May 2021

State guideline:

Flood evacuation route improvements

Queensland Government

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The guideline was peer reviewed by:

- Associate Professor Matthew Burke, Griffith University
- Ben Patterson, Royal HaskoningDHV, New South Wales
- Jaap-Jeroen Flikweert, Royal HaskoningDHV, United Kingdom
- Stein Grodum, TransGroup Australia.

Important contributions were made by all parties involved in the development of the guideline.

Disclaimer

Planning and development for flood mitigation and recovery, including flood evacuation routes, is complex and is unique to local regions and environments.

The information provided in the guideline has been provided to support users in identifying 'fair and reasonable' improvements to flood evacuation routes and improving evacuation. The information in the guideline is not intended to be exhaustive and neither TMR nor QRA make any representations or warranties about the accuracy, reliability, completeness or suitability for any particular purpose of the information contained in the guideline. Neither TMR nor QRA will be liable for any loss or damage suffered by users, caused by any error, inaccuracy, incompleteness or other similar defect in the information in the guideline.

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Yeppen floodplain bridges, Rockhampton

Maranoa

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Yeppen Floodplain Crossing, Bruce Highway following Ex-Tropical Cyclone Debbie.

Preface

Background

The Brisbane River Strategic Floodplain Management Plan (BRSFMP) represents the third phase of the *Brisbane River Catchment Flood Study,* which was developed in response to recommendations from the Queensland Flood Commission of Inquiry. This guideline delivers on BRSFMP Action FM12.3 which requires the development of state guidelines to support the identification of 'fair and reasonable' flood immunity for evacuation routes.

The guideline undertakes a broader approach to the action by supporting the identification of 'fair and reasonable' evacuation route improvements. This includes a range of options beyond improvements to the flood immunity of evacuation routes such as flood warning systems, evacuation centres, road upgrades to improve capacity or resilience, new roads, and levees. This approach ensures that low cost options, which may achieve similar outcomes to larger infrastructure projects, are included.

Guideline purpose

The guideline outlines an options assessment process to support the identification of 'fair and reasonable' flood evacuation route improvements to inform decision making. The guideline may be used to inform flood risk management activities particularly when identifying and assessing options.

Users of the guideline may include local governments, state agencies and Queensland's disaster management groups, supported as needed by suitably qualified or experienced persons. This recognises that the governance of flood risk management in Queensland is based on a collaborative, decentralised model with shared roles and responsibilities (QRA, 2021b). Please see *Queensland Flood Risk Management Framework* for further guidance on roles and governance.

The guideline is a non-mandatory, state-wide guideline developed to consider different flood risk profiles (flooding types, size, severity, duration and exposure) and support flexible implementation of options by entities who vary in resource capability and funding capacity.

Relationship with evacuation planning

Evacuation planning is the development of plans or arrangements to co-ordinate and execute evacuation, if required, when a flood event occurs. Evacuation plans or arrangements are developed based on existing measures and infrastructure, such as existing evacuation centres and routes. Further information on evacuation planning can be found in *Evacuation: Responsibilities, Arrangements and Management – Manual.1.190, Evacuation Planning - Handbook 4 and Flood Emergency Planning for Disaster Resilience Handbook.*

In contrast, the identification of evacuation route improvements is a process of identifying new or improved infrastructure or measures to improve evacuation capability and resolve evacuation constraints.

Evacuation plans and the identification of evacuation route improvements are undertaken separately. However, evacuation plans may need to be revised to consider changes to evacuation planning resulting from evacuation route improvements.

What is excluded from the guideline?

This guideline does not provide guidance, or a recommended process, for:

- evacuation capability assessments (ECAs)
- economic assessments for flood risk management projects or
- evacuation planning.

The guideline may be applied to new development, however, this is not the intended purpose and specific guidance has not been provided. Further information about managing flood risks for new development is provided in the *State Planning Policy* (SPP) and associated guidance material, *Queensland Urban Drainage Manual* and the *Road Drainage Manual.*

The guideline does not address flooding as a result of dam failure. Please refer to the *Guideline for failure impact assessment of water dams* for further information.

How to use this guideline

The guideline is divided into three parts:

- **Part A: Introduction and principles** – provides a brief overview of the assessment process and discusses the supporting guiding principles, information on identifying stakeholders and pre-assessment data collation
- **Part B: Assessment process** – outlines the process for identifying and assessing options
- **Part C: Implementation** – provides information to assist with option implementation.

The guideline is supported by the *State guideline: Flood evacuation route improvements – Worked example* and *State guideline: Flood evacuation route improvements – Supporting tool* which assist in understanding and implementing the assessment process.

Users unfamiliar with flood risk management can find further resources and information in Appendices A and B.

The Ross River in Flood, Townsville, February 2019

Part A: Introduction and principles

A1. Guiding principles and assessment process

A1.1 Fair and reasonable evacuation route improvements

Evacuation is a hazard mitigation strategy and a risk reduction activity that lessens the effects of flooding on a community (Queensland Fire and Emergency Services (QFES), 2018b). An evacuation route improvement must, first and foremost, reduce risk to life by improving evacuation capability.

For an evacuation route improvement to be 'fair and reasonable,' it needs to be fit-for-purpose and respond to the local circumstances and scale of the evacuation problem. This includes matters such as constraints in the evacuation network, alignment with existing flood risk management measures, meeting the needs of the community and being reasonable with respect to the scale of the evacuation problem.

To be 'fair and reasonable' an improvement also needs to be pragmatic, considering and balancing a number of determining factors beyond risk mitigation, such as social, economic, environmental, and flood behaviour factors (for example, value for money, level of community acceptance and impacts from changed flood behaviour).

A1.2 Guiding principles

The guiding principles shown in Table 1, support and complement the process outlined in the guideline. These principles are based on the national best-practice approach to flood risk management outlined in *Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia - Handbook 7* (Australian Institute for Disaster Resilience (AIDR) Handbook 7) (AIDR 2017d).

Table 1 - Guiding principles

Adopt a risk based approach

Understand and respond to flood risk

- Evacuation route improvements respond to the level of risk posed to a community.
- A risk-based approach aligns with current best-practice flood risk management and recognises that a standards-based approach may not be fair and reasonable.
- The full range of flood risk is considered by assessing multiple flood events, including rare events.

Support with evidence

Support decisions with a sufficient level of information

- The nature, scale and factors contributing to the evacuation problem are understood in detail.
- Identification of evacuation route improvements is supported by robust, fit-for-purpose data, including information sourced from flood risk assessments, ECAs and flood studies.

Coordinate and consult with stakeholders

Engage and consult with stakeholders early and throughout the process

- Community consultation is undertaken to understand the nature of the evacuation problem and support for potential options.
- A collaborative partnership between local governments, state agencies or other stakeholders is promoted which recognises different roles and responsibilities.
- Early and ongoing engagement is undertaken with stakeholders responsible for resourcing, implementing or delivering potential options.

Optimise existing infrastructure

Optimise the existing evacuation route network

- Consider:
  - a broad range of options including non-infrastructure options and options that improve existing infrastructure
  - low cost options over high cost infrastructure options that achieve similar outcomes (Department of Infrastructure Local Government and Planning (DILGP), 2016)
  - combining options to improve effectiveness.

Recognise that all flood risk cannot be eliminated

Recognise residual risk always exists

- The development and consideration of potential options recognises that living on flood-prone land has an inherent risk and that a residual risk always remains after a preferred option has been delivered.
- The development and consideration of potential options recognises that evacuation route improvements are only one measure to mitigate flood risk and need to be considered as part of a broader flood risk management process.

A1.3 Assessment process

The options assessment process outlined in this guideline (see Figure 1) is one method to assess and compare options against assessment criteria. The assessment process is a decision support tool for the identification of 'fair and reasonable' flood evacuation route improvements by providing information on the effectiveness and efficiency of options based on their benefits, impacts, cost and constraints.

Following stakeholder identification and data collation, options are identified and assessed using the following process:

- **Understand the evacuation problem** – evacuation issues are investigated before defining the evacuation problem, service need and desired outcomes
- **Identify potential options** – potential options are identified (long list)
- **Options assessment** – options are assessed through the following stages:
  - **Stage one: option feasibility assessment** – high level assessment of all relevant potential options to eliminate options that are not practical or feasible to create a short list of options
  - **Stage two: multi-criteria assessment (MCA)** – detailed assessment of short-listed options against criteria and targeted indicators
  - **Financial and economic assessments** – financial and economic assessment of short-listed options
- **Review outcomes** – assessment outcomes are reviewed to identify a preferred option or a combination of options. Where no options are suitable or further refinement is required, options can be redefined before repeating the assessment process.

The level of detail required for each assessment depends on the evacuation problem, the scale and the type of options being assessed. For example, where options are non-infrastructure, small scale or low cost, options are assessed through each stage of the process, however, detailed studies or assessments may not be necessary to inform the process.

In summary

The options assessment process provides a method to assess and compare options. The level of detail required to assess options depends on the evacuation problem, scale and type of options being assessed.

ADF deploys 'The Chinook' to aid recovery , Townsville, February 2019

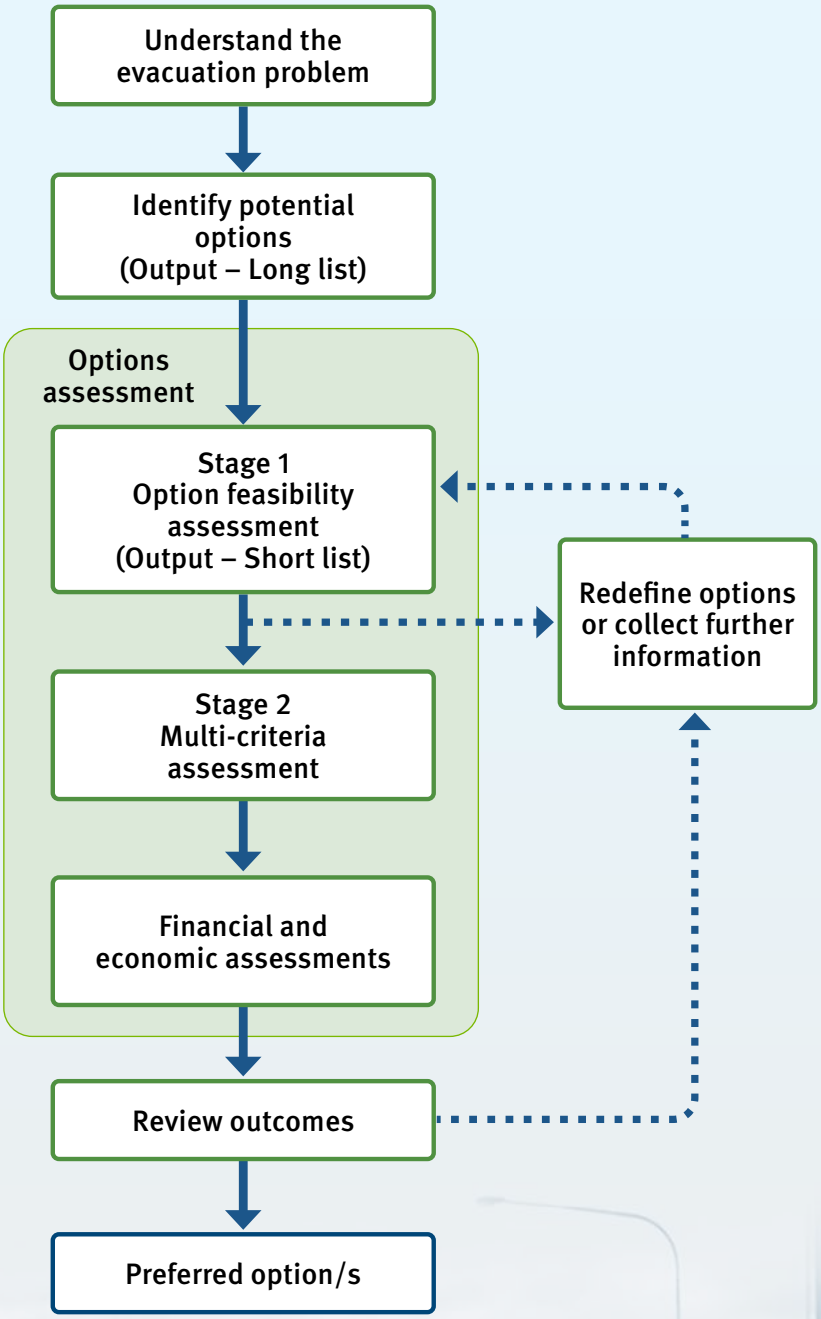


Figure 1 - Assessment process

A2. Stakeholders, governance and consultation

A2.1 Stakeholder engagement

Identifying and engaging stakeholders is critical to the assessment process, as stakeholders can provide valuable local knowledge and expertise when investigating the evacuation problem and identifying and assessing potential options. It is intended that stakeholders who have a responsibility or consequence in relation to resourcing, implementation or delivery of potential options are engaged throughout the process. Engaging with these stakeholders ensures policies, planning, and funding requirements related to an option's delivery are considered. Failing to engage with these stakeholders may result in difficulties implementing preferred options.

Undertaking early and ongoing liaison with stakeholders ensures that:

- the practicality and/or impacts of potential options are identified
- preferred options align with other floodplain management measures and forward-planning for infrastructure and future development
- potential issues are identified early, avoiding unnecessary rework
- changes or opportunities due to new information are communicated
- funding sources to deliver an option can be identified.

Following each stage of the assessment process, review the stakeholder list to ensure appropriate advice and input for options is obtained. A list of potential stakeholders is provided in Table 2. The *Queensland State Disaster Management Plan* and the *Queensland Flood Risk Management Framework* contain roles and responsibilities for disaster and flood risk management that may also assist in identifying stakeholders. The list of stakeholders in Table 2 is provided as an example only and is not intended to be exhaustive. There may be other stakeholders who may be engaged based on local circumstances.

Table 2 - Potential stakeholders

Local government stakeholders

- Floodplain managers
- Disaster managers
- Transport and infrastructure planners
- Asset managers
- Civil designers
- Community development and engagement officers

Other stakeholders

- Local Disaster Management Group
- TMR
- QRA
- State department/agency responsible for planning (to determine impacts on future development)
- Dam operators (where dam releases are a potential source of flooding)
- Government landowners (e.g. state department/ agency responsible for parks or forests where evacuation may be required through a state-owned park)
- Major community groups, such as chambers of commerce, environmental groups, etc. (where there is interest in the evacuation problem or proposed option)
- District Disaster Management Group
- Police and emergency service agencies
- Bureau of Meteorology
- State department/agency responsible for seniors and disability services to inform considerations for vulnerable people)
- Adjacent council (where there is, or could be, shared use of evacuation infrastructure)
- Significant private entities such as mine owners/ operators (where there is, or could be significant use of private evacuation infrastructure)
- Large land holders and employers
- Others as appropriate

A2.2 Establishing governance arrangements

To promote a proactive and coordinated approach, establish governance arrangements with key stakeholders, including agencies represented on disaster management groups, affected government landowners, relevant infrastructure providers and stakeholders responsible for delivering or implementing potential options.

These arrangements should support decision making throughout each stage of the assessment process, including when weighting and scoring MCA criteria (stage two: MCA). This approach supports users in considering the organisational requirements of potential options, including compliance with internal policies, priorities and processes for committing resources.

A2.3 Relationship with road infrastructure planning and delivery

The identification and assessment of evacuation route improvements involving new or upgraded road infrastructure requires coordination with road infrastructure stakeholders. Facilitating engagement with these stakeholders is important as they often operate under different processes and/or in separate organisations to floodplain management processes.

Road infrastructure stakeholders provide valuable input on the practicalities of road infrastructure options when assessing and identifying evacuation route improvements. Similarly, when road infrastructure stakeholders are planning and delivering infrastructure, engaging floodplain management stakeholders ensures projects take into account impacts to flood evacuation route functions. Engagement between these two groups assists in identifying if projects may be altered to incorporate evacuation benefits and to ensure any changes to flood behaviour do not affect the performance of flood evacuation routes.

A2.4 Community consultation

Community consultation is an integral part of the assessment process as effective evacuation requires community acceptance and a willingness to cooperate and respond in an emergency. An understanding of how certain sections of the community are more or less vulnerable, resilient or tolerant to the effects of flooding also ensures that selected improvement options are fit-for-purpose and meet the needs of the community.

The nature of the community and scale of the evacuation problem informs the degree of community consultation required. It is important that all relevant sections of the community are represented as communities, even in small towns, are not homogeneous.

Outside of the assessment process, community education may be undertaken following the selection of a preferred option, particularly where the option requires behavioural change from the community (for example, use of a new evacuation route, understanding flood warning systems, etc.).

Refer to AIDR's *Community Engagement for Disaster Resilience* for information on principles and practices for community engagement for disaster resilience in Australia. Community Recovery and the International Association for Public Participation also provide resources to support community consultation for vulnerable groups (https://www.qld.gov.au/community/disasters-emergencies/supporting-people-with-vulnerabilities).

In summary

Stakeholder and community engagement is critical to the assessment process. Implement early and ongoing engagement and establish governance arrangements with key stakeholders such as those required to provide resources to deliver or implement options.

A3. Pre-assessment data collation

Before identifying options, collate data to inform the assessment process. Data can be collated from flood studies, flood risk assessments, ECAs, economic assessments, records of historic floods and through stakeholder and community consultation. Note, further information may need to be collated to assess options during the assessment process. For example, ecological assessments may be required for the detailed assessment of options which may result in impacts to vegetation and habitat.

The following sections outline key information for the assessment process and potential considerations for determining if further studies are warranted.

Available data needs to be evaluated and/or validated at appropriate stages throughout the assessment process and additional data collected if considered necessary.

