tier of methodology (Tier 1 – Tier 3)*
Industrial	*Where possible, quantify the number by flood extent based on best available information*	*Low/ Medium/ High/ Unknown*	*List key assumptions, uncertainties and constraints if quantification were to occur*	*Flag if intended for quantification (Y/N) and select tier of methodology (Tier 1 – Tier 3)*
Public assets	*Where possible, describe assets and quantify the number by flood extent based on best available information*	*Low/ Medium/ High/ Unknown*	*List key assumptions, uncertainties and constraints if quantification were to occur*	*Flag if intended for quantification (Y/N) and select tier of methodology (Tier 1 – Tier 3)*
Critical infrastructure	*Where possible, describe assets and quantify the number by flood extent based on best available information*	*Low/ Medium/ High/ Unknown*	*List key assumptions, uncertainties and constraints if quantification were to occur*	*Flag if intended for quantification (Y/N) and select tier of methodology (Tier 1 – Tier 3)*
Vulnerable facilities	*Where possible, describe assets and quantify the number by flood extent based on best available information*	*Low/ Medium/ High/ Unknown*	*List key assumptions, uncertainties and constraints if quantification were to occur*	*Flag if intended for quantification (Y/N) and select tier of methodology (Tier 1 – Tier 3)*
Transport: Road, rail, bridges	*Identify relevant assets in floodplain affected by varying flood extents*	*Low/ Medium/ High/ Unknown*	*List key assumptions, uncertainties and constraints if quantification were to occur*	*Flag if intended for quantification (Y/N) and select tier of methodology (Tier 1 – Tier 3)*
Airports, train stations, ports	*Identify relevant assets in floodplain affected by varying flood extents*	*Low/ Medium/ High/ Unknown*	*List key assumptions, uncertainties and constraints if quantification were to occur*	*Flag if intended for quantification (Y/N) and select tier of methodology (Tier 1 – Tier 3)*
Motor vehicles	*Consider whether motor vehicle damage is likely to be significant in area and whether there is enough warning time and access for cars to be moved to high ground*	*Low/ Medium/ High/ Unknown*	*List key assumptions, uncertainties and constraints if quantification were to occur*	*Flag if intended for quantification (Y/N) and select tier of methodology (Tier 1 – Tier 3)*
Agriculture	*Consider whether agricultural uses are significant in area, describe area/typical use*	*Low/ Medium/ High/ Unknown*	*List key assumptions, uncertainties and constraints if quantification were to occur*	*Flag if intended for quantification (Y/N) and select tier of methodology (Tier 1 – Tier 3)*

Indirect tangible

Damage category	Description	Relative magnitude of costs	Assumptions, uncertainties and constraints for quantification	To be quantified and chosen methodology
Emergency costs	*Consider past events, number of people, location of emergency providers*	*Low/ Medium/ High/ Unknown*	*List key assumptions, uncertainties and constraints if quantification were to occur*	*Flag if intended for quantification (Y/N) and select tier of methodology (Tier 1 – Tier 3)*
Alternative accommodation	*Consider past events, flood duration and severity*	*Low/ Medium/ High/ Unknown*	*List key assumptions, uncertainties and constraints if quantification were to occur*	*Flag if intended for quantification (Y/N) and select tier of methodology (Tier 1 – Tier 3)*
Clean up and rehabilitation	*Consider past events, flood duration and severity*	*Low/ Medium/ High/ Unknown*	*List key assumptions, uncertainties and constraints if quantification were to occur*	*Flag if intended for quantification (Y/N) and select tier of methodology (Tier 1 – Tier 3)*
Business disruption	*Consider past events, flood duration and severity*	*Low/ Medium/ High/ Unknown*	*List key assumptions, uncertainties and constraints if quantification were to occur*	*Flag if intended for quantification (Y/N) and select tier of methodology (Tier 1 – Tier 3)*
Disruption of public services	*Consider past events, flood duration and severity*	*Low/ Medium/ High/ Unknown*	*List key assumptions, uncertainties and constraints if quantification were to occur*	*Flag if intended for quantification (Y/N) and select tier of methodology (Tier 1 – Tier 3)*

