Guide for Flood Studies and Mapping in Queensland

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Queensland Government

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Version History

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1	Jan 2016	Released
2	Oct 2017	Updates to web links in Table 1-1, minor updates to Figure 1-3 and section 5.5.

Cover photo: Emerald – December 2010 flood (DNRM)

This publication has been compiled by Operations Support, Department of Natural Resources and Mines.

Preface

Since 2011, and in response to the Queensland Floods Commission of Inquiry, the Queensland Government has supported Councils and disaster management entities by delivering flood projects, and producing flood maps and information at town and catchment scales. With the Queensland Flood Mapping Program now completed, the Queensland Government now seeks to establish a process which guides the procurement, management and implementation of cost-effective and fit-for-purpose flood studies and mapping for the Queensland environment and context.

The multiple flood events of 2010 to 2013 provided a reminder of the devastating cost of flooding to the community. While the impacts of flooding cannot be eliminated, a sound understanding of flood behaviour enables informed decision making on the management of risk (to existing and future) where practical, feasible and cost-effective to do so.

Historically, flood damage is greater than that of any other natural hazard. However, it is also the most manageable disaster, because its behaviour and location can be estimated and considered in decisions. For a particular floodplain, flood behaviour can be studied, and the likely location, type and scale of effects for a range of floods can be determined within reasonable confidence to inform its management. Understanding flood behaviour, including potential alterations due to changes in climate, enables us to assess the likely impact of flooding on the community and examine options to manage the community's exposure to flood risk.

Background to the Guide

The guide was developed by BMT WBM on behalf of the Department of Natural Resources and Mines. During the guide development numerous stakeholders from Queensland Councils, State Government departments, Local Government Association of Queensland, Floodplain Management Australia and interstate agencies were consulted.

Purpose of the Guide

The guide seeks to assist flood practitioners in Queensland create fit-for-purpose flood studies and mapping which encompass best-practice principles. Application of the guide will promote a consistent approach to flood studies and mapping throughout the state.

Intended Users of the Guide

The guide is primarily intended to assist Councils and other floodplain management entities (such as river improvement trusts). Engineering consultants and other agencies involved with flooding may also use the guide when bidding for or preparing flood studies, or when interpreting flood study outputs. It is anticipated that all users have some technical background, preferably in engineering, land use planning and / or disaster management.

Contents

1 Part 1 – Overview

1.1 Introduction

This guide seeks to establish a standardised approach which facilitates greater consistency for flood studies and mapping throughout the state. The guide extends the groundwork established through the Queensland Flood Mapping Program by enabling Councils and other flood management entities (such as river improvement trusts) to create fit-for-purpose flood studies and mapping.

This guide comprises four sections:

- **Part 1** provides general advice on using the guide.
- **Part 2** helps to understand and define the flood issues and why there is a need to commission a flood study. Through a series of high-level questions supported by explanatory text, the guide helps to define the need. The answers to the questions in this section can be used for State Government funding applications and to populate the flood study brief template in Part 3 of this guide.
- **Part 3** provides the information needed (including standardised text) to prepare a flood study brief. The brief is informed by the answers to the questions in Part 2 of this guide and can refer to Part 5 (the technical guide) where additional technical detail is required.
- **Part 4** provides advice to help manage the procurement and execution of flood studies, including on topics of intellectual property, peer review and flood study implementation.
- **Part 5** is a technical guide and provides clear and prescriptive guidance on issues which will require a consistent approach state-wide, including mapping style guidance, and data handover advice.

The development of this guide has been directly informed by Australian Emergency Management Handbook 7 (Handbook 7), **Managing the floodplain: best practice in flood risk management in Australia,** to make it compatible with that document and to ensure this guide is consistent with national best practice.

It should be noted that this guide is considered to be a dynamic document which will continue to be updated as flood risk management best practice in the Queensland evolves. In addition, users of this guide should also refer to the technical advice provided on flood estimation in the latest version of Australian rainfall and runoff: a guide to flood estimation (Australian Rainfall & Runoff, Engineers Australia). Note that updates of chapters of Australian Rainfall & Runoff are progressively released and users should always consult the most up to date version.

1.2 How to use this guide

This guide was developed to establish a consistent and best practice approach to flood studies and mapping in Queensland. Use of the guide is optional, though applications for State Government funding assistance will be assessed against the process outlined in this guide as illustrated in Figure 1-1. As a result, this guide has been developed in a format which allows users to utilise the same information in their grant application and flood study brief (Part 3 of this guide).

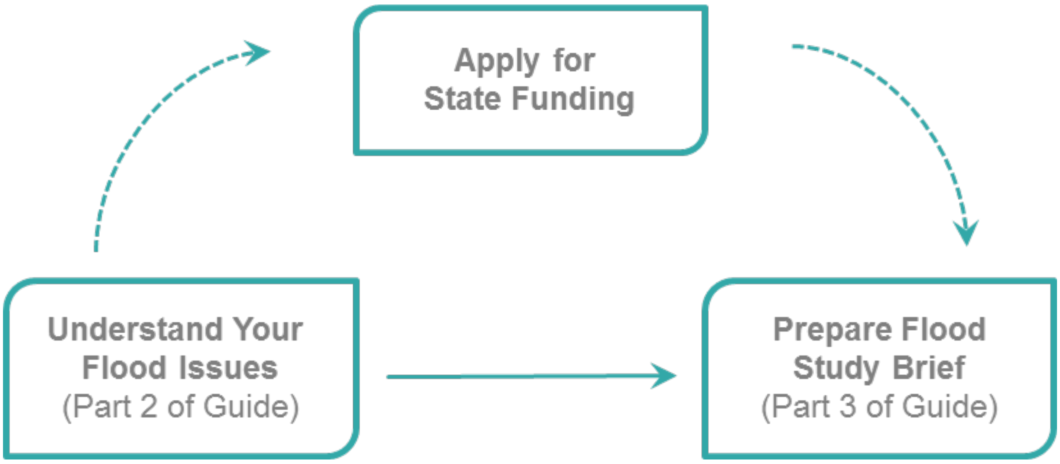


Figure 1-1 How to Use this Guide

This guide aims to provide advice to those with roles in understanding and managing flood risk and its consequences on the community. In particular, Parts 2 to 4 are intended for use by Councils, with Part 5 recommended for use by both flood practitioners (e.g. consultants) and Councils.

To use this guide to develop a flood study brief, Councils should read the entirety of Part 2 and respond to each question in the order written. At the bottom of each sub-section within Part 2, the user will be asked to fill in a box, providing information about their particular flood situation or flood study requirements. The information provided in these boxes can be directly copied by the user to populate the flood study brief template in Part 3 of the guide.

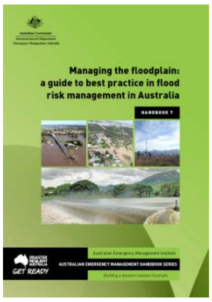
Once the flood study brief has been prepared, it is recommended that Council familiarise themselves with the information provided in Part 4 which will aid in the selection of tenderers, development of a flood study contract and the management of flood studies throughout the life of the study and beyond.

Part 5 of the guide might be used by Councils during the preparation of the flood study brief if they wish to understand the particulars of flood mapping styles and data handover. Alternatively, Council may wish to simply refer tenderers to Part 5 of this guide, rather than including prescriptive requirements in the flood study brief. It is anticipated that tenderers will refer to Part 5 during preparation of the flood study proposal, and during the course of the flood study, to ensure the study deliverables are consistent with the requirements of the guide.

1.3 Intersection with other guidance

This guide acts as the primary source of guidance for Councils seeking to scope, commission, manage and implement a flood study, however it is recognised that the guide sits within a framework of existing guidance, policies and legislation at both state and national levels which are described in more detail below.

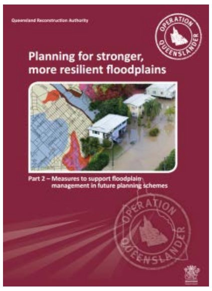
Managing the floodplain; a guide to best practice in flood risk management in Australia



The national guideline on the identification and management of flood risk is **Managing the floodplain: a guide to best practice in flood risk management** (Handbook 7), which is intended to provide broad advice on all important aspects in managing flood risk in Australia. The handbook was developed with consideration of the **National strategy for disaster resilience**, and the findings of recent State and national reviews following the multiple flood events of 2010 to 2012 that resulted in widespread flooding, including the **Queensland Floods Commission of Inquiry**. The approach outlined in the handbook is consistent with the **National emergency risk assessment guidelines** (NERAG) and **ISO 31000:2009 Risk management – principles and guidelines**. The NERAG provides a contextualised approach for the conduct of risk assessments for emergency events and is consistent with ISO 31000:2009.

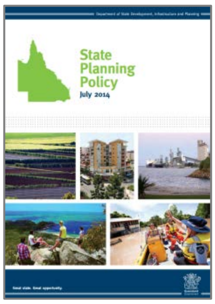
This guide was directly informed by Handbook 7 (and its supporting documents), to ensure consistency of approach and language at both a state and national level and is, by extension, consistent with the advice in the documents which informed the development of Handbook 7.

Planning for stronger more resilient floodplains



Following the 2010 / 2011 floods, the Queensland Reconstruction Authority (QRA) was established, with a stated mission to reconnect, rebuild and improve Queensland, its communities and economy. During the post-flood recovery period, the QRA produced two major documents (in addition to interim reviews etc.): **Rebuilding a stronger, more resilient Queensland**, which provides an overview of resilience in a disaster management context and initiatives that were implemented at an international, national, state and local level to build disaster resilience in response to the disaster events of 2010 / 2011, and **Planning for stronger, more resilient floodplains**, which provides Councils with a suite of practical measures to better align floodplain management and land use planning.

State Planning Policy



The State Planning Policy (SPP) outlines the State's interests in land use planning in Queensland. It articulates natural hazards, risk and resilience as a State interest, and provides a range of policy outcomes sought for local government planning schemes, development assessment, and community infrastructure in meeting that State interest. The policy provides (by default) the State's position on the treatment/management of flood risk by local government outside of disaster management arrangements of the *Disaster Management Act 2003* and its subordinate components. Supplementary guidance material to the SPP is also provided to help Councils meet the policy outcomes and make informed decisions about appropriate land uses in flood prone areas. This material includes **Natural hazards, risk and resilience - a state interest guideline** which provides advice on integrating State Government policy on natural hazards into planning schemes and strongly promotes a fit-for-purpose approach to undertaking hazard and risk assessments; **Natural hazards, risk and resilience - a technical manual** which outlines a methodology which may be used to undertake flood hazard investigations and develop flood maps to include in a planning scheme; and **Natural hazards, risk and resilience - Evaluation report: Flood hazards**, which guides Councils through a self-assessment process to determine if their flood hazard assessment process and outputs are sufficient to meet State interest requirements. The Evaluation Report is then provided to the Department of Infrastructure, Local Government and Planning to support signing-off on planning scheme approval by the State under *Statutory Guideline 04/14: Making and amending local planning instruments*. The Evaluation Report is not intended to meet any specific flood risk management requirements or standards other than the policy outcomes sought by the SPP as they relate to the local government's planning scheme.

Flood mapping implementation kit

The Queensland Flood Mapping Program (QFMP) was established by the Department of Natural Resources and Mines to deliver fit-for-purpose flood mapping for all communities across Queensland, in response to the 2010 / 2011 floods. These maps used one of three standard approaches depending on the need of particular locations (Level 1, 2 and 3 mapping). More recently, the QFMP produced the **Flood mapping implementation kit** to assist a range of stakeholders implement the outcomes of flood studies through flood mapping outputs. The kit identifies nine key areas (themes) which can benefit from consideration of information derived from flood studies and maps.

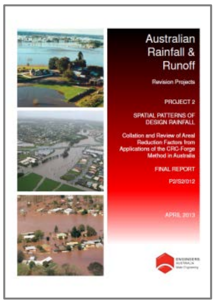
Queensland Strategy for Disaster Resilience

Disaster resilience is guided by the **Queensland Strategy for Disaster Resilience**, which sits under the National strategy for disaster resilience and outlines a vision to make Queensland a disaster resilient state. The strategy provides strategic direction to help build resilience across all sectors, identify goals and outcomes for improvement in resilience, and provide metrics to measure the performance of the State's disaster resilience activities.

Emergency Management Assurance Framework

The **Emergency Management Assurance Framework** was developed by the Office of the Inspector-General Emergency Management, in accordance with Section 16C of the Disaster Management Act 2003, and includes the Standard for Disaster Management in Queensland. The framework was developed in collaboration with Queensland disaster management practitioners and empowers front-line disaster management service providers by providing a standard which can be applied by all Queensland disaster management stakeholders to ensure their legislative responsibilities are met and that disaster management programs are effective, aligned with good practice, and meet the needs of Queensland communities. The Standard outlines a shared responsibility of hazard identification and risk assessment, and notes that a key outcome from the standard is risk assessments that are robust, replicable and authoritative, and undertaken following an international standard or other industry recognised methodology that is agreed as valid by stakeholders and approved by the entity for which they are undertaken.

Australian Rainfall and Runoff: a guide to flood estimation



Underpinning all technical work undertaken as part of flood hazard and risk identification and management is **Australian Rainfall and Runoff: a guide to flood estimation (ARR)**. This technical manual is a national guideline for the estimation of design flood characteristics in Australia, including estimation of rainfall, hydrologic and hydraulic modelling, and selection of climate change parameters. ARR has been undergoing a revision process in recent years with the aim of filling knowledge gaps that have arisen since the 1987 edition was published. The revision process has been undertaken through 21 projects addressing various topics. The outcomes of the projects will inform the updated ARR chapters or books (though will not necessarily translate directly).

Table 1-1 Reference Documents

Publication	Author / Publisher /Date	Location
Managing the floodplain: a guide to best practice in flood risk management	Emergency Management Australia (2013)	https://ema.infoservices.com.au/items/HB7-2ND

Publication	Author / Publisher /Date	Location
(Handbook 7) [including supporting documents]		
National Strategy for Disaster Resilience	Council of Australian Governments (2011)	https://www.ag.gov.au/EmergencyManagement/Documents/NationalStrategyforDisasterResilience.PDF
Queensland Floods Commission of Inquiry	State of Queensland (Queensland Floods Commission of Inquiry) (2012)	http://www.floodcommission.qld.gov.au/publications/final-report/
Emergency Management Assurance Framework	Inspector General Emergency Management (2014)	https://www.igem.qld.gov.au/assurance-framework/Pages/default.aspx
Australian Rainfall and Runoff	Engineers Australia (2016)	http://www.arr.org.au/revision-projects/project-list/
State Planning Policy - state interest guideline - Natural hazards, risk and resilience A 'fit-the-purpose' approach in undertaking natural hazards studies and risk assessments Evaluation report: Flood hazards	Department of Infrastructure, Local Government and Planning (2017)	http://dilgp.qld.gov.au/planning/state-planning-instruments/state-planning-policy-guidance-material.html
Flood Mapping Implementation Kit	Department of Natural Resources and Mines (2014)	https://www.dnrm.qld.gov.au/__data/assets/pdf_file/0009/230778/flood-mapping-kit.pdf
Queensland Strategy for Disaster Resilience	Department of Infrastructure, Local Government and Planning (2014)	http://www.statedevelopment.qld.gov.au/resources/plan/local-government/queensland-strategy-or-disaster-resilience.pdf
Planning for stronger, more resilient floodplains	Queensland Reconstruction Authority (2011-2012)	http://qldreconstruction.org.au/publications-guides/land-use-planning/planning-for-stronger-more-resilient-flood-plains
Rebuilding a stronger, more resilient Queensland	Queensland Reconstruction Authority (2011)	http://qldreconstruction.org.au/publications-guides/resilience-rebuilding-guidelines/rebuilding-astronger-more-resilient-queensland
ISO 31000:2009 Risk management – principles and guidelines	International Organisation for Standards (2009)	http://www.iso.org/iso/home/standards/iso31000.htm

1.4 Flood Study Benefits

Flood studies and flood mapping forms the basis for our understanding of flood behaviour and risk and provides the foundation for flood risk management decisions. Development and implementation of flood studies and flood mapping impacts a wide-range of key users in areas as diverse as land use planning, emergency management and community awareness. Communication of this information helps to build flood resilience within the community and informs a framework for Council and State agencies to manage flood risk into the future.

The **Queensland Strategy for Disaster Resilience** outlines a vision for making Queensland the most disaster resilient state in Australia, and defines a resilient community as:

> *… one that possesses the capacities, skills and knowledge that enable it to prepare for, respond to, and recover effectively from a disaster and adapt positively to a changing environment. It is a community that works together to understand and manage the risks and vulnerabilities that it confronts, and enhances its capacity to address its vulnerabilities to all hazards.*

By undertaking fit-for-purpose flood studies and implementing the study outputs through mapping, Councils, supported by the State Government, will improve the flood resilience of the community.

1.5 The flood risk management framework

Management of flood risk is essential to limiting the impacts of flooding on the community in balance with maintaining the benefits of occupying the floodplain to society and the benefits of flooding to the environment. The goal is to have flood risk management that is sustainable, provides long-term benefits for the community and environment, and improves community resilience.

Best practice promotes the understanding of flood behaviour so that the full range of flood risk to the community can be understood, effectively communicated and, where practical and justifiable, mitigated. It facilitates informed decisions on the management of this risk, and economic investment in development and infrastructure on the floodplain.

The flood risk management framework promotes a risk management approach that facilitates the effective understanding and management of flood risk within a Local Government Area and / or catchment. The framework encourages Councils to collect, improve and disseminate the best available information on flood behaviour, and associated risks to the community, decision makers and other agencies with a responsibility for managing flood risk. This information may be derived from a floodplain-specific management process and other sources (e.g. historic events and other studies), and by applying approaches of different degrees of sophistication that are fit-for-purpose. The framework and its emphasis on communication and consultation supports the dissemination of this information so that flood risk can be better understood and managed.

Flood studies (and associated mapping) sit within this flood risk management framework, as shown in Figure 1-2. The outcomes from flood studies are used to inform the flood risk assessment and management process.

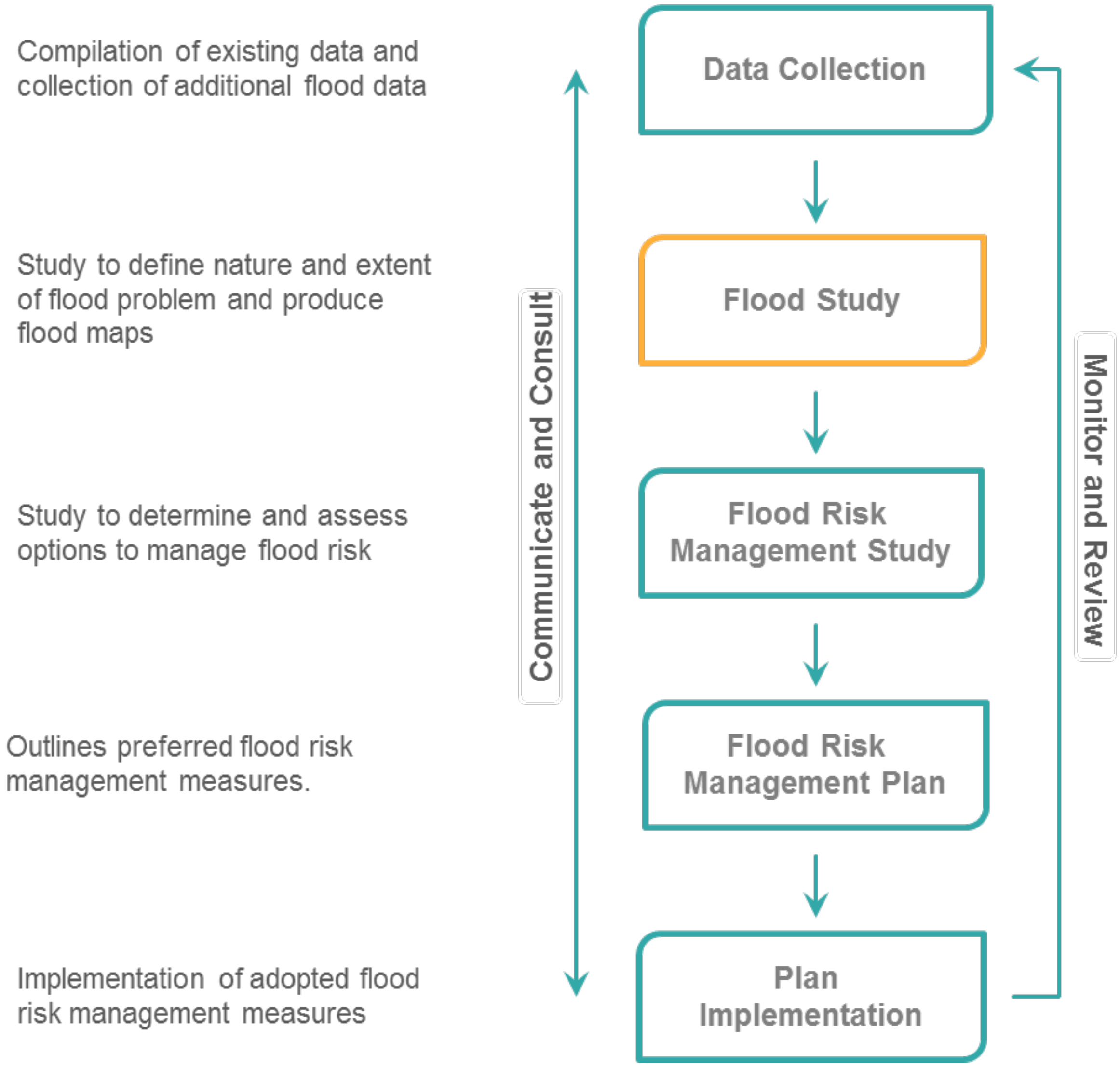


Figure 1-2 Flood Risk Management Framework

1.6 The flood study process

Flood studies seek to better define the nature and extent of a flood problem to inform flood risk assessment and management. In general, flood studies rely on some form of hydrologic and / or hydraulic model to improve our understanding of flood behaviour. The choice to use a model and the type and complexity of the selected model is guided by data availability, flood risk and end-user needs, however most studies follow a similar structure:

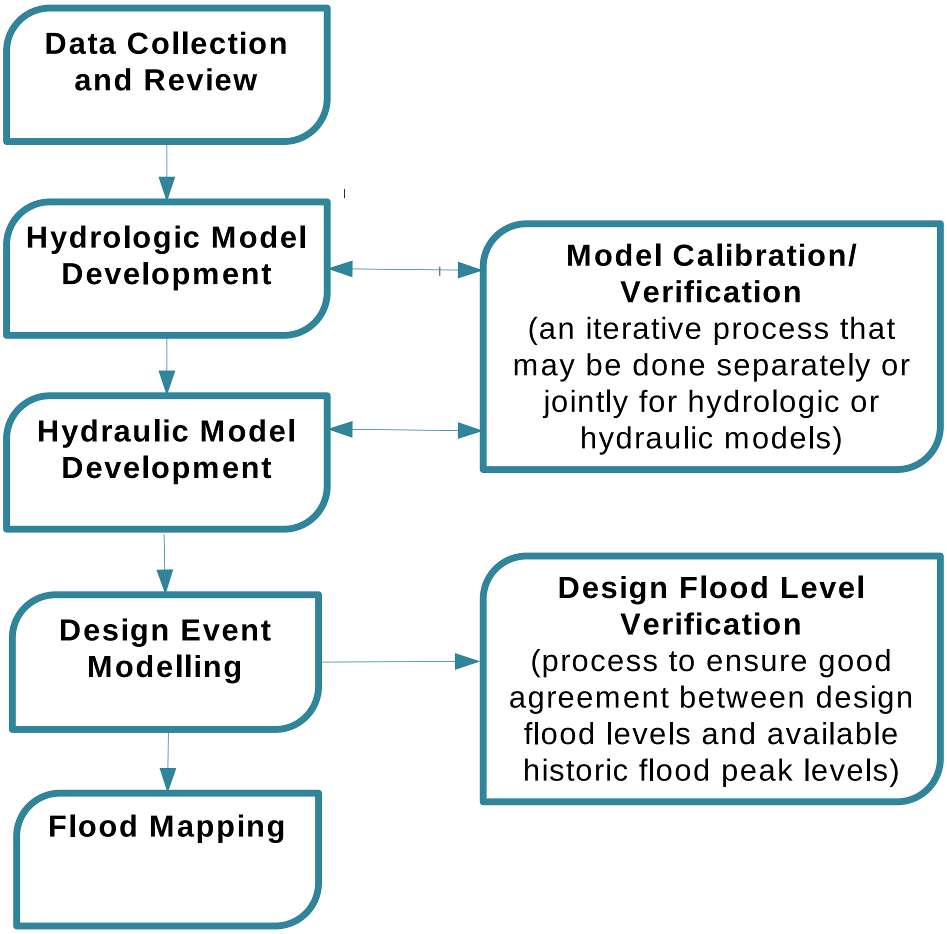


Figure 1-3 Flood Study Process

Data collection and review

Flood studies rely on a range of data, including terrain data (such as topography, bathymetry, aerial photography, land use zonings, structures and land use); historic data (such as recorded rainfall or stream height, flood marks and anecdotal data); and design rainfall (i.e. rainfall inputs based on statistical analysis of past records). This data must be collated and analysed to check for completeness, accuracy, relevancy and spatial extent. Gaps in existing data may be identified and Councils may need to consider whether additional data collection is required at this stage.

