Guidance on Flood Recovery, Bridge Assessment and Risk Management

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| **Abstract**  The objective of Austroads project ABT1925 is to develop new guidelines for flood response, bridge management and operational requirements during extreme weather events. The project will produce a new Austroads guideline for flood recovery, assessment and risk management for bridges and an update to the Austroads Guide to Bridge Technology Part 8: Hydraulic Design of Waterway Structures (AGBT08)1 to incorporate best practice for managing the risk of bridge flooding and scour and improving resilience to flooding.  This paper will highlight the development of a scour risk assessment method, detailed scour impact evaluation and operational requirements during extreme weather events as developed for the Austroads project.  The development of the scour risk assessment includes the evaluation of the current state of local industry practice, focusing on commonalities and disparities in the scour risk management approach to establish vulnerability criteria, methods and guidelines that will determine the scour potential and risk prioritisation for each bridge.  The detailed scour impact evaluation aims to quantify the scour impact to establish appropriate mitigation measures through flow estimations, scour depth predictions, intervention and treatment options. It incorporates the 2019 Australian Rainfall and Runoff Guideline2 and the updated Austroads Guide to Road Design Part 5: Drainage – General and Hydrology Considerations3 (Australian Rainfall and Runoff Alignment).  The operational requirements during extreme weather events involve a broad review of local and international learnings for flood response, best industry practice and stakeholder consultation with transport agencies, network operators and owners and address the operational management of bridges during and post-flood events. It also involves a review of government strategies and policies that addresses resilience of infrastructure to environmental changes, emergency response and disaster management operations of critical infrastructure.  **Keywords:** Flood, Bridges, Scour, Risk, Management |

# Background

There is an increasing focus on the need for enhancing the resilience of bridge infrastructure during severe flood events. Australia has experienced recurring cycles of extreme weather events which has had significant and far reaching social, financial and economic costs. The resilience of roads and bridges is critical in post-disaster response operations and recovery. Damage to bridge structures has an adverse impact on the reliability of the road network and amplifies the vulnerability of the communities significantly.

Austroads recognised the need to evaluate the influencing factors which impact the resilience of bridge structures including scour prediction, scour risk evaluation and management of network operations during and post-flood emergencies. Austroads therefore initiated a project to produce a new Austroads guideline for flood recovery, assessment and risk management for bridges and an update to the Austroads Guide to Bridge Technology Part 8: Hydraulic Design of Waterway Structures (AGBT08)1 to incorporate best practice for managing the risk of bridge flooding and scour and improving resilience to flooding. The update incorporates the 2019 Australian Rainfall and runoff guideline and the updated Austroads Guide to Road Design Part 5: Drainage – General and Hydrology Considerations3 (Australian Rainfall and Runoff Alignment). The guideline will reference AGBT081 for technical scour aspects.

This paper highlights key aspects considered during the development of the guideline which is in draft at the time of writing this paper.

# Purpose of the guideline

The purpose of the guideline is to provide a structured framework for managing bridge infrastructure resilience in the context of flood events. This document is being developed in response to increasing flood-related damage and failures observed in bridge structures, particularly those vulnerable to scour and high-flow conditions.

The guideline addresses these vulnerabilities by establishing best practices for inspection, monitoring, risk assessment and operational management of bridges. Specifically, the guideline aims to equip engineers, asset managers and decision-makers with actionable strategies for preparing, protecting and restoring critical infrastructure in flood-prone areas.

# Methodology used to develop the guideline

The guideline development was based on:

* A comprehensive literature review to gather existing knowledge on scour risk assessment, hydraulic modelling and structural integrity monitoring. Relevant guidelines from Australian and international transport and infrastructure managers were reviewed to identify effective procedures for bridge management during flood events.
* Stakeholder consultation with Austroads member agencies to ensure the guidelines reflect the current best practice.

# Flood impacts on bridge infrastructure

Flood events are significant natural hazards that can lead to multiple forms of damage to bridge infrastructure, primarily due to the interaction of hydraulic forces with structural elements. Fast-moving floodwaters, debris carried by the flow, and sediment erosion create complex hydraulic conditions that bridges must withstand. Understanding these damage mechanisms is crucial for bridge management, particularly as climate change increases the frequency and intensity of extreme weather events in Australia and globally (Austroads 2019)1.