Direct intangible

Damage category	Description	Relative magnitude of costs	Assumptions, uncertainties and constraints for quantification	To be quantified and chosen methodology
Mortality (loss of life)	*Consider past events, flood hazard and probability*	*Low/ Medium/ High/ Unknown*	*List key assumptions, uncertainties and constraints if quantification were to occur*	*Flag if intended for quantification (Y/N) and select tier of methodology (Tier 1 – Tier 3)*
Morbidity (injury, stress and mental health, other flood-related health impacts)	*Consider past events, flood hazard and probability, duration and severity*	*Low/ Medium/ High/ Unknown*	*List key assumptions, uncertainties and constraints if quantification were to occur*	*Flag if intended for quantification (Y/N) and select tier of methodology (Tier 1 – Tier 3)*
Environmental values	*Consider at-risk assets, impacts from flooding*	*Low/ Medium/ High/ Unknown*	*List key assumptions, uncertainties and constraints if quantification were to occur*	*Flag if intended for quantification (Y/N) and select tier of methodology (Tier 1 – Tier 3)*
Cultural, heritage and recreational values	*Consider at-risk assets, impacts from flooding*	*Low/ Medium/ High/ Unknown*	*List key assumptions, uncertainties and constraints if quantification were to occur*	*Flag if intended for quantification (Y/N) and select tier of methodology (Tier 1 – Tier 3)*

Indirect intangible

Damage category	Description	Relative magnitude of costs	Assumptions, uncertainties and constraints for quantification	To be quantified and chosen methodology
Welfare	*Consider past events*	*Low/ Medium/ High/ Unknown*	*High uncertainty in currently available quantification methods and readily accessible data, not recommended as standard for assessments unless justified at project level*	*N*
Societal function	*Consider past events*	*Low/ Medium/ High/ Unknown*	*High uncertainty in currently available quantification methods and readily accessible data, not recommended as standard for assessments unless justified at project level*	*N*

APPENDIX B. Non-market valuation techniques

Often, flooding or flood management options involve impacts that do not have market economic values. These will be issue specific. Several possible valuation techniques may be used when seeking to estimate the monetary benefits of an option; alternatively, inferring values from studies undertaken elsewhere will be required – a technique called 'benefit transfer'. A summary of the valuation methods is provided in the table below.

Table B.1:. Common economic valuation techniques

Method	Based on …	Example uses …	Data
Benefit transfer	Studies undertaken in similar locations for similar impacts	Meta-analysis of previous studies undertaken elsewhere, where values are inferred on the attributes being valued in the study area (such as aesthetic benefits of parks)	Available data for physical impacts and previous economic studies
Approaches that rely on market approaches or using market values			
Market values	Actual market transactions	Where there are established markets (e.g. infrastructure costs)	Estimates of financial costs of each option
Productivity-based	Inputs to production of commercial goods	Changes to values of commercial tourism due to a disruption to access	Changed daily visitors, value adding from tourism operator
Replacement cost/avoided	Costs of replacing a service or avoiding costs	Impact on potable water supplies from water quality decline	Marginal costs of different water supplies (treatment plant energy and chemical costs vs manufactured water such as indirect potable recycled)
Non-market approaches			
Hedonic pricing	Value of goods traded in related markets (e.g. housing)	The recreational and aesthetic value of improvements in protecting habitat and waterway access reflected in property prices	Impact on property adjacent to river
Travel cost	Costs incurred in visiting a site	Valuing tourism, recreation or cultural *use* of a site	Estimates of visitors (e.g. from traffic counters) and data available from studies elsewhere
Stated preference techniques	Surveys and community willingness to pay to protect an asset	The value of the existence of green space	Bespoke surveys (very expensive to undertake)

Given the complexity of these issues, it may be most appropriate to consult with an internal economist for Tier 1 assessments and potentially an external expert in Tier 2 and 3 assessments.

Value types that are affected by flooding and its mitigation, described in terms of changes in final outcomes (note: not all outcomes are independent), are described below.