A3.1 Flood studies

Flood studies are a key resource for the assessment process. Where unavailable, some assessment may also be undertaken with, or supplemented by, historic flood information. Details of the flood study process are provided in Appendix B. Outputs from flood studies can vary and may be determined by the age of the model, the original intent of the flood study and (potentially) the project budget. Consider the following flood study outputs for the assessment process:

- **Understanding of flood source:** Consider what type of flooding affects the location of the evacuation problem and if the available flood data was intended to describe this source of flooding. Users may consider multiple flood sources simultaneously (that is, the joint probability of coincident flooding occurring), however, many flood studies assess different flooding sources in separate studies. If considering multiple flood sources, users may consider the dominant flood source while recognising additional limitations that may be imposed due to other sources.
- **A full range of flood events:** Aim to have access to flood model results for a full range of flood events, including events larger than those experienced in the past, to ensure the assessment process is informed by an understanding of the full spectrum of flood risk. Some flood events may be historic events with records of various sizes rather than design events. Typically a full range of flood events includes:
  - a 'defined flood event' (usually the 1 per cent annual exceedance probability (AEP) flood event or the event generally used to define planning levels)
  - several more frequent and less frequent flood events
  - a probable maximum flood (PMF).
- **Various flood output types:** These may be in mapped or digital format and typically include flood levels or depths, flood velocity and flood hazard. For recent flood studies, it is preferable for flood hazards to be categorised in accordance with recommendations from AIDR Handbook 7, shown in Figure 2 and Table 3. Flood hazard categories are used in flood studies to determine the variation and magnitude of hazard across flood-prone land and are an important tool for understanding risk. However, mapped hazard categories should not be used to determine if areas are safe or trafficable during an event and further investigations may need to be undertaken.
- **Climate change mapping** representing one or more future climate scenarios. This information can help users understand how changes in rainfall intensity and sea levels might influence flooding in the future.
- **Timing information** is valuable in understanding how much flood warning time is available. Flood warning time is the time available from the first sign of a flood to when properties or evacuation routes begin to be inundated. Timing information also assists in understanding which sections of the community or evacuation routes are inundated first and how long flooding is likely to persist (affecting flood isolation). Timing information includes available warning time, time available to undertake evacuation (discussed further in section A3.3) and the duration of isolation. Duration of isolation is determined by considering a number of factors including the likely duration of road inundation, road closure (including clean-up, inspection, etc.) and average annual time of closure (AATOC) (discussed further in the *Road Drainage Manual*). Consider timing information for a range of flood event sizes and flood onset patterns (where data is available). If possible, there is value in linking timing information to levels on reference stream

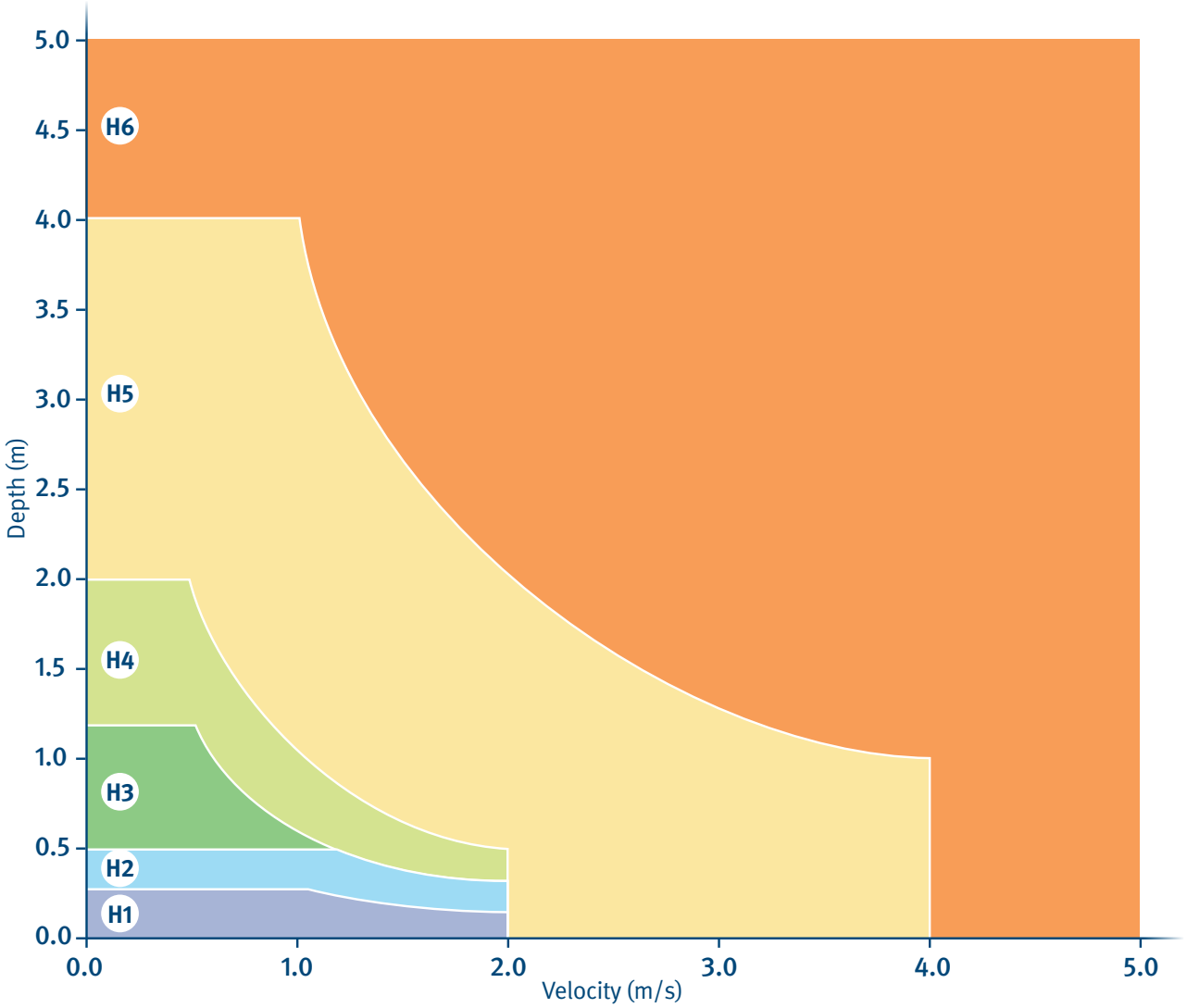


Figure 2 - Flood hazard categories (AIDR 2017c)

Table 3 - Definitions of flood hazard categories (AIDR 2017c)

Flood hazard category	Description*	Depth-velocity limit	Upper velocity limit	Depth limit
H1	Generally safe for vehicles, people and buildings	≤ 0.3 m2/s	2 m/s	≤ 0.3 m
H2	Unsafe for small vehicles	≤ 0.6 m2/s	2 m/s	≤ 0.5 m
H3	Unsafe for vehicles, children and the elderly	≤ 0.6 m2/s	2 m/s	≤ 1.2 m
H4	Unsafe for vehicles and people	≤ 1.0 m2/s	2 m/s	≤ 2.0 m
H5	Unsafe for vehicles and people All building types vulnerable to structural damage	≤ 4.0 m2/s	4 m/s	≤ 4.0 m
H6	Unsafe for vehicles and people All building types considered vulnerable to failure	› 4.0 m2/s	N/A	› 4.0 m

*Mapped hazard categories should not be used to determine if areas are safe or trafficable during an event.

gauges to tie in with standard disaster management and flood warning practices. Note, timing information is typically the least certain output from flood models, but also one of the most valuable inputs in evacuation planning.

- **Flood impact assessment** modelling and mapping may need to be obtained if potential evacuation route improvement options are likely to modify flood behaviour. Impact assessments may consider the change in peak flood levels, velocity, hazard and timing for a range of flood events and the type of land uses likely to be affected by changes in flood behaviour. If modelling and mapping are not obtained, users may not fully understand potential adverse flood impacts due to changes to existing flood behaviour.

A3.2 Flood risk assessment

The level of flood risk to an affected population comprises many components including flood behaviour, frequency, exposure and the nature of the community (see Appendix B). A flood risk assessment assesses these components to identify the level of risk to the affected population. Risk assessments should align with AIDR Handbook 7 and the *Queensland Emergency Risk Management Framework – Risk Assessment Process Handbook*. Consider the following outputs from flood risk assessments for the assessment process:

- understanding of flood behaviour, including the flood velocity, depth, duration and hazard, for a range of flood sizes (see section A3.1), including information about flood timing
- the number of people likely to be isolated, inundated or require evacuation in each flood event size (isolation might include loss of access due to inundated roads or being fully surrounded by water)
- the characteristics of the affected population likely to be isolated, inundated or require evacuation in each flood event size. This should consider both demographic attributes (such as age, mobility, ability to receive flood warnings, etc.) and institution-scale vulnerabilities (such as schools, childcare, aged care, hospitals, detention facilities, etc.)
- flood immunity of evacuation infrastructure, including evacuation routes and evacuation centres. When considering the immunity of an evacuation route, the immunity of the overall route is limited by the lowest immunity at any point along the route, as once this point is closed, the evacuation route is closed. Also consider if different areas have different immunities, which may influence phasing of evacuation for evacuation planning
- the duration of isolation for a range of different flood events and any other information which may contribute to inundation or isolation risk, such as potential loss of service and access to essential goods
- any existing risk management measures which may alter the flood risk, such as flood warning systems
- a flood risk map which visually identifies levels of risk affecting different locations.

The above information is intended to be considered for both existing conditions and future climate conditions. In addition, consider changes to development patterns and population increases, particularly where there is potential for high growth.

A3.3 Evacuation capability assessments (ECA)

An ECA is the process of developing an evacuation timeline to determine if safe evacuation is possible. Where safe evacuation is not possible for a full range of flood events, an ECA can help to identify and understand constraints in the evacuation plan and infrastructure. ECAs are one of the key references to help users understand evacuation problems and assess potential improvements to evacuation routes. ECAs may be undertaken as part of a standard flood risk management study to inform a complete understanding of flood risk or as a standalone study.

ECAs can range from very simple to complex. The simplest forms are an acknowledgement of a problem based on a past flood and assessment of the constraints that may have caused the problem. The most complex forms can include traffic and behavioural modelling. It is intended that users consider the scale and complexity of their evacuation problem and determine a fit-for-purpose approach which is sufficient to determine the effectiveness of evacuation for a range of potential flood sizes and to identify constraints in the evacuation plan and infrastructure.

There is currently no standardised approach to the ECA process or established guidance. However, when undertaking an ECA, consider the key factors that may influence each stage of the evacuation process discussed in Appendix B. *Evacuation Planning – Handbook 4* and E*vacuation: Responsibilities, Arrangements and Management – Manual.1.190* also provide information to further understand the evacuation process. Additionally, the New South Wales State Emergency Service has published conference papers on their suggested 'timeline' approach to evacuation planning which may assist in framing the evacuation problem and incorporating industry-standard assumptions (see Opper et at., 2010).

Bundaberg, 2013

To inform the assessment process, the primary output required from an ECA is an understanding of constraints in the evacuation plan and/or infrastructure. This may be informed by the following data:

- time required for responsible authorities to make flood predictions, decide to evacuate and issue warnings
- total time needed for evacuation which includes time for the community to accept and respond to warnings and time needed for vehicle movements. When determining time needed for evacuation, consider the ability to evacuate the most vulnerable members of the community including groups who have limited access to motor vehicles, and the road capacity for evacuation routes, including feeder and linking roads
- time available before routes are cut off by flood waters, including the time available following the issuing of warnings
- flood immunity of evacuation infrastructure including safer locations and evacuation centres
- sufficiency of resources, services and essential goods available for evacuees at safer locations and evacuation centres for the duration of the shelter phase
- where shelter-in-place (either at the household or community scale) forms part of evacuation planning, whether sufficient resources are available to support the duration of the shelter phase
- time of road closure (affecting both isolation and return to the community) which includes consideration of road inundation and road closure, including the resilience of infrastructure (for example: are bridges likely to withstand flood impacts? Will high velocity waters cause scour and require lengthy road repairs?).

Undertaking an ECA for a range of flood event sizes identifies which constraints are critical for different flood events. Similarly, consider if the community, or parts of the community, have different evacuation needs according to various risk parameters including flood behaviour and community attributes such as vulnerability, resilience and tolerance to flooding. Additionally, consider if some of the stages of the flood evacuation timeline may be impacted by things such as time of day (for example, flood evacuation may take longer during the night). These risk factors are critical considerations when developing and testing an evacuation plan through the ECA process.

Findings from an ECA should be captured in the Local Disaster Management Plan (LDMP) or evacuation sub-plan.

A3.4 Community consultation

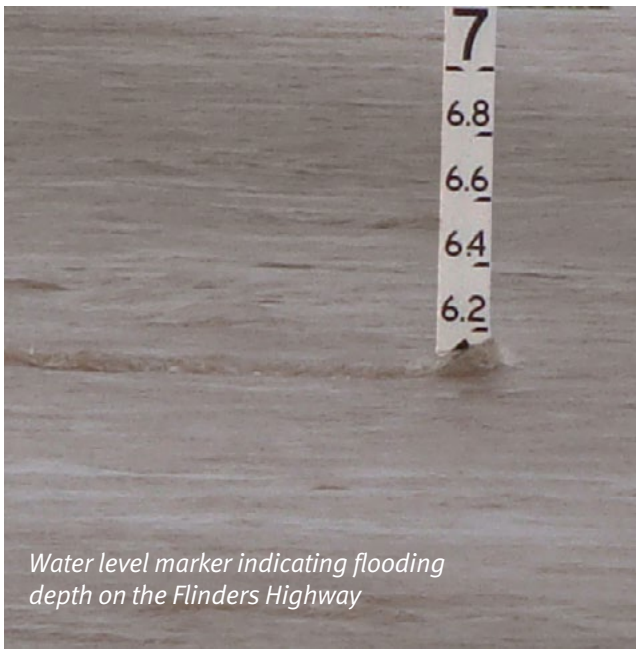
As discussed in section A2.4, community consultation can provide valuable information to understand the evacuation problem and ensure options are fit-for-purpose for the community they intend to service. Information derived from community consultation required to inform the assessment process may include:

- community vulnerability, including vulnerability related to age (both older and younger), ability to receive and understand flood warnings and ability to evacuate independently. Vulnerability may occur at the individual/household scale or be associated with certain types of institutions, such as schools, hospitals, aged care, childcare, detention facilities etc.
- community tolerance to flooding and isolation, such as consideration of how long community members might be prepared to be isolated at either a property or community scale
- community resilience to flooding and ability to recover from flooding, including consideration of community support networks, socio-economic position, insurance, etc. Resilience of individuals or households is linked to broader community resilience, including support structures in the community and the ability for businesses to recover and recommence trading.

A3.5 Other useful information

In addition to the above sources of information, consultation with stakeholders and an understanding of LDMPs, including evacuation sub-plans, and flood warning infrastructure will also be relevant. Other information which can inform the assessment process may include:

- information related to historic floods. This may include flood records, flood marks, community experience, etc. It is also useful to have an estimate of the AEP of historic floods so that magnitude is understood
- economic assessments which identify the economic impact of the evacuation problem based on tangible and intangible damages. This may inform the level of investment that might be justified to resolve the evacuation problem. Guidance on economic assessments is provided in the *Economic Assessment Framework of Flood Risk Management Projects*
- if a flood risk assessment has not been completed, census data and other information about the population (for example, vulnerability) and the existence of vulnerable institutions (such as aged care facilities, etc.) helps in defining current flood risk.



Water level marker indicating flooding depth on the Flinders Highway

A3.6 Review collated data

Some of the information described in the previous sections may not be available and the quality of data may vary. Reduced quality or availability of data may affect confidence in assessment results. If a comprehensive understanding of the evacuation problem is not achievable with the existing information, it may be necessary to collect additional data. To determine if further studies or information is required, refer to Table 4 and consider if the level (availability and quality) of data may be sufficient or fit-for-purpose considering the scale of the evacuation problem.

In summary

Flood studies, flood risk assessments, evacuation capability assessments and community consultation are key resources for the assessment process. The level (availability and quality) of data should be fit-for-purpose to the evacuation problem, scale and type of options being assessed.

Table 4 – Level of data availability and quality

These considerations are provided as a guide only and are not intended to be exhaustive or determinative.

Level of data availability and quality			
Data type		**High level of data**	**Medium level of data**
Flood study			
	**Range of flood events**	Full range of design flood events from frequent to the PMF event	Small range of flood events
	Information on timing	Time series data available for all design flood events and recorded information from historic events	Time series data available for some design events or reliable upstream gauge data with recorded historic events
	Flood immunity	Sufficient design flood event information to determine flood immunity at all locations of interest	Enough information to determine flood immunity in some locations, but not all
Flood risk assessment			
	**Population at risk**	Full flood risk assessment that has determined the population at risk	No flood risk assessment but available information on populations at risk
	Flood risk to properties and infrastructure	Full flood risk assessment that has determined flood risk to properties and infrastructure	No flood risk assessment, but information available on properties and infrastructure at risk
	Community vulnerability assessment	Desktop assessment of individual and institution vulnerabilities supplemented by community consultation	Desktop assessment of individual and institution vulnerabilities
Evacuation capability assessment			
	**Evacuation capability assessment (ECA)**	ECA completed for full suite of design flood events. Good understanding of constraints for various flood events	ECA completed for at least one design flood event or large historic flood event. Some understanding of constraints in the evacuation network
Community/stakeholder consultation			
	**Stakeholder/ community input and opinion**	Project-specific community consultation undertaken and have a good gauge on community and stakeholder views	Some incidental understanding of community and stakeholder views (e.g. those expressed after a historic event)
Other information			
	**Economic assessment**	Flood damages assessment undertaken using full suite of design flood events, with consideration of direct, indirect and intangible flood damages	General understanding of expected property and infrastructure damages and ability to fully cost potential options for comparison on cost

Hinchinbrook, 2014

Part B: Assessment process

This section outlines the process for options identification and assessment: understanding the evacuation problem, identifying potential options, options assessment and reviewing the outcomes to select a preferred option. The guideline is supported by the *State guideline: Flood evacuation route improvements – Worked example* and *State guideline: Flood evacuation route improvements – Supporting tool* which assist in understanding and implementing the assessment process.

B1. Understand the problem

Potential options cannot be identified without firstly understanding the evacuation problem that the options need to resolve. A comprehensive understanding of the evacuation problem is critical to identify potential options that are fit-for-purpose and respond to local circumstances. This process brings together information from pre-assessment data collation and consultation with stakeholders and the community.

B1.1 Investigating the evacuation problem

This section provides a number of questions that can assist in understanding the evacuation problem.

B1.1.1 Why has flood evacuation been identified as a problem for this location, and what is the problem?

Consider the reasons why flood evacuation has been identified as a problem, such as:

- during a recent flood event existing evacuation procedures and/or routes were not adequate
- changes to urban development or road/rail infrastructure have constrained evacuation capability and increased risk to life
- a comprehensive flood study or flood risk management study has been undertaken and shown that there is considerable risk that was previously not understood
- a flood risk management study and/or ECA has identified evacuation as a problem.

It is also important to consider the nature of the evacuation problem which may be due to inundation and/or isolation risks.

B1.1.2 What is acceptable to the community?

It is important to understand what level of residual risk is acceptable to the community. For example, communities each have different tolerabilities to the duration of isolation and the level of resourcing available during isolation.

Communities are not homogeneous and may not have a uniform approach to flood risk and its management. Consultation should ensure that all relevant sections of the community are represented and that a complete understanding of community acceptability is developed. It is worth noting that 100 per cent community acceptability may be difficult to achieve.

B1.1.3 What is the flood risk?

Understanding the flood risk (as discussed in Appendix B) is fundamental to fully understanding the evacuation problem. The following questions may help articulate the level of risk for an area, how the risk is spatially distributed, the number of people at risk of inundation and/or isolation, and the characteristics of the at-risk population:

- What areas are at risk of inundation and in what size flood events? What is the probability of inundation for different areas?
- What is the timing of inundation? Are some areas inundated earlier in an event allowing less time for evacuation?
- How many people are likely to be inundated in each flood event size?
- How many people are likely to be isolated in each flood event size and what is the duration of isolation? Note that some areas may become isolated in smaller floods, then subsequently inundated in larger floods.
- What are the characteristics of the affected population likely to be inundated and/or isolated in each flood event size? This may consider both demographic attributes (such as age, mobility, ability to receive flood warnings, etc.) and institution-scale vulnerabilities (such as schools, childcare, aged care, hospitals, detention facilities, etc.). Statistics that indicate access to a car or vehicle may also be useful to determine the ability of people to evacuate.
- Is there any other information that may contribute to inundation or isolation risk, such as potential loss of services or insufficient essential goods to sustain the duration of isolation?
- Are there any existing risk management measures which may alter the flood risk, such as flood warning systems?

