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Department of Climate Change, Energy,
the Environment and Water

Update to the Climate Change Considerations chapter in Australian Rainfall and Runoff: A Guide to Flood Estimation

Discussion Paper



ENGINEERS
AUSTRALIA

Technical Working Group

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Acknowledgement of Country

Our department recognises the First Peoples of this nation and their ongoing connection to culture and country. We acknowledge First Nations Peoples as the Traditional Owners, Custodians and Lore Keepers of the world's oldest living culture and pay respects to their Elders past, present and emerging.

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1 Introduction

The Climate Change Considerations chapter (the guidance) (Bates et al. 2019) in *Australian Rainfall and Runoff: A Guide to Flood Estimation* (ARR) (Ball et al 2019) provides ‘practitioners, designers and decision makers with an approach to address the risks from climate change’. The advice provided in the guidance was largely based on the [Working Group I contribution](#) to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) (Stocker et al. 2013) and was intended to be updated as ‘new and detailed research findings are released’.

The Department of Climate Change Energy, the Environment and Water (DCCEEW) in partnership with Engineers Australia has commenced an 18-month project funded under the National Emergency Management Agency’s Disaster Risk Reduction Package to update the *Climate Change Considerations* chapter of ARR. This update will be based on a review of the latest climate change science, together with stakeholder engagement to ensure the updated guidance meets user needs. This discussion paper presents high level guiding principles for the revision process for stakeholder feedback. This document has been developed through engagement with a Technical Working Group¹ that is responsible for developing the guidance, and a Project Control Group that is responsible for managing the update process. The authors are members of the Technical Working Group.

1.1 Overview of the role of *Australian Rainfall and Runoff*

Policy and design standards for flood risk management and infrastructure are developed by jurisdictions or industry in consideration of the context of the jurisdiction, location, type, and longevity of the decision being made. ARR supports the implementation of these policies and design standards through guidance on how to estimate the flood risk. The guidance provided in ARR is largely seen as the collective wisdom of the hydrologic engineering community, hence representing best practice in design flood estimation. This includes the development of fit for purpose hydrological and hydraulic models and the use of these models for design flood estimation.

¹ The Technical Working Group was assembled by the Department of Climate Change, Energy, the Environment and Water, in consultation with Engineers Australia, to represent a diverse range of academics, scientists, practitioners, and decision makers.

There are many examples where advice regarding the flood magnitude, and hence design flood estimation, is required (Ball et al. 2019):

- the design of culverts and bridges for cross drainage of transport routes
- understanding the full range of flood behaviour and the constraints that floods place on land management and planning
- design of minor and major urban drainage systems
- design of flood mitigation levees and other flood mitigation structures
- setting insurance premiums
- planning evacuation routes
- decisions on where to develop and setting of flood planning levels
- design of dam spillways.

For any given design or planning decision, depending on the nature of the problem, a different flood characteristic may be of the most importance. For example, it may be one or more of the following: the peak flow rate, the flood level (inundation extent), the flood volume, or the rate of flood level rise. The design flood analysis may focus on a single location (such as a bridge waterway or levee protecting a township) or consider the performance of the whole catchment as a system, as required in land use planning and urban drainage design. It is ARR that describes the methods of estimating these characteristics.

1.2 Current climate change guidance

As many decisions for which flood estimation is used have a *design life* or *effective service life*² they represent decisions that need to consider that the design flood estimate may change over an extended period of time.

Traditionally, design flood estimation has assumed that historical observations used to derive flood magnitudes are representative of current and future conditions, and hence the design flood estimate is static. However, with climate change altering both current and future conditions, and flood exceedance probabilities changing over time, there is a requirement to consider adjusting design flood estimates. The current guidance is a response to this need and provides guidance on the treatment of design flood estimates where the climate is changing over time.

² As described in Section 5.9 of *Australian Rainfall and Runoff* Book 1, Chapter 5 ('Risk Based Design'), the duration of a proposal can be considered in terms of (1) the economic service life, (2) the design service life, and (3) the effective service life. These concepts can be very different from each other, with estimates of effective service life expectancy provided in Table 1.5.2 of that Chapter.

The guidance largely draws on:

- information contained in the contribution of Working Group I (Stocker et al. 2013)
- derivation of future Intensity-Frequency-Duration (IFD) curves for Greater Sydney and South-East Queensland using 2 climate change projections for Sydney and one for Queensland.