Table B.2:. Value types affected by flooding and its mitigation

Value type	Event or mitigation outcomes
Physical health	Change in the number of fatalities Change in the number of serious injuries, hospitalisations and minor injuries Change in the number of illnesses or diseases Change in pain to individuals
Mental health	Change in reported cases of grief, stress and anxiety Change in the number of self-harm fatalities and hospitalisations
Ecosystems	Change in the number of flora and fauna species Change in the number of identified endangered species Change in the status of identified endangered specifies Change in native vegetation coverage Change in ecosystem function Change in status of identified threatened ecosystems Change in carbon storage in vegetation and soils Change in number of fauna crossings
Water quality	Change in riparian vegetation coverage Change in the number of flora and fauna species or populations
Recreation	Change in the recreation activity in the area Change in the number of walking hours or distance Change in the area of land identified as parks or open space
Amenity	Change in the scenic amenity in the area
Safety	Change in the perceived safety of a dwelling location
Cultural heritage	Change in Aboriginal heritage significance Change in natural heritage significance Impact to sense of place Change in the number of cultural artefacts Change in the quality of cultural artefacts
Social disruption	Breakdown of existing family and support networks Change in availability of basic services
Animal welfare	Displacement, death or injury to animals

APPENDIX C. **Floor-level survey capture methods**

C.1. Capture methods

There are several methods available for obtaining floor-level estimates, each with corresponding levels of accuracy commonly measured by a confidence percentage of being within a certain tolerance level (for example ± 0.1 m). A brief discussion of these methods is provided below, ranked by decreasing accuracy (with corresponding decreases in time and cost required for capture).

Traditional survey

This method offers the highest level of accuracy as a team of surveyors will individually survey the floor level and ground level of each property. Floor-level accuracy often exceeds ± 0.075 mm and offers higher accuracy collection of other building data (except for approximate building size, which is estimated from the road). This is by far the most time consuming and costly method of obtaining the data.

Mobile laser scanning extraction

Mobile laser scanning (MLS) involves the capture of new survey and imagery using car-mounted, side-facing survey methods. This results in very high accuracy survey points, comfortably within +/- 0.1 mm for surveyed levels where there is a direct hit on the floor level. Assumptions need to be made for floor levels that are obstructed (i.e. where there is no direct hit from the MLS, or which exceed approximately 30 m from the road). In these instances, it is common to assume floor levels based on surrounding window, door or eaves heights.

Given the extraction of floor levels is done remotely (i.e. not at the time of capture), additional quality assurance of the outputs is required to ensure they meet the necessary accuracy targets, which may incur an additional fee depending on the sample size.

Airborne laser scanning extraction

This method involves using existing airborne laser scanning (ALS) or LiDAR capture and Google Street View to extract building eaves heights remotely, from which an assumed floor level is derived based on assumed ceiling heights. This method is done using a series of algorithms. As a result of the lower level accuracy survey and assumptions required to obtain floor levels from eaves heights, overall floor level accuracy typically varies between 0.3–0.5 m for obtained floor levels. Other data is extracted from Google Street View so depends on the clarity of the image and how recently the imagery has been updated.

Given the extraction of floor levels is done remotely (i.e. not at the time of capture) and is based on a number of assumptions, additional quality assurance is required of the outputs to ensure they meet the necessary accuracy targets, which may incur an additional fee depending on the sample size.

Desktop extraction

This method involves utilising existing ALS/LiDAR capture and Google Street View to manually extract building floor levels based on a desktop visual inspection of a building. The floor level is recorded as the relative difference from the ground, and these point values are then compared with available topographic data. Overall floor-level accuracy typically varies between 0.3–1 m for obtained floor levels. Other data is extracted from Google Street View so depends on the clarity of the image and how recently the imagery has been updated.

This method can only be undertaken in areas where LiDAR and building imagery is available.

Algorithmic extraction

Algorithmic capture involves using a combination of python and a GIS-based algorithm. This algorithm uses the eaves level and ground level from available LiDAR, and assigns an assumed building type (e.g. slab on ground, lowset) based on the difference. For each building type, a floor rise is adopted to estimate the floor level.

Algorithmic extraction requires LiDAR and building footprints, but is not dependent on Google Street View availability.