Collate the above information to gain an understanding of the spatial variation in risk across the community in terms of hazard and demographics.

Alice River Bridge, 2019

B1.1.4 What is the source of flooding that affects the area?

There are several possible sources of flooding described in Table 10 (see Appendix B). Refer to this table to assist in determining the flood mechanism (or mechanisms) and relevant considerations for evacuation.

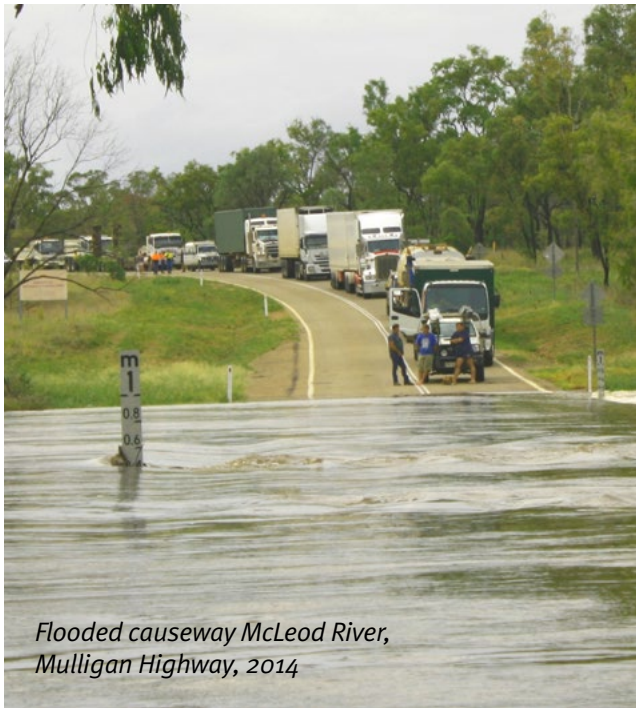
Based on the sources of flooding, evacuation may not be possible and sheltering in place may be more appropriate.

B1.1.5 What is the flood immunity of the area, and what is the flood immunity of associated evacuation infrastructure?

Flood immunity is generally established through flood studies, though it may also be assessed in a flood risk management study and/or an ECA. Immunity needs to be determined for essential evacuation infrastructure, including evacuation centres and the evacuation route network. The flood immunity of the subject area also needs to be identified to determine if sheltering in place is viable, for example, to identify if a community is likely to be isolated or if they are also at risk of inundation.

All sections of the evacuation route network should be considered, including feeder roads which may link properties to major evacuation routes, as evacuation routes are limited by the lowest immunity at any point along the route. Once the point with the lowest immunity is closed, the evacuation route is closed.

Not all areas have the same flood immunity and communities may require staged evacuation or a variety of evacuation route improvement options to address the localised risk. Understanding the variation in flood risk across an area assists in identifying and prioritising locations for evacuation route improvements.



Flooded causeway McLeod River, Mulligan Highway, 2014

B1.1.6 What is the nature of the flood behaviour, including flood hazard and timing?

Flood hazard and flood behaviour are key elements of flood risk. They provide an indication of how an event might unfold, the timing and relative sequencing of inundation and the hazard posed to the community from flood waters. Consider flood management infrastructure, such as dams and levees, in the overall risk assessment as they may also influence the flood behaviour. Also consider general flood behaviour, including the source of inundation in the area and/or evacuation route and if flood behaviour is influenced by hydraulic controls. For example:

- Does the water rise slowly from a waterway?
- Does inundation occur suddenly due to levee overtopping or flash flooding?
- Is there a combination of these behaviours?
- What is the duration of flooding?
- What are the hydraulic controls? Are there weirs or hydraulic structures that affect the behaviour of flood water?
- Is the flood-prone land wide and/or are there areas of narrower, more confined flow?
- What is the timing of the different sources of flooding? Is coincident flooding an issue?

Coincident flooding is when flooding occurs from more than one source at the same time, such as at the confluence of a river and a creek. For example, the river flood may be more significant, but the creek may flood faster due to a smaller catchment size. This may lead to the closure of evacuation routes before the main river flood arrives.

If coincident flooding is possible in the subject area, a flood study that considers coincident flooding may be undertaken (aligned with guidance within *Australian Rainfall and Runoff: A Guide to Flood Estimation*). Alternatively, users may prioritise the flood source with the highest risk if it is understood that most evacuation problems are caused by that source. The evacuation problem can be overly complicated to resolve if an option must solve every potential source of flooding. Ultimately, different solutions may be required for each flood source.

It is also important to consider the uncertainty that comes with estimating flood behaviour, hazard and timing. Engage experienced flood engineers/scientists to consider a range of possible flood behaviours to gain a better understanding of flood risk, rather than focussing on a single design event.

B1.1.7 Is there sufficient warning time available for evacuation?

It is critical to determine if there is sufficient warning time for the at-risk population to evacuate (this may be determined by applying information from an ECA). Sufficient warning time is required for estimating the severity of a possible flood based on information available, deciding on a strategy for evacuation, issuing warnings, mobilising resources, and evacuating the population at risk.

B1.1.8 What are the constraints to evacuation?

Evacuation constraints are typically identified through an ECA, although constraints may also be identified through flood risk management studies or from historic evacuations. For example, users may consider the following:

- Is the ability to evacuate impacted by a lack of warning time?
- Is the ability to evacuate impacted by current disaster management planning or warning systems?
- Is evacuation impacted by low community engagement, participation and/or response to warnings?
- Are there effective evacuation planning processes but the current evacuation route is submerged too early in the flood event? Or does the evacuation route have insufficient capacity for the number of people requiring evacuation to evacuate in time?
- Is there insufficient time to evacuate due to the need to assist vulnerable sectors of the community?
- Is there a feasible evacuation destination? Is evacuation feasible at all or should shelter in place be considered as a solution?
- Will future population growth and development further contribute to current evacuation constraints?

B1.2 Define the evacuation problem

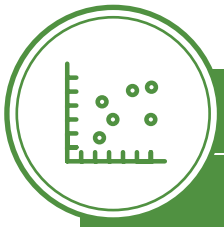
Following investigation of the issues, consider the following when defining the evacuation problem:

- **The nature of the problem:** Determine if the risk to life is due to inundation and/or isolation risks.
- **The scale of the problem:** Determine the significance of the evacuation problem based on the level and type of flood risk. This information can be obtained from the flood risk assessment and the factors which make up flood risk (see Appendix B). Where an economic assessment has been undertaken, include the economic impact of the evacuation problem when defining the scale.
- **Contributing factors:** Determine the factors causing the evacuation problem. For example, this may include an inability to evacuate due to time available before routes are inundated or insufficient warning time, the duration of isolation, access to essential goods and services during periods of isolation, community vulnerability or tolerance to isolation, flood behaviour and/or low flood immunity of infrastructure.

If the definition of the evacuation problem is unclear, consider if further information should be collected before proceeding with the options assessment process.

B1.3 Service need and desired outcome

Typically, in options assessment frameworks, the service need and desired outcome need to be defined to identify and assess potential options. For evacuation route improvements, the primary service need and desired outcome is to reduce risk to life. Regardless of whether an option reduces isolation time or improves the ability to evacuate, it must have the effect of reducing risk to life.



In summary

Investigate the key issues to comprehensively understand the evacuation problem. This assists in identifying options that are fit-for-purpose and respond to local circumstances.

B2. Identify potential options

Based on an understanding of the evacuation problem, identify a long list of options which may resolve the defined evacuation problem and may achieve the service need and desired outcome.

To appropriately assess options, ensure they are clearly defined by their location and key design considerations (such as design flood immunity) which are likely to have a material effect on cost, scope or impact.

A range of potential evacuation route improvement options and considerations are outlined in detail in Table 5 (page 21). These options may be standalone or combined to proceed as a single option through the assessment process. For example, an option may include a new evacuation centre and improvements to the flood immunity of an evacuation route to facilitate access. Non-infrastructure options may also be combined with infrastructure options to improve performance. Options for evacuation route improvements may include:

- community awareness, preparedness and resilience
- disaster management planning
- implementing new, or improving existing, flood warning systems
- shelter in place
- building new, or improving existing, building/s for use as an evacuation centre
- relocating high-risk communities
- improving existing road to increase resilience
- improving condition of, or access to, existing road
- improving existing road to increase evacuation capacity (widen road)
- improving flood immunity of an existing road (raise road)
- building new road/s
- building new, or improving existing, structural flood mitigation options.

The options in this guideline are provided as examples only and are not intended to be an exhaustive list. Other options may be identified specific to the evacuation problem and local circumstances. Note, 'road' is used as a general term and may include ungazetted or unsealed roads.

Contraflow is not discussed in this guideline as it is generally considered difficult to implement by emergency planners. However, if it is selected as a potential option, the relevant police and emergency services agencies should be engaged early to confirm if the option is compatible with their contraflow access requirements.

B2.1 Resolving the evacuation problem

The ability of an option to resolve the evacuation problem is one of the key considerations when determining the long list of potential options. The assessment process assists in determining the benefits, impacts, constraints and costs of each option to identify which is preferred for progression and ultimately implementation. However, to ensure all options are explored at this stage of the process, identify a wide range of solutions to the evacuation problem.

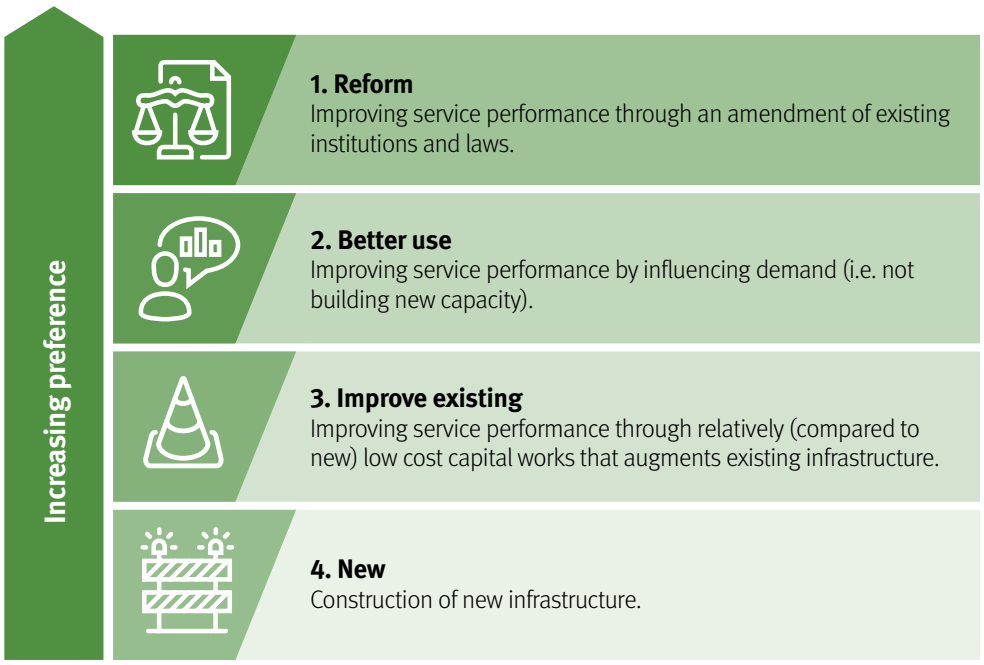


Figure 3 - Hierarchy of responses (DILGP, 2016)

When identifying potential options, consider solutions which address each stage of the evacuation process. For example, evacuation problems related to time constraints, such as time available before routes inundate, can be resolved by solutions other than improving the immunity of evacuation routes. This may include:

- at the decision to evacuate stage, new or improved flood warning systems may enable the early identification of flood impacts which can achieve additional time for members of the community to evacuate
- at the warning stage, improved disaster management planning can achieve efficiencies in communicating warnings and appropriate actions to the community
- at the withdrawal stage, improving community awareness, preparedness and resilience, can improve the amount of time it takes for the community to accept and respond to warnings
- at the shelter stage, new evacuation centres can be provided in locations that have better access or require less time for vehicle movements.

In addition, consider how options may improve the return stage of evacuation. Improving the resilience of a road can ensure that it is able to withstand flood impacts and re-open earlier after flood waters recede, facilitating the return of evacuees back to the flood affected area.

Users may also consider low cost and non-infrastructure options which may achieve similar outcomes as high cost infrastructure projects.

The hierarchy of responses (see Figure 3), adapted from the *State Infrastructure Plan – Part A: Strategy* generally reflects how potential options may be considered so they align with the strategic direction of government investment policy (TMR, 2019a) and the guideline's principle of optimising existing infrastructure.

When identifying potential options other considerations include:

- options which facilitate evacuation to a node in the network that provides access to a number of different safer locations or evacuation facilities
- building resilience into the design and engineering of options to ensure they are able to withstand impacts during and after flood events
- the community capability and tolerability for potential options. For example:
  - is the community likely to respond appropriately to warnings and notifications?
  - is the option suitable for the community? (e.g if a four wheel drive track is a potential option, does the community have access to the appropriate vehicles)
- options that can provide benefits in addition to improved evacuation capability (e.g road infrastructure options can provide improved road network efficiency and evacuation centres can be used for other community or recreational purposes)
- for areas at risk of isolation, options which facilitate evacuation, reduce isolation risks (e.g by providing for essential goods or services) or reduce the duration of isolation.

Burke River, Boulia

B2.2 Consultation

Consult with a wide range of stakeholders when identifying potential options. Flood risk management stakeholders and infrastructure providers can provide expert, local knowledge and advice on potential or planned projects that could be altered to incorporate evacuation benefits. For example, if there is a planned road upgrade to improve general network efficiency, a potential option may be identified which incorporates flood immunity improvements into the upgrade. These projects can deliver multiple benefits, which may assist in business cases or obtaining funding. Early engagement is important to ensure these options can be identified before a project is too far developed to alter.

B2.3 Design flood immunity for linear infrastructure

When defining linear infrastructure options, identify the design flood immunity. The design flood immunity will have an impact on the assessment results and the ability of an option to address the evacuation problem.

Design flood immunity significantly impacts several critical factors in evacuation including the amount of time available before routes become inundated, length of isolation and level of residual risk (that is, the risk that remains after an option is delivered). It is important to be aware that risk can never be completely eliminated, and any option or design flood immunity has a level of residual risk that needs to be considered.

The design flood immunity determines the time available before the road is inundated and the duration of inundation. The design flood immunity of the entire evacuation route, including any feeder roads, also needs to be considered as immunity of the route is limited by the most constrained location at any point.

The design flood immunity may be difficult to identify prior to assessing options due to the need to balance a number of determining factors including risk mitigation, standards, affordability and environmental and flood behaviour factors (for example, high immunity may be difficult to achieve in existing urban areas due to engineering and environmental constraints).

Therefore, include similar options with broadly different design flood immunities which are likely to result in materially different costs, scope or impacts, such as a frequent and infrequent event. For example, two options may be included to raise the same road, one to achieve a 5% AEP immunity and another to achieve a 1% AEP immunity.

Following the assessment process, further refinements to the design flood immunity of potentially suitable options can be made in the design stage or by repeating the assessment process.

In summary

Identify a wide range of options which address the evacuation problem and meet the service need and desired outcome. Clearly define options by including location and key design considerations.

Condamine River, Victoria St, Warwick, January 2011

Table 5 - Summary of potential evacuation route improvement options

The options and considerations in Table 5 are provided as examples only and are not intended to be an exhaustive list. The relevance and feasibility of each option is unique to the user and are to be determined after the user assesses the evacuation problem and criteria. Considerations for each option are categorised under the assessment criteria (see section B3.1).

Option: Community awareness, preparedness and resilience

What is it?

- measures to improve the community's awareness of flood risk, evacuation procedures and overall flood resilience
- measures range from provision of information (e.g. via letterbox drops, online) to development of household evacuation plans and broader resilience measures such as community network building

How can it improve evacuation capability?

- reduces the evacuation timeline by increasing organisation and mobility
- improves broader community awareness, preparedness and resilience to flooding, beyond the evacuation context
- improves the amount of time it takes for the community to accept and respond to warnings

Considerations

Safety
- not highly effective if insufficient warning time available

Economic
- low cost

Environmental and cultural heritage impact
- negligible environmental and cultural heritage impacts

Social
- requires community engagement to be effective

Flood behaviour/impact
- does not impact flood behaviour

Additional constraints
- unlikely to have technical or physical constraints

Option: Disaster management planning

What is it?

- development or review of plans and procedures to plan, prepare, respond to and recover from flooding, typically captured in a LDMP or evacuation sub-plan
- may include aspects of flood warning, evacuation procedures, assembly points, traffic management, shelter-in-place, etc.

How can it improve evacuation capability?

- addresses evacuation constraints by implementing plans and procedures
- supports more efficient evacuation
- improves broader flood (and disaster) outcomes, beyond the evacuation context

Considerations

Safety
- improves management of risk

Economic
- low cost, may be captured under standard business costs

Environmental and cultural heritage impact
- negligible environmental and cultural heritage impacts

Social
- depending on the plan, it may require a specific community response

Flood behaviour/impact
- does not impact flood behaviour

Additional constraints
- unlikely to have technical or physical constraints

(continued on next page)

Table 5 - Summary of potential evacuation route improvement options (continued)

Option: Implementing new, or improving existing, flood warning systems

What is it?

- the 'total flood warning system' includes all aspects of flood warning from monitoring and prediction of flooding to review of the warning delivery
- flood warning systems can range from relatively simple paper-based systems which link rainfall or stream gauge triggers to actions, to complex and highly automated systems which undertake real-time flood modelling
- flood warning systems typically include one or more rain or stream gauges and procedures linked to forecast or recorded values at those gauge locations. The distribution of flood warnings can be through a range of media including flood sirens, door knocking, text messages, phone calls, television, newspapers, internet and radio

How can it improve evacuation capability?

- increases time available to evacuate by predicting flood impacts earlier
- increases community confidence in evacuation messages by linking actions to data
- reduces flood risk

Considerations

Safety
- may not provide sufficient warning time to be useful in flash flooding situations
- flood warning based on forecast data is less reliable than warnings based on recorded data (but does provide more warning time)

Economic
- usually low cost
- implementation can be staged

Environmental and cultural heritage impact
- negligible environmental and cultural heritage impacts

Social
- requires community engagement and cooperation to respond to flood warnings

Flood behaviour/impact
- does not impact flood behaviour

Additional benefits or constraints
- unlikely to have technical or physical constraints

Option: Shelter in place

What is it?

- measures to facilitate shelter in place by ensuring locations are appropriate to shelter in during a flood
- is an alternative, or in addition, to evacuation where individuals shelter within their homes, workplace or with family/friends, if considered safe to do so (QFES, 2018b)
- may include flood proofing of buildings, ensuring that sufficient resources are available to support shelter in place (e.g. continuity of services, food drops) and house raising
- may be applied at the household scale or at a larger scale to support flood island areas (neighbourhood scale)

How can it improve evacuation capability?