The information in the guidance states that the 5 aspects of design flood estimation that are likely to be impacted by climate change are:

- rainfall Intensity Frequency Duration (IFD) relationships
- rainfall temporal patterns
- continuous rainfall sequences
- antecedent conditions and baseflow regimes
- compound extremes (e.g., riverine flooding combined with inundation).

The guidance focuses on changes in rainfall intensity ‘given the paucity of climate change projections for other factors that influence flood risk’ (Bates et al. 2019). Because climate model simulations of temperature have less uncertainty than those for rainfall it is recommended that a climate change adjustment factor that is proportional to temperature be applied to IFD rainfall bursts. The guidance states that ‘the expected change in heavy rainfalls is between 2%/°C and 15%/°C’ and given the uncertainty and regional variability in potential rainfall increase it is recommended to increase the design rainfall by 5%/°C of warming’.

The guidance provides a decision tree that shows the climate change adjustment factor only needs to be used where the infrastructure service life is long, and consequences of failure are medium to high. The climate change adjustment factor is applicable for events ranging from the annual maxima to the 1% AEP (Annual Exceedance Probability) with a recommendation to use a Representative Concentration Pathway RCP-4.5 and only consider the high concentration pathway of RCP-8.5 where the additional expense can be justified. Finally, the guidance recommends that design which factors in climate change should only be adopted if the cost of modifying the design is low compared to the associated benefits.

1.3 Purposes of this document

This document is intended to frame the update of the guidance and serve as a foundational document for consultation with stakeholders. It provides proposed principles to update the chapter that best reflect the available science as well as user needs.

The Technical Working Group will combine feedback on this discussion paper obtained through a survey on the Have your Say website with peer-reviewed science to update the *Climate Change Considerations* chapter of ARR.

The short online survey covers the questions highlighted in this document, as well as optional questions about use of the current guideline.

You will have an opportunity to provide feedback on the draft update later in 2023, before the document is finalised in the first quarter of 2024.

More information on how to make a submission is at the end of this discussion paper.

2 Update to the Climate Change Considerations chapter (the guidance)

2.1 Stakeholder perspectives on current guidance

To understand the basis for the proposed guiding principles for the update, context needs to be established by understanding user experiences as they relate to the guidance. These experiences were initially elicited based on the collective experiences of the Technical Working Group and Project Control Group.

User groups can be divided into two distinct categories (1) *end users*: those responsible for representing the interests of their stakeholders. A non-exhaustive list of *end users* includes government regulators, floodplain managers, asset owners (e.g., roads, drainage networks, dams), insurers, decision agencies, policy makers and the like, and (2) *next users*: those responsible for application of ARR for flood estimation (i.e., engineering practitioners).

An example of the relationship of these users to ARR is of a government agent (*end user*) obliged to advise their stakeholders to consider climate change. This is often defined through a standard such as the 1% annual exceedance probability event, or across a range of exceedance probabilities as would be required for a risk-based assessment. The *end user* increasingly requires climate change to be considered in their decision making, for which the *next user* applies the *Climate Change Considerations* for their design flood estimation techniques. Based on interviews undertaken in the preparation of this discussion paper, there is a strong sentiment from both the *end user* and *next user* that the guidance may not be aligned with the best available science.

From the position of the *next user*, based on the interviews that were undertaken there is also an overwhelming sentiment that ARR is cumbersome to apply. ARR not only contains guidance on design flood estimation, but also reflects the science upon which the guidance is founded. The result is that ARR can be difficult to understand and interpret: some aspects can only be applied by highly specialised experts. This means that the guidance in ARR is not always adopted, or when adopted, it is not adopted consistently – and this is also true of the guidance.

Decision makers often have a legal and/or other duty of care to their stakeholders to consider climate change, but there is little information on how to consider climate change in design flood estimation. As a result, practitioners feel ‘hamstrung’ by the guidance that is currently provided, and decision makers are concerned that the latest science is not always being appropriately applied in policy outcomes.

Do you broadly agree with this statement?

Please provide further comments.

2.2 Proposed guiding principles for the update

Based on the above reflections, the following 5 principles are proposed to guide the update of the *Climate Change Considerations* chapter of ARR. Each principle is explained further below.

Summary of proposed guiding principles

- 1) Reflect contemporary science.
- 2) Be practical and easy to use.
- 3) Be consistent and comprehensive.
- 4) Acknowledge that climate science continues to evolve and provides opportunities to incorporate new lines of evidence.
- 5) Reflect best practice in communicating language around uncertainty and risk to better reflect community needs.