Table C.1:. Methodology cost and accuracy comparison

Capture methodology	Estimated accuracy	Average cost per property	Limitations
Traditional survey	± 0.075 m	$$$$$	Time consuming and costly
MLS	± 0.1 m	$$$	Accuracy limitations in heavily vegetated or rural areas where a direct floor-level capture is not possible
ALS	± 0.3–0.5 m	$$	Less accurate than both traditional and MLS capture. Increased accuracy limitations in rural areas and heavily vegetated areas where the property cannot be viewed on Google Street View
Desktop extraction	± 0.5 m	$	Comparable accuracy to ALS methods where recent LiDAR and Google Street View are available. Relies on manual processing which can be time consuming for large areas
Algorithmic	± 0.5 m or more	$	Least accurate methodology but also the least expensive. Limitations are that there is no visual verification of the floor type and standard floor-rise assumptions are made for each floor type

C.2. Influence of survey accuracy on flood damage assessments

In 2019, the Queensland Reconstruction Authority commissioned the *Brisbane River Floor Level Survey Analysis* (WMA Water) to determine the influence the composite methods of floor-level survey capture had on the flood damage estimates undertaken as part of the development of the *Brisbane River Strategic Floodplain Management Plan* (SFMP) (Queensland Government, 2018).

The floor-level database developed as part of the SFMP is the most extensive floor-level survey database in Australia. Developed from the acquisition of more than 200,000 floor-level estimates using MLS, ALS and desktop algorithmic extraction, as well as an independent verification survey for 1,000 properties using traditional survey (Global Navigation Satellite System and total station shots using datums from local survey marks), it provided the unique opportunity to interrogate the influence of accuracy on flood damage assessments.

Findings from the statistical assessment demonstrate that the errors in the SFMP floor-level dataset had up to a 5% impact on the true total ADD. The impact was comparable for differing capture methods, most likely as a result of the similar spread of errors. The largest impact from floor-level survey error on total AAD was seen in the more frequently inundated areas of the floodplain (defined as more frequent than 2% Annual Exceedance Probability), due to the greater contribution these areas have on AAD calculations.

The assessment concluded that higher accuracy survey methods, which are considerably more costly, may not be warranted where the outputs are used solely for flood damage assessments, or, if employed, should be targeted to areas most at risk.

The assessment also identified that the error introduced from the flood frequency analysis and stage-damage curves provided a more significant contribution to AAD error, with flood frequency analysis uncertainty contributing up to 520% impact on AAD.

APPENDIX D. Indicative unit values for Tier 1 assessments

Direct tangible damages

Description	Quantification approach – level of detail	2020 dollars				
	Tier 1	Low	Mid	High	Unit	Source
Property – Residential						
Damage caused to dwellings due to external and over-floor inundation. Includes all dwelling types. Treats structural, internal and external sources of damage separated.	Application of generalised stage-damage curves.	$714	$1,428	$2,142	$/m²	From stage damage curves (0.5m over floor slab on ground). Natural Capital Economics (2019). Bundaberg East Levee Business Case.
		$918	$1,836	$2,754	$/m²	From stage damage curves (1.5m over floor slab on ground). Natural Capital Economics (2019). Bundaberg East Levee Business Case.
		$34,969	$39,853	$75,839	$	From stage damage curves (0.5m over floor slab on ground). BMT et al (2018) Brisbane River SFMP Technical Evidence Report
		$42,323	$49,072	$86,434	$	From stage damage curves (1.5m over floor slab on ground). BMT et al (2018) Brisbane River SFMP Technical Evidence Report
Property – Commercial						
Damage caused to business premises due to external and over-floor inundation.	Application of costs based on best available commercial damage curves.	$200	$400	$600	$/m²	From stage damage curves (0.5m over floor commercial). Natural Capital Economics (2019). Bundaberg East Levee Business Case.
		$700	$1,400	$2,100	$/m²	From stage damage curves (0.5m over floor commercial). Natural Capital Economics (2019). Bundaberg East Levee Business Case.
Building and contents treated separately.	Floor level database based on gross estimated levels (desktop algorithm or gross assumptions).	$206	$418	$1,563	$/m²	From stage damage curves (0.75m over commerical). BMT et al (2018) Brisbane River SFMP Technical Evidence Report
		$619	$1,674	$5,246	$/m²	From stage damage curves (1.75m over commerical). BMT et al (2018) Brisbane River SFMP Technical Evidence Report
Property – Industrial						
Damage caused to industrial premises due to external and over-floor inundation.	Application of costs based on proportion of best available industrial damage curves	$150	$300	$450	$/m²	From stage damage curves (0.5m over floor industrial). Natural Capital Economics (2019). Bundaberg East Levee Business Case.
		$488	$975	$1,463	$/m²	From stage damage curves (1.5m over floor industrial). Natural Capital Economics (2019). Bundaberg East Levee Business Case.
Property – Public assets						
Buildings and facilities that do not have commercial uses but provide a service/facility to the community, including community halls, recreational facilities, parks.	Provide a count and measure of assets affected (by type).	$200	$400	$600	$/m²	From stage damage curves (0.5m over floor commercial). Natural Capital Economics (2019). Bundaberg East Levee Business Case.
	Identify significance (scale and or number).	$700	$1,400	$2,100	$/m²	From stage damage curves (1.5m over floor commercial). Natural Capital Economics (2019). Bundaberg East Levee Business Case.
	Obtain indicative values from council asset management systems, renewals annuity assessments or similar.					
Utilities						
Direct damage to properties and utilities that provide critical services to the (local and/or broader) community (electricity, water supply, sewerage, telecommunications, emergency services).	Provide a count of assets affected by type.					
Community services infrastructure						
Direct damage to properties that provide services to vulnerable occupants, such has hospitals, education and care facilities	Provide a count of assets affected, by type.					