- reduces isolation risk
- provides an alternative approach to protect human life where evacuation may be more dangerous than sheltering in place

Considerations

Safety
- if isolated for a significant amount of time, emergency access may be needed
- not suitable for high hazard areas where there is a risk of building failure
- not suitable for locations where there are significant inundation risks (where properties may become inundated over floor)
- may be less suitable for highly vulnerable communities

Economic
- low cost, depending on scale of retrofit required

Environmental and cultural heritage impact
- negligible environmental and cultural heritage impacts

Social
- benefits from community engagement and requires cooperation

Flood behaviour/impact
- does not impact flood behaviour

Additional benefits or constraints
- unlikely to have technical or physical constraints

(continued on next page)

Table 5 - Summary of potential evacuation route improvement options (continued)

Option: Building new, or improving existing, building/s for use as an evacuation centre

What is it?

- develop infrastructure for use as an evacuation centre
- may involve developing a new building or providing for essential goods, utilities and services to facilitate the use of an existing building for use as an evacuation centre

How can it improve evacuation capability?

- improves evacuation by providing a location for a population to evacuate to, that does not have access constraints and has high flood immunity
- reduces isolation risk by providing essential goods and utilities

Considerations

Safety

- the design flood immunity of the building influences the level of residual risk
- a high design flood immunity is required to ensure it is likely to be safe to shelter for most flood events
- need to ensure there are no isolation risks and residents can evacuate to the evacuation centre
- determine how long the community is willing to stay in the evacuation centre if isolated

Economic

- can be moderate or high cost

Environmental and cultural heritage impact

- may require clearing of vegetation or habitat to accommodate development
- depending on location and scale, may have cultural heritage impacts

Social

- may provide additional benefits if used for other community or recreational purposes

Flood behaviour/impact

- may have minor flood impacts

Additional constraints

- may have physical or technical constraints including availability of flood-free sites to accommodate the development
- *Queensland Urban Drainage Manual*, planning schemes and the SPP and associated guidance material – may contain flood immunity standards that will need to be adhered to

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Bundaburg, 2013

Table 5 - Summary of potential evacuation route improvement options (continued)

Options: Relocating high-risk communities

What is it?

- relocation of high-risk community to an area with lower flood risk

How can it improve evacuation capability?

- reduces flood risk by reducing exposure to flood hazard and isolation
- reduces the need for evacuation or reduces evacuation demand
- may provide more warning time, depending on availability of sufficiently flood immune infrastructure in the relocation area

Considerations

Safety

- the flood immunity of the relocation area influences the level of residual risk

Economic

- moderate to high cost

Environmental and cultural heritage impact

- may have environmental impacts
- depending on location and scale may have cultural heritage impacts

Social

- needs significant community engagement and support

Flood behaviour/impact

- may cause flood impacts (though should be reduced compared to development in current location)

Additional benefits or constraints

- may be broader land use planning considerations

Option: Improving existing road to increase resilience

What is it?

- an existing road can be made more resilient to inundation impacts through, for example, improved capacity of cross-drainage structures or use of resilient material
- may include improving resilience of pavement or other design features for inundation to reduce time required for post-inundation repairs (and reducing overall time of closure)
- may include improvement to road maintenance such as ensuring roads critical for evacuation are clear and in good order before flood season
- *Natural Disaster Program Design and Eligibility Guidelines* contains further guidance on improving resilience of roads

How can it improve evacuation capability?

- may reduce time of closure due to reduced repair time required after inundation
- may extend time available for evacuation
- may achieve route flood immunity
- may reduce or eliminate isolation for a given flood immunity

Considerations

Safety

- depending on the method for improving resilience, there may be no additional evacuation time or capacity as an outcome of the option
- may reduce duration of isolation due to reduced repair time after inundation
- the design flood immunity of the road influences the level of residual risk

Economic

- usually moderate cost to implement, depending on the size and number of crossings
- can be delivered in a staged approach as iterative improvements as part of routine maintenance
- can reduce costs to repair the road from flood damages and reduce business costs by reducing the overall time of closure, for example, if used as a freight route

Environmental and cultural heritage impact

- may have environmental impacts
- depending on location and scale may have cultural heritage impacts

Social

- If considering improved resilience or maintenance to reduce overall closure time, consider the requirements of the community (e.g. being isolated for a short period may be acceptable if the community is currently isolated for a long period)

Flood behaviour/impact

- may cause flood impacts by altering flood conveyance

Additional constraints

- Often a route has several 'vulnerable' points. Consider how many crossings would need to be upgraded in total to achieve evacuation.

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Table 5 - Summary of potential evacuation route improvement options (continued)

Option: Improving condition of, or access to, existing road

What is it?

- condition of, or access to, an existing road is improved to enable its use as an evacuation route
- may include negotiations with land holders to improve public access or improving the condition of a road to enable trafficability by motor vehicles

How can it improve evacuation capability?

- creates a new evacuation route with an existing road

Considerations

Safety
- can reduce risk by improving the ability to evacuate
- the design flood immunity of the road influences the level of residual risk
- effectiveness depends on location and design including capacity, resilience, and flood immunity level

Economic
- likely to have a lower cost than building a new road

Environmental and cultural heritage impact
- may have environmental impacts
- depending on location and scale, may have cultural heritage impacts

Social
- agreements with land holders may be required where public access is limited
- the community must be able to understand and use the evacuation route during flood events

Flood behaviour/impact
- may cause flood impacts by altering flood conveyance

Additional constraints
- location and design of the existing road may have physical and technical constraints

Option: Improving existing road to increase evacuation capacity (widen road)

What is it?

- widening roads to increase capacity and reduce evacuation congestion
- may include addition of another formal lane, or improvements to the road shoulder to enable use as a temporary lane during evacuation

How can it improve evacuation capability?

- increases road capacity to reduce congestion and reduce the time needed for evacuation

Considerations

Safety
- widening reduces time required for evacuation but is unlikely to delay the inundation of the route. Therefore, the design flood immunity of the road must also be considered
- if the capacity issues are across an entire route rather than in a single location, there may be extensive upgrades needed, or issue may be moved to a different location

Economic
- usually moderate cost

Environmental and cultural heritage impact
- may have environmental impacts
- depending on location and scale, may have cultural heritage impacts

Social
- may require community agreement in chosen upgrade locations
- may provide additional benefits by reducing non-evacuation congestion

Flood behaviour/impact
- may cause flood impacts by altering flood conveyance

Additional constraints
- location and design of the existing road may have physical and technical constraints

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Table 5 - Summary of potential evacuation route improvement options (continued)

Option: Improving flood immunity of an existing road (raise road)

What is it?

- raise part or all of a road to increase flood immunity
- depending on the situation, increased immunity may be achieved through additional cover or could require more substantive design and construction effort
- may or may not include an increase in waterway area (depending on flood impacts)

How can it improve evacuation capability?

- extends time available for evacuation
- may achieve route flood immunity
- reduces or eliminates isolation for a given flood immunity

Considerations

Safety

- the design flood immunity of the road influences the level of residual risk
- consider the intended use of the route, if it is to reduce isolation time rather than for evacuation, it is important that it is a practical route for the community to use when other routes are cut off
- often a route has several 'vulnerable' points - consider how much road would need to be upgraded in total to achieve evacuation

Economic

- usually moderate to high cost
- can reduce business costs as routes remain open for longer and are not as frequently inundated in smaller more frequent floods than its design flood immunity
- implementation can be staged

Environmental and cultural heritage impact

- may have environmental impacts
- depending on location and scale may have cultural heritage impacts

Social

- can improve access to services by reducing the overall time of closure of a road caused by flooding

Flood behaviour/impact

- may cause flood impacts by altering flood conveyance

Additional constraints

- may have physical or technical constraints e.g. sufficient space to achieve required embankments

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Haack Rd bridge, Scenic Rim, 2017

Table 5 - Summary of potential evacuation route improvement options (continued)

Option: Building new road/s

What is it?

- building a new road to provide new evacuation route infrastructure

How can it improve evacuation capability?

- depending on location and design, a new road can resolve or bypass constraints in the evacuation network
- may increase time available before routes inundate by being:
  - designed or located to achieve a higher immunity than existing routes
  - located in an area where flood waters rise more slowly
  - located in an area that is flood free
- may provide additional capacity to relieve bottlenecks in the network
- may provide access to a node in the evacuation route network that facilitates access to safer locations and evacuation centres

Considerations

Safety

- can reduce risk by improving the ability to evacuate
- the design flood immunity of the road influences the level of residual risk
- effectiveness depends on location and design including capacity, resilience and design flood immunity level

Economic

- likely to be high cost
- may reduce business operation costs, e.g. by providing an alternative freight route when the main route has been inundated

Environmental and cultural heritage impact

- may have impacts to fauna connectivity or require clearing of vegetation and habitat
- depending on location and scale, may have cultural heritage impacts

Social

- consider location and any objections from the community
- may improve access to services during smaller more frequent flood events
- can have additional benefits by improving the efficiency of the road network during daily use (e.g. provides alternative route to access locations for non-evacuation purposes)

Flood behaviour/impact

- may cause flood impacts by altering flood conveyance
- location of new infrastructure should consider existing flood behaviour, nature of flood-prone land, etc.
- important to consider flood behaviour when determining where effective evacuation routes can be situated

Additional constraints

- potential for various other constraints such as engineering, construction and approval constraints

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Jimboomba Creek flooding, Camp Cable Road, Jimboomba

Table 5 - Summary of potential evacuation route improvement options (continued)

Option: Building new, or improving existing, structural flood mitigation options

What is it?

- constructing new, or improving existing, structural flood mitigation options, such as levees, dams, detention basins, etc.

How can it improve evacuation capability?

- increases time for evacuation by reducing the inundation area or changing the flood behaviour affecting a route

Considerations

Safety

- the design flood immunity influences the level of residual risk
- potential for catastrophic flooding if a structure such as a dam or levee fails

Economic

- new structures are likely to be high cost and improvements to existing structures are likely to be moderate cost, depending on the scale and nature of existing works
- may reduce property damage by reducing the inundation area or by changing flood behaviour

Environmental and cultural heritage impact

- depending on nature and scale, likely environmental impacts
- depending on location and scale, may have cultural heritage impacts

Social

- may not provide any additional benefits as it only addresses flood hazard

Flood behaviour/impact

- likely to impact flood behaviour (may be beneficial in some locations)
- may reduce inundation in some areas but increase in others, a high level of consultation is likely to be required

Additional constraints

- engineering, construction and approvals may impose additional constraints to be addressed

Burdekin Shire, 2020

B3. Options assessment

The options assessment phase comprises an options feasibility assessment (stage one), followed by an MCA (stage two) and financial and economic assessments. The options feasibility assessment eliminates impractical options to generate a short list for more detailed options assessment. Note, not all assessments stages require the same level of detail for assessment as discussed in section A1.3.

B3.1 Assessment criteria

The assessment process in this guideline is based on the six criteria outlined in Figure 4.

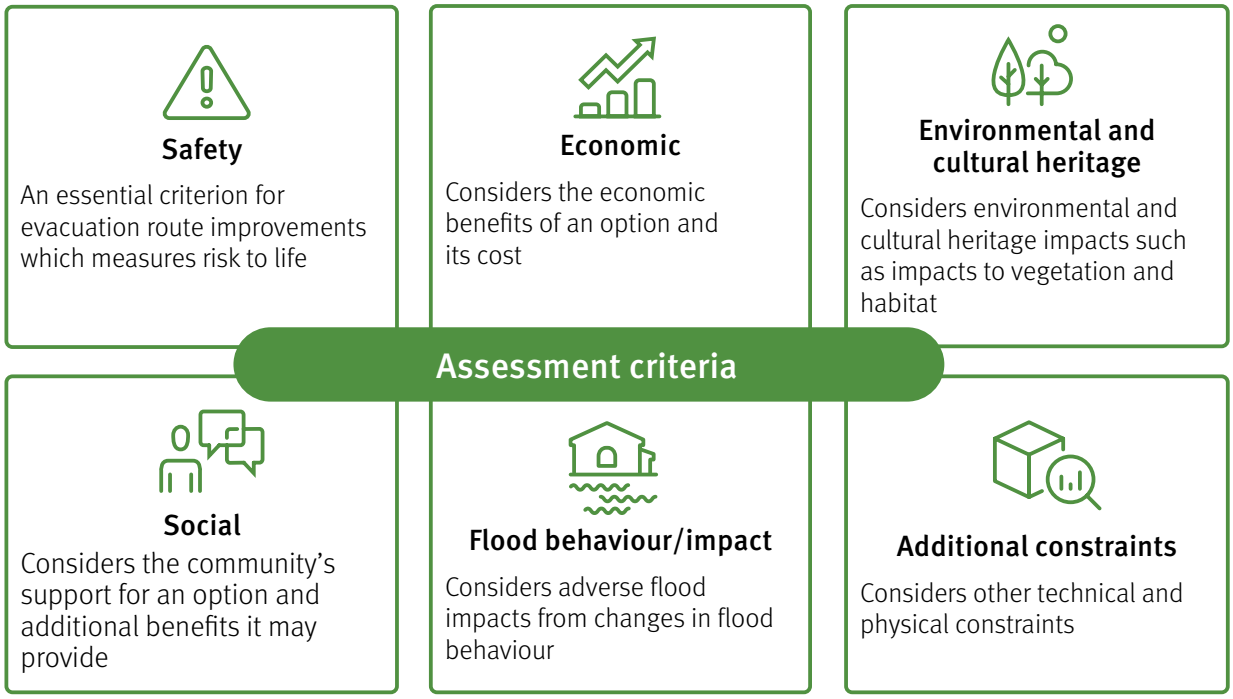


Figure 4 - Assessment criteria

Considering flood behaviour/impact criterion

The 'flood behaviour/impact' criterion considers whether an option is likely to cause adverse flood impacts due to changes to existing flood behaviour. This criterion is important as flood impacts may affect the feasibility of an option or require expensive mitigation to minimise unacceptable impacts. Whilst the criteria in Figure 4 are also considered in more detail in the stage two MCA, consideration of flood behaviour and impacts at the option feasibility stage of the assessment process can help refine options to ensure they are located in areas that reduce adverse impacts.

Flood impacts may be more likely if an option requires construction in a high flood hazard area or across significant flood-prone land. Impacts can be mitigated by blocking as little of the waterway as possible (high bridge, limited piers, limited embankment), however, this may make an option cost prohibitive.

Infrastructure corridors (new or upgraded) across wide areas of flood-prone land are likely to require significant cross-drainage to manage unacceptable changes to flood behaviour (such as concentration of flow and increases in flood levels upstream) as a result of the significant width of flow that must be directed under the infrastructure in events up to, and including, its design flood immunity.

Experienced flood engineers/scientists or floodplain managers may be required to investigate flood impacts and mitigation requirements.

B4. Stage one: Option feasibility assessment

The option feasibility assessment in this guideline is an initial screening process to eliminate impractical or unfeasible options and generate a short list to progress to stage two. Users assess options against feasibility indicators before conducting a high-level cost estimate.

Stakeholder engagement is critical at this stage (such as engaging with agencies that may have a responsibility in relation to resourcing, operation or delivery of potential options) as stakeholders can provide valuable feedback on the practicality and feasibility of options.

B4.1 Feasibility indicator assessment

Using the feasibility indicator assessment in this guideline, options are assessed against the feasibility indicators shown in Table 6. For this high-level assessment, users assess each option as either having 'met' or 'not met' a feasibility indicator while considering local circumstances and evacuation problem specific variables. Where there is not enough information, note this as the response for review at the end of this assessment stage (see section B4.3.3).

Table 6 - Feasibility indicators

Feasibility indicators	Response		
	Met	Not met	More information required
The option is likely to reduce risk to life for the affected population			
The option is unlikely to cause significant environmental or cultural heritage impacts that are unable to be mitigated			
The community supports the option and is likely to respond (can be determined through community consultation)			
The option is unlikely to cause adverse significant flood impacts that cannot be mitigated (high level assessment, based on judgement, considering location of option and known flood behaviour)			
The option is physically and technically feasible when considering engineering, constructability or legal constraints			

Thomson River Cruises, Longreach

Cattle Creek Bridge on the Bruce Highway, Ingham

B4.2 High level cost estimate

Following the feasibility indicator assessment, prepare a high-level cost estimate for each option to determine affordability. High level cost estimates can be undertaken most simply by comparison to similar previous projects. However, where unavailable, consider preliminary or concept engineering design to estimate cost.

Determine if the cost is practical considering the scale of the evacuation problem, budgets, potential funding and delivery program. When determining cost practicalities, liaise with stakeholders or organisations that may be responsible for committing resources to deliver a potential option to determine if it would qualify for funding or investment under their programs, processes, practices and policies. Identify if there are any additional benefits to improved evacuation capability as it may assist an option qualifying for funding, particularly if it can be delivered in conjunction with another project.

When preparing a high-level cost estimate, it is essential to engage with the likely owner and operator of the potential option. This assists in identifying maintenance, operation and other whole-of-life costs.

B4.3 Determining outcomes of the option feasibility assessment

Review the results of the option feasibility assessment to determine the outcome for each option and create a short list of options to progress to the stage two MCA. In this guideline, outcomes for each option are as follows:

- **Eliminate or progress to MCA** – Eliminate unfeasible options and progress feasible options.
- **Redefine options** – Redefine an option by combining with other options, altering or staging before re-assessing the redefined option.
- **Collect further information** – If an outcome cannot be determined due to a lack of information, consider collecting further information to re-assess.

B4.3.1 Eliminating or progressing to MCA

All options should reduce risk to life (and satisfy the 'risk to life' feasibility indicator) to be considered feasible. For other feasibility indicators, local circumstances and priorities determine whether to eliminate an option or progress an option to the stage two MCA.

B4.3.2 Redefining options

Options may be redefined to improve performance, address any feasibility indicators or overcome cost limitations. Options can be altered by revising location or design or combining it with other options into a suite of measures.

Options may also be staged to spread the cost over a longer period to alleviate affordability limitations. If considering a staged road upgrade approach, consider the relative flood immunity or AATOC for different sections of the route and consider prioritising upgrades to the most frequently inundated sections. If construction of an option is to be staged, it is important to preserve and protect the corridor for future delivery of the later stages of the option.

Once options are redefined, repeat the options feasibility assessment. For staged options, assess each stage to ensure each is practical and provides benefits (this also applies to the stage two MCA to ensure each stage is comparatively assessed against other options).

Redefining options can help address constraints identified in the feasibility assessment.

For example, the cost of a bridge may be reduced by optimising the alignment.

B4.3.3 Is more information required?

If some of the feasibility indicators cannot be determined due to a lack of information, options can be eliminated if ultimately, they are not feasible. Similarly, there may be strong support for an option, or users may feel they have sufficient confidence in the outcome of the overall assessment to justify progressing that option, on the basis that the feasibility indicators (excluding the community support feasibility indicator) will be assessed in more detail in the stage two MCA. Where an outcome cannot be determined, consider the approximate cost of obtaining additional information and whether investment is justified to support further assessment.

In summary

The stage one: option feasibility assessment should eliminate impractical or unfeasible options to generate a short list for more detailed assessment.