1. The guidance reflects contemporary science

The recommendations in the guidance summarised the latest scientific understanding at the time and was based on literature published prior to 2012 (Stocker et al. 2013). Hence the current guidance is based on science that is over a decade old. Since that time significant scientific advancements have been made, particularly in the understanding of changes to extreme weather events, with increased recognition changes to the drivers of flood risk are being observed in the instrumental record. Hence, any update to the guidance should reflect a synthesis of the best available science, with the scientific basis both accessible and well documented.

2. The guidance is practical and easy to use

There is a critical distinction between guidance to inform design flood estimation, and the scientific evidence on which such guidance is based. The current ARR document is perceived to be overly long because it combines the scientific basis for guidance with the guidance itself. The updated version of *Climate Change Considerations* should consider next-user and end-user needs in terms of ease of application, the need to minimise ambiguity and potential for misinterpretation, the development of appropriate representations of uncertainty, and so forth. This also will ensure equity in application for *next users* in applying the *Climate Change Considerations* so that those without expert knowledge of the climate science are not dissuaded from use of the guidance.

The current guidance can be difficult to understand and interpret.

Do you agree with this statement?

Do you have any recommendations to enhance accessibility to next users or other audiences?

3. The guidance is consistent and comprehensive

There are a broad range of application areas for the guidance by *end users*, and there are also many methods used by *next users* for design flood estimation, including flood frequency analysis, rainfall-routing of design rainfall, continuous simulation, and Probable Maximum Precipitation (PMP) methods. Further, there are also multiple decision frameworks that might be used by both *next* and *end* users in applying design flood estimates. These may be the use of flood design standards (e.g. 1% AEP event + 500 mm freeboard), qualitative and quantitative risk assessment methods such as described by AS/NZS ISO 31000:2018 and various other documents, or methods specifically designed to support risk management in the face of changing risk profiles, such as the use of adaptive pathways. Any guidance therefore needs to recognise and support the diversity of application areas, risk assessment methods and decision frameworks, while maintaining consistency between those areas.

4. The guidance should acknowledge that climate science continues to evolve, and provide opportunities to incorporate new lines of evidence

While the climate science as it pertains to flood risk has matured considerably relative to the science used to inform the current guidance, it can be anticipated that the evidence of the impacts of climate change will continue to evolve. Moreover, addressing recommended guidance provided in ARR may not always be sufficient to meet an appropriate standard of care; there may be additional concerns that should be addressed due to local influences, new and emerging risks, or documented evidence in best practice or common law that more should be done. Hence, there needs to be an acknowledgement that improved methodologies of undertaking design flood estimation under climate change, as well as new lines of evidence, may develop, and the guidance should provide key considerations to be taken into account when incorporating new lines of evidence, to ensure that rigorous scientific standards are preserved.

5. The guidance should reflect best practice in communicating language around uncertainty and risk to better reflect community needs

The revision of ARR in 2019 made a concerted effort to improve the communication of risk. It moved away from the use of Annual Recurrence Intervals (i.e., 100 year) which is often interpreted as implying that the associated event magnitude is only exceeded at regular intervals, towards the use of Annual Exceedance Probabilities (i.e., 1%), the probability of an event being equalled or exceeded within a year. This terminology however remains problematic with the general community as it is not always well understood or appreciated and does not reflect the true risk over the lifetime of an asset. Compounding issues with current risk terminology is that climate change is changing the flood risk, and the use of any such terminology implies that the risk is static. Future flood advice, including that of the guidance, needs to explore different avenues of communicating risk to aid outcomes that better reflect community needs.

Do you agree with the proposed guiding principles?

Please provide any further comments on the proposed guiding principles.

Are there any guiding principles missing?

2.3 Proposed key considerations for the update

Reflecting the above principles, the following proposed key considerations for the update of the guidance have been developed for stakeholder feedback. Each consideration is explained further below.

Summary of the Key Considerations:

- 1) Separate the guidance and the scientific evidence.
- 2) Use language to highlight the increased confidence of the impacts of climate change on design.
- 3) Ensure climate change is adopted in design flood estimation consistently for both current and future climate conditions by enabling a range of decision making approaches.
- 4) Ensure climate change adjustment factors informed by current scientific understanding.
- 5) Provide appropriate climate change adjustment factors from the annual maxima up to and including the PMP.
- 6) Provide guidance on best practice for adopting climate change for all methods of design flood estimation.
- 7) Treat uncertainty consistently with non-climate change elements of ARR guidance.
- 8) Consider the flood causing mechanism when incorporating climate change.
- 9) Evaluate updated guidance across large samples and be scientifically robust.