Hydrologic model development

Hydrologic modelling calculates the quantity and rate of catchment runoff from rainfall during a flood event. The model produces estimates of the discharges in the river and its tributaries during the course of a flood. The amount of runoff from the rainfall and the attenuation of the flood wave as it travels down the river are dependent on catchment characteristics (such as catchment slope, area and vegetation); rainfall (including its distribution, intensity and quantity); and the antecedent conditions of the catchment. The output from the hydrologic model is a series of flow hydrographs at selected locations such as at the boundaries of the hydraulic model.

Note that some types of hydraulic models, (particularly those for use in urban areas) known as direct rainfall or rain-on-grid, apply rainfall directly to the hydraulic model, thus negating the need for a separate hydrology model.

Hydraulic model development

Hydraulic modelling simulates the passage of water through the catchment. Inflow hydrographs, estimated using the hydrologic modelling, are applied at the upstream ends of waterways and floodplains. The essential aim of hydraulic modelling is to represent realistic flow behaviour.

A hydraulic model may adopt a one-dimensional approach (1D), two-dimensional approach (2D) or some combination of the two. In general, the use of 1D models is restricted to modelling single waterway branches, or simply connected channel systems, where flow in the floodplain is well connected to the main channel. 2D models are capable of providing a detailed description of the flow in urban or rural floodplains and overbank areas, and can be integrated with 1D model elements.

Hydraulic models are generally more complex and data intensive than hydrologic models, however they are able to produce a more realistic representation of flow behaviour, including flood level / depth, velocity, flow rate and hazard.

Model calibration / verification

To establish a degree of confidence that the models are suitably representing actual site conditions, model calibration and verification is undertaken. Recorded rainfall and tides from historical events are applied to the models where appropriate. Model parameters and inputs are then adjusted using reasonable values, until the model suitably replicates recorded flood behaviour. The performance of the model is assessed against information such as recorded flood levels and flows at gauging stations; peak flood levels from field survey; photographs and videos; and anecdotal evidence of flood behaviour.

Calibration can be undertaken on the hydrology and hydraulic models separately, or on both models concurrently, as part of a joint calibration. The calibration exercise can be lengthy and iterative and the definition of calibration ‘success’ should reflect the quality of the underlying data and the nature of the catchment and flood event.

Design event modelling

Following model calibration, design events are used to establish an understanding of the flooding that can be expected to occur during different time periods. Design event modelling uses statistically derived rainfall inputs, based on the rainfall record of a given location.

Design floods are often defined according to their likelihood of occurring in any given year. The standard way to describe flood likelihood in Queensland is the ‘annual exceedance probability’ (AEP) which provides a percent chance that a flood of a given size or larger will occur in any given year. The chance of experiencing different sized flood events in a given period of time can be estimated mathematically and can be a useful tool to communicate the lifetime likelihood of experiencing a flood of a given size. Design flood events are typically used for planning and floodplain management purposes.

Table 1-2 Probability of Experiencing a Given Size Flood Once or More in a Lifetime

Chance of a flood of a particular size occurring or being exceeded in any one particular year	Chance of experiencing a flood in a 70 year period	
	At least once	At least twice
10% (1 in 10 odds)	99.9%	99.3%
5% (1 in 20 odds)	97.0%	86.4%
2% (1 in 50 odds)	75.3%	40.8%
1% (1 in 100 odds)	50.3%	15.6%
0.5% (1 in 200 odds)	29.5%	4.9%

The design flood levels obtained should be verified with other information where possible (refer section 5.5).

Model outputs and mapping styles

Flood maps are the principal communication tool used to convey various aspects of flood behaviour, including depth, level, velocity, flow rate and hazard. The maps generally display a representation of peak flood values (e.g. maximum flood depth), presented as an 'envelope' of results, such that although the peak values do not occur everywhere at the same time, the values presented are based on taking the maximum which occurred at each computational point in the model during the entire flood. Hence, a presentation of peak levels does not represent an instantaneous point in time, but rather an envelope of the maximum values which occurred over the duration of the flood event. In addition to peak values, flood maps can also be created from any time in the flood simulation (e.g. three hours from start of flood), or any time which correlates to a critical value (such as the time a levee overtops in a particular design event). Flood maps are generally modified in their presentation depending on the intended end-users.

1.7 Flood Models and Limitations

Flood models are extremely valuable tools to improve understanding of probable flood behaviour, however it should be noted that all flood models are approximations and have limitations in their application. Users of flood models and model outputs should be aware of the following issues when using flood models to define flood behaviour in the study area or catchment:

- All models are coarse simplifications of very complex processes. No model can therefore be perfect, and no model can represent all of the important processes accurately.
- Model accuracy and reliability will always be limited by the availability and accuracy of the terrain and other input data.
- Model accuracy and reliability will always be limited by the reliability/uncertainty of the inflow data.
- A poorly constructed model can usually be calibrated to the observed data but will perform poorly in events both larger and smaller than the calibration data set.
- No model is "correct" therefore the results require interpretation preferably by an experienced person.

- A model developed for a specific purpose is probably unsuitable for another purpose without modification, adjustment, and recalibration. The responsibility must always remain with the modeller to determine whether the model is suitable for a given problem.

1.8 Fit-for-purpose approach

The creation of this document was guided by the principle of a fit-for-purpose approach to flood studies and mapping. The degree of effort required, and approaches used to understand flood behaviour will vary depending upon the complexity of the flood situation, and the information needs of Council and other stakeholders to understand and manage flood risk. These techniques can also vary within a catchment, with more sophisticated techniques used in areas with concentrated exposure to risk (e.g. urban areas) and simpler techniques used in areas where development is more widespread (e.g. rural areas).

This guide uses a series of questions (in Part 2) to better understand the local flood problem and identify the required outcomes of the study and potential end-users. Answers to these questions will inform selection of hydrologic and hydraulic model types, including the level of complexity required. Through this process, the guide helps Council identify a flood study type which is fit-for-purpose.

It should be recognised that the fit-for-purpose approach leads to the minimum required actions to meet the local needs however if funds allow, a more detailed and / or complex approach could be used. Similarly, the flood study and flood modelling process can be iterative, with opportunities to add detail or complexity to the model at a later date.

Flood study outcomes can be broadly classified into nine themes, which relate to various end-uses (noting that storm-tide assessment is not included in this guide). These themes and associated areas of interest should be considered throughout the flood study scoping process to ensure that the flood study design is appropriate to meet the requirements of a range of end-users.

Table 1-3 Outcome Themes and Areas of Interest

Themes	Area of Interest
Land use planning	• Zoning and urban design • Land use strategies • Resumption programs
Building controls	• Minimum floor levels • Resilient materials • Structural resilience
Structural works	• Engineering design • Levees (existing, new) • Flood gates
Infrastructure	• Planning operations • Dams, roads, railways • Infrastructure design
Landscape and environment	• Riparian and wetland management • Erosion and sediment control • Strategic vegetation management
Education and information	• Hazard awareness • Impact understanding • Learning from experience
Emergency management	• Flood warning • Business continuity • Evacuation and recovery plans
Insurance	• Premium calculations • Insurance coverage • Customer offerings
Coastal management	• Storm surge • Erosion areas • Coincidence flooding

1.9 Engagement

Engagement is fundamental to the scoping and delivery of a fit-for-purpose flood study which meets the needs of all identified end-users and can be used to inform flood risk management planning. It should be undertaken with internal and external stakeholders during all stages of the flood study process. It may also play an important role in developing an improved understanding of historic floods to feed into a gap analysis of existing data, which may be undertaken as part of a scoping study or when preparing a flood study brief.

Design and implementation of an effective engagement strategy should enable:

- Gathering information from the community, stakeholders and other agencies so that a reasonably clear picture can be put together about historic flooding, and the vulnerability of people and the built environment to past floods.
- Understanding the information needs of those who have a role in managing flood risk or facilitating community recovery.
- Informing the community and key groups on the progress and outcomes of studies.

It is important to ensure that all those who need to be involved (i.e. those with responsibility for managing flood risk and those with a vested interest in its management, such as property owners) are kept informed and invited to contribute to the process.

2 Part 2 – Scoping Guide

2.1 Introduction

This part of the guide steps through a series of questions to determine the available inputs and required outputs of the study. This part of the guide can be used independently as a standalone Scoping Study to understand the flooding issues and the outcome desired.

Under each question heading, there is background information (including hyperlinks to external guidance where more information can be found). At the conclusion of the sub-section, there are prompts to enter text based on the guidance in the box. Example, text is provided to show the appropriate style, format and length of response for some of the boxes. These boxes will help to populate the Brief which is described in Part 3 of this guide which draws upon the standard generic brief provided in **Managing the floodplain: a guide to best practice in flood risk management in Australia** (Handbook 7).

2.2 Why do a flood study?

There are a range of reasons why a Council may decide that there needs to be some definition of flood behaviour within their catchment or area. They tend to fall into the following categories (as per Handbook 7):

A. A recent flood event has identified that a flood problem exists in Council's area, and the full risks need to be determined and/or managed.

B. Council's planning scheme needs to comply with the State Planning legislation regards natural hazards. Council requires flood mapping to establish land-use planning controls (including setting minimum floor levels) for a new development across an area.

C. There is an existing study that is not meeting Council's information needs, including due to change in the study area of new data.

D. The Council believes there is a flood problem, and wants to pre-emptively define and manage flooding in the area.

E. Other external factors or pressures, such as the disaster planning and management, community, strategic planning or insurance requirements, mean that the flood hazard in Council's area needs to be defined.

Box 1: Why Do a Flood Study?

[Describe which of the above categories above best fits the reason for needing to undertake a flood study?]

2.3 Where to start

To prepare a targeted brief that will allow tenderers to understand the Council's needs and therefore tender appropriately, a range of items need to be considered initially. If the Council are not in a position to answer the questions in Part 2, guidance can be sought from a range of sources including:

- Others in the organisation
- Relevant state government agencies
- Others in a similar position at nearby Councils
- Engineers Australia
- Floodplain Management Australia
- Tenderers with experience in the scoping or preparation of flood studies, ideally in Council's jurisdiction.

2.4 Are there any previous flood studies?

An important consideration when considering undertaking a flood study is the existing of any previous flood studies. If there is uncertainty after having consulted within the organisation, FloodCheck can be used http://dnrm-floodcheck.esriaustraliaonline.com.au/floodcheck/. The FloodCheck maps are an interactive guide to flood lines, imagery, and data and the extent of floodplains in Queensland which enable the following to be viewed:

- The likely extent of floodplains
- Historic flood lines dating back to 1893, including flood and cyclone imagery for 2010–2011 for some areas
- Data relating to drainage basins, river gauges and flood studies. This includes QSpatial datasets and state-wide overlays
- Flood simulations for selected towns.

Having ascertained whether a previous study exists, it is important to consider how the outcomes have been used and is it sufficient to meet the current needs. Consideration should be given to any limitations of previous studies and why they are not sufficient to meet the current needs.

Box 2: If the Council has past flood studies, why are they not meeting current requirements?

[Provide a succinct overview of relevant findings from previous studies. If previous flood studies are not sufficient, list the existing limitations of the past study, e.g. study area, level of detail, new flood information, new topographical information, new flood mitigation infrastructure etc.]

2.5 What are the risk management objectives?

Flood studies are typically required to inform and support of flood risk management actions. The following Economic and Community Resilience Framework figure was developed to allow Councils and local disaster management groups understand the key areas that benefit from consideration of information derived from flood studies and their outputs. Each key area is called a theme (e.g. land use planning or emergency management). Each theme is examined in more detail within the Flood Mapping Implementation Kit. Figure 2-1 illustrates the interconnections between the many aspects of flood risk management.

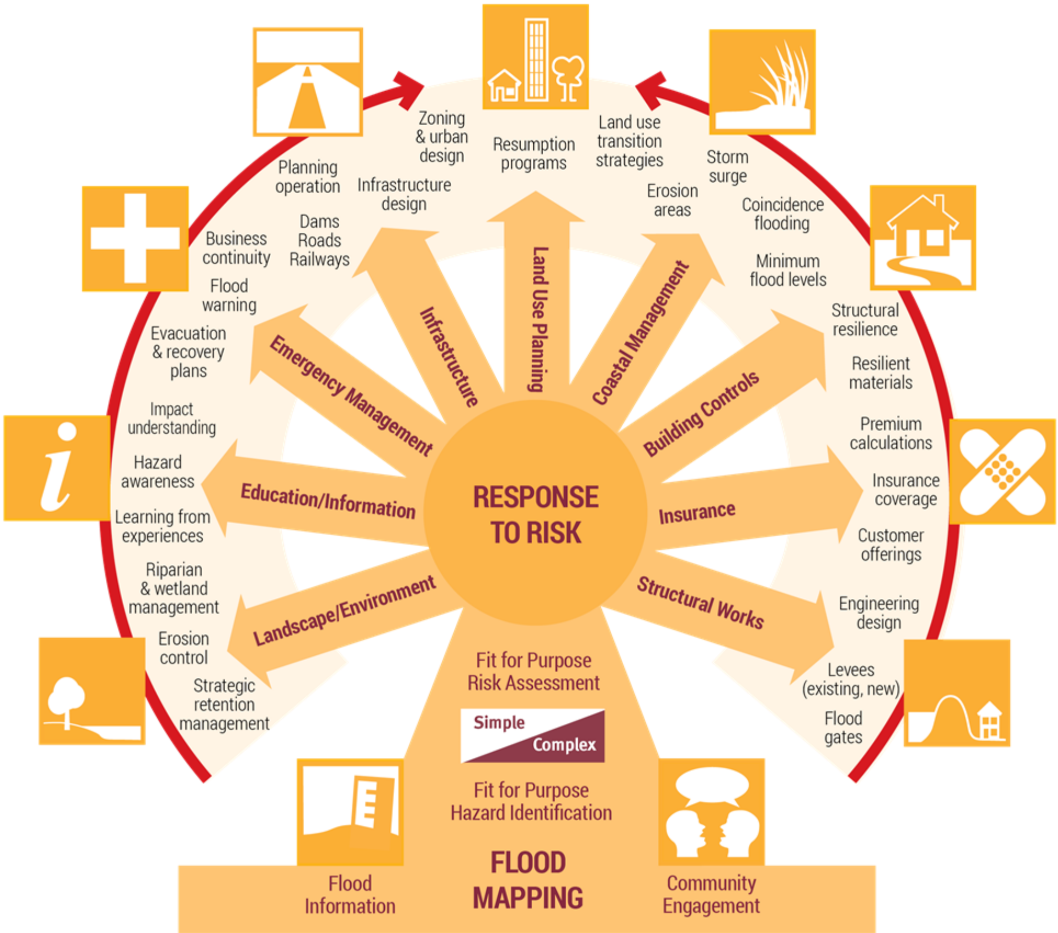


Figure 2-1 Economic and Community Resilience Framework

Box 3: Which key flood risk management areas or themes will the flood study support?

[Identify which themes the flood study will support and describe outcomes required from the flood study.]

2.6 Who are the end-users of the flood study outputs?

A critical aspect of scoping a flood study is to determine the possible end-users and their outcome needs. By considering the range of end-user needs appropriate to the flood situation being investigated at the start of the project, the best study approach can be specified.

This is crucial for understanding trade-offs between issues such as available budgets, level of study and project timing. It also enables tenderers to make recommendations regarding approach and methodology to satisfy the required outcomes in the most cost-effective and efficient manner.

It is important to identify and confirm the requirements of external stakeholders as part of scoping the study, as this may also influence the type of flood study, the level of detail and the optional items required.

End-users may be at different levels of government or be in the non-government sector but typically fall into the following groups:

- High-level strategic decision makers within Council or the State Government
- Community
- Other users or departments within Council, such as land use planners, stormwater/drainage engineers, and water-sensitive urban designers
- Flood risk management professionals
- Engineers involved in designing, constructing, maintaining and operating flood mitigation works
- Emergency management planners and responders
- Land-use planners (setting strategic planning direction and planning controls)
- Hydrologists and meteorologists involved in flood prediction and forecasting
- Other Councils in the river catchment
- Insurers
- Hydrologists, other scientists and engineers in State Government agencies
- Others.

When commissioning a flood study it is essential that a range of parties is consulted both within Council's organisation and externally. Checks should be made as to whether others who are not directly involved in the study are doing work that may assist the flood study, whether they would benefit from the outcomes or whether any significant scientific developments are expected in the near future which may influence the timing of the study (for example, should the flood study be delayed in order to benefit from these developments?).

The following checklist provides a guide for consultation for stakeholders within the Council or relevant external agencies.

Table 2-1 Stakeholders for Flood Studies

Potential Internal Stakeholders	Potential External Stakeholders
Land Use Planners	Bureau of Meteorology (BOM)
Development Control Engineers	Department of Natural Resources and Mines (DNRM)
Emergency Management Planners	Department of Infrastructure, Local Government and Planning (DILGP)
Stormwater and Drainage Engineers	Department of Energy and Water Supply (DEWS)
Asset Planners and Managers	Department of Science, Information Technology and Innovation (DSITI)
Mayor and Councillors	Department of Transport and Main Roads (DTMR)
Local Disaster Management Group (LDMG)	Queensland Fire and Emergency Service (QFES)
	Utility Providers (Bulk Water Supply, Reticulated Water& Sewerage services; Power, Telecommunications)
	Surrounding Councils
	Dam operators

Box 4: Who are the end users?

[Identify and list all the potential end users of the flood study; the outcomes they require and their linkages to the themes described in Box 3]

2.7 What is the study area of interest?

Defining the study area is important to ensure that information is gathered where needed, and that opportunities for understanding flooding and the value of the study are maximised while managing costs. Consideration needs to be given to the purpose of the study, who the end-users of the information are likely to be and how sophisticated the modelling is likely to be. The study may focus on a relatively small area (e.g. development proposal, overland flooding catchment, a single town or a single town including surrounding rural areas), or it may focus on a catchment or a floodplain that crosses a number of Council areas.

The study area should not define the extent of the modelling, but rather the extent of the area for which reliable information on flood behaviour is required. The flood model will need to go beyond the boundaries of the study area to provide reliable information within the bounds of the study area.

Box 5: What is the study area of interest?

[Provide a summary of the town/area of interest, study area location in the catchment, catchment size, major hydrological features, geographic features such as topography (e.g. steep upper sections, flat floodplain), soils and any flood-dependent ecosystems (e.g. wetlands), description of development (sparse or dense) and development pressure if it exists. Note, that the study area of interest does not define the extent of flood modelling required.]

2.8 What is the flood history?

An understanding of previous flood history within the study area is an important consideration when undertaking a flood study. Records and information about previous floods can provide important information to assist with the development of the flood models and add credibility and reliability to the outputs derived. The following checklist provides a guide to the types of data which may exist which could add value to the flood study:

- Have there been major historical floods? How did they affect the study area?
- For each recorded flood event
  - What were the antecedent conditions e.g. had it rained for a prolonged period prior to flooding?
  - What was the duration of the flooding?
  - How many people / properties were affected?
  - Was there any damage to infrastructure?

Records of past floods are very valuable and may greatly support the development of the flood model. It is therefore important to consider what records may exist both within the organisation and externally, particularly within the community.

- What records does the Council have of past floods?
  - Photos, videos (preferably with dates and times)
  - Anecdotal evidence, damage reports
  - Aerial photos
  - Flood level marks, flood extents etc.

Additional information can be gained from external sources such as the community during a consultation program which could commence at the start of the study. This can perform two functions, firstly as a means of informing the community that a flood study is being undertaken and as a way of obtaining additional information associated with past floods; also to facilitate engagement with later study outputs. State agencies may have additional data.

Box 6: What is the flood history?