Yeppen crossing and roundabout, Bruce Highway (Benaraby - Rockhampton) Tropical Cyclone Oswald and associated rainfall and flooding, 2013

Flooding near Malanda

B5. Stage two: multi-criteria assessment (MCA)

The MCA is a detailed assessment of the short-listed options against targeted indicators for each criterion. Each criterion in this guideline comprises one or more targeted indicators against which the options are scored. The scoring is based on a scale from one to five, with one being the lowest score (indicates an option provides the lowest benefit) and five the highest (indicates an option provides the highest benefit).

The level of detail required to assess the targeted indicators varies depending on the type of options being assessed, local circumstances and the scale of the evacuation problem. Additional studies, consultation or engagement of a suitably qualified or experienced person may be required to determine an appropriate score for a targeted indicator. Alternatively, in some circumstances, detailed studies may not be required for assessment. For example, if assessing only non-infrastructure options which do not require significant investment to deliver, detailed studies may not be required.

Consider local priorities and desired outcomes when scoring against the targeted indicators. For example, scores for the 'flood behaviour/impact' targeted indicator may be impacted by local policies regarding changes to flood behaviour.

Note, there are some limitations to an MCA approach (such as the potential for subjectivity and double counting of benefits and impacts) which may affect a balanced comparison of options. The MCA in this guideline has been developed to limit these issues. However, users should remain alert to MCA limitations during assessments, especially when weighting criteria, scoring options and interpreting results.

Once complete, it is important to review MCA scores to determine if the results accurately represent the benefits, impacts and constraints of each option. Where options achieve similar scores, review any data or resources which have informed the assessment, including studies and stakeholder feedback, to discriminate between the two options. Under these circumstances, scores should not be amended to differentiate between two similarly scored options and a more detailed review should be undertaken.

B5.1 Assessment against MCA criteria

B5.1.1 Safety

The MCA safety criterion considers three targeted indicators:

1. ability to evacuate to safer locations or evacuation centres
2. population at risk
3. isolation duration and risk.

Assessment of the safety criterion may require input from an experienced floodplain manager or flood engineer/scientist, except where risk has been identified as low for an option.

Ability to evacuate to safer locations or evacuation centres

Targeted indicator	Description
Ability to evacuate to safer locations or evacuation centres	Measure of the ability of the at-risk population to evacuate to safer locations or evacuation centres

Score descriptors				
1 (LOWEST)	**2**	**3**	**4**	**5** (HIGHEST)
Insufficient ability to evacuate	Some ability to evacuate	Sufficient ability to evacuate	Substantial ability to evacuate	Very substantial ability to evacuate

This targeted indicator measures the ability of the at-risk population to evacuate to safer locations or evacuation centres following implementation of an option. To determine this capability, several factors can be considered, as outlined in *Timeline modelling of flood evacuation operations* including:

- time for responsible authorities to make flood predictions, decide to evacuate and issue warnings
- time for the community to accept and respond to warnings
- total time needed for evacuation, which may include consideration of the road capacity for evacuation routes, including feeder and linking roads
- time needed for vehicle movements, which can be influenced by the type and number of vehicles (including emergency service vehicles) using routes and the capacity of routes
- time available before routes are cut off by flood waters, including the time available following the issuing of warnings.

To fully understand the variability in time available before routes are inundated, assess the time for a range of flood events. For infrastructure options with an assigned flood immunity, assess flood events larger than the design flood immunity to determine the residual risks.

Consider the vulnerability and mobility of the community when determining the time needed for evacuation. Assistance may be needed to evacuate more vulnerable sectors of the community or where there is low vehicle ownership. Also consider that some stages of the evacuation may be impacted by time of day (for example, evacuations may take longer during the night).

Population at risk

Targeted indicator	Description
Population at risk	Measure of risk to life

Score descriptors

1 (LOWEST)	2	3	4	5 (HIGHEST)
Extreme risk	High risk	Medium risk	Low risk	Very low risk

This targeted indicator measures risk to life following implementation of an option. This can be assessed by using a full flood risk assessment that examines the level of hazard and the probability and consequence of that hazard occurring (see Appendix B). Alternatively, this targeted indicator can be simplified to calculate the number of people at risk of inundation or isolation for a range of flood events, both before and after option implementation, and annualised.

Isolation duration and risk

Targeted indicator	Description
Isolation duration and risk	Measures risk to life due to isolation

Score descriptors

1 (LOWEST)	2	3	4	5 (HIGHEST)
Extreme risk to life due to isolation	High risk to life due to isolation	Medium risk to life due to isolation	Low risk to life due to isolation	Very low risk to life due to isolation

This targeted indicator measures risk to life due to isolation following implementation of an option. This can be determined by considering the likelihood and number of people likely to be isolated and the community's tolerability and vulnerability to isolation. When assessing this targeted indicator, isolation risks at the location where the community is being evacuated also needs to be considered.

Determine the community's tolerability to isolation based on how long the population is prepared to be isolated. Determine the vulnerability of the population by considering the duration of isolation, the need for, and access to, essential goods and services such as medical supplies and the potential for interaction with flood waters. Measure isolation duration by assessing the likely length of isolation for a range of flood events, before annualising the time. Isolation risk may be high where isolation persists for a significant duration, essential services are cut-off or isolated members of the community require medical attention.

Cloncurry River Bridge, Cloncurry Shire

B5.1.2 Economic

The MCA economic criterion considers two targeted indicators:

1. economic growth and investment
2. damages and costs (including property, assets and operations).

Assessment of the economic criterion may require expert input (such as an economist) except where risk is identified as low for an option (for example, small-scale projects or where construction is not required in flood-prone land).

Economic growth and investment

Targeted indicator	Description
 **Economic growth and investment**	Measure to determine potential economic growth and investment as a result of increased confidence in flood resilience

Score descriptors

1 (LOWEST)	2	3	4	5 (HIGHEST)
No potential economic growth and investment	Minor potential economic growth and investment	Moderate potential economic growth and investment	Significant potential economic growth and investment	Very significant potential economic growth and investment

This indicator measures potential economic growth and investment as a consequence of increased flood resilience and can be determined by assessing the potential for future development, investment and population growth as a result of mitigating flood risks. For example, an option may alleviate concerns in communities with known flooding issues, stimulate population growth and encourage investment in business and development. These benefits can be important in regional areas to promote economic growth.

Damages and costs (property, assets and operations)

Targeted indicator	Description
 **Damages and costs (property, assets and operations)**	Measure to determine reduction in flood damages and costs to property and business

Score descriptors

1 (LOWEST)	2	3	4	5 (HIGHEST)
No reduction in flood damages and costs	Minor reduction in flood damages and costs	Moderate reduction in flood damages and costs	Significant reduction in flood damages and costs	Very significant reduction in flood damages and costs

This targeted indicator measures the reduction in flood damages and costs to property and business following implementation of an option. Damages to property may be measured by considering the financial cost of damages to infrastructure, buildings and other assets as well as business costs, including those related to the impact of road closure on business operations (for example, lack of access to services and supplies). To measure these costs, consider the reduction in AATOC of an important route and the costs associated with the closure. Further information on quantification methods for flood damages to property and business can be found in the *Economic Assessment Framework of Flood Risk Management Projects*.

B5.1.3 Environmental and cultural heritage impact

There are three targeted indicators in this guideline for the environmental and cultural heritage impact criterion:

1. overall impact on fauna connectivity (fish passage/fauna movement)
2. overall impacts to vegetation and habitat
3. impacts on cultural heritage.

When assessing these targeted indicators, consider relevant policies, legislation and approvals. Assessment may require input from an experienced environmental engineer, scientist, ecologist or cultural heritage specialist. The Queensland Government Development Assessment Mapping System or local government planning schemes may help identify areas subject to environmental or cultural heritage constraints.

Overall impact on fauna connectivity (fish passage/fauna movement)

Targeted indicator	Description
Overall impact on fauna connectivity (fish passage/ fauna movement)	Measure of impact on fauna connectivity caused by an option

Score descriptors

1 (LOWEST)	2	3	4	5 (HIGHEST)
Significant negative impact to fauna connectivity	Moderate negative impact to fauna connectivity	Minor negative impact to fauna connectivity	Negligible impact to fauna connectivity	Positive impact to fauna connectivity

This targeted indicator measures the impact on fauna movement following implementation of an option. Fish passage and other fauna movement can be impacted by development, particularly within a waterway or on a previously undeveloped site. Determine the scale of impact on fauna connectivity and incorporate mitigation into the option so that it can be assessed based on the residual impact. Also, consider any change to design for mitigation in the financial and economic assessment stage (see section B.6).

Overall impacts to vegetation and habitat

Targeted indicator	Description
Overall impacts to vegetation and habitat	Measure of impacts to vegetation and habitat

Score descriptors

1 (LOWEST)	2	3	4	5 (HIGHEST)
Significant negative vegetation and habitat impacts	Moderate negative vegetation and habitat impacts	Minor negative vegetation and habitat impacts	Negligible vegetation and habitat impacts	Positive vegetation and habitat impacts

This targeted indicator measures the impact of an option on vegetation and habitat, including loss of vegetation, loss of habitat, impact to endangered species (both flora and fauna), scour and sediment loss and impact on sites of environmental significance. Determine the scale of impact on vegetation and habitat and incorporate mitigation into the option so that it can be assessed based on the residual impact. Also consider any change to design for mitigation in the financial and economic assessment stage (see section B.6).

Impacts on cultural heritage

Targeted indicator	Description
Impact on cultural heritage sites	Measure of impact on cultural heritage sites

Score descriptors				
1 (LOWEST)	**2**	**3**	**4**	**5** (HIGHEST)
Very significant cultural heritage impacts	Significant cultural heritage impacts	Moderate cultural heritage impacts	Minor cultural heritage impacts	No cultural heritage impacts

This targeted indicator measures the impact of an option on cultural heritage sites and requires consideration of relevant cultural heritage policies. Determine the scale of impact on cultural heritage sites and incorporate mitigation into the option so that it can be assessed based on the residual impact. Also consider any change to design for mitigation in the financial and economic assessment stage (see section B.6).

B5.1.4 Social

The MCA social criterion in this guideline is assessed against two targeted indicators:

1. disruption to daily life
2. additional community benefits.

Community consultation may be required to assess the targeted indicators.

Disruption to daily life

Targeted indicator	Description
Disruption to daily life	Measure of improvements in the ability of a population to go about daily life during or after a flood event. For example, being able to access services, recreational facilities and visit friends and family

Score descriptors				
1 (LOWEST)	**2**	**3**	**4**	**5** (HIGHEST)
No improvement in disruption to daily life	Minor improvement in disruption to daily life	Moderate improvement in disruption to daily life	Significant improvement in disruption to daily life	Very significant improvement in disruption to daily life

This targeted indicator measures the improvement in the community's ability to access, during or after a flood event, locations that are important to a community's daily life (but would not contribute to causing a risk to life if restricted). These locations may include places of work, friends, family and recreational facilities. Consider the community's resilience, as tolerability towards disruptions may vary.

This targeted indicator should be clearly distinguished from the 'isolation duration and risk' targeted indicator in the safety criterion. For example, an option may score highly in the 'isolation duration and risk' targeted indicator by reducing the amount of time access is restricted to medical services (essential service), however, it may not score highly in this targeted indicator if access is restricted to workplaces in the town's central business district (non-essential services).

Additional community benefits

Targeted indicator	Description
Additional community benefits	Measure to capture any benefits in addition to improved evacuation capability

Score descriptors

1 (LOWEST)	2	3	4	5 (HIGHEST)
No additional community benefits	Minor additional community benefits	Moderate additional community benefits	Significant additional community benefits	Very significant additional community benefits

This targeted indicator considers the benefits an option may provide the community in addition to improvements in evacuation capability or flood mitigation. These additional benefits may include improved road network efficiency or capacity for future planned development due to new or upgraded roads, or additional recreational or community facilities provided as part of a new evacuation centre. Consultation with stakeholders and the community can inform the identification of additional community benefits.

Townsville suburbs inundated, February 2019

B5.1.5 Flood behaviour/impact

Assessment of the 'flood behaviour and impact' MCA criterion requires a detailed assessment of adverse flood impacts due to changes in flood behaviour and may require an experienced flood engineer/scientist or floodplain manager. The flood behaviour/impact criterion in this guideline is assessed against one targeted indicator, flood impacts.

Flood impacts

Targeted indicator	Description
Flood impacts	Measure of adverse flood impacts due to changes in flood behaviour caused by an option

Score descriptors

1 (LOWEST)	2	3	4	5 (HIGHEST)
Very significant adverse flood impacts	Significant adverse flood impacts	Moderate adverse flood impacts	Minor adverse flood impacts	Negligible flood impacts

Consider the level of constraint for each option due to potential or modelled adverse flood impacts and the likelihood that each constraint can be mitigated. Include all potential mitigation measures to ensure the assessment of the option is based on residual impact. Also consider any changes made to the design for mitigation in the financial and economic assessment stage (see section B.6).

The significance of flood impacts can be informed by assessing a number of factors, including flood level impacts and changes in duration of inundation, flow distribution and velocities. Details of these factors, including suggested acceptable limits adapted from the draft *Austroads Guide to Road Design Part 5,* are provided below (Note, the acceptable limit is a score of three or higher, with no other flood impact factors considered):

- Flood level impacts: the change in peak flood level for a range of flood events. Table 7 (adapted from the draft *Austroads Guide to Road Design Part 5: Drainage – General Hydrology Considerations)* below provides suggested thresholds for scoring against flood level impacts.
- Change in duration of inundation: the change in duration of inundation for a range of flood events. Generally, a change of time of inundation of less than 10% is acceptable but it is important to consider local conditions, for example crop resilience.
- Change in flow distribution: the diversion of flow from one location to another, or increased flow in one location and corresponding decreased flow in another location. Generally, a change in distribution of less than 10% is acceptable but consider local conditions such as water supply issues.
- Change in velocities: A change in peak flow velocities of less than 10% is generally acceptable but consider local conditions.

To measure this targeted indicator, conduct a flood impact assessment using hydraulic modelling. Consider the 5% AEP and 1% AEP flood events as a minimum standard, as well as other flood events relevant to the option under consideration. Larger events such as the 0.05% AEP or PMF may be used as part of the flood impact assessment to provide an additional understanding of changes in flood behaviour and residual risk. Given their low likelihood, these events may not contribute to the scoring of the flood impact criteria, unless the impacts are identified as severe (for example, if a large number of properties would be impacted).

For the suggested thresholds for flood level impacts included in Table 7, a score of 3 or higher should not be assigned for the flood level impact threshold unless the option also achieves acceptable changes to duration of inundation, flow distribution and velocities (as suitable for the area of interest).

Consider all local requirements or sensitivities to flood impacts and behaviour along with the suggested measures provided in this guideline.

Table 7 - Scoring of flood impact targeted indicator based on flood level impacts

The flood level impacts in Table 7 may be generally acceptable but users should consider local conditions and adapt the thresholds accordingly.

Location	Suggested flood impact thresholds (flood level impact in mm)				
	1 (lowest)	2	3*	4*	5 (highest)*
General (e.g. general rural landholdings, open space, non-habitable structures, industrial yard areas)	>400mm	200-400mm	100-200mm	50-100mm	Less than 50mm
Sensitive receivers (e.g. residential buildings, commercial buildings, emergency services/ hospitals)	>30mm	20-30mm	15-20mm	10-15mm	Less than 10mm

* This score should only be selected if acceptable changes to duration of inundation, flow distribution and velocities are also achieved.

B5.1.6 Additional constraints

The additional constraints MCA criterion is assessed against one targeted indicator, engineering/construction constraints. Input may be required from a suitably qualified and experienced person, such as a civil, geotechnical or structural engineer.

Engineering/construction constraints

Targeted indicator	Description
Engineering/construction constraints	Measure of any other constraints to the engineering design and construction of an option

Score descriptors

1 (LOWEST)	2	3	4	5 (HIGHEST)
Very significant evidence of potential engineering or constructability issues	Significant evidence of potential engineering or constructability issues	Moderate evidence of potential engineering or constructability issue	Minor evidence of potential engineering or constructability issues	No evidence of potential engineering or constructability issues

This targeted indicator measures the level of technical and physical constraints that may impact on the delivery of an option. These constraints may include geotechnical issues, site constraints, site availability, access and material storage location issues, difficulties in sourcing materials or traffic and structural considerations. To assess this targeted indicator, consider the level of constraint and incorporate mitigation so that options can be assessed based on the residual impact. Also consider any changes made to the design for mitigation in the financial and economic assessment stage (see section B.6).

Wyaga Creek, Gore Highway

B5.2 MCA weighting

The MCA in this guideline allows for weightings to be assigned to each criterion to capture the relative importance of each contributing decision factor and issue to decision makers. Weightings are intended to capture the relative importance of issues to decision makers and are most effective when developed in conjunction with project stakeholders. Community input might also be used to shape weightings, however, community involvement in the direct process of weighting selection may be challenging. It is also important to recognise that the weighting process can be limited by personal biases which may be addressed by ensuring stakeholders involved in weighting clearly understand the significance of the criteria and targeted indicators.

Stakeholder engagement is important when determining weightings to ensure they are not limited by personal biases.

Weightings are assigned as a percentage which add up to 100 percent and are expressed by:

- criterion weighting – assigned weightings to each criterion
- targeted indicator weighting – determined by dividing the assigned criterion weighting by the number of targeted indicators within the criterion.

The overall score of each option is determined by totalling the weighted scores for each targeted indicator. The weighted scores are calculated by multiplying the targeted indicator weighting by its score. If specific criteria weighting is not applied, distribute weightings evenly amongst the criteria before calculating the weighted scores. For an example of how overall scores are calculated, refer to the *State guideline: Flood evacuation route improvements – Worked example.*

There are numerous valid approaches to the selection of weightings and the decision to apply weightings such as:

- rank sum
- rank reciprocal
- rank order centroid
- pairwise.

The selection of an approach is at the user's discretion. See *Smarter Solutions – Multi-Criteria Analysis Tool – User Guide* for further information.

Pairwise is a ranking tool used to assign priorities to multiple options. The pairwise method has been adopted for this guideline as it is transparent, easy to understand and well suited to an assessment of this level of detail. To avoid bias, ensure all key stakeholders are represented and have the opportunity to provide input into the pairwise process.

An overview of the pairwise method is provided below and is used in the supporting worked example.

Firstly, compare each criterion to the other criteria and decide which is more important. This is usually done in a matrix similar to Table 8 below.

Once relative importance has been determined, ranking is based on the occurrence of each criterion in the table, plus one, converted to a percentage. The weightings must total 100 per cent.

Table 8 - Pairwise method – Criteria weighting

Criteria	A	B	C	D	E	F	Occurrence +1	Criteria Weighting
A	-	A	C	A	A	A	5	23.81%
B	-	-	C	D	B	B	3	14.29%
C	-	-	-	C	C	F	5	23.81%
D	-	-	-	-	D	D	4	19.05%
E	-	-	-	-	-	E	2	9.52%
F	-	-	-	-	-	-	2	9.52%
						Total	21	100%

Damage to road at Elliott River Bridge on Goodwood Road, Wide Bay Burnett

B5.3 Sensitivity testing of criteria weighting

To assess the robustness of the final ranking against the assigned weightings, conduct a sensitivity analysis. Sensitivity testing typically involves adjusting the weighting of criteria to identify the impact on the results. Various methods of sensitivity testing can be applied to an MCA to detect bias towards particular options and to enable a balanced comparison of options. Methods for sensitivity testing include:

- stepwise testing method – determines how much the criteria weighting must change to alter the highest scoring option
- thresholding – changes the proportional weightings of each criteria by increasing and reducing weighting by 50 per cent and 25 per cent, whilst the weighting of other criteria remains proportionally unchanged
- balanced assessment - applies equal weighting among all criteria
- applying a 40 per cent weighting to each criterion and distributing weightings equally among remaining criteria
- adding cost as a criterion and weighting heavily to influence results. This is useful if weighted scores are close between options.