1. Separate the guidance and scientific evidence on which such guidance is based

It is proposed that the scientific basis for the guidance be contained in a separate document that has undergone scientific peer review, such as that available in the publishing of a journal article, and that the updated guidance chapter references the document that contains this scientific basis. A user would then be able to seek additional information with all the scientific evidence on which the guidance is based contained in a single document in the public domain. The scientific basis should convey the consensus between multiple scientific lines of evidence using confidence and likelihood statements consistent with the scientific standards to ensure confidence in the science on which the guidelines are based. On the other hand, the guidance—while being based on best-available science—should also consider issues such as ease of use (Principle 2), communication issues (Principle 5) and so forth, which are not purely scientific in nature.

2. Use language that conveys the confidence of climate science as it relates to flood risk

Although the guidance does not bind *end users* in how climate change is considered, the language in the guidance carries significant weight in decision making. Currently, anecdotal evidence suggests that the guidance is frequently being interpreted as an optional consideration, and hence give little weight for incorporation of climate change by *end users* in decision making. The language in the guidance should reflect the increased confidence and maturity of the impacts of climate change on design flood estimation.

3. Ensure climate change is adopted in design flood estimation consistently for both current and future climate conditions by enabling a range of decision-making approaches

The guidance currently suggests that climate change only be considered if the service life is long, and the consequences of failure are high. It recommends using RCP-4.5 and ‘where the additional expense can be justified’ to use RCP-8.5. This implies that climate change considerations only pertain to a small subset of decisions such as the design of critical infrastructure. Moreover, the decision tree provided in the guidance for adopting climate change in design does not reflect the current understanding that climate change effects are already being experienced, and thus are not solely a matter of future risk. To ensure consistency, climate change should be considered for all current and future design flood estimates, with best estimates of the current and future impact of climate change informed by the scientific basis.

The current guidance provides a decision tree that shows the climate change adjustment factor only needs to be used where the infrastructure service life is long, and consequences of failure are medium to high. However, there are many decision-making approaches available for addressing uncertainty and changing risk profiles over time, and the guidance should provide the enabling information on flood risk to support a range of decision-making approaches.

What decision-making approaches should the updated guidance recognise and support to ensure that the guidance be considered for all current and future design flood estimates?

4. Ensure the climate change adjustment factors to reflect current scientific understanding

Unless climate change is explicitly considered in developing design flood estimates (for example through non-stationary IFD curve development), updating historical data with the most recent observations will not provide design flood estimates consistent with future climate change, meaning the use of climate change adjustment factors will remain necessary. There is evidence that, with increasing temperatures, shorter duration rainfall extremes are projected to increase more than longer duration rainfall due to the different process that govern short and long duration rainfall extremes. For short duration extremes (relevant to flash flood events), the observed and projected increases are considerably greater than 5%/°C. There is also evidence that more extreme rainfalls with lower AEPs will increase more in a future warmer climate than those more frequent extreme rainfalls with higher AEPs. Hence, the climate change adjustment factors may need to be updated and may need to differ with storm duration and AEP.

5. Provide consistent guidance across the AEP spectrum

The 5%/°C climate change adjustment factor in the guidance only applies from the annual maxima to the 1% AEP. However, design flood estimation is often undertaken across the AEP spectrum up to and including the PMP, with the latter often used for floodplain delineation, and the consideration and management of residual risk. Extreme events are projected to increase, with greater increases for more extreme events, up to a plateau for the most extreme events. For spanning across the range of AEPs considered in design, and for consistency with current science, the guidance should provide appropriate climate change adjustment factors from the annual maxima up to and including the PMP.

6. Provide guidance that is relevant to all design flood estimation methodologies

The 5%/°C climate change adjustment factor in the *Climate Change Considerations* only applies to IFD curves, but other design methods such as continuous simulation are also used for design flood estimation. The *Climate Change Considerations* currently do not give recommendations for how to consider climate change for all the methodologies of design flood estimation that are provided in ARR. Where scientific evidence exists, the *Climate Change Considerations* should provide guidance on best practice for adopting climate change for all methods of design flood estimation.

What methodologies of design flood estimation should the *Climate Change Considerations* chapter provide best practice guidance for?

7. Treat uncertainty consistently with non-climate change elements of Australian Rainfall and Runoff

Whilst some level of uncertainty associated with climate change is inevitable, there is also significant uncertainty associated with other aspects of design flood estimation (e.g. IFD curves, rainfall-runoff modelling, flood-frequency analysis). Where uncertainty in the climate change projection is provided, the uncertainty due to climate change should not be considered in isolation from the other sources of uncertainty in the design flood estimate. Rather, for situations where epistemic uncertainty³ in the flood estimate is considered (e.g., due to the uncertainty in the design rainfall), a consistent approach should be applied for all key sources of uncertainty.