[Provide an overview of the area's flood history, including:

- A description of the most recent events and the largest recorded events (in terms of their peak height or flow)
- Areas of inundation
- Impacts on the community (e.g. damage to property and community facilities, loss of life, areas cut off, disruption to community function, photos/video availability)
- Any notable occurrences (e.g. levee was overtopped, dam was full, bridge was blocked and/or overtopped).
- Any information the Council or any other organisation has on historical floods – for example, flood photography or videos, flood height marks, flood extents, anecdotal evidence and damage reports. This should include access to any information made available to the community on flooding.]

2.9 Riverine or overland flooding

A flood study in an area where the primary flood influence is riverine (i.e. water escaping from waterways) can be significantly different from a study where the primary influence is due to water flowing overland towards waterways. The associated flood investigations often need a different methodology and different deliverables.

Riverine studies are typically focused on towns or communities affected by flooding from a major waterway. Overland flood studies tend to focus on smaller parts of larger riverine catchments. They have smaller catchments and greater emphasis on confined flow paths, and may include overland flow and drainage infrastructure. These categories are very broad, and some overland studies will exhibit characteristics of a riverine study and vice versa.

The main differences between riverine and overland studies include the following:

- Overland catchments tend not to have reliable information on historical floods for the purposes of calibration and validation. If they do, it is not of great significance, because urbanisation has often occurred in the interim and resulted in changes to the flood behaviour. In these studies, historical information tends to be used to identify areas with flooding issues rather than for calibrating model behaviour.
- Overland flow studies generally require a greater level of detail and resolution.
- Simple riverine flood studies often produce flood profiles along a watercourse. However, due to the complexity of flood behaviour in overland flow paths, flood profiles along these paths are often not appropriate for use.
- Velocities are of more interest in an overland flow area, where there can be large variation in the velocities between different flow paths, compared with the more uniform velocity of a river or waterway. However, once floodwater has escaped from the waterway and on to the floodplain, velocities of floodwater across the floodplain are of equivalent interest.
- Riverine flood information describing inundation of different roads, properties and critical structures in the study area is often able to be related to a nearby river water level gauge.

However, stream gauges are less likely to be located in an overland flow path and, if they are, the limited available warning time means that a coordinated emergency response requires prior preparation.

2.10 What type of flood situation exists?

The type of flood situation in the study area will influence the modelling approach adopted, the range of end-users, their information requirements and the outcomes required from the study. The flood situation can generally be classified into one of the following categories (as per Handbook 7[1]):

- **Type 1**: Rural (riverine) catchment with scattered development. Here, there is often a long warning time and, generally, a limited population is at-risk.
- **Type 2:** Large rural (riverine) catchment with township, plenty of warning. In this category, there is often a long warning time and a more significant population at-risk.
- **Type 3**: Small rural (riverine) catchment with township, little warning. In this flood situation, flood waters often rise rapidly, but there could be limited population at-risk.
- **Type 4:** Large urban (riverine) catchments. Here, there may be a moderate warning time and a large population at-risk.
- **Type 5**: Small urban catchments (overland flow). Here, flood waters often rise rapidly, but at generally shallow depths; however, there is a significant population at-risk.

It should be noted that any of these categories may involve a coastal flooding mechanism in the catchment – for example, an ocean boundary or a coastal lake. This does not normally affect the classification of the area into one of the five categories.

These categories have been provided to help articulate the general types of flood risk which might be found in study areas, based on catchment size and urbanisation. Not all catchments will fit neatly into one of the above categories and there are other factors which may influence the local flood risk. Nonetheless, identification of the flood situation type which *best* fits the study area will help guide the selection of the minimum flood study requirements. Examples of each type of flood situation are provided in Table 2-2 below. If there is uncertainty about which flood situation type best describes the study area, it is advised to seek advice from State agencies or suitably experienced consultants.

Table 2-2 Type of Flood Situation and Examples

Type of Flood Situation	Example*
Type 1 (Riverine)	Condamine-Balonne River basin Burnett River basin
Type 2 (Riverine)	Roma – Bungil Creek catchment Emerald - Nogoa River catchment
Type 3 (Riverine)	Kin Kin – Noosa River catchment
Type 4 (Riverine)	Brisbane River Catchment

[1] Handbook7: Guideline for using the national generic brief for flood investigations to develop project-specific specifications

Type of Flood Situation	Example*
	Bundaberg - Burnett River
Type 5 (Overland)	Mitchell Mission Beach

*These examples are intended to be used as a guide only.

Box 7: What Type of Flood Situation Exists?

[Identify which type of flood situation best fits the study area or catchment followed by a broad description of the flood behaviour in the study area and what is known about flooding in the area, such as:

- Is it overland or riverine flooding and/or influenced by oceanic inundation?
- Is there a lot of warning time, or does the catchment respond rapidly?
- What is the flooding duration in the study area (hours, days, months)?
- Are there flooding hot spots in the study area?

This section should also identify frequently inundated areas and exacerbating factors (e.g. blockage, high tides, antecedent conditions, and natural or constructed hydraulic controls, including dams, bridges, levees, backflow devices (or not) on trunk drainage), as well as coincident tributary flooding.]

2.11 What available existing studies exist?

Councils are encouraged to compile relevant data before tendering, so this information can be considered in writing the specification, and be available as a reference to inform both the tendering process and the study itself. Having the information available electronically on request is recommended. Access to detailed information:

- Allows the tenderer to better scope the project and to build upon rather than replicate existing work
- Reduces the potential for rework or variations that could have otherwise been avoided if key information comes to light during the project
- Can inform the tenderer's recommended methodology for the project and modelling software choice.

The kind of information that should be gathered together includes studies and relevant documents such as:

- Land use and cadastral data
- Local design standards,
- GIS layers

- Previous flood studies including hydrologic and hydraulic models
- Previous data collection studies
- Flood risk management studies, or other studies into mitigation works or other relevant structures on the floodplain and asset management data
- Details of infrastructure affecting or affected by floods
- Data that other agencies or industries within the study area or wider catchment may hold (e.g. mining, gas, agricultural)
- Any other relevant studies.

Where other relevant third-party studies are known to exist (e.g. flood study for upgrade of a main road in the study area), the Council should try to make these available for tendering. Where this is not possible, the Council should add third-party and document details to the brief.

Box 8: What existing studies exist which could assist the flood study?

[Identify any of the following existing studies which are available to assist the flood study.

- Land use and cadastral data)
- Previous data collection studies
- Existing hydrologic and hydraulic models and associated files
- GIS data.

Will data be available for tendering and the project, if so, what format and how? Summarise existing available data in a table with a brief description, format, author or source, year etc.]

2.12 What hydraulic model development data exists?

As well as existing studies there are a range of data sets which are required for flood studies. The data sets required and the level of detail in those data sets will depend on the flood study objectives, the flooding behaviour and flood model used. Whilst not all flood studies will require the same level of data, the best available data should always be sought as this may also influence study objectives and model selection – particularly if data acquisition requirements significantly impact on the available study budget.

The following data sets which are classified as 'Terrain' data are used to build or update flood models and it is critical to understand what is currently available in order to be able guide the choice of hydrologic and hydraulic models to produce fit-for-purpose flood behaviour outputs.

The reliability of outcomes from a flood study is dependent upon the quality and quantity of the input data.

There are three primary data sets which can be described as terrain data required to develop the flood study models:

(1) Topographic data

(2) Bathymetric data

(3) Infrastructure data

Topographic Data

Topographic data defines the elevation of the ground surface in the floodplain (i.e. including the waterway itself). This data can include cross-sections and/or bathymetric (under the water) survey and/or overland (above water) survey. This information can be collected using a number of methods of field survey with varying accuracies. The most accurate is traditional ground survey, followed by RTK GPS (Real Time Kinematic Global Positioning System), followed by the airborne techniques of photogrammetry, LiDAR (Light Detection and Ranging), and SRTM (Shuttle Radar Topography Mission), the last of which is of the lowest accuracy. LiDAR is currently the most favoured due to its lower relative cost balanced against reasonable accuracy. However, it will be necessary to supplement the LiDAR data with other topographic data, particularly bathymetric.

Traditional ground survey involves the re-establishment of cadastral surveys and land boundaries based on documents of record and historical evidence, as well as certifying surveys of subdivision plans or maps, registered land surveys, engineering surveys, judicial surveys, and space delineation. The accuracy of land survey is high as it relies on the ground truthing to known reference points. All elevation values are measured relative to those points. It is horizontally accurate to about +/-0.02m and vertically to +/-0.01m. Survey is best utilised for determining structure details (elevations, dimensions and location) and watercourse bed cross sections.

LiDAR (also known as ALS (Aerial Laser Survey)) is a remote sensing (airborne) technology that measures distance by illuminating a target with a laser from a fixed wing aircraft and analysing the reflected light. The accuracy of LiDAR data is dependent on flying height, ground survey control, laser specification and ground surface coverage. Vertical accuracy can typically vary from +/- 0.15m to +/-0.4m. Note that these accuracy estimates only apply to hard ground with no surface coverage. LiDAR is generally useful for all aspects of flood studies from determining catchments for hydrology through to using as a base for hydraulic models. The unfiltered classified LiDAR data can be used to create building, and vegetation polygons for the landuse layers in hydraulic and hydrologic modelling. DNRM has details of LiDAR capture projects and coverage which can be found at:

- https://www.dnrm.qld.gov.au/__data/assets/pdf_file/0003/109344/lidar-capture-projects.pdf.

SRTM or Shuttle Radar Topography Mission was an international research effort that obtained DEMs on a near-global scale from 56° S to 60° N, to generate the most complete high-resolution digital topographic database of Earth and covers the entire state of Queensland. The horizontal resolution of the raw data is 30 m. The accuracy of SRTM is approximately +/-7m in the horizontal plain and +/-6m in the vertical plain. SRTM data should only be considered for those areas where:

- There is no LiDAR;
- The cost of obtaining new LiDAR is prohibitive; and
- The area is outside the study focus area or the required accuracy outcomes of the study are amenable to the high level of elevation data inaccuracy.

The SRTM data is provided by NASA on their website[2].

Bathymetric Data

Bathymetric survey is the mapping of underwater topography. It involves obtaining measurements of the depth of the ocean and is equivalent to mapping the topography on land. It is useful in providing bed elevation for watercourses, lakes and waterbodies. It can be collected using traditional survey techniques or by using echo sounders, sonar or ADCP (acoustic doppler current profiler). As none of the current airborne techniques are capable of penetrating water, bathymetric data is usually used in conjunction with ground LiDAR for hydraulic models to ensure that the model has appropriate representation of the topography both above and below water.

It is important to note when establishing what existing topographic data are available that there may be the following potential limitations associated with the data:

- When using multiple datasets that have been collected at different points in time, the elevation data may not align due to datum changes or inaccuracies; or landuse/development activities that may have occurred between the times of collection.
- The vertical accuracy of the data sets may result in elevation steps at their boundaries where combining data sets from different sources.
- All elevation data sets are inherently a snapshot of the topography at the point in time that the data was collected, and as such may not be representative of the current topography and or the topography at the time of the calibration/validation event.
- The Cartesian coordinate projection of the data needs to be determined. If different datasets are to be used, they need to be all converted to the same projection to ensure they align.

Infrastructure Data

Infrastructure data includes information on specific man made features within a catchment such as roads/rail embankments, culverts, weirs, bridges, levees etc. For riverine studies, it is the infrastructure that is contained within the waterway or on the floodplain that is important. For overland flow studies, stormwater drainage infrastructure is of importance. Infrastructure can have a significant influence on flood behaviour, and the availability of such information is often critical to the outcomes of the flood study. The effects on flood behaviour may be intentional (such as a weir) or unintentional (such as blockage by a rail embankment).

[2] A link has not been provided as the NASA website is constantly updated and the potential lies of the link to be broken.

Existing structure data can be sourced from a range of places:

- Council records and data, existing surveys
- Department of Transport and Main Roads, Queensland Rail, Department of Energy and Water Supply

Box 9: What existing model development data exists to assist the flood study?

[Identify any of the following data which is available to assist the flood study.

- Any survey data the Council or any other organisation has available for use in the study – for example, digital elevation models (DEMs), LiDAR data, creek/river cross-sections or bathymetric surveys, location and dimensions of drainage assets
- Any survey data the Council or any other organisation has that describes current or previously existing structures (e.g. bridges, culverts, weirs, levees, irrigation channels, dams, developed areas). Asset management information systems may assist.
- Geographic information system (GIS) layers the Council or any other organisation has, including waterways, natural environment areas, street names, roads and land-use planning areas.

Will data be available for tendering and the project, if so, what format and how? Summarise existing available data in a table with a brief description, format author or source, year, etc]

2.13 What model calibration data exists?

Model reliability is a direct function of the quality and quantity of historical information used to calibrate/verify the models. Confidence in model predictions decreases if the data is of poor quality and/or limited quantity.

Historical hydrologic datasets required to calibrate the models are:

(1) Rainfall (Inflow data)

(2) Streamflow (Inflow data)

(3) Anecdotal historic flood information (Flooding Data)

Rainfall Data

Rainfall data is required to estimate the inflows into a catchment or study area and can be found at the following sources:

- Bureau of Meteorology http://reg.bom.gov.au/climate/data/ and http://reg.bom.gov.au/climate/data/stations/

- DNRM https://www.dnrm.qld.gov.au/water/water-monitoring-and-data/portal
- Council records
- Landholder records
- DSITI SILO rainfall data

Bureau of Meteorology has the following types of recorded historical rainfall data:

- Pluviograph - Data is short intervals either instantaneous or at 6 minute (and less) intervals
- Sub Daily – Data is totals for blocks of hours (1, 3 or 6 hour)
- Daily – Data is 24 hour totals to 9am on the recorded day of record
- Radar – 6 or 10 minute radar observations.

DNRM has the following types of historical recorded rainfall data:

- Pluviograph - Data is short intervals either instantaneous or at 6 minute and less intervals.

Council historical recorded rainfall records may contain:

- Pluviograph - Data is short intervals either instantaneous or at 6 minute (and less) intervals
- Sub Daily – Data is totals for blocks of hours (1, 3 or 6 hour)
- Daily – Data is 24 hour totals to 9am on the recorded day of record.

Water service providers may have stream flow data.

Landholder records may contain daily data.

Rainfall data is used to estimate the total rainfall as well as spatial and time varying rainfall intensities across study areas and/or catchments during historical flood events. The estimated rainfall distributions are traditionally input into the hydrologic model to simulate the conversion of rainfall to runoff flows due to the historical flood events during model calibration and verification. Rainfall can also be entered directly into the hydraulic model as 'rainfall on grid' (also known as 'direct rainfall').

It is important to note when establishing what existing rainfall data are available, the following potential limitations may be associated with the data:

- The data may not be representative of the whole catchment – gauges in the upper catchment, particularly in mountainous areas, can record substantially higher rainfall than low land areas.
- Gauges on one side of range/mountain may record substantially different rainfall to the other side of the range/mountain.
- If not distributed well-enough throughout the catchment, the true spatial and temporal variation in the rainfall may not be well-represented by the data and this may affect the accuracy and timing of flows derived by the hydrology model.
- In order to adequately represent an historical rainfall event within the hydrologic model, rainfall records with record intervals of less than a day are typically required. The smaller the catchment, the smaller the record interval needed. For example, a smaller catchment that responds to rainfall

in less than 6 hours cannot be modelled with daily 24 hour rainfall totals as the critical time-varying nature of the rainfall is not recorded. Thus, the record interval of the rainfall record must be appropriate for the catchment size.

- There may also be gaps in pluviograph, sub-daily and daily data which could miss a flood event or part of the flood event. Sub Daily data can have limited uses for hydrology as it can only provide totals for the time periods. Daily data has limitations for short duration events and landholder data can have inconsistencies in readings and is unlikely to be quality assured.

However, despite the limitations outlined above, the more data that is available, the greater the likelihood of being able to identify inconsistencies or gaps or valid variations in the datasets. All available datasets should be considered as potentially being useful until proven otherwise.

Streamflow Data

Historical stream data can be of two types:

(1) Event Flow Gauging

(2) Water Level and Flow Hydrograph.

Event flow gauging (measurement of flow using current meters during an event can yield direct flow estimates during an event. These flow estimates can be compared to model predictions for calibration purposes.

Water level hydrographs recorded by stream gauges can be used to assist in understanding the inflows into a catchment or study area. They are used to calibrate and verify the flood modelling and, where sufficient data exists, inform a Flood Frequency Analysis (FFA). The water levels recorded at a stream gauge site can be used to derive stream flows at the same location and the agencies that operate the gauge will typically provide both the recorded water level, derived stream flow estimates and a guide as to expected accuracy/quality of the flow estimate. Information about the gauge sites including their location and period of record can be found at the following sources:

- Bureau of Meteorology http://www.bom.gov.au/qld/flood/networks/section6.shtml and http://www.bom.gov.au/qld/flood/networks/section3.shtml
- DNRM https://www.dnrm.qld.gov.au/water/water-monitoring-and-data/portal.

It is important to note when establishing what existing stream data are available that the following potential limitations may be associated with the data:

- Gauges may record water level to a local datum. For older gauges in particular, the relationship between the local datum and Australian Height Datum (AHD) may not be known (or may have changed over time), which means conversion of the recorded water levels to AHD may not be possible or require field survey to establish.
- Stream gauges are prone to failure during large events due to being washed away or damaged, which means the data set for that event may not be complete. Sometimes the event dataset has obvious gaps but sometimes the gauge failure is signified by a flat-line or spiky records. Sometimes it is not obvious that the gauge has failed so vigilance is advised for all records.

Ideally, another gauge or peak flood record nearby can be used to verify the shape of the hydrograph or the peak level.

- It is important to recognise that stream flow is not recorded. Stream flow is derived from the water level record using a rating curve (an estimated relationship between level and flow). Rating curves may be based on a combination of the following data: physical gauging during a flood event, model estimates and/or extrapolation using engineering judgement. Relationships between flow and level can change with time if there are changes to stream cross-section, overland flow paths or tailwater levels.

Anecdotal historic flood information

Anecdotal information can often be valuable in assisting with calibration of flood models such available such as flood height marks and photos. Information gathered as part of understanding the study area's flood history should be collated to use in the flood study calibration process [see Box 6].

Box 10: What hydrologic data is available which could assist the flood study?

[Identify the data which is available for tendering and the project, including:

- Hydrologic data the Council or any other organisation is in possession of, such as rainfall gauges, stream flow records, rating curves and ocean and water level data
- Historic flood information [Box 6]

Will the data be available for tendering of the project, if so, what format and how? Summarise existing data in a table with a brief description, format, author or source, year, etc]

2.14 Is the available data adequate?

The quality and quantity of data has a large influence on the type of flood models which can be used to undertake a flood study and the confidence that can be applied to the model output. The following section provides a guide in terms of how data quality and quantity will influence the choice of flood model. If there is any uncertainty about the suitability of the data for the intended study, it is strongly advised that advice is sought from relevant State agencies or a suitably experienced consultant.

The quality and quantity of available data will affect every step in the modelling process, including modelling approach, schematisation, calibration and analysis. Initially, the available data needs to be reviewed to ensure it is adequate for the type of study proposed.

Data can be broadly classified into three categories which feed into different parts of the flood study:

- Inflow data (rainfall and stream flow data)
- Terrain data (topographic, bathymetric and structure data)
- Flooding data (flood marks, flood extent local knowledge).

The following tables provide a guide in terms of assessing the overall quality and quantity of existing data sets to assist in the identification of the most appropriate flood models to deliver the required output. They are not intended to be fixed as each study area and/or catchment will be unique. However, they will help to inform the choice of hydrologic and hydraulic model used for the flood study and the confidence in the outputs derived. In general, more data will give allow greater choice in modelling approach and may improve the confidence in model outputs. It is expected that tenderers will review the available data at the start of the flood study and confirm the approach to be used.

Table 2-3 Inflow Data Assessment Guide

Inflow Data	Multiple Data Sets	Limited Data Sets	Poor Data Sets
Rainfall	2+ rainfall gauges in catchment and/or 1+ rainfall gauge in study area	1+ rainfall gauge in catchment	No rainfall gauges within catchment
Stream flow	2+ stream gauges in catchment and/or 1+ stream gauge in study area	1+ stream gauge in catchment	No stream gauges in catchment

Table 2-4 Terrain Data Assessment Guide

Terrain Data	High	Medium	Poor
LiDAR	LiDAR coverage of entire study area and beyond	LiDAR coverage of study area	SRTM data
Bathymetry	Bathymetric survey undertaken in previous 5 years	Previous historic bathymetric survey	No data
Structures	Structural survey data of all major waterway crossings for riverine studies and/or pit and pipe structures for overland flow studies	Structural survey data of major waterway crossings	Some structural survey data for major waterway crossings

Table 2-5 Flooding Data Assessment Guide

Flooding Data	High	Medium	Poor
Flood history / local knowledge	Multiple flood level marks, photos/ videos/ anecdotal evidence	Some flood level marks, extent information	No historic flood data

Box 11: Box 11: Is there sufficient data to define the fundamental components of the flood model, such as inflow data, terrain data and historical flood data for calibration and terrain data for the hydraulic model build? If not, are the limitations of the existing critical in terms of the outputs required from the flood study?

[Provide information on the sufficiency of data, using the classifications in the tables for the inflow data, terrain data and flooding data, noting the identified limitations and how this might influence the required flood study outputs.]

2.15 Are there any additional data requirements which would benefit the outcome required?

While it is not possible to obtain improvements in historical inflow (input and calibration) data such as rainfall and streamflow information, it is possible to improve terrain data within the hydraulic model or gather additional historic information from the community. The option to undertake additional data collection will be influenced both by the cost of survey and the improvement in outcome the survey(s) may allow.

Examples of additional data which could be obtained include:

- Ground survey of critical hydraulic controls such as levees, bridges, weirs, defining parameters required, (if this data is not readily interpreted from existing plans, LiDAR or other airborne survey)
- Topographic and/or bathymetric survey of watercourses and the adjoining floodplain
- LiDAR survey data
- Infrastructure survey
- Community information, such as flood marks, records and photos etc
- Ground truthing.

Box 12: What additional data is needed to be collected for the flood study?

[Provide details of type of data, noting the approximate extent of additional survey, number of structures etc. as appropriate.]

2.16 What type of hydrologic model is appropriate?

Hydrologic models simulate rainfall over the catchment and estimate the resultant flows through the catchment. They calculate the quantity and rate of catchment runoff from rainfall during a flood event. The model produces estimates of the discharges in rivers and their tributaries during the course of a flood.

There are a number of options for a hydrologic analysis, depending on previous work and available data, and their adequacy for the intended purpose. Some of the influencing factors for selections of a hydrologic model include:

- The adequacy of an existing hydrologic model for use in this study
- The availability of adequate stream flow gauging records in the catchment, which may make flood frequency analysis a viable hydrologic method.