In summary

The stage two: MCA is a detailed assessment of the short-listed options. Each option is scored against six criteria which are comprised of one or more targeted indicators. Scores can be weighted to capture the importance of each criterion and sensitivity testing can be conducted to detect bias towards particular options.

B6. Financial and economic assessments

Financial and economic assessments are key decision support tools to support the options assessment process. Financial assessments consider investment decisions from the perspective of an organisation, entity or individual, assessing the viability of a project based on the direct effects on cash flow (QRA, 2021a). Economic assessments seek to quantify the damages caused by flooding and the benefits resulting from option implementation (QRA, 2021a).

Cost estimations and cost benefit analyses (CBAs) are economic assessment methodologies which can provide valuable information to compare options. The level of detail and use of these methodologies can be fit-for-purpose for the scale of the evacuation problem and type of options being assessed (for example, CBAs may only be required for large projects that warrant the investment). However, at a minimum, conduct a cost estimation to understand the level of investment required to deliver different options. See below for further guidance on both methodologies.

B6.1 Cost estimation

Comparing MCA scores of options against their cost can assist in identifying the efficiency of options in resolving the evacuation problem. When conducting a cost estimate, assess both upfront capital cost and whole-of-life costs, including ongoing operating, maintenance, refurbishments, rehabilitation and disposal costs. Include the cost of mitigating potential impacts and constraints that may have been identified in the MCA stage, and consider how the cost aligns with budgets, potential funding and the scale of the evacuation problem. When conducting cost estimates consult with stakeholders who may be responsible for committing resources to implement or deliver a potential option.

For information on cost estimation methods refer to the *Economic Assessment Framework of Flood Risk Management Projects*.

B6.2 Cost-benefit analysis

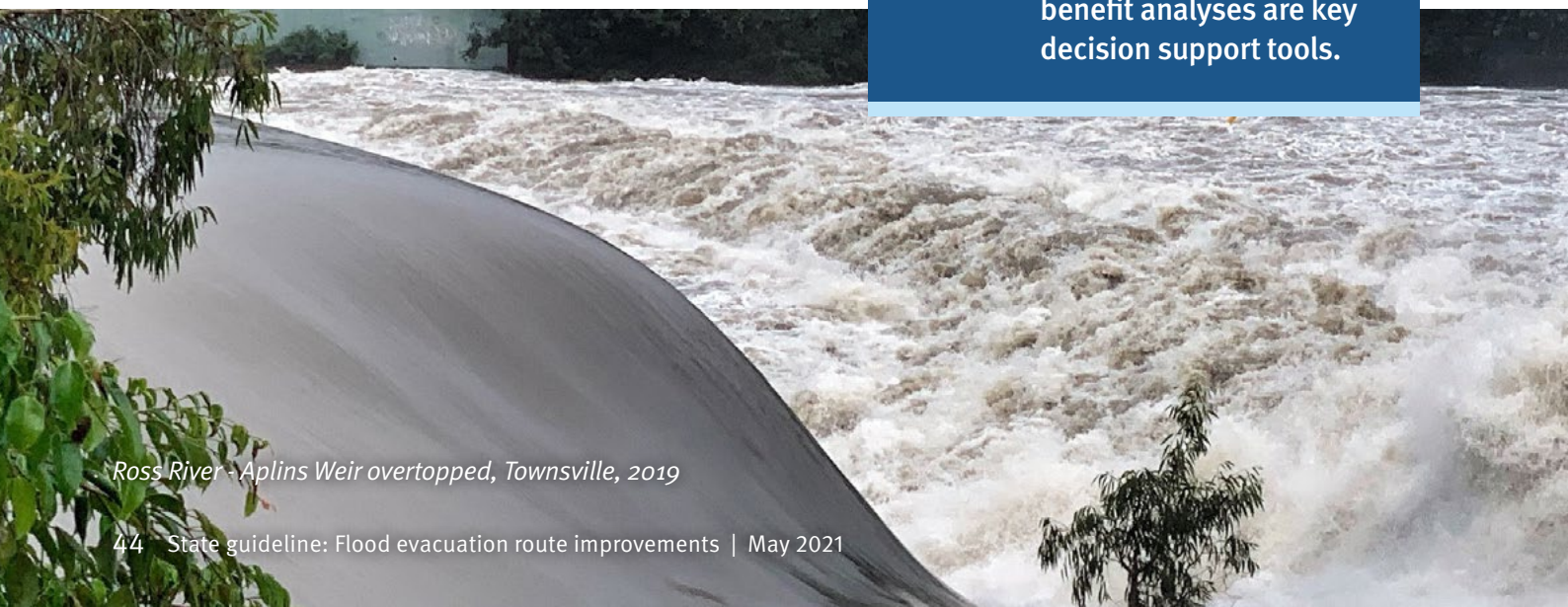
CBAs are an economic assessment method to support decision making which assesses the long-term value of benefits and costs in monetary terms (QRA, 2021a). In a CBA, the project case (option) is assessed against the base case (business as usual) to determine the marginal benefits gained from investing in the project throughout the assessment period (life of the asset).

Included in CBAs are Benefit Cost Ratios (BCRs) and Net Present Value (NPV). BCRs provide a ratio of the benefits to costs and NPVs measure the absolute net economic gain by subtracting costs from benefits. Typically, for a project to be deemed viable it must achieve a BCR greater than one and a positive NPV. It is likely to be rare for evacuation route improvements to achieve these thresholds given the difficulty or sensitivity of quantifying risk to life benefits. Therefore, BCRs and NPVs should be used to compare the economic performance of options and not for the purposes of determining if an option is suitable for investment.

When conducting a CBA for an evacuation route improvement, capture both flood and non-flood related costs and benefits (for example, improved network efficiency may be a non-flood related benefit of a road upgrade option). Further information on how to conduct a CBA for flood management projects is provided in the E*conomic Assessment Framework of Flood Risk Management Projects*. CBAs should be conducted by a suitably qualified or experienced person.

In summary

Financial and economic assessments such as cost estimations and cost benefit analyses are key decision support tools.



Ross River - Aplins Weir overtopped, Townsville, 2019

B7. Reviewing outcomes of the assessment process

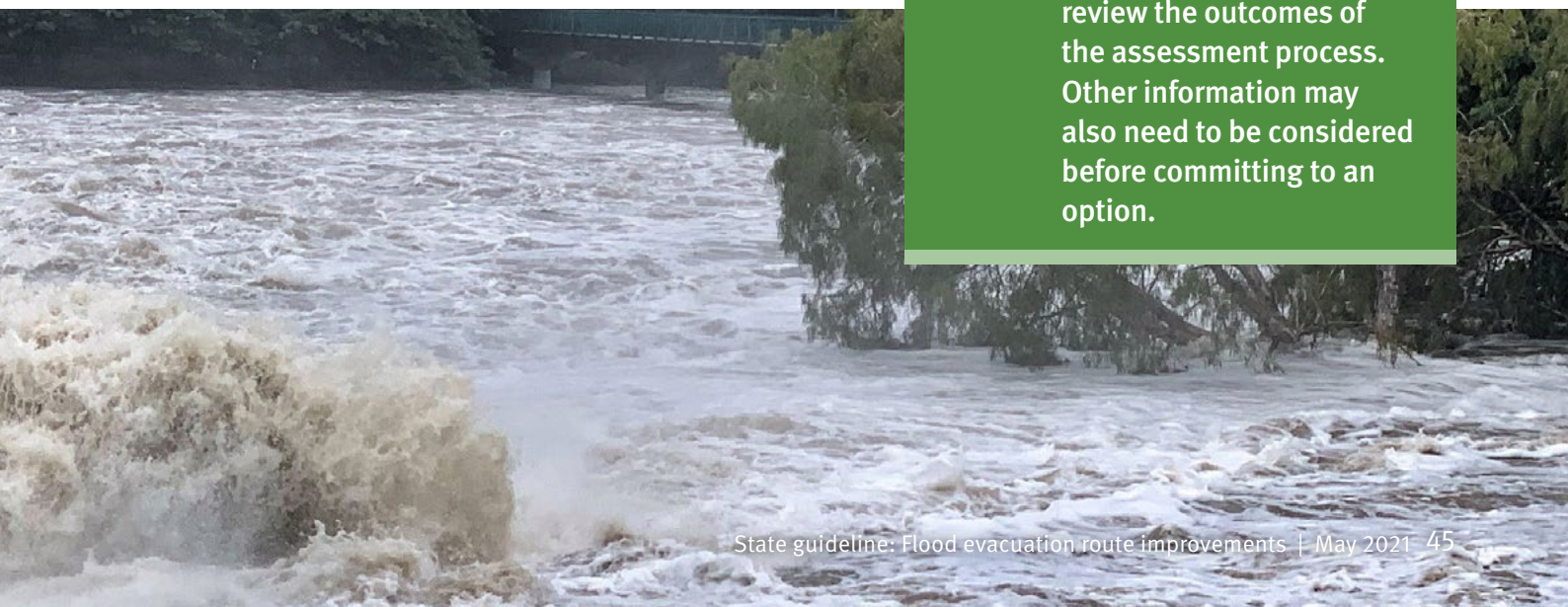
The options assessment process provides information on the effectiveness and efficiency of options based on their benefits, impacts, cost and constraints to support decision making. Review the outcomes of the assessment to determine which evacuation route improvement(s) is most 'fair and reasonable'. Other information may also need to be considered before committing to a preferred option(s). Consider the following when reviewing the outcomes of the assessment process:

- **Do the options sufficiently address the evacuation problem, service need and desired outcomes?**
  Review options to ensure they resolve the evacuation problem and meet the service need and desired outcomes (for example, reduce risk to life). An option may score favourably in the MCA, however, it may not reduce the length of isolation or improve the ability to evacuate enough to resolve the evacuation problem.
- **Was it possible to appropriately capture all benefits, impacts, costs and constraints in the assessment process?**
  Intangible issues, such as reduction in mental health impacts, may be difficult to quantify but can be an important driver in option selection.
- **Should scores for a targeted indicator eliminate an option, irrespective of the overall MCA score?**
  In all cases, low scores for targeted indicators in the safety criterion should eliminate an option. Scores for other targeted indicators may also eliminate an option due to the significance of the impact. For example, an option may achieve a high overall MCA but is eliminated due to cultural heritage impacts.
- **How do the MCA results compare with the economic and financial assessments?**
  Consider cost estimates and the results of economic and financial assessments with the MCA scores. Where CBAs have been conducted, it is important to be aware BCRs and NPVs have limitations in quantifying and monetising benefits for safety and risk to life. For evacuation route improvements, BCRs and NPVs are valuable for comparative purposes to indicate which option has the greater economic performance. In general, if two options have similar BCRs, the option with the highest MCA score is usually more preferable.
- **Is the cost of each option affordable and commensurate with the scale of the evacuation problem?**
  Review the feasibility of options based on their costs when considering budgets or funding availability and consider if proposed options warrant the required investment. Throughout the process, engage and consult agencies, stakeholders or organisations who may be required for delivery or ongoing operations.

Following the review, if a clear preferred option or options cannot be identified, options can be continually refined or further information collated before repeating the assessment process.

In summary

In summary, to support the identification of 'fair and reasonable' evacuation route improvements, review the outcomes of the assessment process. Other information may also need to be considered before committing to an option.



Part C: Implementation

Further approvals and agreements may need to be obtained and the scheduling of the project may be dependent on the priorities of the organisation responsible for delivery. The implementation process commences once the preferred option is ready to be considered for investment.

The implementation process is influenced by local policies, practices and processes; however, it typically follows the steps described below:

- **Business case:** Development of a business case to identify the merit of the option and seek funding.
- **Implementation plan:** Development of a roadmap to implement the option.
- **Implementation:** Delivery of the option.

The following are key considerations for implementation of the preferred option/s as a result of the assessment:

- Prior to, and during, implementation, engage relevant stakeholders, including the owner(s) of the relevant infrastructure and assets and decision makers responsible for funding and implementation. Once the preferred option has been agreed with these stakeholders, refer the option to the infrastructure owner(s) to progress or capture in forward planning and prioritisation. If a project requires delivery by another agency, asset owner, or internal area, it may need to be transferred to them for progression.
- When developing a business case, consider that evacuation route improvements may not have direct tangible economic benefits, so place emphasis on quantifying the likely reduction in risk to life and other intangible economic benefits. The evacuation problem, options analysis, preferred option, project benefits and way forward need to be clearly communicated to support a strong business case.
- Establish governance arrangements with clear roles and responsibilities, including identification of the project owner, sponsor and the project management arrangements to ensure accountability for the project is clear.
- Once a preferred option has been implemented, inform stakeholders responsible for executing evacuation arrangements. The option may also be captured in an LDMP or evacuation sub-plan.
- If contemplating evacuation route signage to support a measure, liaise with TMR, police and emergency services agencies to confirm evacuation route signage requirements (see Appendix C).

Toowoomba

Glossary

Term	Definition
Acceptable risk	The extent to which a disaster risk is deemed acceptable or tolerable depends on existing social, economic, political, cultural, technical and environmental conditions. A sub term of disaster risk. Also known as tolerable risk (Inspector-General Emergency Management, 2018).
Annual Exceedance Probability	The chance that a flood will reach or exceed a particular level in any given year. For example, a 1% (1 in 100) AEP (QRA, 2019a).
Assembly Point	A designated location specifically selected as a point which is not anticipated to be adversely affected by a hazard (QFES, 2018b).
Average Annual Time of Closure (AATOC)	The expected average time per year of closure of the road caused by flooding. It is expressed as time per year (DTMR, 2019b).
Benefit Cost Ratio	Ratio of the present value of benefit over the present value of costs (QRA, 2021a).
Brisbane River Catchment Flood Studies	The full package of investigations of the Brisbane River carried out on behalf of the Queensland Government since 2013 covering data collection, hydrological and hydraulic modelling, the Strategic Floodplain Management Plan and Local Floodplain Management Plans (QRA, 2019a).
Capability	The ability to achieve a desired effect in a specific environment/context (QFES, 2018b).
Coastal/storm surge flooding	Flooding as a result of the rising of the sea due to a storm (typically a low pressure weather system, such as a cyclone) and which may be exacerbated by wind waves or other coastal processes, such as erosion.
Community	A group with a commonality of association and generally defined by location, shared experience, or function. A social group which has a number of things in common, such as shared experience, locality, culture, heritage, language, ethnicity, pastimes, occupation, workplace, etc. (QFES, 2018b).
Community resilience	A community's ability to rapidly accommodate and recover from the impacts of hazards, restore essential structures and desired functionality and adapt to new circumstances. Community resilience is closely linked to the awareness of the community regarding flooding and the potential for impacts and damages from different sizes of events (QRA, 2019a).
Controlled releases from a dam (flooding source)	Flow in a waterway due to a controlled dam release which exceeds the capacity of the channel and results in water overtopping the channel banks.
Cost Benefit Analysis	An economic assessment methodology to support decision making which assesses the long-term benefits and costs in monetary terms (QRA, 2021a).
Creek flooding	Flooding within creeks and small river systems where floods increase and break out of the channel banks.
Disaster	A serious disruption in a community, caused by the impact of an event, that requires a significant coordinated response by the state and other entities to help the community recover from the disruption (QFES, 2018b).
Disaster Management Group	Means the state group, a district group or a local group (QFES, 2018b).
District Disaster Management Group (DDMG)	The group established under section 22 of the *Disaster Management Act 2003*. The DDMG provides whole-of-government planning and coordination capacity to support local governments in disaster management and operations (QFES, 2018b).
Evacuation	The planned movement of persons from an unsafe or potentially unsafe location to a safer location and their eventual return (QFES, 2018b).
Evacuation centre	A building located beyond a hazard to provide temporary accommodation, food and water until it is safe for evacuees to return to their homes or alternative temporary emergency accommodation (QFES, 2018b).

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Glossary (continued)

Term	Definition
Evacuation facilities	Describe a variety of sites which may need to be established to accommodate people during an evacuation. Categories of evacuation facilities comprise: ▪ evacuation centre ▪ public cyclone shelter* ▪ place of refuge* (QFES, 2018b). * Note, public cyclone shelter and place of refuge are specifically for cyclones.
Evacuation sub-plan	An appendix to a disaster management plan, evacuation sub-plans provide further detailed arrangements, methods and protocols relating to evacuation activities undertaken by the disaster management groups and their member agencies.
Evacuation route	A designated road, not anticipated to be adversely affected by the hazard, to be used for travel to a safer location (QFES, 2018b).
Essential goods	Essential goods are considered to include: ▪ basic foodstuffs, basic cleaners ▪ disinfectants, etc. to enable communities to maintain adequate hygiene practices ▪ baby foods, formula feeds for babies and nappies ▪ foodstuffs to meet special dietary requirements ▪ medicines and medical supplies, water purification tablets/treatments ▪ dried pet foods ▪ fuels for essential activities ▪ batteries ▪ other goods deemed necessary to maintain the physical and/or psychological welfare of the inhabitants of isolated communities (see QFES, 2018b for detailed definition).
Exposure	The land use and population that exists within the floodplain, and hence is exposed to flood hazards (QRA, 2019a).
Flood conveyance	Where the vast majority of flood water flows through a floodplain and is typically deep and fast flowing during big flood events. Even partial blockage of flood conveyance areas would likely cause significant redistribution of flood flow or significant increase in flood levels (QRA, 2019a).
Floodplain	An area of land that is subject to inundation by floods up to and including the probable maximum flood event – that is, flood-prone land (AIDR, 2017d).
Flood-prone land	Land susceptible to flooding by the Probable Maximum Flood event. Flood-prone land is synonymous with the floodplain (AIDR, 2017d).
Hydraulic behaviour	Where and how flood waters flow across a floodplain. This includes flood depths, levels, velocities and flows (QRA, 2019a).
Hydrologic and hydraulic models	Computer modelling of rainfall and surface runoff to simulate real world flood conditions and therefore estimate likely flood extents and flood behaviour for theoretical future conditions and events. These models are calibrated to historical events to ensure they provide an adequate representation of actual conditions (QRA, 2019a).
Immunity / Flood Immunity	The probability of the storm event for which flood extents do not exceed above or encroach beyond defined limits. Expressed as either an Annual Exceedance Probability (AEP) or a number of Exceedances per Year (EY).
Likelihood	The chance of something happening whether defined, measured or determined objectively or subjectively, qualitatively or quantitatively and described using general terms or mathematically. (Standards Australia/ Standards New Zealand Standard Committee, 2009)
Localised flooding/ overland flow	Flooding generated from rainfall occurring over a local area only. Localised flooding is concentrated in small creeks and ephemeral waterways, while overland flow is the surface runoff following rainfall, concentrated in natural lower lying areas and swales across the landscape. Flooding is usually 'flashy' with peaks occurring shortly after rainfall (QRA, 2019a).
Local Disaster Management Group	The group established under section 29 of the *Disaster Management Act 2003,* in place to support Local Government in the delivery of disaster management services and responsibilities in Preventing, Preparing for, Responding to and Recovering from Disaster Events (QFES, 2018b).