Separate projections and associated uncertainty bounds should be provided for low and high emissions scenarios.

8. Consider the flood causing mechanism when incorporating climate change

The design flood estimate is impacted by various components of the design flood (rainfall intensity, temporal pattern of rainfall, antecedent conditions, and tail water conditions, to name a few). Although rainfall intensity is the key input into design flood estimation, other changes – such as changes to antecedent conditions or sea level rise – may also need to be considered depending on the flood mechanism. The flood mechanism in turn will vary with the design problem, the geographical location, as well as catchment characteristics. The guidance chapter should list the key inputs into the design flood estimation calculations that are affected by climate change and (1) indicate whether the

³ Epistemic uncertainty is uncertainty due to a lack of knowledge or information. In the context of climate change, this includes uncertainties associated with how climate change influences flood risk, uncertainties in specific projections per level of global warming, and uncertainties due to future emissions and associated levels of warming. Other uncertainties in flood estimation not directly associated with climate change include uncertainty in the baseline IFD estimates, uncertainty in rainfall/runoff model parameters and so forth.

changes are significant enough to alter the design flood estimate, and (2) explicitly state whether there is enough scientific understanding for factoring the historical (baseline) values. This includes changes to sea level rise which are relevant to estuarine flooding and are currently not discussed in the guidance. Where appropriate, the guidance should refer a *next user* to other documents for updated methods or climate change adjustment factors.

9. Evaluate updated guidance across large samples and be scientifically robust

Australia's climate is not homogenous and the mechanisms causing flooding around Australia differ. The guidance in ARR in some instances was based on science that was relevant to the study area or study of interest. For example, the report which accompanies the guidance only considered 2 study regions (Greater Sydney and South-East Queensland) and only a single global climate model-regional climate output pairing. It is recommended that updates to methods provided in ARR are based on (1) multiple lines of evidence including observations, modelling and physical process knowledge (2) consider the spatial and temporal variability in Australia's climate, and (3) evaluate the guidance on a wide range of catchments with long term flood records. This is consistent with 'hierarchy of evidence' frameworks for evaluating evidence from scientific studies, whereby evidence from synthesised assessments is generally considered to be stronger than evidence from individual studies in isolation. It is noted that this approach should not only be undertaken in revising *Climate Change Considerations*, but also be recommended in the guidance to support *next users* who wish to evaluate additional studies that may be locally applicable to a particular context.

Do you agree with the proposed key considerations?

Please provide further comments on the proposed key considerations.

Are there any key considerations missing?

Make a submission

We are seeking input to update the *Climate Change Considerations* chapter (the guidance) of *Australian Rainfall and Runoff: A Guide to Flood Estimation (ARR)*.

Both the scientific and engineering community recognise that the guidance is based on science that is now over a decade old. The Department of Climate Change Energy, the Environment and Water (DCCEEW) in partnership with Engineers Australia has started a project funded under the National Emergency Management Agency, Disaster Risk Reduction Package to update the *Climate Change Considerations* chapter of ARR.

We have developed draft guiding principles and key considerations for this update and would like your feedback so that the update reflects the needs of users and anyone else with an interest in the guidance.

The project team will combine your input on the guiding principles and key considerations with peer-reviewed science to update the guidance. You will have an opportunity to provide feedback on the draft replacement *Climate Change Considerations* chapter later in 2023, before the document is finalised in the first quarter of 2024.

Have your say

- Use this [link](#) to answer questions.
- You will need to register or sign in to participate. Read our privacy notice before you register.
- Before you share your feedback, read this discussion paper.
- We have included questions for you to consider. You may address all or some of these, or provide more general comments.
- Ensure you provide your feedback by 5 pm (AEDT) on 19 June 2023.

Next steps

Your ideas will help us to incorporate user needs into the update of the *Climate Change Considerations* chapter of ARR. We may contact you to seek more information about your submission.

The Technical Working Group will combine your input with peer-reviewed science to update the *Climate Change Considerations* chapter of ARR.

You will have an opportunity to provide feedback on the draft update later in 2023, before the document is finalised in the first quarter of 2024.

Contacts

For information about the update of the *Climate Change Considerations* chapter of *Australian Rainfall and Runoff: A Guide to Flood Estimation* please email climate.science@dcceew.gov.au.

References

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