The assessment of the quality and quantity of inflow data carried out in Table 2-3 will inform the choice of hydrologic model for the flood study, including the use of an existing hydrologic model if available.

Hydrologic models can be broadly defined into two categories (as per Handbook 7) and the fit-the-purpose choice will be guided by the quantity and quality of existing data:

- Regional methods
- Rainfall runoff routing, which can be further sub-divided depending on the available quality and quantity of calibration data (recorded datasets) that are available. Thus, dependent on this, rainfall runoff routing can be undertaken:
    - Without calibration
    - With calibration
    - With calibration and validation.

The choice of hydrological model can be further optimised by:

- The review of a stream gauge rating curve as part of the flood frequency analysis (FFA) if the Council is aware of an issue with the rating curve
- Combination of regional method and rainfall-runoff routing
- Combination of flood frequency analysis with rainfall-runoff routing.

It may be possible to undertake a FFA on stream gauges where the data set is sufficient; this can provide additional information on historical flood events and aid in understanding the likelihood of a similar event occurring in the future. The FFA can be used to compare derived peak flows from the stream gauge to peak design event flows predicted from the hydrologic model and can be used to validate the design flows estimated in the hydrologic model. Advice on appropriate FFA techniques can be found in **Australian Rainfall & Runoff, Engineers Australia**.

The period of time over which a record is available will also influence the selection of the hydrologic model. A longer record of data will provide more information (including records of previous flood events) which will improve the confidence in the hydrologic model. There will be locations where only a short record of data exists. Where this is the case, it is worth noting whether the short record includes a flood event which could be useful for calibrating or verifying the hydrologic model.

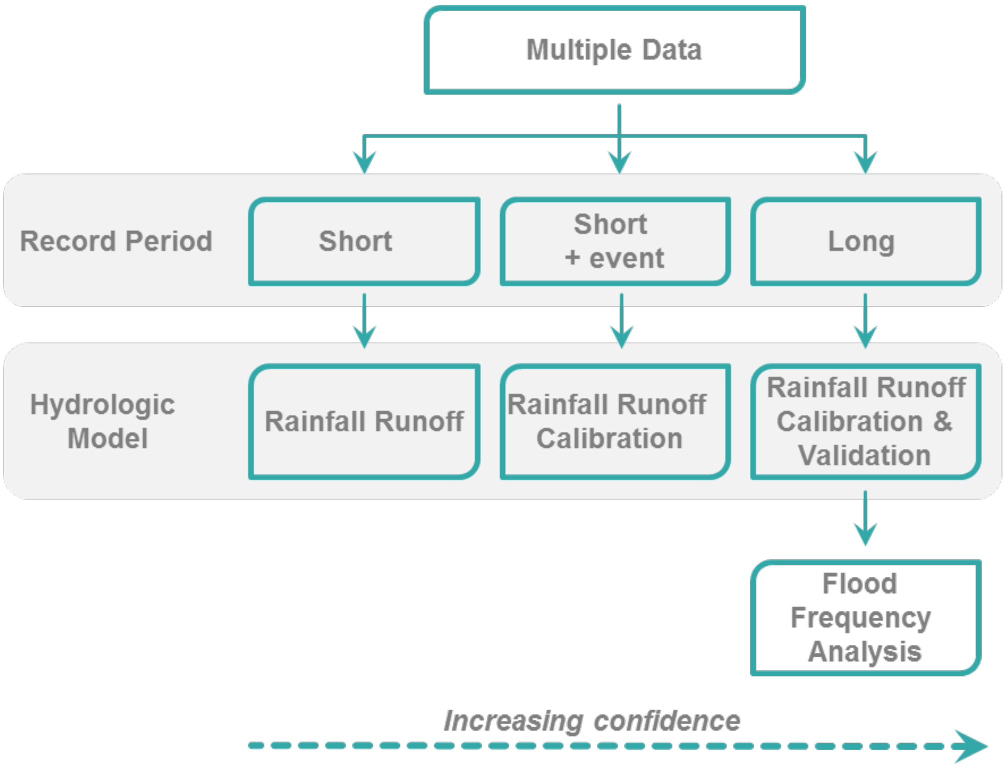
All of the hydrologic model types can be used to provide flow inputs into the hydraulic models. However, some approaches are more appropriate depending on the existing data. The following decision trees provide a simple guide to the choice of hydrologic model for the study area which is dependent on existing data sets and indicate a confidence level that can be applied to the data and the hydrologic analysis.

Some types of hydraulic models, known as direct rainfall or rain-on-grid, apply rainfall directly to the hydraulic model, thus negating the need for a separate hydrologic model. This technique is generally used for flood models developed to understand overland flooding behaviour.

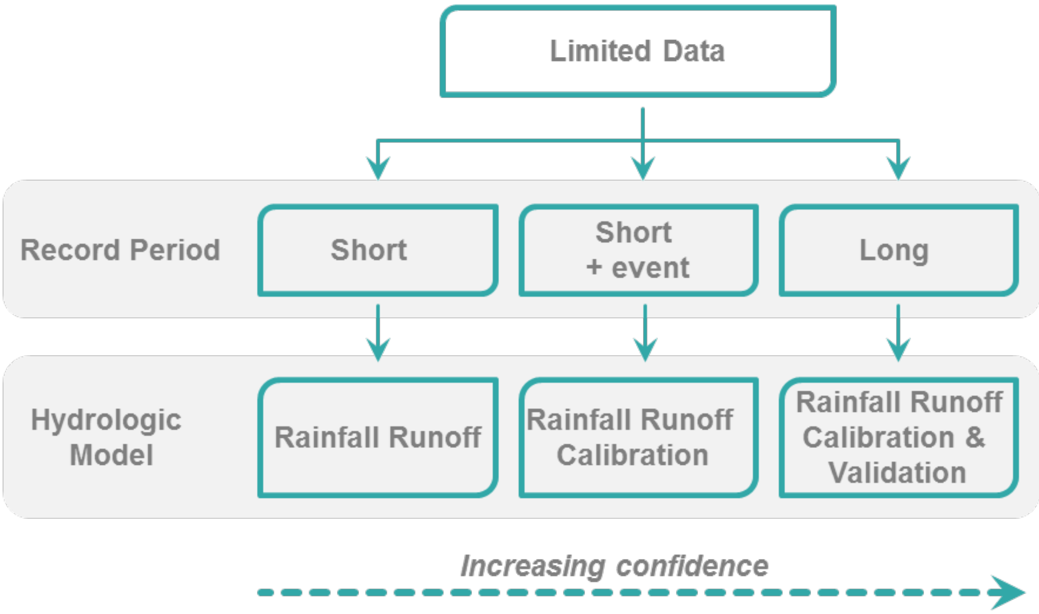
The following three decision trees are to be used to guide the selection of the most appropriate hydrologic model based on the existing inflow data available for the flood study. The Council will need to make an assessment based on a best fit approach with the data to guide the selection of the hydrologic model. Generally, the more data sets and the longer the length, the better confidence can be applied to the flood study's hydrology.

If there is uncertainty about the suitably of the hydrologic model for its intended purpose it is strongly advised that advice is sought from relevant State agencies or suitably experienced consultants.

If the study area contains multiple inflow data sets



If the study area contains limited inflow data sets:



If the study area contains poor inflow data sets:

Box 13: Which type of hydrologic model best fits the existing inflow data?

[Provide details of the most appropriate hydrologic model and why it is the best for the existing inflow data.]

2.17 What type of hydraulic model is required?

Hydraulic models simulate how the flow determined by the hydrologic model moves through the river system, over overland flow areas and estimates flood levels, velocities, discharges and depths. There are a number of options available to undertake the hydraulic analysis part of the flood study and they can depend on the work which has been undertaken in the past, what data and information are available for the catchment, type of catchment and the objectives for the flood study.

Some types of hydraulic models, known as direct rainfall or rain-on-grid, apply rainfall directly to the hydraulic model, thus negating the need for a separate hydrology model.

Broadly, there are three model options which may be fit-for-purpose depending on the complexity of the required analysis and the end-user needs:

- Dynamic Models - these models are capable of providing a detailed description of the flow in urban or rural floodplains and overbank areas. There are four sub categories of dynamic models which are described in Table 2-6.
- 1D steady state
- Historical information.

Table 2-6 describes six hydraulic model types along with their suitability and assigns them each a reference number for use within Table 2-7 when choosing the appropriate hydraulic model.

Table 2-6 Hydraulic Model Type and Reference

Hydraulic Model Type	Common applications	Reference Number
Dynamic 1D/2D overland	Suitable for small urban catchments (overland flow) where a detailed understanding of the overland flood behaviour is required.	**I**
Dynamic 1D/2D riverine	Suitable for large urban (riverine) catchments where a detailed understanding of riverine flood behaviour is required including storage, timing and spatial distribution of velocity and hazard	**II**
Dynamic 2D rural	Suitable for large rural (riverine) catchments which may span across Council areas with a township where a moderate understanding of flood behaviour is required including storage, timing and spatial distribution of velocity and hazard.	**III**
Dynamic 1D or coarse 2D	Suitable for rural (riverine) catchment with scattered development which may span across Council area where a broad scale understanding of flood behaviour is required.	**IV**
1D steady state	This type of model is only appropriate when storage or timing are not relevant and flow is largely within the watercourse and the immediate overbank area. Hence this type of model is generally not suitable for most flood studies and is more likely used for individual infrastructure design (i.e. waterway crossings).	**V**
Historical Information	This includes a combination of historical flood extents/flood frequency analysis/digital elevation model etc. to define the historical flood extent, levels and depths in the area.	**VI**

In addition, an existing hydraulic model can be reviewed and updated where appropriate.

Table 2-7 has been designed to guide the selection of the most appropriate fit-for-purpose hydraulic model for the study area or catchment where development of a new hydraulic model is required. The choice of model type will be dependent on the reason for the flood study being undertaken as previously identified in Box 1 (Reason A to E) and the type of flood situation (Types 1 to 5) previously identified in Box 7. If there is any uncertainty about the suitably of the hydraulic model for its intended purpose it is strongly advised to seek advice from State agencies or suitably experienced consultants.

Table 2-7 Hydraulic Model Choice

	Reason for Flood Study (Box 1)				
Type of Flood Situation (Box 7)	**Recent flood (A)**	**Statutory requirement (B)**	**Existing study not meeting needs (C)**	**Pre-emptive opportunity (D)**	**External Factors (E)**
Type 1	V	IV	V	V	VI
Type 2	III	III	III	IV	IV
Type 3	II	II	III	III	III
Type 4	II	II	II	II	II
Type 5	I	I	I	I	I

Note: The **State Planning Policy – State interest technical manual** sets out a broad methodology for selecting and preparing flooding investigations and mapping for use in a planning scheme. It provides guidance in the context of meeting the policy requirements of the State interest for natural hazards, risk and resilience provided for in the **State Planning Policy** (SPP) and the **SPP State interest guideline for natural hazards, risk and resilience** (the SPP Guideline). The technical manual provides three modelling/mapping options under fit-for-purpose approach, and a methodology for selecting the mapping option (or suite of mapping options) that meets the local government's needs. A summary of the three levels of mapping is as follows:

- Level 1 – State-wide flood mapping
- Level 2 – Intermediate flood hazard investigation
- Level 3 – Advanced flood hazard investigation.

Table 2-8 provides additional guidance on linking the Level 1 to 3 levels of mapping described in the SPP to the types of hydraulic models available described in this guide, and referenced to in this guide where shading indicates the intersection between the SPP mapping and the hydraulic model types described Table 2-6. If there is any uncertainty about how future flood modelling may relate to SPP mapping it is strongly advised to seek advice from relevant State agencies.

Table 2-8 Intersection with SPP

SPP Level of Mapping	Hydraulic Model Type					
	I	II	III	IV	V	VI
Level 1						
Level 2						
Level 3						

Box 14: Which type of hydraulic model best fits needs of the flood study?

[Provide details of the most appropriate hydraulic model and why it is most appropriate to provide the flood study outputs.]

2.18 Which flood event sizes are required?

The selection of appropriate modelled design flood events (these are not historical events) will be guided by the intended end-use of the model results, and the catchment characteristics.

Most Councils will require modelling and mapping of a range of flood event sizes. Choice of these event sizes might be influenced by the following factors:

- The potential flood risk in the study location, where very low-risk locations will require few flood event sizes to be modelled and mapped, and higher risk locations will require a greater range of flood event sizes.
- The characteristics of the catchment area, where more confined valleys will require a greater range of flood events to be modelled and mapped, and broad floodplains may not require as many flood events.
- Legacy issues from previous flood studies, such that where a flood study has previously been undertaken at the study location, the same flood event sizes should be used in the new study, as a minimum.
- Design levels of critical infrastructure or design flood immunity levels to check whether existing infrastructure is providing the intended design protection, and to inform planning of future infrastructure.
- Requirements for flood mitigation infrastructure or floodplain risk management studies where a broader range of flood events will be required for options assessment.

In general, it is relatively inexpensive to simulate additional flood event sizes, compared to the costs associated with establishing and potentially calibrating a flood model. Councils should therefore seek to commission a greater range of flood event sizes to develop a wide-ranging and nuanced understanding of flood behaviour. Table 2-9 illustrates standard design events which could be considered within the flood study.

Table 2-9 Standard Design Events

Frequency of flooding	Standard Design Events (AEP)
Most frequent	50%, 20%, 10% and 2%
Less frequent	1% and 0.5%
Extreme (rare)	0.1%, 0.01% and PMF

All flood studies (except for those with historical information only models) should model and map the defined flood event (DFE). The DFE is the flood event that is adopted by the Council for the management of development in a particular area. Generally a 1% AEP flood is adopted for the DFE. However, it may be appropriate to adopt a different DFE depending on circumstances of individual localities. As the selection of a DFE is driven by land use planning requirements, Councils are encouraged to discuss selection of an appropriate DFE with the relevant State agency.

In addition to the DFE, most Councils will require some understanding of flood behaviour for flood events which are both larger (rarer) than the DFE and smaller (more frequent). the guide advocates that a very large flood event be modelled to provide an understanding of the full extent of the potential floodable area in a particular location. For most flood studies, this rare event will be the probable maximum flood (PMF), an extreme flood deemed to be the largest flood that could conceivably occur at a specific location. The PMF is the event produced by the probable maximum precipitation (PMP), which is the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year (with no allowance made for long-term climatic trends). In locations where a particularly complex modelling approach has been used (such as Monte Carlo analysis), the PMF might need to be substituted for an alternative rare flood event, such as 0.01%AEP.

Box 15: What design flood event sizes are appropriate for the flood study?

[Provide details of required design events based on the factors key to the study.]

2.19 What sensitivity analyses should be undertaken?

Model sensitivity analysis is an important aspect of model establishment. It is particularly important if model calibration or validation is unlikely. Sensitivity analyses assess the degree of influence different model parameter values have on the results of the calibration and validation. Sensitivity analyses can provide an indication of the relative uncertainty associated with design model results. Minimum parameters which must be tested include:

- Hydrologic – spatial and temporal variation, rainfall losses, lag and catchment storage
- Hydraulic – roughness/friction, energy losses, bridge coefficients and boundary conditions (e.g. tailwater levels from tides/sea level rise for coastal studies).

Sensitivity assessments are also important to understand how changes in parameters affect the resulting flood behaviour. These analyse impacts of climate change, (sea level rise, rainfall intensity increases and/or other climate change variations). It is recommended that the sensitivity of the flood model to a range of parameters is assessed against the DFE. Additional guidance can be found here: https://www.nccarf.edu.au/content/resilience-inland-flooding-queensland-flood-risk-management-framework.

If there is uncertainty about the range of sensitivity analyses required for the flood study, it is strongly advised that advice is sought from relevant State agencies or suitably experienced consultants.

2.20 Community Consultation

The local community both flood prone and otherwise, has a key role to play in the development, implementation and success of a flood study. Engagement of the community generally occurs at three points during the study:

(1) At the scoping phase or commencement of the study to assist with data collection, particularly information about past floods such as flood marks, photos or video, newspaper clippings and recollections about flood behaviour (timing, depth, extent).

(2) At the calibration phase, to provide feedback on the preliminary calibration results and provide any additional information which may assist the calibration process. However, it should be noted that there can be residual risk at this point in the study and the Council should proceed with caution to ensure the flood model is replicating the results as best as possible and any consultation is undertaken with clear messages about what can be expected from the flood model to manage the community's expectations. Peer review of the hydraulic model prior to consultation is strongly encouraged to promote community confidence in the adopted modelling approach and preliminary results.

(3) At the conclusion of the study, when the Council shares outputs of the flood study (primarily flood maps) with the community.

Separate to the development of a flood study, the community should be engaged on an ongoing basis to build community flood resilience and ensure the community is prepared to respond and recover to future flood events. The **Community Engagement Framework** (Handbook 6) produced by Emergency Management Australia provides guidance for those working in emergency management to effectively engage with the community, based on the internationally recognised Public Participation Spectrum of the International Association for Public Participation (IAP2).

It is important to note that careful consideration should be given to the communication of difficult modelling issues, such as uncertainty, limitations and assumptions.

While some mapping style advice is given in Part 5 of this guide, the Council is encouraged to seek out best practice examples and advice from other Councils, Local Government Association of Queensland, Floodplain Management of Australia (QLD) and the State Government.

The level of any community consultation program also needs to consider the type of flood situation, the community and the scale of issues present. The Council itself is generally well placed to guide the scale of program required, since they understand:

- Who the key strategic decision makers are
- The likely stakeholder and agency interpretation of the issues or concerns
- The preparedness of people to engage
- The likely resources required to undertake the engagement.

For a study that is expected to have a range of issues, a very vocal community or a large community, it may be advisable to engage a community consultation specialist to design and develop a program for the study. For a tailored study program, it is ideal for the Council to understand the issues and requirements before the study starts. A community consultation specialist can be a costly addition to a project, and it is important that their focus meets the Council's and study area's needs and any strategy is developed with input from the entire project team.

Table 2-10 provides a guide as to the level of community consultation that the Council may wish to undertake depending on the level of perceived existing interest in the study where shading indicates a suggested tool to be considered for use during the flood study development. It is likely that if the study is being undertaken immediately following a flood event the interest will be greatest and it is likely that the flood study will benefit greatly from the additional information the community may be able to share, such as flood marks which could assist the flood model calibration and verification process.

Table 2-10 Guide to level of community consultation

Suggested Tools	Low interest	Some interest	Very interested
Questionnaire			
Community newsletter			
Project website			
Media release / Social media			
Targeted meetings			
Community meetings			

Box 17: What level of interest in flooding matters is there within the community and which tools are most appropriate to use in a community consultation program?

[Indicate which level of interest is likely within the community and the consultation tools which are most appropriate. Discuss any known community factors which might influence the selected consultation approach.]

3 Part 3 – Brief Preparation

This flood study brief has been carefully prepared to contain discrete sections that complement each other and provide a linear sequence of activities. When adapting the study brief template to specific circumstances, the structure should be as follows:

(1) **Introduction.** Provides an overview of project, including the Council, funding partners, associated framework.

(2) **Objectives of this study**. Describes why the study is being undertaken and what it will achieve. It frames the project in the context of the Council's broader agenda and gives the tenderer an initial idea of what is being asked for.

(3) **Background and study area.** Provides essential background information such as the study area and key features.

(4) **Available information.** Lists available references, data and sources of further information relevant to the study.

(5) **Scope of work.** Outlines how the objectives will be achieved and deliverables will be produced.

(6) **Deliverables.** Outlines what needs to be delivered, in what format, how, where to and when.

(7) **Timing and hold points.** Details key study milestones, hold points and project duration.

(8) **Meetings**. Lists the type and number of meetings required as part of the study.

There are three sources of information which the Council should use to populate each section of the brief:

(1) **Advice for completing subsection**, this text is provided for the Council's information only and should not form part of the brief.

(2) **Standard text**, provided in boxes and preceded by the words, "the following text should be used". Where square brackets [ ] are included in the standard text sections, the Council should modify these sections of text to suit their circumstances and requirements.

(3) **Cross-referenced text**, linking to the information provided by the Council during the scoping stage of this guide (Part 2). Prompts to these cross-referenced sections are also provided in boxes which include the reference to the Part 2 question (and question number).

In addition to these sources, Councils should be aware of the information provided in Parts 4 and 5 of this guide which relate to flood study management and technical guidance, respectively. In particular, Part 5 of the guide has been designed to limit the need for Councils to provide technical specifications on matters which are standardised by this guide.

All subsequent sections of this Part of the guide, including headings, form part of the flood study brief template.

3.1 Introduction

This section should provide some background to the project, name the Council and funding partners, and outline associated process and high-level aims. It should set the high-level context for the project, which should be in accordance with Australian Emergency Management Handbook 7 Managing the floodplain: best practice in flood risk management in Australia (AEM Handbook 7, AEMI 2013a). It should also include details on the governance of the study and guide the tenderer in understanding how they will interact with the Council. For example, the Council may have a committee that is responsible for steering the study, and may comprise representatives from the Council's organisation, other stakeholders and end-user groups, and jurisdictional government. There may also be a subcommittee that guides the technical aspects of the study. It may include representatives from the Council's organisation and jurisdictional government.

The following text should be used in subsection 1

[The Council] in partnership with [partner Councils/authorities] wishes to undertake a flood study of the [location and/or catchment name]. The flood study should be undertaken to be consistent with Australian Emergency Management Handbook 7: Managing the floodplain: best practice in flood risk management in Australia (AEM Handbook 7) (AEMI 2013).

3.2 Objectives of this study

This section should state what the project will achieve in relation to understanding flood behaviour within the study area and how it fits within flood risk management in the Council's domain. It gives the tenderer context for the deliverables and methodology and allows them to tailor their proposal to suit. This section should provide high-level objectives in the context of the overall outcomes desired and should not be used to list outputs or deliverables. This section also allows the flood study end-users to be identified and any key considerations regarding those end-users.

At the end of this section of the brief, the aims and high-level objectives of the project should be clear to the tenderer.

The following text should be used in the subsection 2 along with the text from Boxes 1 and 2.

This project involves conducting a flood study, which is a comprehensive technical investigation of flood behaviour. It aims to provide a better understanding of the full range of flood behaviour. It should consider the local flood history, available collected flood data, and the development of hydrologic and hydraulic models that are calibrated and verified, where possible, against historic flood events and extended, where appropriate, to determine the full range of flood behaviour.

Box 1: Why Do a Flood Study?

[*Describe which of the above categories above best fits the reason for needing to undertake a flood study?]*

Box 2: If there are have past flood studies, why are they not meeting requirements?

[Provide a succinct overview of relevant findings from previous studies. If previous flood studies are not sufficient, list the existing limitations of the past study, e.g. study area, level of detail, new flood information, new topographical information , new flood mitigation infrastructure etc.]