Description	Quantification approach – level of detail	2020 dollars				
	Tier 1	Low	Mid	High	Unit	Source
Transport (roads, rail & bridges)						
Direct damage caused to transport infrastructure due to inundation, scouring and erosion.	Apply a proportion of residential damage. MCM (2013) recommends road damages are taken as 15.9% of residential damages.					
Transport (Airports/ Train Stations, Ports)						
Direct damage to buildings and infrastructure at transport interchanges.	Provide a count and broad measurement (e.g. ha) of assets affected.					
Agriculture						
Livestock, crops, pastures, fences, equipment.	Measure of affected agricultural land areas (ha).	$67	$136	205	$/ha/pa for grazing*	DPI (2019). Livestock gross margin budgets. Department of Primary Industries, NSW. Accessed at: https://www.dpi.nsw.gov.au/agriculture/budgets/livestock (Grazing)
		$2,664	$3,383	$4,101	$/ha/pa for sugar	AgMargins (2019). Sugarcane reports. AgMargins, QLD Govt. Accessed at: https://agmargins.net.au/Reports/Index# (Sugar)
		$2,347	$5,970	$9,594	$/ha/pa for macadamias	Queensland Government (2018). Macadamia, Agbiz tools. Queensland Government. Accessed at: https://www.publications.qld.gov.au/dataset/agbiz-tools-plants-fruits-and-nuts/resource/30550a45-006a-40b6-8758-58786db7e526
Motor vehicles						
Vehicles are highly susceptible to flood damage, even at shallow depths (MCM):	Average insurance claim for vehicles.	$4,505	$9,010	$13,515	$/vehicle claim	ISA (2016). Motor Syndicate Data. Insurance Statistics Austalia Ltd. Accessed at: https://insurancestats.com.au/coverage/motor-syndicate/
Vehicles generally written off if water enters the cabin, due to health risks from the water itself (e.g. Legionnaires disease) as well as damage to electricals;						
Engine damage due to water entering via air intake and/or exhaust - requires total replacement (not cost effective - write off).						
Consideration of bow waves and local surge - damage can be caused at even shallower depths						

Indirect tangible damages

Description	Quantification approach – level of detail	2020 dollars				
	Tier 1	Low	Mid	High	Unit	Source
Alternative Accommodation (opportunity cost of loss of use); event displacement; repair displacement						
Where accommodation is required for the duration of the repair and recovery phase of a flood event.	Allowance per residential property based on a standard number of days multiplied by a daily rate. Obtain daily rate for short-term rental in the areas from Airbnb or similar.	$80	$240	$350	$/night*	AirBnB (2020). Accessed at https://www.airbnb.com.au/ 10th June 2020
		$90	$200	$310	$/night*	AirBnB (2020). Accessed at https://www.airbnb.com.au/ 10th June 2020
		* for 5 person family in Townsville				
Business interruption						
	Multiplier of direct tangible estimates.	$113,805	$227,610	$341,415	Loss of stock in $/impacted business	NineSquared (2019). Bundaberg 10-Year Action Plan, Bundaberg East Levee, Economic Appraisal Report.
		0.6	1.3	1.9	Loss of value add in $/day/m²	NineSquared (2019). Bundaberg 10-Year Action Plan, Bundaberg East Levee, Economic Appraisal Report.
Loss of earnings						
Flooding of residential properties may require households to take time off work to attend to the evacuation and organising repairs. This time off work is reflected as a loss of earnings.	Apply Average Weekly earnings data (ABS) to workplaces flooded (average employees).	$802	$1,604	$2,405	$/week	ABS (2020). 6302.0 - Average Weekly Earnings, Australia, Nov 2019. Australian Bureau of Statistics. Accessed at: https://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/6302.0Nov%202019?OpenDocument
Emergency costs						
	Simple flat rate per household impacted.	$45	$3,173	$14,018	$/house/pa*	BTRE (2002). Benefits of flood mitigation in Australia. Accessed at: https://www.bitre.gov.au/sites/default/files/report_106.pdf
		* (5% AEP, 1% AEP, probable maximum flood respectively)				
Clean-up costs						
Immediate clean-up works following flood event (removal of damaged items, washing out mud and debris, sanitisation)	Apply a flat $ amount per property based in a predetermined number of hours (and costs) and an allowance for materials.	$6,081	$7,257	$8,433	$/property	NineSquared (2019). Bundaberg 10-Year Action Plan, Bundaberg East Levee, Economic Appraisal Report.