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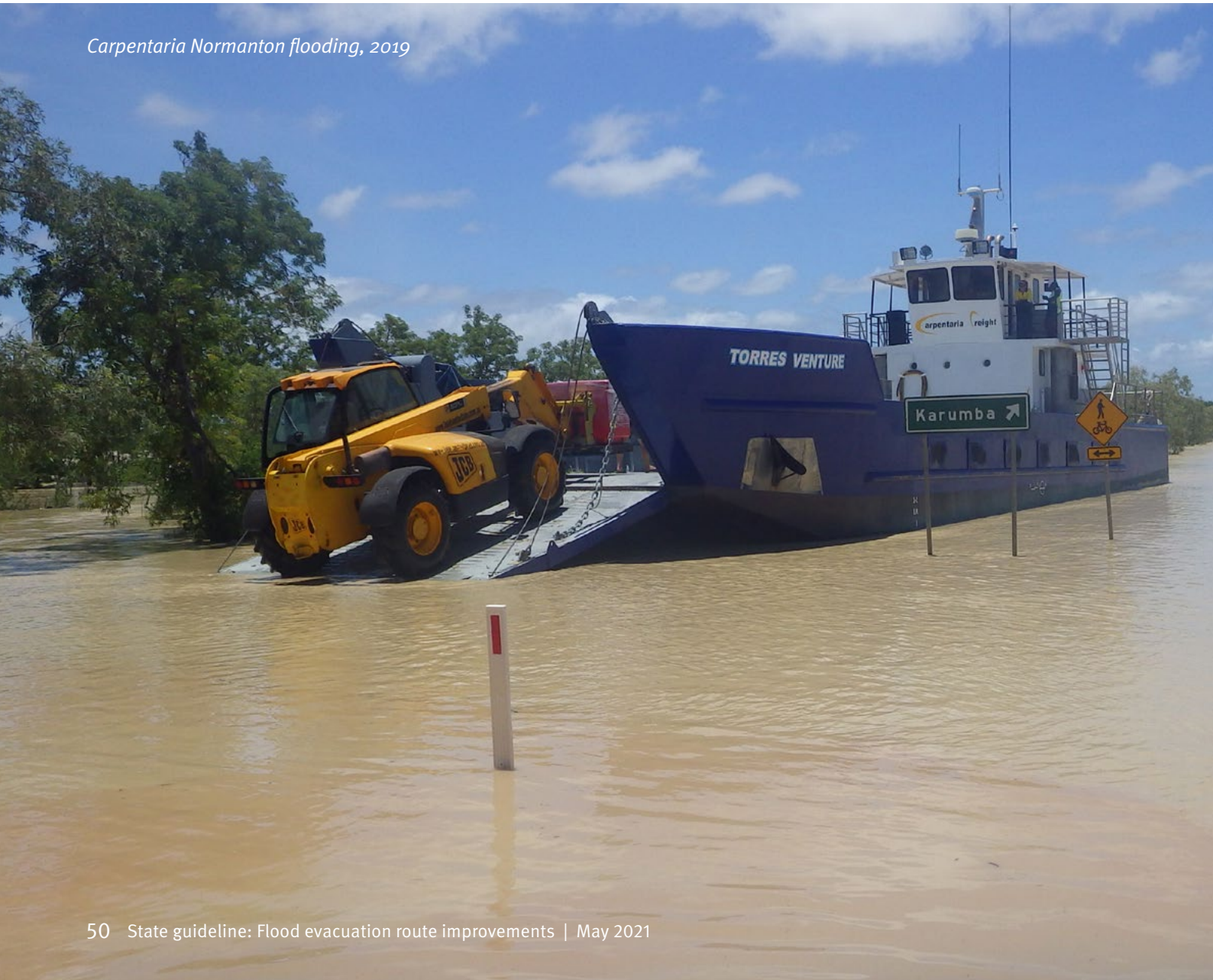
Glossary (continued)

Term	Definition
Local Disaster Management Plan (LDMP)	A plan prepared under section 57 of the *Disaster Management Act 2003* that documents arrangements to manage disaster planning and operations within the local government area of responsibility (QFES, 2018b).
Net Present Value (NPV)	A present value (all values discounted to present day terms) of the benefits less the present value of costs (QRA, 2021a).
Phases of disaster management	Prevention, Preparedness, Response and Recovery.
Preparedness	The taking of preparatory measures to ensure that, if an event occurs, communities, resources and services are able to cope with the effects of the event (QFES, 2018b).
Prevention	The taking of preventative measures to reduce the likelihood of an event occurring or, if an event occurs, to reduce the severity of the event (QFES, 2018b).
Probable Maximum Flood (PMF)	The PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation and, where applicable, snow melt, coupled with the worst flood-producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood-prone land – that is, the floodplain. The extent, nature and potential consequences of flooding associated with a range of events rarer than the flood used for designing mitigation works and controlling development, up to and including the PMF event, should be addressed in a floodplain risk management study (AIDR, 2017d).
Recovery	The taking of appropriate measures to recover from an event, including the action taken to support disaster-affected communities in the reconstruction of infrastructure, the restoration of emotional, social, economic and physical wellbeing, and the restoration of the environment (QFES, 2018b).
Residual risk	The risk that remains in unmanaged form, even when effective disaster risk reduction measures are in place, and for which emergency response and recovery capacities must be maintained (Inspector-General Emergency Management, 2018).
Response	The taking of appropriate measures to respond to an event, including action taken and measures planned in anticipation of, during, and immediately after an event to ensure that its effects are minimised and that persons affected by the event are given immediate relief and support (QFES, 2018b).
Riverine flooding	Flooding within large river systems where floods increase and break out of the riverbanks to inundate adjacent floodplains. Flooding is generated from rainfall across the broad catchment area. It may take many hours, or even days, for peak flood levels to occur as rainfall slowly drains from the catchment (QRA, 2019a).
Safer location	A variety of designated locations which are not anticipated to be adversely affected by the hazard. Categories of safer locations comprise: ▪ shelter in place ▪ friends and family ▪ neighbourhood safer places* ▪ assembly points (QFES, 2018b). *Neighbourhood safer places are specifically for bushfire hazards.
Shelter in place	An alternative or in addition to evacuation where individuals shelter within their homes, workplace or with family/friends if considered safe to do so (QFES, 2018b).
Tolerability	Tolerability is the community's readiness to bear the risk of flooding, after risk treatment. Risk tolerance can be influenced by legal or regulatory requirements, as well a community's awareness and experience of floods, knowledge of previous flooding history, what type of uses are exposed, extent of social and community cohesiveness. A range of demographic and socio-economic characteristics of a community may also affect current and future community views on flood risk (QRA, 2019a).
Tangible/intangible damages	Tangible damages are flood damages that can be measured in economic terms such as financial loss. Intangible damages cannot be directly linked to financial measures and include impacts such as stress and anxiety, as well as loss of life (QRA, 2019a).
Vulnerability	A measure of the sensitivity of the land use and/or population exposed to flooding. Vulnerability can relate to physical, socioeconomic, mobility or flood-awareness factors (QRA, 2019a).

Acronyms

AATOC	Average annual time of closure
AEP	Annual exceedance probability
AIDR	The Australian Institute of Disaster Resilience
BRSFMP	Brisbane River Strategic Floodplain Management Plan
BCR	Benefit cost ratio
CBA	Cost benefit analysis
DILGP	Department of Infrastructure Local Government and Planning
ECA	Evacuation capability assessment
LDMP	Local Disaster Management Plan
MCA	Multi-criteria assessment
NPV	Net present value
PMF	Probable maximum flood
QFES	Queensland Fire and Emergency Services
QRA	Queensland Reconstruction Authority
SPP	State Planning Policy
TMR	Department of Transport and Main Roads



Carpentaria Normanton flooding, 2019

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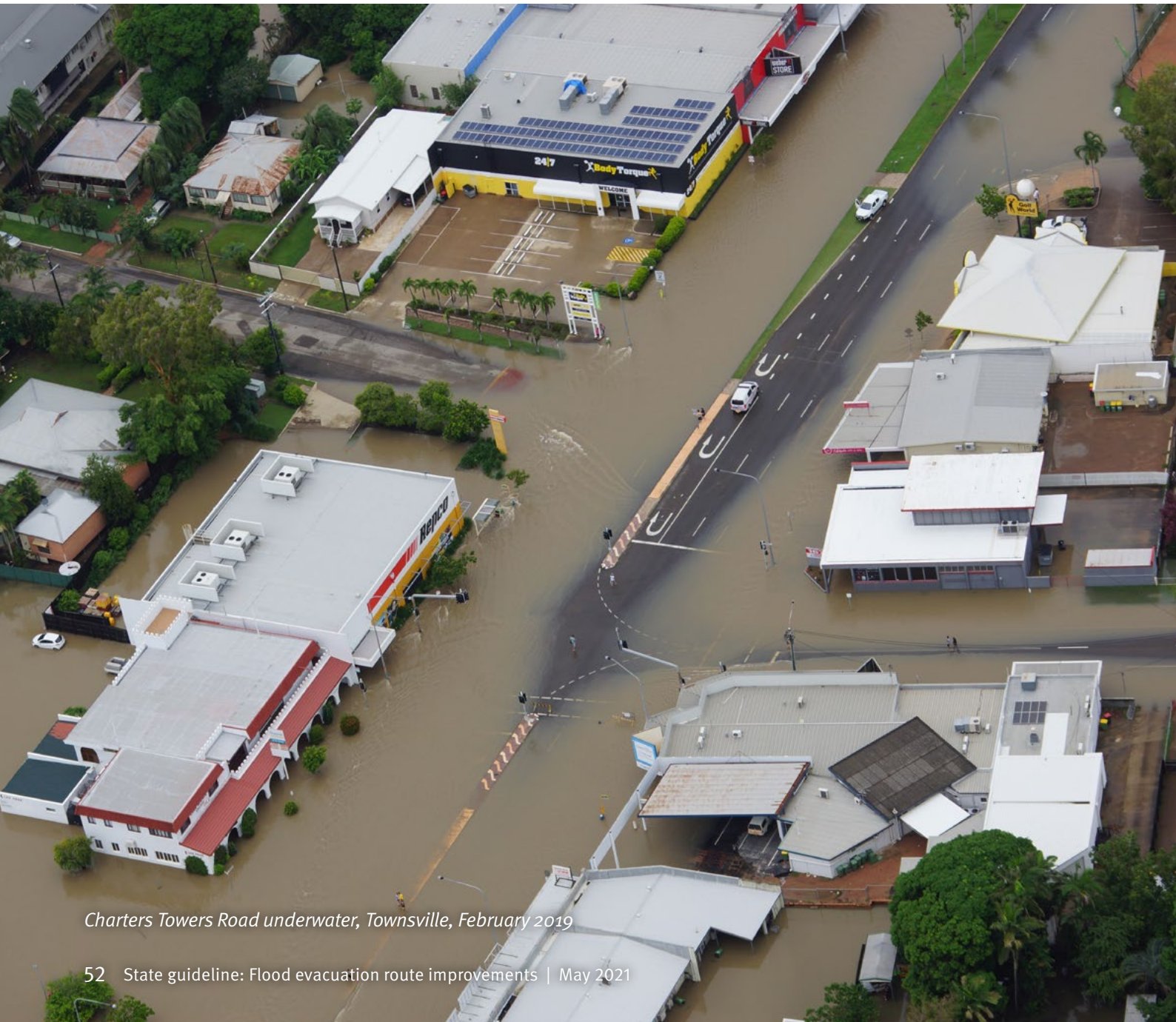

Charters Towers Road underwater, Townsville, February 2019

Appendix A – Intersection with other guidance

Key documents which support and intersect with this guideline at the date of publication are provided in Table 9 below.

Table 9 - Intersection with other guidance

Publication	Author/publisher and date	Scope and access location
Evacuation Planning – Handbook 4	AIDR (2017b)	Incorporates guidelines and considerations for developing community evacuation plans underpinned by an all-hazards approach. https://knowledge.aidr.org.au/media/5617/aidr-evacuation-planning-handbook.pdf
Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia	AIDR (2017d)	National guideline on the identification and management of flood risk. https://knowledge.aidr.org.au/media/3521/adr-handbook-7.pdf
Community Engagement for Disaster Resilience Handbook	AIDR (2020a)	Presents nationally agreed principles of community engagement for disaster resilience and provides high-level guidance to support those who engage with communities at all phases of disaster. https://knowledge.aidr.org.au/resources/handbook-community-engagement/
Flood Emergency Planning for Disaster Resilience	AIDR (2020b)	Provides guidance on the development and application of flood emergency plans for community safety. https://knowledge.aidr.org.au/media/8266/aidr_handbookcollection_flood-emergency-planning_2020.pdf
Australian Rainfall and Runoff: A Guide to Flood Estimation	Ball et. al (2019)	National guidance document used for the estimation of design flood characteristics in Australia. http://www.arr-software.org/pdfs/ARR_190514.pdf
State Planning Policy – July 2017 and associated guidance material	DILGP (2017a)	The SPP defines matters of state interest in land use-planning and development. The guidance material provides support for implementation and interpretation of the SPP including for the natural hazards, risk and resilience state interest (floods). The guidance material is intended to be read in conjunction with the SPP and is not statutory in effect, nor does it contain any new policy requirements. https://planning.dsdmip.qld.gov.au/planning/better-planning/state-planning/state-planning-policy-spp
Network Optimisation Framework	TMR (2019a)	TMR framework to help prioritise consideration of low-cost and non-infrastructure solutions or network optimisation solutions within the departments planning and investment process. https://www.tmr.qld.gov.au/business-industry/Business-with-us/Getting-the-most-out-of-existing-infrastructure
Road Drainage Manual	TMR (2019b)	Guidance on the planning, design, construction, maintenance and operation of road drainage infrastructure. https://www.tmr.qld.gov.au/business-industry/Technical-standards-publications/Road-drainage-manual

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Table 9 - Intersection with other guidance (continued)

Publication	Author/publisher and date	Scope and access location
Queensland State Disaster Management Plan	Queensland Disaster Management Committee (2018)	Outlines how Queensland will prevent, prepare, respond to and recover from disasters by outlining the principles, frameworks, arrangements, roles and responsibilities for disaster management in Queensland. https://www.disaster.qld.gov.au/cdmp/Documents/Queensland-State-Disaster-Management-Plan.pdf
Evacuation: Responsibilities, Arrangements and Management Manual – M1.190	QFES (2018a)	Part of the suite of non-mandatory tool kit items supporting the Disaster Management Guideline. Provides guidance on the responsibilities, arrangements and management of evacuation in Queensland. https://www.disaster.qld.gov.au/dmg/st/Documents/M1190-Evacuation-Manual.pdf
Queensland, Prevention, Preparedness, Response and Recovery Disaster Management Guideline	QFES (2018b)	Provides flexible, good practice suggestions and information to those responsible for implementing disaster management practices. https://www.disaster.qld.gov.au/dmg/Documents/QLD-Disaster-Management-Guideline.pdf
Queensland Emergency Risk Management Framework (QERMF) – Risk Assessment Process Handbook	QFES (2018c)	Provides a risk assessment methodology that can be used within disaster management planning at all levels of Queensland's disaster management arrangements. https://www.disaster.qld.gov.au/qermf/Documents/QERMF-Risk-Assessment-Process-Handbook.pdf
Brisbane River Strategic Floodplain Management Plan	QRA (2019a)	Provides a framework for a consistent approach to managing flood risk across the floodplain. It is a significant regional plan that considers current and future flood risk, disaster management, mitigation infrastructure, community resilience, building guides, land use planning and landscape management. https://www.qra.qld.gov.au/brcfs
Queensland Disaster Resilience and Mitigation Investment Framework	QRA (2019b)	Provides guidance on effective investment decision-making and prioritisation to support disaster resilience and mitigation across Queensland. https://www.qra.qld.gov.au/sites/default/files/2019-01/queensland_disaster_resilience_mitigation_framework_-_february_2019.pdf
Economic Assessment Framework of Flood Risk Management Projects	QRA (2021a)	Establishes a framework for Queensland-based flood risk management projects to undertake economic assessments for risk management options. www.qra.qld.gov.au
Queensland Flood Risk Management Framework	QRA (2021b)	The framework articulates the roles and responsibilities of agencies and entities that share responsibility to manage flood risk in Queensland. www.qra.qld.gov.au
Project Assessment Framework	Queensland Treasury (2015)	Framework used across government to ensure a common, rigorous approach to assessing projects at critical stages in their lifecycle, from the initial assessment of the service, through to delivery. https://www.treasury.qld.gov.au/programs-and-policies/project-assessment-framework/

Police remind motorist – If it's flooded, forget it, Townsville, 2019

Appendix B - Understanding flood risk management and evacuation

Evacuation

Evacuation is a hazard mitigation strategy and a risk reduction activity that lessens the effects of a disaster on a community (QFES, 2018b). It involves the movement of people to a safer location and their subsequent safe return (QFES, 2018b). An evacuation involves five stages as described in Figure 5.

Decision to evacuate	Warning	Withdrawal	Shelter	Return

	Decision to evacuate: Decision makers analyse event intelligence and assess the necessity to evacuate people exposed to a range of hazards.
	Warning: Notification of event conditions and appropriate actions required are conveyed to the public.
	Withdrawal: Exposed people move or are moved from a dangerous or potentially dangerous area to a safer location.
	Shelter: Refuge and basic needs for evacuees are provided in evacuation facilities and safer locations.
	Return: The disaster area is assessed and managed, with a planned return of evacuees.

Figure 5 - Five stages of evacuation

Flood risk management

Effective flood risk management requires an integrated, multi-disciplinary approach using a suite of implementation tools. In Australia, AIDR Handbook 7 is regarded as the national guide for floodplain management.

The broader flood risk management process (shown in Figure 6) encompasses flood investigation stages from data collection and flood studies through to floodplain management plan implementation. Sometimes the term 'flood risk management' is used to apply to the final two stages only.

Flood studies generate flood maps that help to describe likely flood behaviour in a particular area under certain circumstances. This information may be used, in conjunction with information about land use and community attributes to understand flood risk. Floodplain management studies assess the scale and nature of flood risk and consider various options to manage the flood risk to an acceptable risk. Floodplain management plans provide a roadmap for implementing preferred risk management options.