3.3 Background and Study area

This section of the brief provides essential background to the tenderer, statistics on the area, and a definition of study area. It is important to include a clear figure of adequate resolution to describe the study area and key features, such as waterways, towns, roads, bridges and key infrastructure (e.g. weirs, levees, reservoirs, dams). It should include an overlay aerial image or cadastral information. The figure should include a legend of all items shown on the figure. A4 size should be the minimum.

The text from Boxes 5, 7, 6, 3 and 4 in this order should be used in the subsection 3:

Box 5: What is the study area of interest?

[Provide a summary of the town/area of interest, study area location in the catchment, catchment size, major hydrological features, geographic features such as topography (e.g. steep upper sections, flat floodplain), soils and any flood-dependent ecosystems (e.g. wetlands), Description of development (sparse or dense) and development pressure if it exists. Note, that the study area of interest does not define the extent of the flood modelling required.]

Box 7: What Type of Flood Situation Exists?

[Identify which type of flood situation best fits the study area or catchment followed by a broad description of the flood behaviour in the study area and what is known about flooding in the area, such as:

- *Is it overland or riverine and/or influenced by oceanic inundation?*
- *Is there a lot of warning time, and does the catchment respond rapidly?*
- *What is the flooding duration (hours, days, months)?*
- *Are there flooding hot spots in the study area?*

This section should also identify frequently inundated areas and exacerbating factors (e.g. blockage, high tides, antecedent conditions, and natural or constructed hydraulic controls, including dams and bridges), as well as coincident tributary flooding.]

Box 6: What is the flood history?

[Provide an overview of the area's flood history, including:

- *a description of the most recent events and the largest recorded events (in terms of their peak height or flow)*
- *areas of inundation*
- *impacts on the community (e.g. damage to property and community facilities, loss of life, areas cut off, disruption to community function, photos/video availability)*
- *any notable occurrences (e.g. levee was overtopped, dam was full, bridge was blocked and/or overtopped).*
- *Any information the Council or any other organisation has on historical floods – for example, flood photography or videos, flood height marks, flood extents, anecdotal evidence and damage reports. This should include access to any information made available to the community on flooding.]*

Box 3: Which key flood risk management areas or themes will the flood study support?

[Identify which themes the flood study will support and describe outcomes that the flood study is seeking to achieve.]

Box 4: Who are the end users?

[Identify and list all the potential end users of the flood study and the outcomes they require and their linkages to the themes described in Box 3]

3.4 Available information

To assist the tenderers, any documents referenced should include title, author and year of publication. A table should include a listing and description of known (and compiled) existing data. The identification of existing data allows tenderers to make informed decisions about approach and methodology, and allows reasonable estimates of time for additional data collection or amalgamation of existing datasets.

The text from Boxes 8, 9 and 10 should be used in the subsection 4.

Box 8: What existing studies could assist the flood study?

[Identify any of the following existing studies which is available to assist the flood study.

- *Land use and cadastral data*
- *Previous data collection studies*
- *Existing hydrologic and hydraulic models and associated files*
- *GIS data*

Will data be available for tendering and the project, if so, what format and how? Summarise existing data in a table with a brief description, format, author or source, year, etc]

Box 9: What existing model development data exists to assist the flood study?

[Identify any of the following data which is available to assist the flood study:

- *Any survey data the Council or any other organisation has available for use in the study – for example, digital elevation models (DEMs) or light detection and ranging (LiDAR) data, creek/river cross-sections or bathymetric surveys, location and dimensions of drainage assets, and floor levels.*
- *Any survey data the Council or any other organisation has that describes current or previously existing structures (e.g. bridges, culverts, weirs, levees, irrigation channels, dams, developed areas). Asset management information systems may assist.*
- *Geographic information system (GIS) layers the Council or any other organisation has, including waterways, natural environment areas, street names, roads and land-use planning areas.*

Will data be available for tendering and the project, if so, what format and how? Summarise existing data in a table with a brief description, format, author or source, year, etc]

Box 10: What model calibration data is available which could assist the flood study?

[Identify the data which is available for tendering and the project, including:

- *Hydrologic data the Council or any other organisation is in possession of, such as stream flow records, rating curves, rainfall records, ocean and water level data, and rainfall gauges*
- *Historic flood information [Box 6]*

Will the data be available for tendering and the project, if so, what format and how? Summarise existing data in a table with a brief description, format, author or source, year, etc]

3.5 Scope of work

The scope of work generally outlines how the objectives will be achieved and any specific methodology that should be adopted. It is preferable to allow tenderers to propose a methodology that will achieve the requirements of the study, and will use their experience and expertise within the bounds of current best practice. Restrictions can be placed on the proposed approach; however, this may exclude some tenderers, result in misapplied methodologies and can be more costly for the Council.

3.5.1 Data collection

Compiling data as described in **Boxes 8, 9 and 10** will help the tenderers to determine the scale of the data collection exercise that may be required.

The text from Boxes 11 and 12 should be used in the subsection 5.1

Box 11: Is there sufficient data to define the fundamental components of the flood model, such as inflow data and historical flood data for calibration and terrain data for the hydraulic model build? If not, are the limitations of the existing critical in terms of the outputs required from the flood study?

[Provide information on the sufficiency of data, using the classifications in the tables for the Inflow data, Terrain data and Additional data, noting the identified limitations and how this might influence the required flood study outputs.]

Box 12: What additional data is needed to be collected for the flood study?

[Provide details of type of data, noting the approximate extent of additional survey, number of structures etc as appropriate.]

3.5.2 Site visit

A site visit should be undertaken as part of all studies. This gives an opportunity for the Council and the successful tenderer to inspect the study area, assess infrastructure, identify any potential issues and highlight areas of interest. The tenderer may end up undertaking a study that lacks context if a site visit is excluded.

The following text should be used in the subsection5.2

At least one site visit should be included as part of this flood study. The tenderer should provide details of the intended visit(s), personnel in attendance and purpose of visit.

3.5.3 Community Consultation

Consultation requirements vary significantly between flood studies depending upon their scope, likely community concerns relating to the study outcomes and any associated management options, and the Council's general community consultation processes. These are all factors used to decide how to engage the community, noting that the potential needs of community consultation may change during the study. The Council should provide an outline of the way in which they expect consultation to be undertaken, so that this can be considered in tendering for the project. However, it is important to be flexible as the study progresses to allow for changing needs.

In some cases, it may be prudent to cost several alternatives as part of tendering. Alternatives may not be part of the upper limit fee, but used to provide a reference for variations if needed.

Depending on the needs of the study, consultation and collaboration with the community may be required at various stages or points throughout the study. Although a complex study may involve consultation at several points throughout the study with various tools, a more simplistic study may involve only one or two points with the use of more simple tools.

The text from Box 17 and the following text should be used in the subsection 5.3.

Box 17: What level of interest in flooding matters is there within the community and which tools are most appropriate to use in a community consultation program?

[Indicate which level of interest is likely within the community and the consultation tools which are most appropriate. Discuss any known community factors which might influence the selected consultation approach.]

Given the level of interest within the community, [Council] recommends a community consultation program be undertaken as per the definition of [community consultation] provided in Part 5 of the ***Guide for Flood Studies and Mapping in Queensland****. The offeror should prepare a detailed community engagement plan to compliment the flood study.*

3.5.4 Hydrologic analysis

This section guides the scope of work required as part of the hydrologic analysis. The scope will depend upon the availability and adequacy of existing data as determined in Box 9 of Part 2.

The following text should be used in the subsection 5.4 and be based on the decision made in Box 13.

Given the available data, scope of the study and outputs required, [Council] recommends that a [selected hydrologic model type, as determined in Box 13 of Part 2] hydrologic model be used, as per the definition of [selected hydrologic model type] provided in Part 5 of the ***Guide for Flood Studies and Mapping in Queensland****. The tenderer is to describe how they intend to develop the hydrologic model and provide details and justification for the proposed hydrologic modelling software, based on the available data described in this brief.*

Optional:

The tenderer may, in addition to the above, include other model option/s which will be reviewed on merit with regard to the objectives of the study.

3.5.5 Hydraulic analysis

This section guides the scope of work required as part of the hydraulic analysis. There are a number of options available depending on what work has been undertaken in the past, what data and information are available in the catchment, the complexity of the required hydraulic analysis and end-user needs which have previously been considered in Part 2 of this guide.

The following text should be used in the subsection 5.5 and be based on the decision made in Box 14.

Given the available data, scope of the study and outputs required, [Council] recommends that a [selected hydraulic model type, as determined in Box 14 of Part 2] hydraulic model be used, as per the definition of [selected hydraulic model type] provided in Part 5 of the ***Guide for Flood Studies and Mapping in Queensland****. The tenderer is to describe how they intend to develop the hydraulic model and provide details and justification for the proposed hydraulic modelling software, based on the available data described in this brief.*

Optional:

The tenderer may, in addition to the above, include other model option/s which will be reviewed on merit with regard to the objectives of the study.

3.5.6 Model calibration and validation

Model calibration and validation is an important aspect of defining flood behaviour as it can increase confidence in the results that the models are producing. This is an important component both for a flood study, where model establishment often occurs, and a flood management study, where model modifications may be required. Data availability can limit the scale of calibration that may be undertaken.

The selection of the type of model calibration will be based on the consideration of quality and quantity of available information from Box 10.

The following text should be used in the subsection 5.6.

Given the available data, and the consideration of suitable events [Council] recommends that the following calibration methodology [selected calibration] be undertaken, as per the definition of [calibration and verification] provided in Part 5 of this **Guide for Flood Studies and Mapping in Queensland**. *The tenderer is to describe how they intend to calibrate and verify the flood model (if appropriate) based on the available data described in this brief.*

3.5.7 Modelling events

To understand the flood behaviour in the study area, a range design flood events should be simulated. Selection of these design events is informed by end-user needs and catchment and flooding characteristics. The designs events required can be presented as a list.

The text from Box 15 should be used in the subsection 5.7.

Box 15: What design flood event sizes are appropriate for the flood study?

[Provide details of required design events based on the factors key to the study.]

3.5.8 Model parameter sensitivity

Model sensitivity analysis is an important aspect of model establishment. It is particularly important if model calibration or validation is unlikely. Sensitivity analyses assess the degree of influence different model parameter values have on the results of the calibration and validation. Sensitivity analyses can provide an indication of the relative uncertainty associated with design model results.

The following text should be used in the subsection 5.9 in conjunction with Box 16.

The [Council] requires model sensitivity analyses to be undertaken on the following parameters:

- *Hydrologic – spatial and temporal variation, rainfall losses, lag, catchment storage*
- *Hydraulic – roughness/friction, energy losses, bridge coefficients, boundary conditions*

Box 16: What sensitivity and/or climate change impact modelling is required for the flood study (if any)?

[Indicate which sensitivity parameters and climate change impacts should be considered and why.]

3.5.9 Model outputs and mapping styles

This section summarises the flood events and mapping outputs. The intent is to define the events and scenarios to be modelled or considered as part of the study based on the themes identified as needs and the end-users requirements.

The following text should be used in the subsection 5.9 and be based on the decisions made in Box 3 and Box 4.

The [Council] requires the [selected model outputs and mapping styles], as per the definition of Modelling output and mapping styles provided in Part 5 of the ***Guide for Flood Studies and Mapping in Queensland****.*

3.6 Deliverables

The deliverables section communicates what is expected from the tenderer, as a reference during the study, and indicates what the Council will have in their possession at the conclusion of the study (as part of the handover).

The primary study outputs will include the final report, model files, results from the models and the associated mapping data. Results files and mapping will be used by a number of end-users for a variety of purposes, and will describe the full range of design and historical flood behaviour in detail across the study area. Where possible, all files should be provided electronically for dissemination to end-users through the Council or directly by agreement with the Council.

Communicating the details of the deliverables and their format ensures that the objectives of the study are achieved, and that outputs produced by similar studies are consistent, comparable and able to be effectively and efficiently aggregated where necessary.

Deliverables are to be produced in formats specified and provided in accordance with the milestones of the study. They include progress, draft and final reports, survey data, model set up files, model files and model results and mapping products

The following text should be used in the section 6.

The [Council] requires the reporting to be according to *the definition of Requirements for Reporting and [Council] requires the presentation of the model files and results to be consistent with the File Structure for Data Handover. Both of which are provided in Part 5 of the* ***Guide for Flood Studies and Mapping in Queensland****.*

3.7 Timing and hold points

This section details the key milestone and hold points throughout the project, and assists in identifying the timing and key hold points in the project. It also provides a reference document during the project, and guidance information for pricing and timing during tendering.

The Council will need to determine the timing and hold points linked to key milestones within the flood study. These milestones include but are not limited to:

(1) Data collection

(2) Model setup or review, calibration and validation – both hydrologic and hydraulic

(3) Design results and mapping

(4) Draft flood study report

(5) Final flood study report.

3.8 Meetings

This section describes the location, number and type of meetings required by the study to be defined. Types of meetings to be considered include:

- With the Council's project technical committee
- With the Council's project steering committee
- As part of consultation
- With high-level decision makers.

The Council will need to determine the appropriate number and type of meetings and provide a description of what is required to the tenderer.

4 Part 4 – Flood Study Management

This section of the guide was developed to support Councils during the commissioning and management of flood studies. A number of project and contract management issues are discussed, with the aim of delivering a robust flood study which meets end-user requirements.

4.1 Tender requirements and assessment

It is recommended that the flood study brief include the criteria against which the tenders will be assessed. This will guide the tenderers in their submission and provide the Council with criteria to justify the selection of a successful tenderer. It also gives less-experienced tenderers assistance in what their proposal should contain. An example of things that might be included in the assessment criteria are:

- Appreciation of study requirements and specifications
- Relevant experience and successful performance with particular reference to nominated team members
- Technical skills and availability of the nominated team members
- Proposed methodology, including methods to address data constraints and how the available data will be best used, to produce robust flood modelling outputs
- Proposed hydrologic and hydraulic software (if required)
- Risk identification and treatment
- Management skills and demonstrated ability to deliver the project on time and within budget
- Communication and customer relationship management
- Location
- Tender price / value of proposed services.

Tenders must also include evidence of a quality management system, and cover for professional indemnity insurance, public liability insurance and statutory workers compensation insurance.

The brief will normally involve a range of requirements of the tenderer that are not part of the project's scope. Rather, they are conditions that demonstrate the tenderer's appreciation of the task, but are not related to the outputs of the study. For example, curricula vitae of nominated team members are typically required as part of the proposal so as to evaluate the tenderer's experience. Other suggested requirements include:

- A completed cost which reflects the included scope items. This will increase the ease of comparison between relevant bids
- A timeline of how the various scope items will be completed in the specified study duration
- A section on the limitations and critical assumptions of the proposed methodology to meet the full requirements of the brief, and deliver all deliverables and outcomes

- Information on referees, conflicts of interest and critical tendering assumptions.

4.2 Intellectual property

It is recommended that the contract for the flood study include a clause on intellectual property (IP). The clause should allow the Council and the state government to have an unrestricted licence for the use and distribution of the data collected, models established and accompanying report as part of the study.

This clause ensures that the Council and any other parties (state government departments) are able to access the data and results or use the model for subsequent floodplain management projects or infrastructure assessments. The assessment of additional aspects can become costly if the Council does not have an IP clause and wishes to use a different tenderer for subsequent works.

4.3 Provision of deliverables

The contract should also require a copy of the model data files, results and all deliverables (including GIS spatial data) of the project to be provided to the Council and to another government agency, where required, or their designated location(s) at the completion of the contract.

An electronic copy of the project deliverables should also be provided, which can be included in jurisdictional and/or national mapping projects, in addition to having advantages for the Council. Details of this are provided in Part 5 of this **Guide for Flood Studies and Mapping in Queensland**.

Consideration should also be given to including a requirement for the tenderer to undertake an in-person handover of GIS data, to ensure the outputs are suitable for the Council's native GIS system and that the outputs are understood and accessible by the Council.

4.4 Technical Committee

It is recommended that the Council initiates the establishment of a Technical Committee to provide technical assistance to enable the Council to be confident that the flood study, follows appropriate best practice approaches, and produces outcomes which meet the Council's and other end-user's needs. The Technical Committee should be established at the scoping stage of the study.

The roles of the Technical Committee might include:

- Scoping the flood study, including collating and reviewing the data and information required to answer the questions in Part 2 of this guide
- Submission of funding applications to State Government
- Development of flood study briefs
- Review of proposals from flood study tenderers
- Discussion of issues related to data, flood model development, and model calibration with tenderer
- Dissemination of flood studies and outputs (including mapping) to relevant stakeholders at the conclusion of the study

- Presentation of progress reports and final study to the Local Disaster Management Group.

The Technical Committee should have membership from Council staff from engineering, strategic planning, GIS, and emergency management departments plus relevant local representation from State agencies and major infrastructure owners.

4.5 Peer review

It is recommended that Councils require consultants to conduct a comprehensive internal review process, as part of a quality management system. However, additional independent peer review might also be required to engender confidence in the flood study results. Where this additional review is required, the Council should consider whether an independent reviewer is required (recommended for high-risk locations, such as large urban centres) or if the Technical Committee can provide sufficient review function (more suitable for lower-risk locations).

Peer reviews are most effective when the reviewer (whether an independent reviewer or a technical committee) is engaged from the commencement of the study. Formal hold-points in the study schedule provide opportunities for the reviewer to approve the methodology / findings to that point, before the study proceeds further. A final review of the entire study including methodology and outputs should be undertaken at the conclusion of the study.

4.6 Flood study implementation

Following the completion of a flood study, the Council should seek to disseminate the flood study report and outputs to all relevant stakeholders, including other departments within the Council, the community, relevant state and federal government departments, the local disaster management group and other Councils within the same catchment.

The flood study and its outputs will form the most up-to-date source of flood information for the study area and should therefore be used to update existing land use and emergency management policies as soon as possible, following the completion of the study.

To ensure that the flood study remains current, the Council should implement a five year review time-frame, which is used to revisit the study, identify if the model development and calibration data remains current, and whether the model outputs are continuing to meet the Council and other end-user's needs. Should a major flood event occur before the review process is due, the Council may wish to review the flood model sooner.

Following major flood events, the Council should seek to immediately capture any information which might be used to undertake a flood model calibration, including stream and rain gauge data, maximum water levels (including date and time stamps), photographs, videos and anecdotal information.

5 Part 5 – Technical Guide

This part of the guide is intended to be used by tenderers to assist Councils undertaking flood studies to achieve best practice outcomes which are fit-for-purpose in terms of local flood risk and broader flood risk management goals.

The guide provides guidance on issues which benefit from a consistent approach state-wide, including requirements from various hydrologic and hydraulic model types, and mapping styles.

Supporting this guide, is reference to state and national standards for flood model development, including **Australian Rainfall and Runoff**, and **Managing the floodplain: a guide to best practice in flood risk management in Australia** (Handbook 7).

5.1 Requirements for additional data collection

Where the brief indicates a requirement for additional data collection, the Council may indicate that one or more of the three following data collection types are required:

- Topographic survey collection
- LiDAR acquisition
- Digital elevation model (DEM) development.

Where one or more of these types are specified in the brief, the tenderer should use the advice provided below when preparing their proposed scope of works.

Topographic survey collection

A topographic survey of watercourses and the adjoining floodplain (if necessary) is required, for the purposes of hydraulic modelling. Additional survey of structures such as bridges, culverts and road levels is required if they are likely to control or significantly influence flood behaviour and up-to-date, detailed information for these structures does not exist. If applicable, relevant stream water level gauges should be identified and surveyed. Watercourses to be specifically modelled are shown in an attached figure with the brief prepared by the Council.

Following engagement and a detailed inspection of the study area, the successful consultant shall submit to the Council a brief outlining details of the survey required, as well as an upper limit fee to undertake this portion of the work.

Following receipt of written approval from the Council, the consultant shall arrange for the survey to be undertaken. The consultant shall be responsible for the engagement and supervision of the approved sub-consultant to complete the work. The consultant is also responsible for ensuring any data used is fit-the-purpose.

LiDAR acquisition

Where LiDAR survey data is to be obtained as part of the study, it will be the primary source in defining the catchment's topography and is to be of appropriate resolution for use in defining the hydraulic features of the catchment. The cost of the LiDAR survey is to be included as an additional, separate item on the proposed cost schedule.

Digital elevation model development

The methodology proposed to develop the digital elevation model (DEM) should be identified. The tenderer should identify realistic costs for undertaking this task either in-house or by a specialist subconsultant. This task does not include data acquisition.

5.2 Requirements for Community Consultation

Where the Brief indicates a requirement for community consultation, the Council may indicate that one or more of the eight following community consultation activities are required:

- Community consultation specialist
- Community questionnaire
- Community newsletter
- Project website
- Media release
- Social media
- Targeted meetings
- Community Meetings / Public Presentations.

The following requirements for community consultation tools are provided to ensure consistency of approach and reflect the definitions provided in Handbook 7. Further detail can be found in **Community Engagement Framework** (Handbook 6). Where one or more of these activities are specified in the brief, the tenderer should use the advice provided below when preparing their proposed scope of works. Text contained within square brackets [ ] indicate potential options within consultation activities. Tenderers should discuss these options with Council either at the proposal preparation stage (to better estimate costs for activities) or at the commencement of the study.

Community Consultation Specialist

A community consultation specialist is required to design and develop a consultation strategy and implementation program for this project.

Community Questionnaire

A community questionnaire is to be sent to [flood affected/all] landowners and residents in the study area, informing them about the study objectives and requesting any information they may have on historical floods. The survey is to be [sent in the post/provided as an online questionnaire/both sent in the post and provided as an online questionnaire]. The costs for posted material are to be included within the tender price.

Community Newsletter

A community newsletter is to be sent to [flood affected/all] [landowners and residents/landholders/residents] in the study area, informing them about the study objectives or outcomes. The newsletter is to be [sent in the post/available for download/available from the Council's information centre].

Project Website

A project website should be established by the consultant and hosted [on their own server/on the Council's server]. It should contain functionality for regular updates, document download and comment. The consultant is to regularly update the website throughout the project.

Media Release

The consultant is to prepare a media release with key facts about the study to be sent out [at the commencement of the study/in unison with any newsletter/questionnaire mail outs/ when the study is placed on public exhibition/ when the study is finished].

Social Media

The consultant is to provide information on the study via social media on the study at key stages in the study, such as at the start of the study or in unison with other community consultation. Information will be provided to the Council, who will then manage its distribution via its preferred social media platforms.

Targeted Meetings

The consultant is to hold [number] of smaller, targeted meetings with key project stakeholders.