Intangible damages and losses

Description	Quantification approach – level of detail	2020 dollars				
	Tier 1	Low	Mid	High	Unit	Source
Mortality						
Loss of life as a direct result of a flood	Value of a statistical life (VSL) is currently around $4.65 million (2020 dollars).	0.31	0.61	0.92	Deaths/ 100,000 people (average for Queensland)	Haynes, K. C. (2016). An Analysis of Human Fatalities from Floods in Australia 1900-2015. Melbourne: Bushfire and Natural Hazards CRC.
Morbidity						
Injury, stress and mental health, other health related impacts	WTP to avoid or reduce flood related health impacts (per household per year). Applied as an annual cost, regardless of over-floor flood affectation.	$227,245	$454,491	$681,736	AUD per person for serious injury	Olesen, L., Löwe, R and Arnbjerg-Nielsen, K. (2017). Flood Damage Assessment: Literature review and recommended procedure. Cooperative Research Centre for Water Sensitive Cities, Melbourne, Australia.
		$7,599	$15,198	$22,797	AUD per person for minor injury	Olesen, L., Löwe, R and Arnbjerg-Nielsen, K. (2017). Flood Damage Assessment: Literature review and recommended procedure. Cooperative Research Centre for Water Sensitive Cities, Melbourne, Australia.
		$268	$537	$805	WTP/house-hold/pa	Florec, V, Chalak, M, Hailu, A (2017). Integrating intagible values in economic analyses of flood mitigation: a case study of the Brown Hill and Keswick creeks catchment in Adelaide.
Environmental						
Values relating to biodiversity and ecology – water quality, erosion/accretion, amenity	Revealed or stated preference studies, or other appropriate measure.	$3,663	$5,690	$9,552	$/ha/pa	Mangroves/saltmarshes. Natural Capital Economics (2018). Whitsunday Regional Council Coastal Hazard Adaptation Strategy (CHAS): risk assessment for environmental assets. Brisbane, September 2018.
		$554	$1,696	$3,766	$/ha/pa	Coastal forests. Natural Capital Economics (2018). Whitsunday Regional Council Coastal Hazard Adaptation Strategy (CHAS): risk assessment for environmental assets. Brisbane, September 2018.
No loss of water quality (for consumption and ecology)	(NB this will require specialist advice)					
Cultural / heritage / recreational						
Values relating to society's personal attachment to 'things' (e.g. monuments, landmarks, environmental assets) can be lost or reduced as a result of flood damage.	Revealed or stated preference studies	$0.88	$1.77	$2.65	WTP for protection*	Florec, V, Chalak, M, Hailu, A (2017). Integrating intagible values in economic analyses of flood mitigation: a case study of the Brown Hill and Keswick creeks catchment in Adelaide.
	(NB this will require specialist advice)	$2.48	$4.96	$7.44	Per house-hold/pa**	Rolfe, J. and Windle, J. (2003), Valuing the Protection of Aboriginal Cultural Heritage Sites. Economic Record, 79: S85-S95. doi:10.1111/1475-4932.00094

* one monumental tree per household per year
** 1% increase in the number of Aboriginal cultural heritage sites protected in central Queensland (equating to 27 sites)

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