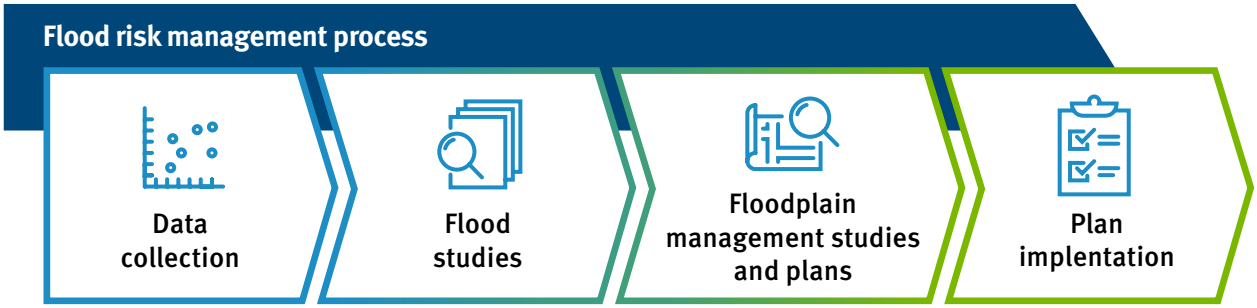


Figure 6 - Flood risk management process

Flood risk

Risk is defined as the combination of the likelihood of the hazard occurring, together with the consequence of the hazard occurring. Likelihoods can range from very frequent to very rare, while consequences can range from insignificant to catastrophic.

Flood risk is determined by considering many components:

- flood behaviour, including the flood velocity, depth, duration and hazard (generally described as a combination of depth and velocity), and flood speed of onset (that is, how quickly flooding evolves following rainfall)
- flood frequency, including very small and regular floods up to extremely rare and large floods
- flood exposure of people, property, infrastructure and agriculture
- nature of the community, including community vulnerability, resilience and tolerance.

Flood risk can occur from both inundation and isolation (as well as the secondary effects of inundation and isolation, such as loss of essential services).

There are three main approaches to the management of flood risk:

- Reducing flood risk at the community scale with structural works. Structural mitigation alters flood behaviour to reduce risk. However, it is often expensive and must be hydraulically assessed to ensure works do not cause unacceptable impacts elsewhere in flood-prone land. Examples of these works may include dams, levees, floodgates, temporary barriers and detention basins. At a broad scale, landscape management activities such as revegetation, re-engaging flood-prone land and naturalisation of waterways also have potential to reduce flood risk through modification of flood behaviour.
- Reducing flood risk at property scale with mitigation works. These may include residential property buyback/voluntary purchase schemes, house raising, flood proofing buildings or improving built design.
- Treating residual risk at the community scale. Measures to treat residual risk primarily focus on disaster management and community awareness and resilience. Examples of these risk treatments may include flood warning systems, emergency response plans or community education programs.

Although not addressed in this guideline, future flood risk to new development may best be managed by avoiding

or minimising the consequences of flooding. This is most effectively achieved through a risk-based approach to land use planning, which takes into consideration both current and future climate conditions and future urban growth plans.

Flood studies

In addition to historic flood events, flood studies seek to better define the nature and extent of a flood evacuation problem by undertaking flood modelling and mapping to understand flood behaviour. The information from flood studies can be subsequently translated to flood risk. The flood modelling process, which produces flood maps, is a standardised process guided in Australia by *Australian Rainfall and Runoff: A Guide to Flood Estimation*. However, there can be significant differences in flood studies due to the accuracy and level of detail in the flood model used.

All flood models are coarse simplifications of very complex processes. Users should be aware of limitations in the model and its outputs to understand if it is fit-for-purpose to inform ECAs and evacuation route improvement options assessment. Information about model limitations and confidence may be provided in the flood study report or may need to be supplemented by discussion with flood modelling specialists.

Flood maps are generally created for a range of design flood events representing theoretical flood events based on rainfall probabilities (for example, the 1% AEP event, previously referred to as the 100-year average recurrence interval or '1 in 100 flood'). Comprehensive flood studies typically model and map a range of design flood events ranging from very frequent (smaller) floods, such as the 20% AEP ('1 in 5 flood') up to the PMF. A PMF is a hypothetical flood estimate relevant to a specific catchment whose magnitude is such that there is negligible chance of it being exceeded. Flood maps may also be available for historic flood events.

As a minimum, flood mapping shows flood extents (where the flood waters reach), however most flood studies also produce flood levels and/or depths (to understand how deep flood waters are at a certain location), velocity and hazard. Flood hazard is a combination of velocity and depth and may be categorised in various ways. Flood timing information is also generated in flood models, however, it is not always provided as part of standard flood study handovers and may need to be requested. This information is extremely valuable when undertaking evacuation planning to understand how much flood warning time may be available, the pattern that flooding might follow as it inundates the community, and how long flooding is likely to persist (affecting flood isolation). Measuring warning time for a variety of events is valuable as timing may vary for different events. Warning time can be determined in several ways:

- For flood waters rising from a waterway where there is an available upstream gauge, warning time can be determined by measuring the time it takes for a flood wave to travel from the gauge to the area of interest based on recorded data.
- For flood waters rising from a waterway and there is no appropriate gauge, flood study timing outputs from a variety of events can provide guidance on warning time available.
- For flooding due to overland flow or flash flooding, where an evacuation trigger is defined on rainfall forecast and radar, warning time can be determined by the time available between becoming aware of the risk and inundation by flood waters.
- For storm surges it can difficult to predict their arrival and scale. For large storm tides caused by tropical cyclones, the Bureau of Meteorology provides forecasts and warnings regarding tropical cyclone storm tides which, where possible, are issued at least 24 hours prior (QFES, 2015a).

Modern flood studies also typically consider climate change and produce flood maps representing one or more future climate scenarios. This information can help users understand how changes in rainfall intensity and sea levels might influence flooding in the future.

Flooding can be caused by various mechanisms or sources and sometimes by multiple sources (either separately or concurrently). Table 10 describes the various sources of flooding and how typical attributes might influence evacuation planning.

Rocky Ned Road, Fredricksfield, 2020

Table 10 - Considerations for flood sources

Source of flooding	Flood mechanism	Typical attributes	Considerations for evacuation
Riverine flooding	Flooding within large river systems where floods increase and break out of the riverbanks to inundate adjacent floodplains. Flooding is generated from rainfall across the broad catchment area (QRA, 2019a).	Flood behaviour can be more predictable than overland flooding. Riverine flooding can present a range of flood behaviours (relating to velocity, depth, hazard) depending on local topography and size of flood. It may take many hours, or even days, for peak flood levels to occur as rainfall slowly drains from the catchment. Flooding in larger, flatter catchments will generally persist for longer.	Often some flood warning time available, depending on the size of the catchment leading to the waterway (smaller catchments have less potential warning time). Major waterways are likely to have stream gauges which support disaster management measures linked to key flood heights. Isolation can be an issue for some catchments where flooding persists. Riverine flood models are more likely to be calibrated to historic flood data and present a higher level of confidence than overland flood models.
Creek flooding	Flooding within creeks and small river systems where floods increase and break out of the channel banks.	Flood behaviour can be more predictable than overland flooding. The small catchment size can produce flash flooding, which is typically more dangerous than flooding observed in large riverine catchments. Flood behaviour depends on local topography and size of flood. Small catchments will typically produce short duration floods which have a fast onset and only persist for a few hours.	Small catchments are unlikely to have much warning time available. Many small creeks do not have stream gauges. Evacuation may be more dangerous than sheltering in place or remaining in place, due to dangerous flood conditions on roads. Prolonged isolation is not likely to be an issue. Creek flood models may be calibrated (if historic flood data exists). Calibrated models present a higher level of confidence than uncalibrated models.

(continued on next page)

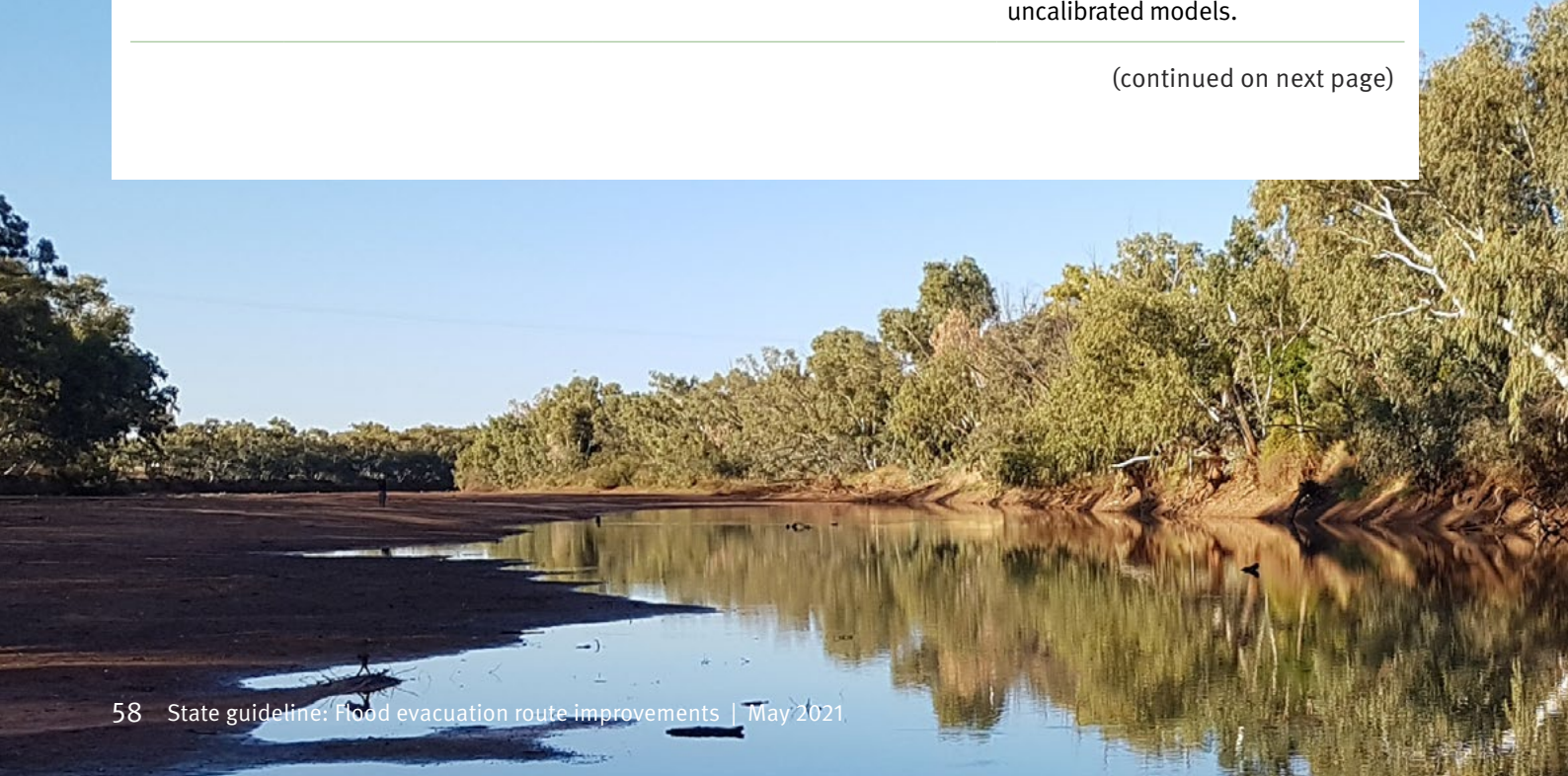
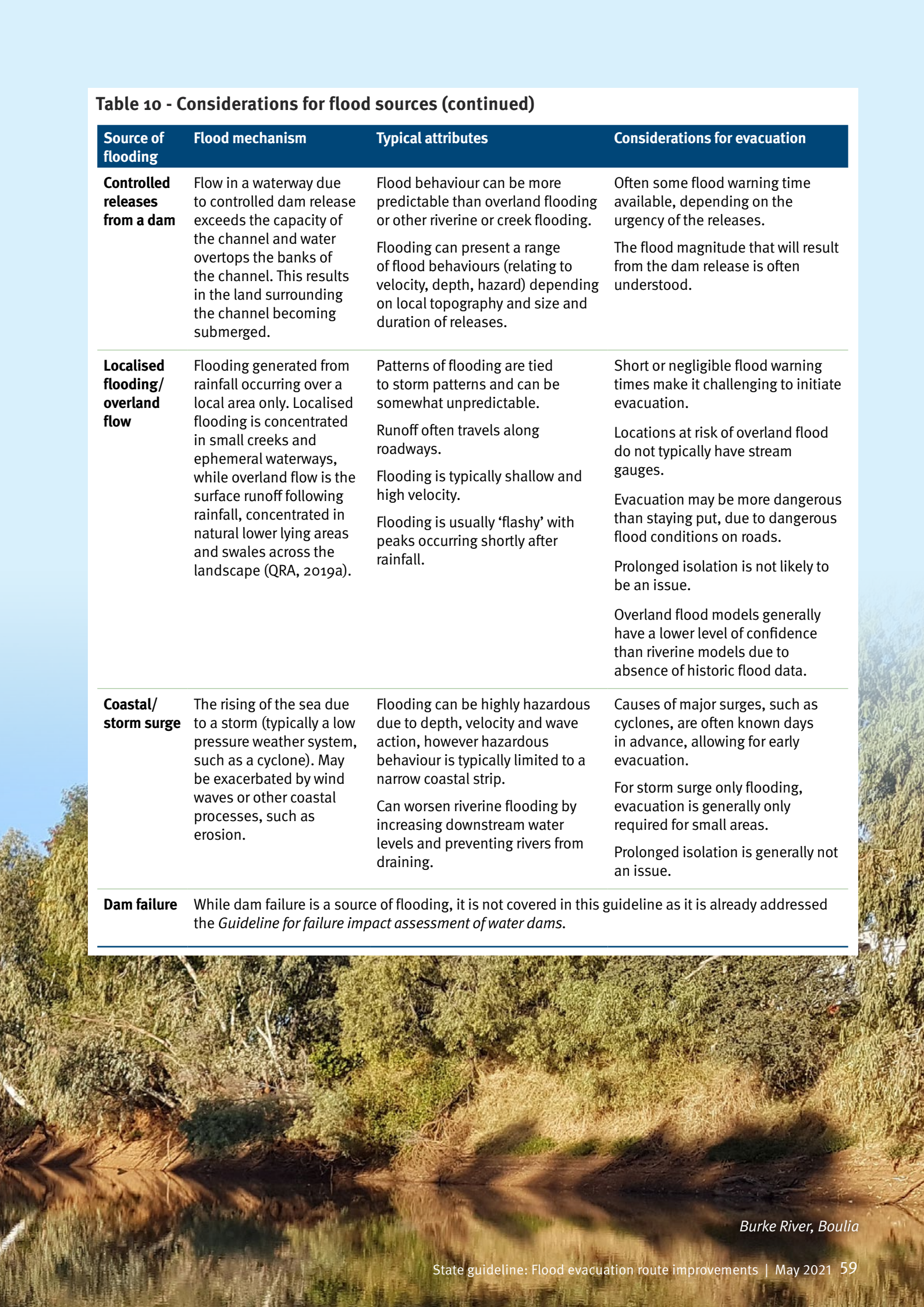


Table 10 - Considerations for flood sources (continued)

Source of flooding	Flood mechanism	Typical attributes	Considerations for evacuation
Controlled releases from a dam	Flow in a waterway due to controlled dam release exceeds the capacity of the channel and water overtops the banks of the channel. This results in the land surrounding the channel becoming submerged.	Flood behaviour can be more predictable than overland flooding or other riverine or creek flooding. Flooding can present a range of flood behaviours (relating to velocity, depth, hazard) depending on local topography and size and duration of releases.	Often some flood warning time available, depending on the urgency of the releases. The flood magnitude that will result from the dam release is often understood.
Localised flooding/ overland flow	Flooding generated from rainfall occurring over a local area only. Localised flooding is concentrated in small creeks and ephemeral waterways, while overland flow is the surface runoff following rainfall, concentrated in natural lower lying areas and swales across the landscape (QRA, 2019a).	Patterns of flooding are tied to storm patterns and can be somewhat unpredictable. Runoff often travels along roadways. Flooding is typically shallow and high velocity. Flooding is usually 'flashy' with peaks occurring shortly after rainfall.	Short or negligible flood warning times make it challenging to initiate evacuation. Locations at risk of overland flood do not typically have stream gauges. Evacuation may be more dangerous than staying put, due to dangerous flood conditions on roads. Prolonged isolation is not likely to be an issue. Overland flood models generally have a lower level of confidence than riverine models due to absence of historic flood data.
Coastal/ storm surge	The rising of the sea due to a storm (typically a low pressure weather system, such as a cyclone). May be exacerbated by wind waves or other coastal processes, such as erosion.	Flooding can be highly hazardous due to depth, velocity and wave action, however hazardous behaviour is typically limited to a narrow coastal strip. Can worsen riverine flooding by increasing downstream water levels and preventing rivers from draining.	Causes of major surges, such as cyclones, are often known days in advance, allowing for early evacuation. For storm surge only flooding, evacuation is generally only required for small areas. Prolonged isolation is generally not an issue.
Dam failure	While dam failure is a source of flooding, it is not covered in this guideline as it is already addressed the *Guideline for failure impact assessment of water dams*.		



Burke River, Boulia

Yeppen Floodplain Crossing, Bruce Highway

Appendix C - Evacuation route signage

If considering evacuation route signage to support an option, liaise with TMR, and Queensland police and emergency service agencies to confirm requirements. Users should consider the following:

- clear delineation and visibility of the evacuation route and signage is very important
- consider target audience and traffic volumes. Seasonal populations such as tourists, seasonal workers and other temporary visitors may be unfamiliar with the road network and may be better diverted to a major road
- evacuation route signage information should be succinct
- evacuation route signage should confirm the emergency radio station
- education and signage about evacuations and evacuation routes, including education of seasonal populations, may be required
- whether heavy and oversize vehicles are appropriate for proposed route, in terms of their dimensions and weight.

This is intended to provide examples only and is not an exhaustive list.

Permanent evacuation route signage

Permanent flood evacuation route signage is appropriate for routes which are likely to be safe for all flood events. When developing permanent signage, refer to the requirements in the *Queensland Manual of Uniform Traffic Control Devices* (https://www.tmr.qld.gov.au/business-industry/Technical-standards-publications/Manual-of-uniform-traffic-control-devices).

When developing permanent flood evacuation route signage, consider the risks of using permanent signage. Consult with the community and seek endorsement from the relevant Local and District Disaster Management Groups.

The *Transport Operations (Road Use Management) Act 1995* requires that all permanent traffic control signs be 'officially approved'. Refer to the *Queensland Manual of Traffic Control Devices Part 1: General introduction and index signs* for officially approved standard signage and approval procedures for circumstances where no suitable standard sign exists. Contact TMR's traffic and engineering team for further information.

TMR's *Traffic and Road Use Management Manual Volume 3 - Signing and Pavement Marking* (Part 9) discusses permanent diversion route signage and may be appropriate for principles relating to permanent evacuation signage (https://www.tmr.qld.gov.au/business-industry/Technical-standards-publications/Traffic-and-Road-Use-Management-manual/Volume-3).

Temporary evacuation route signage

When developing temporary signage, refer to requirements in the *Queensland Manual of Uniform Traffic Control Devices*.

TMR's *Manual of Uniform Traffic Control Devices Part 3: Traffic Control for Works on Roads* provides guidance on temporary signage (see guidance for detour signs and multi-message sign plates – traffic diversion signs).

Notes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