Community Meetings / Public Presentations

[Number of information community sessions and/or public presentations] information sessions held at key stages in the study, aimed at informing residents about the study progress and gathering information on historical flood events.

5.3 Requirements for hydrologic models

The Council may indicate in the brief that one of the six following hydrologic models are required to be used in the flood study:

- Rainfall-runoff routing
- Combination rainfall-runoff routing and flood frequency analysis
- Regional methods
- Direct rainfall methods
- Combination regional method
- Existing hydrologic model/information.

The following requirements for hydrologic model types are provided to ensure consistency of approach and reflect the definitions provided in Handbook 7. Where one of these hydrologic model types are specified in the brief, the tenderer should use the advice provided below when preparing their proposed scope of works.

Note that these requirements are of a high-level nature. The methodology used when scoping and applying these model types should be informed by **Australian Rainfall and Runoff**.

Rainfall-runoff routing

The chosen modelling software should be detailed, including a description of its capability to represent all significant features of the catchment. The extent of the rainfall-runoff routing model shall be sufficient to establish reliable boundary conditions for input to the hydraulic model covering the study area.

Combination rainfall-runoff routing and flood frequency analysis.

This option can only be used if both rainfall-runoff-routing and flood frequency analysis are selected as options. Design flood estimates are to be adopted based on the results of the flood frequency analysis and rainfall-runoff modelling. Rainfall-runoff model parameters should be adjusted to fit the adopted design flood estimates. A flood frequency analysis will draw on the extensive hydrologic record of the area and provide a reliable estimate of peak flow for design events at the gauge location(s). The flood frequency analysis should be undertaken in accordance with the procedures outlined in the current version of **Australian Rainfall and Runoff**.

Regional methods

Examples of this are using the ARR Project 5: Regional flood method or using the ARR Project 5: Regional flood method with a short record (e.g. five years) and a Bayesian maximum likelihood approach (e.g. TUFLOW FLIKE).

The following alternative methods might also be considered by consultants as appropriate, depending on data availability, catchment conditions and study output requirements.

Direct rainfall method

This method, which applies rainfall directly to grid cells in the hydraulic model, is applicable across various catchment types. It is often used when the catchment terrain is flat, when there are cross-catchment flows or when the study is on a detailed urban area. The chosen modelling software should be detailed, and consideration should be given to the limitations of the approach.

Combination regional method

This method should be used where one or more gauges in the catchment have a very short length of record or are not considered reliable for the selection of appropriate model parameters. It is likely that other gauges in the broader region are more representative and provide a more reliable basis for guiding the selection of model parameters. Regional parameters developed via regional methods should be adopted for use in rainfall-runoff modelling.

Existing hydrologic model/information

A review of existing hydrologic model(s) and their appropriateness for use should be undertaken in the initial stages of the study. The hydrologic model might be available for use during this study if considered fit-the-purpose by the consultant.

5.4 Requirements for hydraulic models

The Council may indicate in the Brief that one of the seven following hydraulic models are required to be used in the flood study:

- Dynamic 1D/2D overland (Type I)
- Dynamic 1D/2D riverine (Type II)

- Dynamic 2D rural (Type III)
- Dynamic 1D or course 2D (Type IV)
- 1D steady state (Type V)
- Historical information (Type VI)
- Existing hydraulic model.

The following requirements for hydraulic model types are provided to ensure consistency of approach and reflect the definitions provided in Handbook 7. Where one of these hydraulic model types are specified in the brief, the tenderer should use the advice provided below when preparing their proposed scope of works. Text contained within square brackets [ ] indicate potential options within hydraulic model types. Tenderers should discuss these options with the Council either at the proposal preparation stage (to better estimate costs for modelling scope) or at the commencement of the study.

Note that these requirements are of a high-level nature. The methodology used when scoping and applying these model types should be informed by **Australian Rainfall and Runoff**.

Dynamic 1D/2D overland (Type I)

This model type will represent the floodplain and flow paths in sufficient detail to accurately simulate flow behaviour. The grid cell size selection should be suitable to define the overland flow in a relatively built-up environment. This may be limited by the accuracy of the topographic data, the stormwater drainage network and other hydraulic structures (and blockage of these), land use, and buildings. The consultant should consider these items when setting out their proposed methodology.

The proposed grid cell resolution should be sufficient to appropriately represent the features within the catchment. Guidance on this is provided in **ARR Project 15: Two dimensional simulations in urban areas**.

Furthermore, a 2D hydraulic model will produce spatial and temporal outputs to a level of detail that is appropriate given the range of end-users and their varying needs.

Depending on the model resolution and output requirements, one of the following options should also be included:

(1) *All pipes in*: The drainage system is an important aspect of the management of flooding in significant events. The hydraulic model should include all drainage pipes. The consultant should test the sensitivity of the flood level when including all drainage pipes.

(2) *Greater than minimum size pipes in:* The drainage system is an important aspect of the management of flooding in significant events. The hydraulic model should include all drainage pipes greater than [xx m]. The consultant should test the sensitivity of the flood level when adjusting the minimum size.

(3) *No pipes in:* The pipe drainage network has a relatively minor capacity for the management of flooding. The hydraulic model does not need to include drainage pipes. The consultant is to advise if any drainage structures may significantly influence model results, which would

therefore warrant their inclusion in the model. The consultant should test the sensitivity of the flood level if these drainage structures are to be included.

Dynamic 1D/2D riverine (Type II)

This model type will represent the floodplain and flow paths in sufficient detail to accurately simulate flow behaviour in the hydraulic model. Furthermore, a 1D/2D hydraulic model will produce spatial and temporal outputs to a level of detail that is appropriate given the range of end-users and their varying needs.

The proposed grid cell resolution should be sufficient to appropriately represent the features within the catchment. Guidance on this is provided in ARR Project 15: Two dimensional simulations in urban areas.

Dynamic 2D rural (Type III)

A 2D hydraulic model is suitable for this study. This model type will represent the floodplain in sufficient detail to accurately simulate flow behaviour. Furthermore, a 2D hydraulic model will produce spatial and temporal outputs to a level of detail that is appropriate given the range of end-users and their varying needs.

Dynamic 1D or coarse 2D (Type IV)

A 1D (or coarse 2D) hydraulic model is suitable for this study, with dynamic time-varying inputs. This model type will represent the floodplain in sufficient detail to accurately simulate flow behaviour. Furthermore, a 1D (or coarse 2D) hydraulic model will produce spatial and temporal outputs to a level of detail that is appropriate given the range of end-users and their varying needs.

In the case of 2D modelling, the proposed grid cell resolution should be sufficient to appropriately represent the features within the catchment, including the main channel. Guidance on this is provided in ARR Project 15: Two dimensional simulations in urban areas.

1D steady state (Type V)

A 1D steady state model is suitable for this study. The model type will represent the simple nature of flooding in this study area and provide key outputs such as flood levels, depths and velocities at key locations, in addition to flood profiles. This model type can also provide information inputs for a broad assessment of flood hazard and function for land-use planning purposes.

Historical information (Type VI)

This method includes a combination of [historical flood extents/flood frequency analysis/ DEM/others] to define the [flood extent, levels and depths in the area]. A review of the available information and outputs appropriateness for use should be undertaken in the initial stages of the study.

Existing hydraulic model

A review of the existing hydraulic model and outputs appropriateness for use should be undertaken in the initial stages of the study. The model is available for use during this study if considered fit-the-purpose by the consultant.

Existing model review and update

There have been significant changes to the [modelling approach/study area catchment] that warrant an update of the hydraulic modelling previously undertaken. Differences in model setup may mean that parameters from the previous model may not be directly reusable.

5.5 Requirements for calibration and verification

The Council may indicate in the Brief that model calibration is required, or that insufficient data exists to undertake a calibration.

The following requirements for calibration and verification are provided to ensure consistency of approach and reflect the definitions provided in Handbook 7. The tenderer should use the advice provided below when preparing their proposed scope of works.

Note that these requirements are of a high-level nature. The methodology used when scoping and applying model calibration should be informed by **Australian Rainfall and Runoff**.

No calibration data

A comprehensive calibration and validation of the hydrologic and hydraulic model is unlikely to be possible, due to a lack of calibration data for the catchment. However, tenderers should outline how selection of model parameters in the hydraulic model will achieve reasonable accuracy in model results.

Calibration data (either hydrologic and/or hydraulic)

Suitable hydrologic and hydraulic models to simulate flood behaviour in the study area are to be developed by calibration and subsequent validation of flood behaviour against available data from historical flood events. Historic events to be used have been listed in the Brief or should be identified by the successful tenderer in consultation with the Council.

To achieve a fit to calibration events, consideration should be given to how conditions on the floodplain have changed since the time of the calibration event and what historical topographic features or structures are not represented in the current survey data. Changes in groundwater and base flows may be relevant. Following calibration, the model is to be validated against the historical events.

During the calibration and validation process, features of the catchment that have a distinct influence on flood behaviour should be considered. The calibration/validation process should guide the final model configuration and selection of hydraulic model grid cell resolution if undertaking 2D modelling.

Furthermore the following two optional text extensions are provided for consideration:

(1) Explicitly quantified calibration: The calibrated model is to achieve a satisfactory fit to the historical data. [Sentence describing preferred calibration benchmark (e.g. The calibrated model is to be able to reproduce the flood level recorded at the gauge within 0.X m, for each calibration event.)]

(2) Model has already been calibrated: The model established as part of the previous flood study was calibrated as part of that study. Its calibration is satisfactory for the model to be used in this study and therefore no model calibration is required.

Design flood level verification

Water levels are obtained from hydraulic models based on the hydrologic input corresponding to a particular AEP, providing a peak water level versus AEP relationship. In most flood studies, the AEPs investigated may range from 1 in 2 to the Probable Maximum Flood.

Prior to adoption of design flood model results, it is recommended to carry out a verification of these results using available historical peak water level data. This may include:

- Comparison of the flood frequency assessments (presented as water levels) with the design flood results at locations across a range of probabilities to ensure that they are reasonable. It is noted that the confidence in the range of probabilities for comparison may be limited by the length of available historical record, and/or
- Derivation of estimated flood probabilities of measured historic flood peaks (i.e. Maximum Height Gauge data or surveyed debris marks) from hydraulic model results. Some discussions as to whether the derived probabilities are reasonable should be included. This may be further informed by a review of the flood probabilities estimated from rainfall.

This verification step is intended to provide confidence in the design results prior to adoption, ensuring that the ultimate culmination of hydrologic and hydraulic model configuration, calibration and application of AEP neutral design assumptions remain appropriate.

In areas where no historical flood peak is available, it is recommended that the authority collects flood level measurements at key sites in future, to verify the robustness and suitability of adopted models.

5.6 Modelling approach and parameters

It is strongly recommended that users adopt guidance from **Australian Rainfall and Runoff** (ARR) when selecting appropriate approaches and parameters for hydrologic and hydraulic modelling. Where the selected approach or choice of parameter deviates from ARR, the user must provide justification for their selection. Supporting ARR are three additional guidelines to help select appropriate modelling and calibration parameters:

- **Manning's n for Channels** (Chow, 1959) to guide the selection of appropriate roughness values (recommended values, as well as upper and lower bounds are recommended)
- **Hydraulics of Bridge Waterways** (Bradley, 1978) to guide the selection of appropriate loss parameters when hydraulically modelling structures such as bridges and culverts
- **Queensland Urban Drainage Manual**[3] (Natural Resources and Water, 2007) to guide the design of stormwater management infrastructure

5.7 Requirements for reporting

The draft and final report is to contain the following information as a minimum:

[3] Note, a provisional edition of the Queensland Urban Drainage Manual was published in 2013

- An Executive Summary outlining the purpose of the study as well as well methodology, results and conclusions
- Description of the study area, its catchment(s) and the history of flooding in the area
- A summary of the previous studies completed in the area and their relevance to the current study
- Description of all data collected (data and survey) and used for the study and their limitations and final ownership
- Description of the hydrologic and hydraulic analyses, including calibration and validation and assumed catchment conditions
- Presentation of results showing model fit to calibration and validation events, if applicable
- Presentation of results showing required model outputs and mapping styles
- Description of results of sensitivity analysis and model checks
- Written description of design and historical flood behaviour for a range of events for locations across the study area.

A suggestion for the naming convention for reporting is:

- **Location_Flood_Study_Report_Version_Date**

This could be used for all reportsincluding PDF and WORD documents.

- **Nagoorin_Flood_Study_Report_V1_2015**
- **Nagoorin_Flood_Study_Report_Final_2015**

5.8 Naming convention for mapping

It recommended that the Council establishes a naming convention with the consultant for mapping.

A suggestion for the naming convention for mapping is given below for all types of files such as .PDF, JPG, PNG etc and in GIS files.

- **Location_Event_Duration_Output**

Examples of the naming convention for mapping are shown below:

- **Nagoorin_AEP01_H –** Nagoorin for the 1% AEP design flood event, water surface level map
- **Gordonvale_10m_gauge123456_D** – Gordonvale for the 10m gauge level at gauge number 123456, flood depth map

Table 5-1 Example File Naming Convention

Naming Convention Subpart	Description	Example
Location	Town or study area	Nagoorin Gordonvale
Event	Either AEP design event **or** gauge height and gauge reference number	AEP01 10m_gauge123456
Duration	Duration of rainfall event	12hr
Output	Water surface level Flood depth Flood velocity Flood hazard	H D V Z

5.9 File structure for data handover

The following file structure is required to be used by the tenderer to ensure consistency of data management in the flood study.

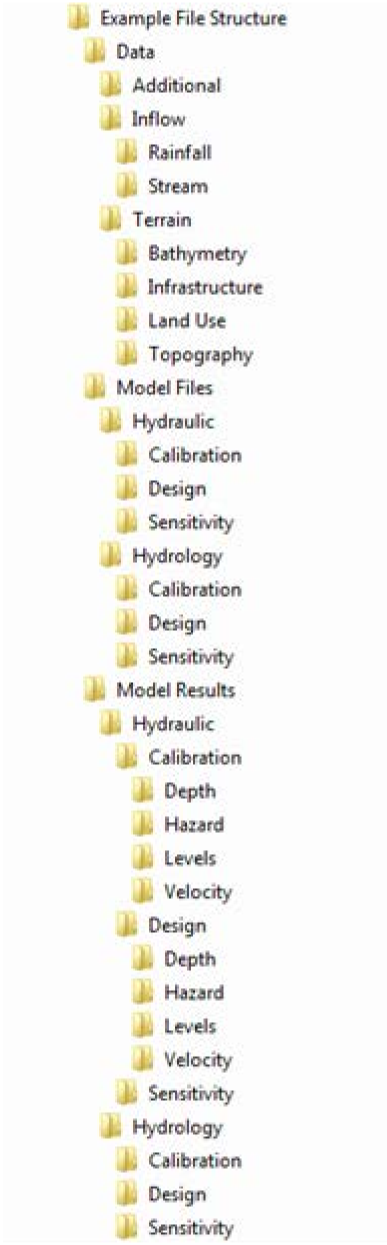


Figure 5-1 File Structure

5.10 Model output and mapping styles

Flood mapping is an essential communication and planning tool for a wide-range of end-users, particularly land use planners, emergency managers and the community. Advice has been provided below regarding important considerations for each of these end-users when identifying flood map outputs and styles and further detail is provided in Part 5 of this **Guide for Flood Studies and Mapping in Queensland**. In addition, recommended mapping styles have been provided for a range of common map types, recognising that some studies may have requirements for additional mapping beyond the styles suggested, or that there may be valid reasons for adopting alternative mapping styles (such as wanting to maintain consistency with existing map styles, greater level of detail required etc.). The map styles recommended for use include consideration of the following issues:

- What is the purpose of the map?
- Who is the intended audience of the map, particularly: are they general public or technical users?
- What content is required on the map?
- What is the required scale and complexity of the map? (this is linked to purpose)?

For additional advice on the development of fit-for-purpose flood maps, refer to the Flood Mapping Implementation Kit (the Kit). The Kit identifies nine distinct themes which make up the economic and community resilience framework. For the purposes of identifying modelling and flood mapping output styles, the themes have been classified under three broad headings:

- **Emergency management**: this includes the theme of emergency management.
- **Land use planning**: this includes the themes of land use planning, building controls, structural works, infrastructure, landscape and environment, insurance and coastal management.
- **Community education and awareness**: this includes the theme of education and information.

The following advice for model output and mapping styles are provided under the above headings.

5.10.1 Emergency Management

One of the areas which most benefits from up-to-date and fit-for-purpose flood mapping is emergency management. Flood maps can inform decisions at multiple stages of the emergency management process, including:

- Provision of flood information
- Identification of possible consequences
- Deciding objectives and strategies
- Coordination of flood response
- Transition to recovery
- Flood review.

In general, emergency management planning will seek to relate on the ground flood consequences to predicted and / or recorded flood levels at a nearby stream gauge. It is therefore strongly recommended that emergency management maps relate flood outputs directly to levels on stream gauges via two processes on the flood map:

- Mapping of flood model results at increments which directly correlate to levels on the gauge, rather than peak values. Depending on local flood behaviour, this might be e.g. at half metre increments or coarser / finer increments as warranted. Additional output levels relating to critical levels (such as development levels or levee immunity levels) are also highly valuable for emergency management purposes.

- Inclusion of a location-specific flood totem icon which shows BoM flood classifications of minor / moderate / major flood levels (if available), peak levels of historic flood (noting the date of the flood), relevant design flood levels (particularly the DFE) and levels of local landmarks (such as the local post office steps). Where flood map output relates to a particular level on the gauge, this value should also be clearly highlighted on the totem. An example flood totem is shown below.

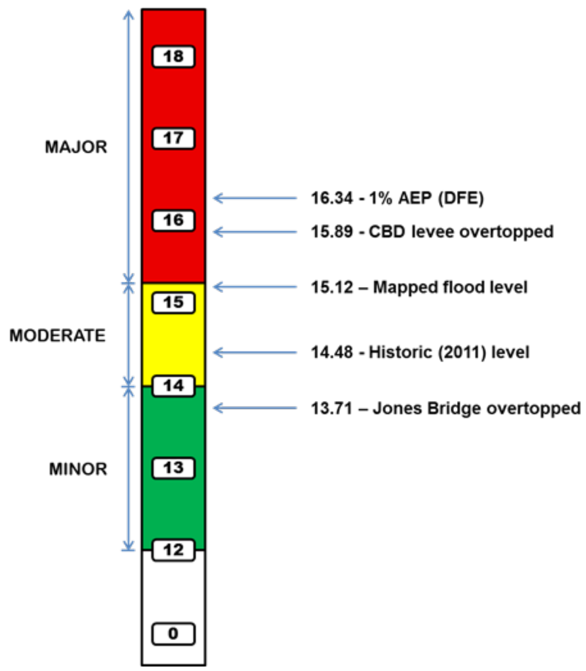


Figure 5-2 Example Flood Totem

Recommended flood mapping styles have been provided for the following flood map types:

- Emergency management – regional scale – extent
- Emergency management – local scale – velocity
- Emergency management – local scale – depth.

Table 5-2 Emergency Management – Regional Scale - Extent

Output Type	Modelled Event (s)	Suggested Inclusions	Suggested Map Style and Colour	Example
Extent	Design events, including DFE and extreme (each event size mapped individually)	Major road, rail and airport infrastructure	Design flood Solid polygon RGB: 209, 229, 240	
Extent	Nearest-sized historic event (if available)		Historic flood Line extent RGB: 255, 0, 255	

Additional notes:

Suggested transparency of flood result polygons: 30-50%

Figure 5-3 Emergency Management – Regional Scale – Extent

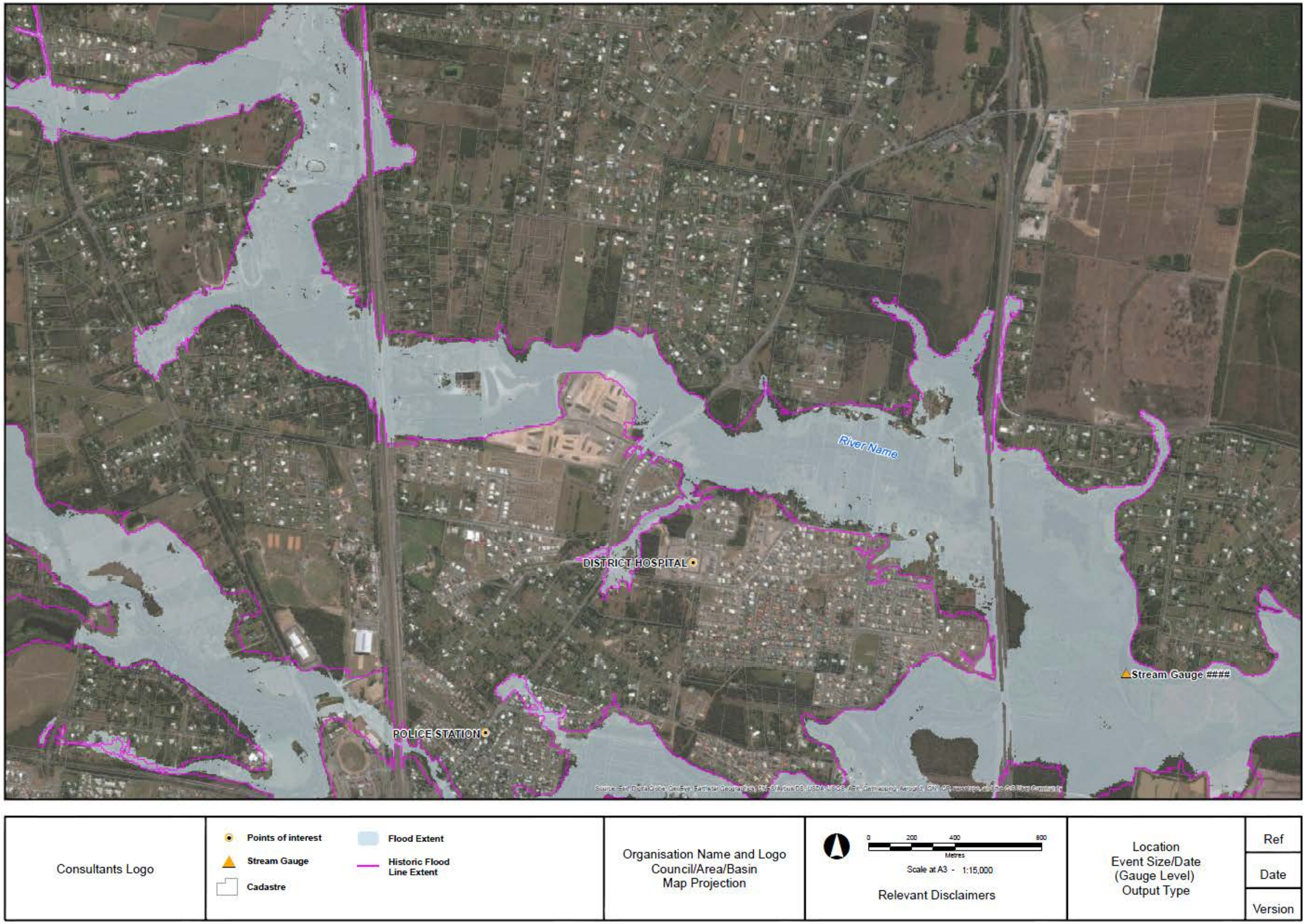


Table 5-3 Emergency Management – Local Scale - Velocity

Output Type	Modelled Event (s)	Suggested Inclusions	Suggested Map Style and Colour	Example
Velocity	Design events, extracted at regular increments and critical levels associated with the local stream gauge (if possible), else peak velocity	Critical infrastructure such as hospitals, schools, airports, power stations and rail	0 – 2km/hr Solid polygon RGB: 33, 102, 172	
			2km/hr – 4km/hr Solid polygon RGB: 103, 169, 207	
			4km/hr – 6km/hr Solid polygon RGB: 209, 229, 240	
			6km/hr – 8km/hr Solid polygon RGB: 253, 219, 199	
			8km/hr – 10km/hr Solid polygon 239, 138, 98	
			More than 10km/hr Solid polygon RGB: 174, 24, 43	
Extent	Nearest-sized historic event (if available)		Historic flood Line extent RGB: 255, 0, 255	

Additional notes:

Suggested transparency of flood result polygons: 30-50%

Include a figure of the local stream gauge totem.

Recommended velocity contours are provided in km/hr units, which are used by emergency services for swift water rescue and other emergency response planning.

The values in m/s which approximately correlate to the suggested contours are provided in Table 5-4.

Table 5-4 km/hr conversion to m/s

km/hr	m/s
2km/hr	0.56m/s
4km/hr	1.11m/s
6km/hr	1.67m/s
8km/hr	2.22m/s
10km/hr	2.78m/s

Figure 5-4 Emergency Management – Local Scale – Velocity

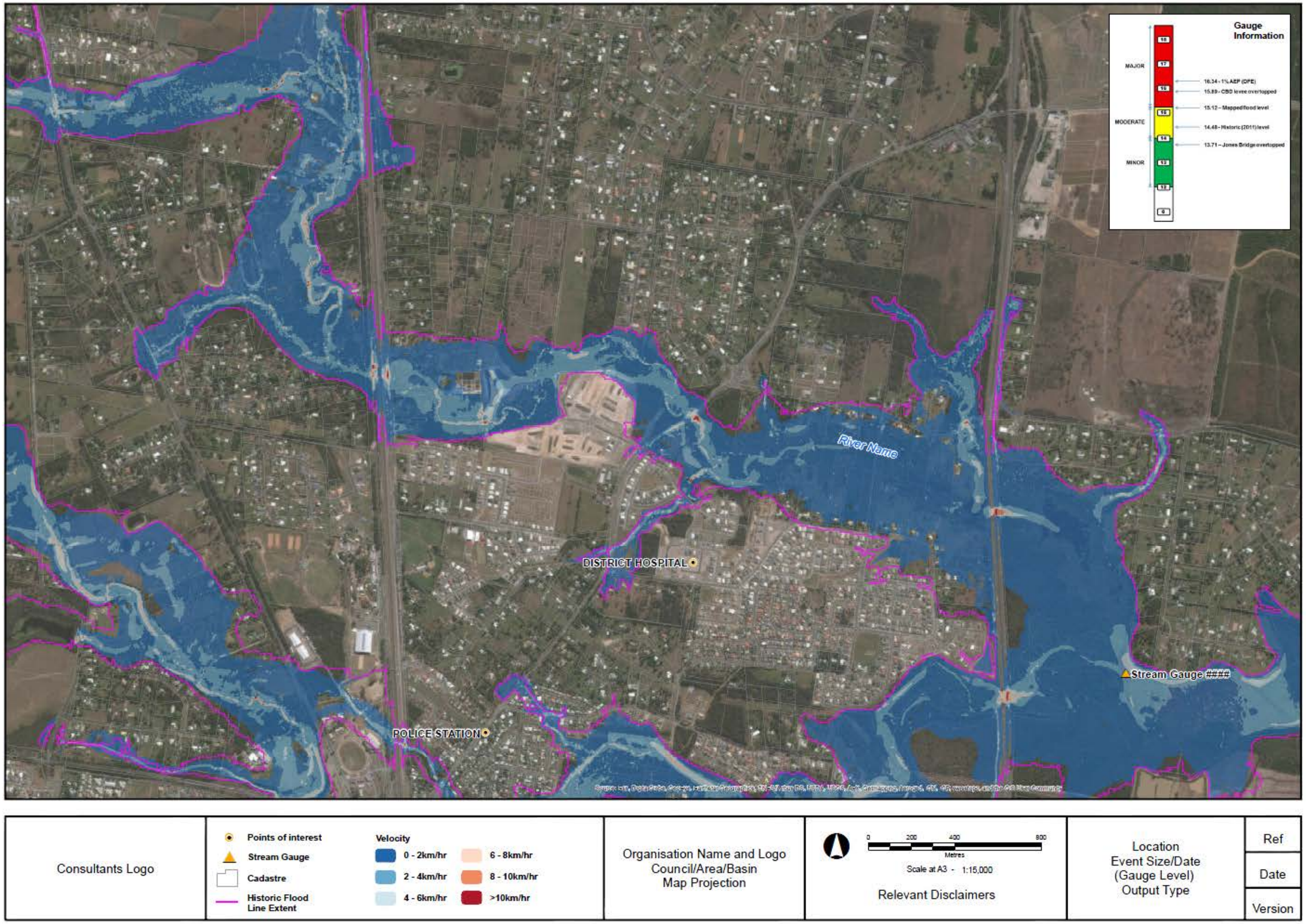


Table 5-5 Emergency Management – Local Scale - Hazard

Output Type	Modelled Event (s)	Suggested Inclusions	Suggested Map Style and Colour	Example
Flood Hazard, as defined in Handbook 7	Design events, extracted at regular increments and critical levels associated with the local stream gauge (if possible), else peak velocity	Critical infrastructure such as hospitals, schools, airports, power stations and rail	Hazard category 1 Solid polygon RGB: 143, 170, 255	
			Hazard category 2 Solid polygon RGB: 189, 231, 255	
			Hazard category 3 Solid polygon RGB: 117, 213, 142	
			Hazard category 4 Solid polygon RGB: 194, 229, 155	
			Hazard category 5 Solid polygon RGB: 255, 255, 147	
			Hazard category 6 Solid polygon RGB: 255, 176, 137	
Extent	Nearest-sized historic event (if available)		Historic flood Line extent RGB: 255, 0, 255	

Additional notes:

Include a figure of the local stream gauge totem.

Include hazard vulnerability classifications in legend, per the below table and figure.

Suggested transparency of flood result polygons: 30-50%

Hazard Vulnerability Classification	Description
H1	Generally safe for vehicles, people and buildings.
H2	Unsafe for small vehicles.
H3	Unsafe for vehicles, children and the elderly.
H4	Unsafe for vehicles and people.
H5	Unsafe for vehicles and people. All building types vulnerable to structural damage. Some less robust building types vulnerable to failure.
H6	Unsafe for vehicles and people. All building types considered vulnerable to failure.

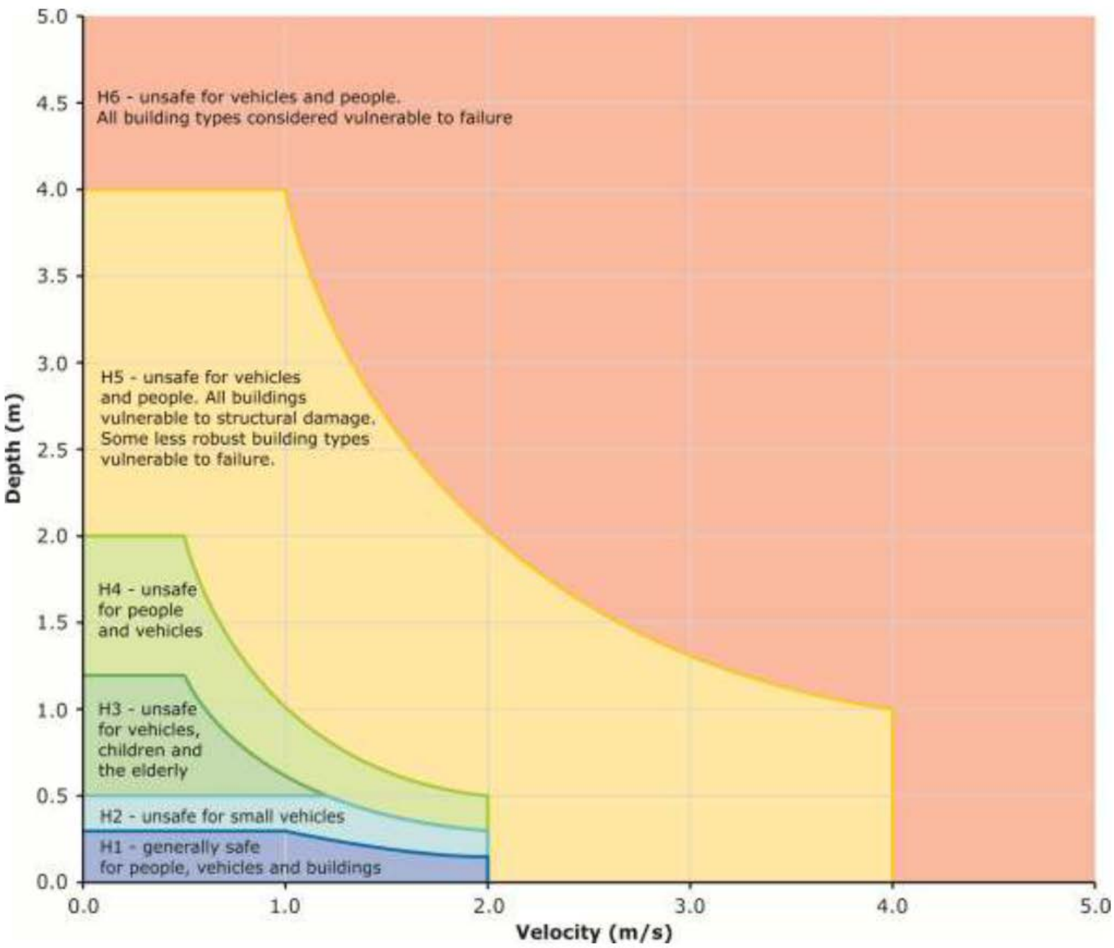


Figure 5-5 Flood Hazard Classification and Curves[4]

[4] Handbook 7: technical flood risk management guideline: Flood Hazard

Figure 5-6 Emergency Management – Local Scale – Hazard

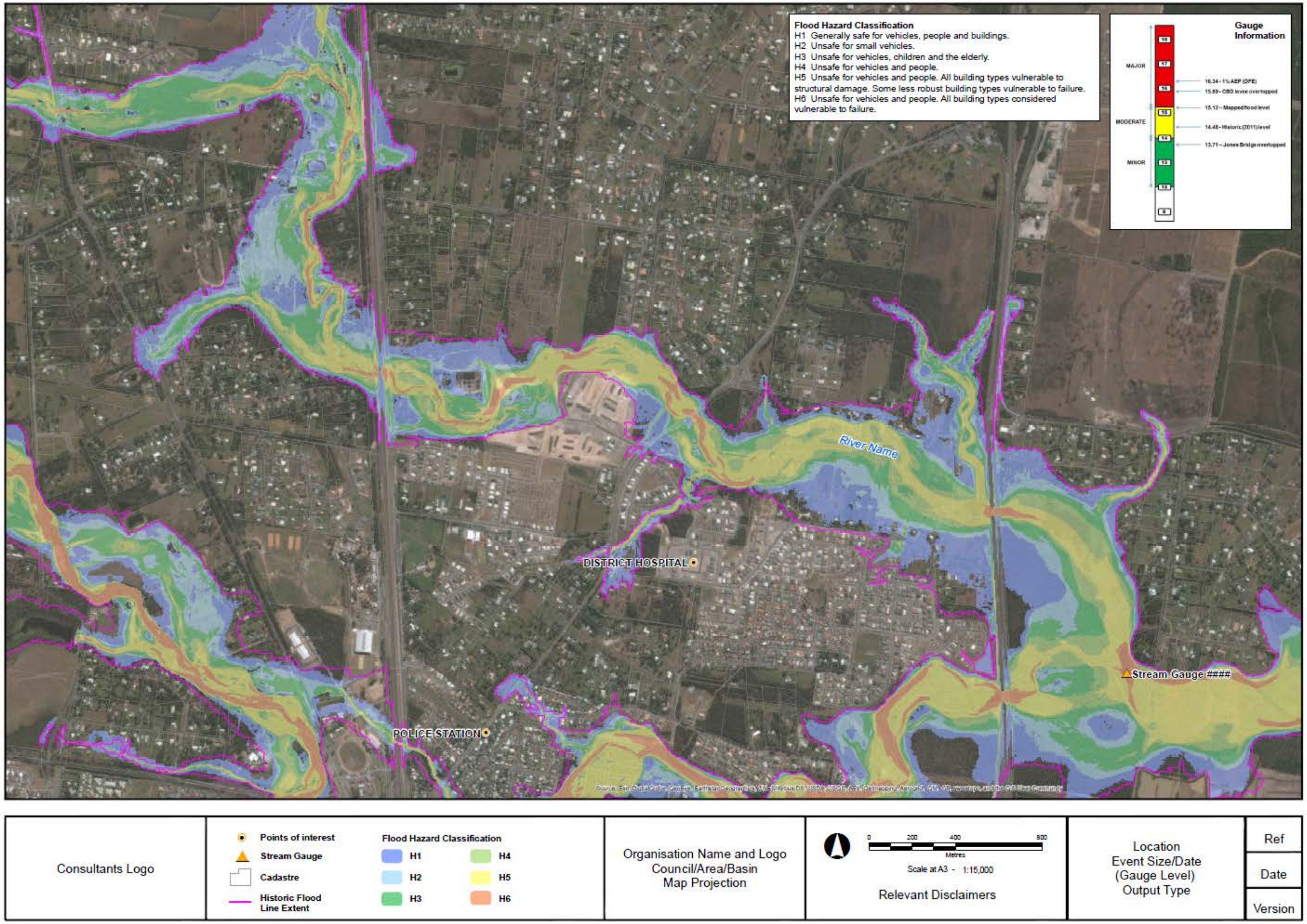


Table 5-6 Emergency Management – Local Scale - Depth

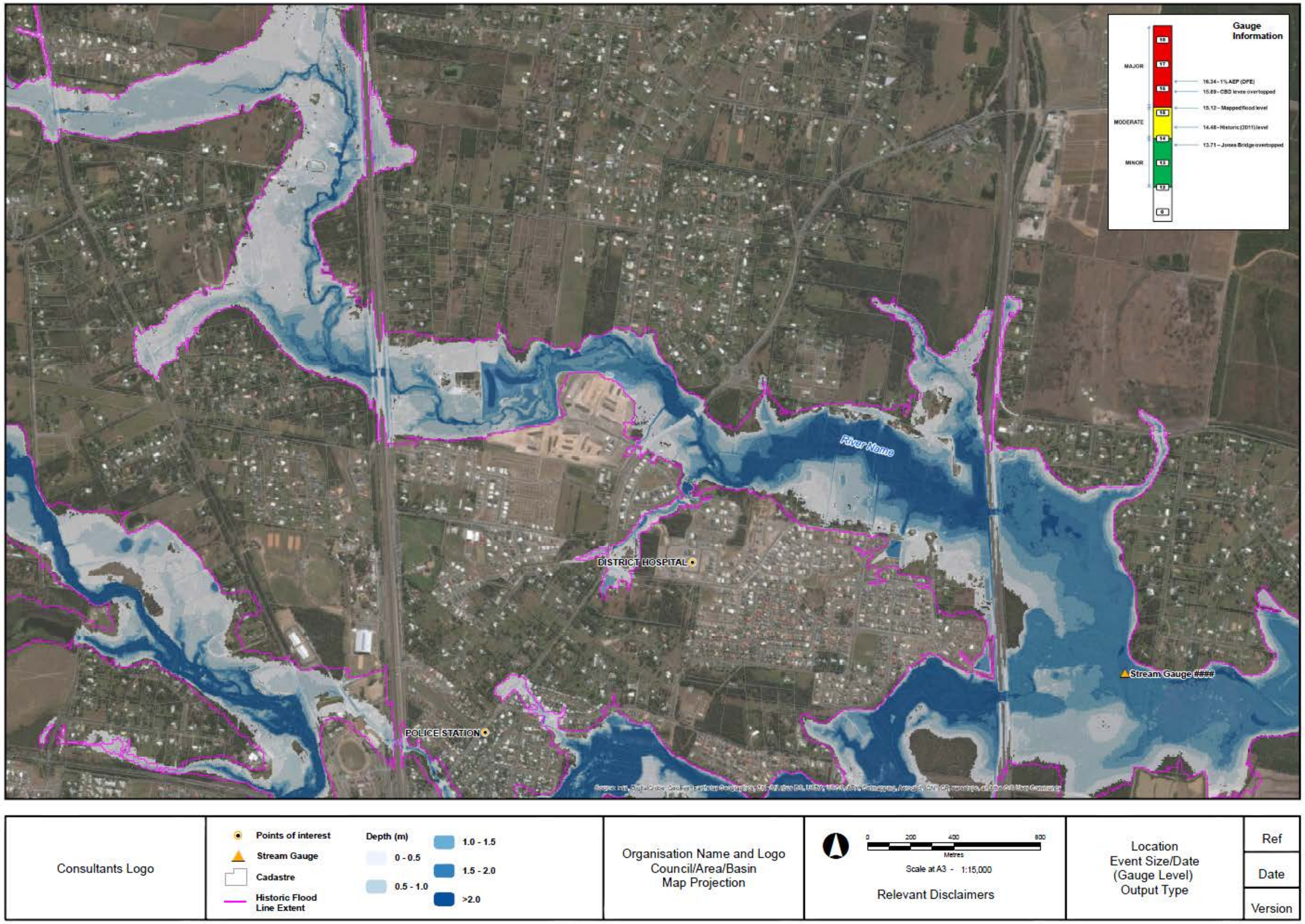
Output Type	Modelled Event (s)	Suggested Inclusions	Suggested Map Style and Colour	Example
Flood Depth	Design events, extracted at regular increments and critical levels associated with the local stream gauge (if possible), else peak depth	Critical infrastructure such as hospitals, schools, airports, power stations and rail	0.0 – 0.5m Solid polygon RGB: 239, 243, 255	
			0.5 – 1.0m Solid polygon RGB: 189, 215, 231	
			1.0 – 1.5m Solid polygon RGB: 107, 174, 214	
			1.5 – 2.0m Solid polygon RGB: 49, 130, 189	
			More than 2.0m Solid polygon RGB: 8, 81, 156	
Extent	Nearest-sized historic event (if available)		Historic flood Line extent RGB: 255, 0, 255	

Additional notes:

Include a figure of the local stream gauge totem

Suggested transparency of flood result polygons: 30-50%

Figure 5-7 Emergency Management – Local Scale - Depth



5.10.2 Land Use Planning

Flood studies can significantly improve the role of land use planning in managing flood risk. Flood study outputs, particularly mapping, is vital to appropriately and effectively support decision making around land use response.

Two general requirements for flood maps to inform land use planning have been identified:

- Statutory requirements under the State Planning Policy, namely the development of a flood hazard overlay.
- General information about design flood levels, used to inform the local planning scheme, including the selection of appropriate zoning, development and building controls, and freeboard.

Maps for the purpose of land use planning usually relate to the DFE which may be either a design or historic flood event.

This guide replicates the map style requirements as outlined in the **Queensland Planning Provisions** for the development of a flood hazard overlay. Where there is any uncertainty in the application of these styles, it is recommended that advice is sought from the Department of Infrastructure, Planning and Local Government.

Additional advice is also provided for use by the Council's land use planners. Recommended flood mapping styles have been provided for the following flood map types:

- Land use planning – flood hazard overlay requirements
- Land use planning – local scale – velocity
- Land use planning – local scale – levels.

Table 5-7 Land Use Planning – Flood Hazard Overlay Requirements

Output Type	Modelled Event (s)	Suggested Inclusions	Suggested Map Style and Colour	Example
Flood Hazard, as defined in State Planning Policy	DFE or appropriate design or historic event(s)		Further investigation Hatch in outline colour RGB: 239, 243, 255	
			Low hazard or likelihood x Solid polygon RGB: 140, 200, 255	
			Medium hazard or likelihood y Solid polygon RGB: 40, 130, 255	
			High hazard or likelihood z Solid polygon RGB: 75, 25, 255	
			Overland flow paths Solid polygon RGB: 153, 184, 255	

Additional notes:

For clarification regarding the application of these mapping requirements, contact Department of Infrastructure, Local Government and Planning.

Suggested transparency of flood result polygons: 30-50%

Figure 5-8 Land Use Planning – Flood Hazard Overlay Requirements

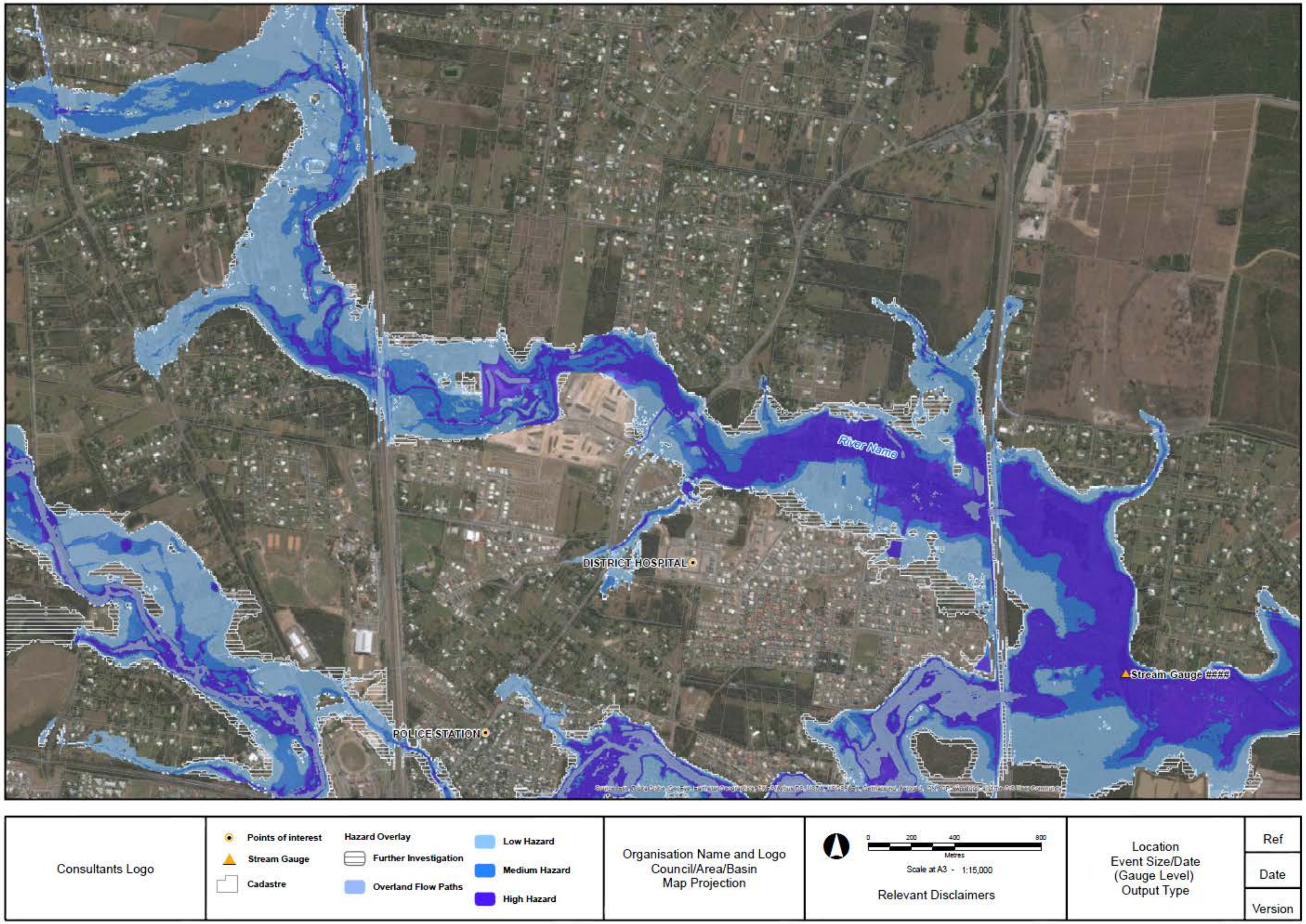


Table 5-8 Land Use Planning – Local Scale - Velocity

Output Type	Modelled Event (s)	Suggested Inclusions	Suggested Map Style and Colour	Example
Velocity	DFE		Low velocity: V<1.5m/s Solid polygon RGB: 254, 224, 210	
			High velocity: V>1.5m/s Solid polygon RGB: 224, 45, 38	

Additional notes:

The velocity threshold correlates to the velocity defined by the Australian Building Codes Board in **Construction of Buildings in Flood Hazard Areas**.

Suggested transparency of flood result polygons: 30-50%

Figure 5-9 Land Use Planning – Local Scale - Velocity

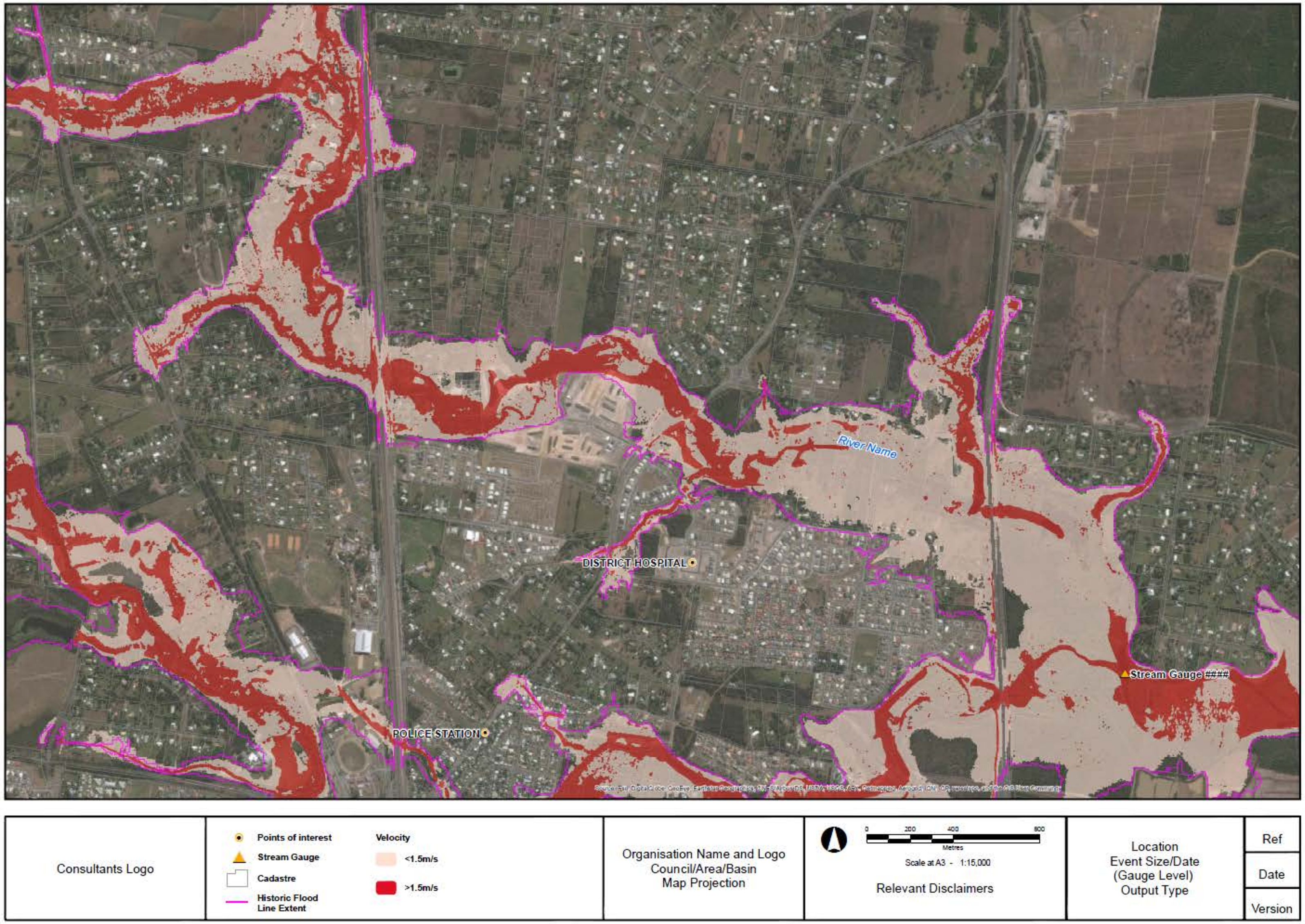


Table 5-9 Land Use Planning – Local Scale - Levels

Land Use Planning – Local Scale - Levels

Output Type	Modelled Event (s)	Suggested Inclusions	Suggested Map Style and Colour	Example
Levels	DFE	Labels on each band (in mAHD)	0.1m increments Solid polygon (alternating bands of colour) RGB: 226, 226, 226	
			0.1m increments Solid polygon (alternating bands of colour) RGB: 157, 157, 157	

Additional notes:

Suggested transparency of flood result polygons: 30-50%

Figure 5-10 Land Use Planning – Local Scale - Levels

Consultants Logo	Points of interest Stream Gauge Cadastre Flood Level (mAHD)	Organisation Name and Logo Council/Area/Basin Map Projection	0 200 400 800 Metres Scale at A3 - 1:15,000 Relevant Disclaimers	Location Event Size/Date (Gauge Level) Output Type	Ref Date Version

5.10.3 Community Education and Awareness

Community education and awareness flood maps are vital for the communication of flood behaviour and hazard to the community and are generally used for two purposes:

- To identify members of the community who are most at risk of flooding
- To provide a visual representation of possible flood consequences

In general, preparation of maps for the community should recognise that some community members can have difficulty reading flood maps and all effort should be made to convey critical information in the simplest form. Further guidance can be obtained within the **Community Engagement Framework** (Handbook 6) produced by Emergency Management Australia

Community education and information mapping will generally seek to relate on the ground flood consequences to predicted and / or recorded flood levels at a nearby stream gauge. It is therefore strongly recommended that education and information maps, including for non-English speaking, relate flood outputs directly to levels on stream gauges via two processes on the flood map:

- Mapping of flood model results at increments which directly correlate to levels on the gauge, rather than peak values. Depending on local flood behaviour, this might be e.g. at half metre increments or coarser / finer increments as warranted. Additional output levels relating to critical levels (such as development levels or levee immunity levels) are also highly valuable for emergency management purposes.
- Inclusion of a location-specific flood totem icon which shows BoM flood classifications of minor / moderate / major flood levels (if available), peak levels of historic flood (noting the date of the flood), relevant design flood levels (particularly the DFE) and levels of local landmarks (such as the local post office steps). Where flood map output relates to a particular level on the gauge, this value should also be clearly highlighted on the totem. An example flood totem is shown below.

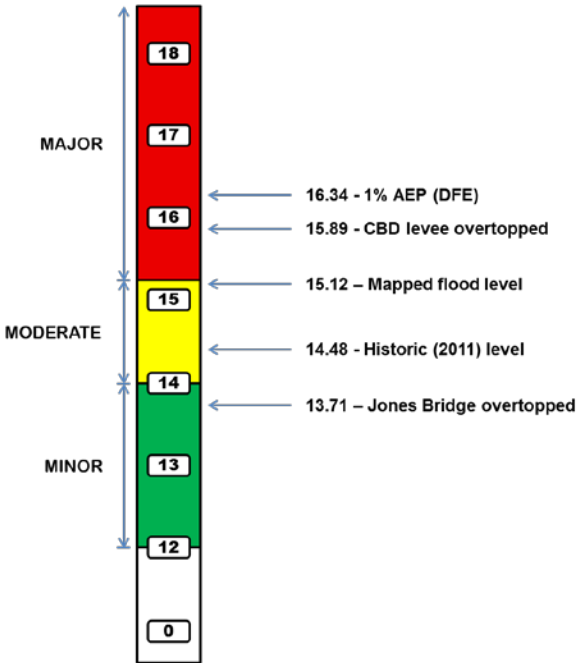


Figure 5-11 Example Flood Totem

Recommended flood mapping styles have been provided for the following flood map types:

- Community education and awareness – local scale – depth

Table 5-10 Community Education and Awareness – Local Scale – Depth

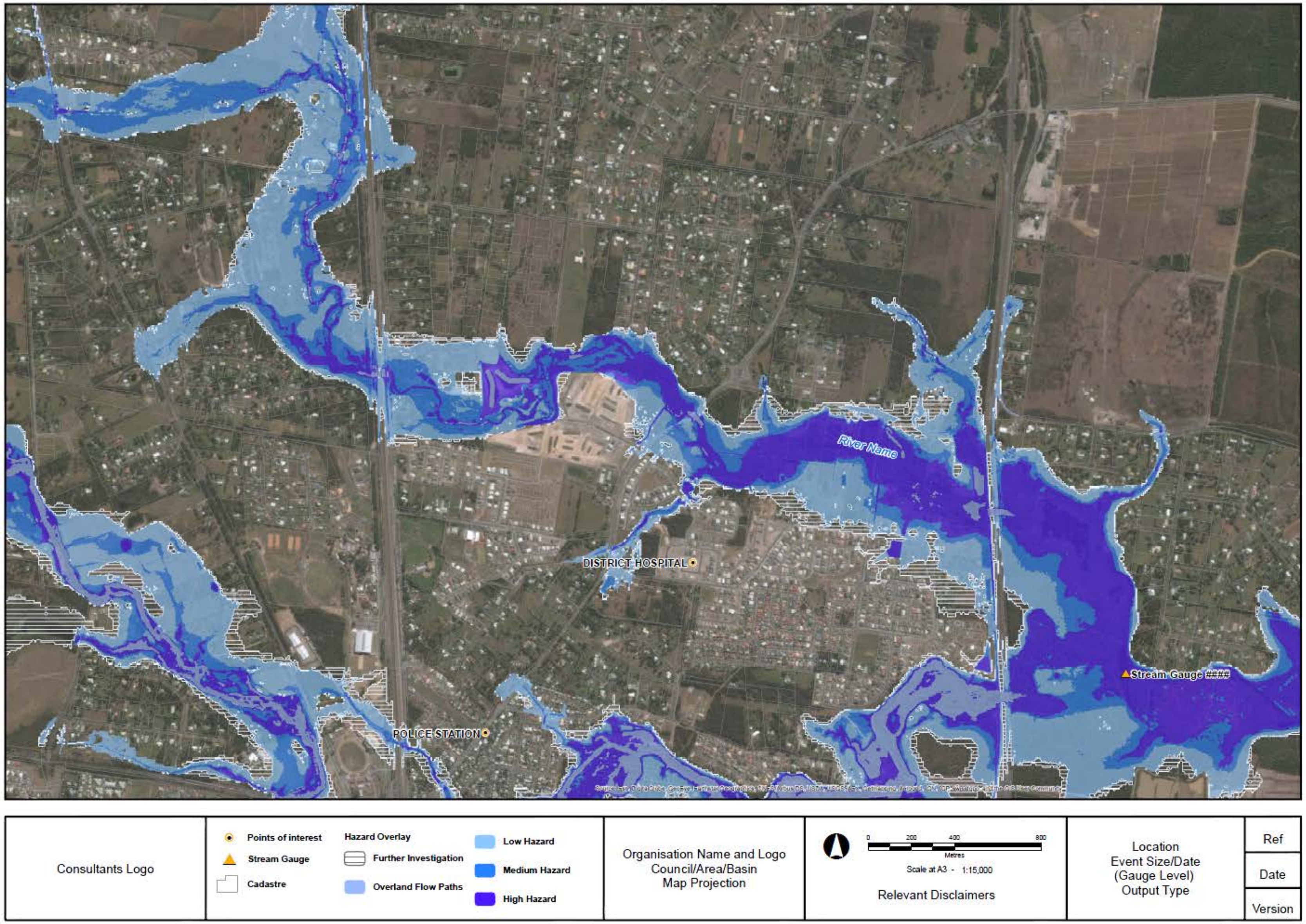
Output Type	Modelled Event (s)	Suggested Inclusions	Suggested Map Style and Colour	Example
Flood Depth	Design events, extracted at regular increments and critical levels associated with the local stream gauge (if possible), else peak depth	Critical infrastructure such as hospitals, schools, airports, power stations and rail Local landmarks and reference points	0.0 – 0.5m Solid polygon RGB: 239, 243, 255	
			0.5 – 1.0m Solid polygon RGB: 189, 215, 231	
			1.0 – 1.5m Solid polygon RGB: 107, 174, 214	
			1.5 – 2.0m Solid polygon RGB: 49, 130, 189	
			More than 2.0m Solid polygon RGB: 8, 81, 156	
Extent	Nearest-sized historic event (if available)		Historic flood Line extent RGB: 255, 0, 255	

Additional notes:

Suggested transparency of flood result polygons: 30-50%

Include a figure of the local stream gauge totem.

Figure 5-12 Community Education and Awareness – Local Scale – Depth



5.10.4 General advice on map creation

Flood maps should always be created with an end-user in mind and, in particular, consideration of whether the end-user has a technical background. Consideration of the end-user at the map concept stage will ensure that the map has an appropriate design and includes sufficient content for the intended user. In general, the best map design conveys the greatest amount of information in the shortest time, free from ambiguity. Maps should be readily interpretable and, where necessary, accompanied by a comprehensible (jargon free) explanatory note.

All flood maps should, as a minimum, include the following:

- Title of the map, making clear reference to the map content including flood event size in AEP or the historic event date, and the mapped data type (flood extent, peak level, peak velocity etc.).
- Location of the map as part of the catchment and / or state
- North arrow and scale bar (preferably using a scale bar to allow for changes in page size)
- Author / creator of the map and any limitations regarding its currency or application
- Base data for the map and date of publication.

5.10.5 Additional mapping considerations

The development of flood maps should also consider how to convey uncertainty in the mapping, whether the map will be accessible by people with colour blindness, and if the maps will be legible if printed in black and white.

Uncertainty

Flood mapping is a tool to provide information to various end-users making critical decisions about flood planning and response. To ensure that the user can make a well-informed decision, it is important that maps communicate the level of uncertainty in the flood modelling and, where possible, highlight the source of the uncertainty. In general, uncertainty in flood modelling derives from two main sources:

- **Uncertainty in the underlying data**. In some cases, such as LiDAR, the degree of uncertainty can be estimated. For other sources of data, such as anecdotal flood information, it can be very difficult to estimate how much uncertainty there is in the data. Uncertain terrain data is likely to have the biggest influence on a model uncertainty.
- **Model schematisation and parameterisation**. Hydrologic and hydraulic models are approximations of real systems and processes and, due to the approximations used during the model development, the modelled output can be uncertain. The degree of uncertainty can be somewhat quantified and potentially reduced though a successful calibration process.

To convey the model uncertainty on a flood map, it is recommended that a statement of limitation be included on flood maps which notes the source of terrain data used (and any known limitations of the data), and whether the underlying flood model has been calibrated (and if so, to how many events).

Colour blindness accessibility

Readers with colour blindness may have difficulty recognising different colour bands, particularly where adjacent mapped colours are of a similar lightness, and where red and green are mapped in adjacent regions. When developing maps, some modifications can be made to the map style to improve the accessibility of maps to readers with colour blindness, including:

- Providing a distinct contrast between foreground and background colours, e.g. between the flood results and aerial photography.
- Using thicker contour borders which are labelled directly and do not rely solely on the polygon fill colour for interpretation.
- Varying the lightness of colours used in the map, e.g. high contrast colours are more easily interpreted than colours of a similar contrast, even if the hues are different.
- Using a colour scheme recommended by the color brewer website as suitable for colour blind use.

Legibility in black and white

Although flood maps are generally designed to be viewed in colour, it should be recognised that maps will sometimes be printed in black and white. The advice provided above for colour blindness accessibility also generally applies to improving legibility in black and white. The color brewer website provides an option for 'photocopy safe' colours, which will increase the legibility of flood maps when viewed in black and white.

6 Glossary

Australian Height Datum (AHD)	The Australian Height Datum is a datum for altitude measurement in Australia
Acoustic Doppler current profiler (ADCP)	This is a current meter similar to sonar which is used to measure water current velocities over a depth range using the Doppler effect of sound waves scattered back from particles within the water column.
Annual Exceedance Probability (AEP)	The likelihood of the occurrence of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, if a peak flood flow of 500m^3/s has an AEP of 5%, it means that these is a 5% chance [that is, a one in 20 chance] of a flow of 500m^3/s or larger occurring in any one year (also see Average Recurrence Interval)
Annual Recurrence Interval (ARI)	A statistical estimate of the average number of years between the occurrence of a flood of a given size or larger than the selected event. For example, floods with a flow as great as or greater than the 20 year ARI [5% AEP] flood event will occur, on average, once every 20 years. (also see Annual Exceedance Probability).
Catchment	The area of land draining to a particular site. It is related to a specific location and includes the catchment of the main waterway as well as any tributary streams.
Defined Flood Event (DFE)	The flood event selected for the management of flood hazard to new development. Selection of DFEs should be based on an understanding of flood behaviour and the associated likelihood and consequences of flooding.
Design flood	A hypothetical flood representing a specific likelihood of occurrence (for example 1% AEP or the 100 year ARI flood).
Digital Elevation Model (DEM)	A three dimensional (3D) model of the ground surface elevation
Flood behaviour	A term used to describe the pattern, characteristics and nature of a flood, including flood levels, velocities and flows.
Flood Frequency Analysis (FFA)	This is a procedure that uses recorded and related flood data to select and fit a probability model of flood peaks at a particular location in the catchment.
Flood Risk	A term that usually embodies both likelihood of flooding and the consequences of flood
Floodplain	An area of land adjacent to a creek, river, estuary, lake, dam or artificial channel, which is subject to inundation by floodwater
Flow velocity	The speed and direction of flood, measured in metres per second (m/s) or kilometres per hour (km/h)
Geographic Information System (GIS)	Is a system designed to capture, store, manipulate, analyse, manage, and present all types of spatial or geographical data.
Hazard	A term used to describe a source of potential harm or a situation with a potential to cause loss. Flooding is a hazard which has the potential to cause damage to the community. The degree of flood hazard varies with circumstances across the full range of floods.
Historical flood	A flood that has actually occurred in the past
Hydrograph	A graph that shows for a particular location, the variation with time of discharge or water level during the course of a flood
Hydrologic model	A computer model that uses rainfall data and estimates of the proportion of the rainfall which turns into runoff and the time which the runoff from each part of the catchment takes to flow into the stream to estimate flow in the stream over time.

Hydrology	The term given to the study of the rainfall and runoff process, in particular the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods
Hydraulic model	A computer model that uses data about the flow in streams and the terrain of a particular area to estimate flood heights, velocities and flow over time. In order to do this, the hydraulic model solves the equations for the conservation of mass and momentum / energy.
LiDAR (light detection and ranging)	Is a remote sensing (airborne) technology that measures distance by illuminating a target with a laser from a fixed wing aircraft and analysing the reflected light.
Monte Carlo analysis	A Monte Carlo analysis, or probability simulation, is a technique used to understand the impact of risk and uncertainty in flood models.
One dimensional (1D) flood model	Is a flood model which is able to simulate flood behaviour along a single axis [such as within a waterway].
Planning Scheme	A local planning instrument for regulating development in Queensland.
Probable Maximum Precipitation (PMP)	Is theoretically, the greatest depth of precipitation for a given duration that is physically possible over a given size storm area at a particular geographical location at a certain time of year.
Probable Maximum Flood (PMF)	An estimate of the largest possible flood that could occur at a particular location, under the most severe meteorological and hydrological conditions.
Rating curve	Is a graph of discharge versus stage (level) for a given point on a stream, usually at gauging stations, where the flow rate is measured across the stream channel with a stream gauge.
Runoff	The amount of rainfall from a catchment that actually ends up as flowing water in the river or creek.
Shuttle Radar Topography Mission (SRTM)	Was an international research effort that obtained DEMs on a near-global scale from 56° S to 60° N, to generate the most complete high-resolution digital topographic database of Earth.
Tailwater	The static or dynamic water level at the downstream boundary of the flood model.
Two dimensional (2D) flood model	Is a flood model which is able to simulate flood behaviour in two directions [such as across the floodplain or in wide waterways]. These models are capable of providing a detailed description of the flow in urban or rural floodplains and overbank areas.