## Impact of hydrodynamic forces

Floodwaters generate a variety of hydrodynamic forces that place immense pressure on bridge elements such as piers, abutments and decks. These forces vary depending on water velocity, flow depth and the overall geometry of the bridge structure (Fwa 2005)4. The following outlines the key mechanisms through which floodwater can compromise bridge performance:

* Hydraulic loads: Lateral forces are exerted by the moving water, particularly where flow velocities are high. The water exerts significant pressure on piers and abutments, pushing against these structural elements. In addition, hydrodynamic uplift occurs as water flows under bridge decks, potentially lifting the deck off its supports if the forces exceed the designed load capacity. This risk is particularly high during flash floods, where rapid changes in water levels create unpredictable hydraulic pressures (Austroads 2019)1.
* Scour: One of the most critical mechanisms of flood damage is scour, which refers to the erosion of the soil or bed material around bridge foundations due to fast-moving water. Scour is the leading cause of bridge failures globally (Arneson et al. 2012)5, as it can rapidly undermine foundations, leaving piers or abutments unsupported. In the Australian context, where many rivers and waterways experience high sediment transport during floods, the risk of scour is particularly pronounced. As floodwaters erode the surrounding material, the structural stability of the bridge is compromised, often leading to collapse if not properly managed.
* Abutment/embankment material: In addition to scour, inundation of abutment/embankment material may cause a reduction in soil strength, dispersion and volume area change depending on the material properties. Queensland Department of Transport and Main Roads’ Manual Geotechnical Design Standard – Minimum Requirements (2024)6 and MRTS04 General Earthworks (2023)7 therefore provide guidance on material selection for inundated embankments.

## Impact of debris accumulation

Floodwaters frequently carry large amounts of debris, including tree branches, vehicles and other materials dislodged by the flood. As this debris is swept downstream, it can impact bridge piers, abutments and decks with significant force, causing direct damage. Moreover, debris can accumulate against bridge structures, blocking openings and increasing the water pressure upstream. This creates a backwater effect, where water levels rise behind the obstruction, intensifying the lateral hydraulic load on the bridge elements (Melville & Coleman 2000)8. In extreme cases, debris accumulation can lead to complete blockages, causing water to flow over the bridge deck and abutments, further exacerbating structural stress on the structure and/or eroding the abutments.

## Structural failure modes

The combined effect of hydrodynamic forces and debris accumulation can lead to several failure modes during flood events. These failures compromise the safety and functionality of the bridge, often necessitating significant repairs or even reconstruction. The following outlines some of the most common failure modes observed during floods:

* Deck displacement: Floodwaters flowing over the bridge deck or exerting lateral pressure beneath it can cause deck displacement. This occurs when the deck is lifted off its bearings or shifted horizontally due to the uplift forces or high lateral pressures. Deck displacement is a common cause of bridge closure during floods, as it can lead to immediate instability (Austroads 2019)1.
* Abutment washout: As floodwaters erode the material around the bridge abutments, the loss of support can cause the abutments to wash out. This exposes the bridge ends, leading to significant structural instability. In severe cases, washouts result in the collapse of the approach embankments, cutting off access to the bridge and making repairs more challenging (Melville & Coleman 2000)8.
* Pier collapse: Piers are often subjected to the greatest hydrodynamic forces during floods. As water flows past the piers, it erodes the supporting soil (scour) while applying lateral pressure. Over time, the weakening of the pier foundation due to scour, combined with the direct pressure of water and debris impacts, can cause the pier to collapse (Arneson et al. 2012)5. Once a pier collapses, the entire span it supports is at risk of failure.

Understanding these flood damage mechanisms is essential for designing and managing bridges that can withstand extreme weather events. By accounting for hydrodynamic forces and debris impacts engineers can develop more resilient structures that are better equipped to handle the challenges posed by flooding.

## Impact of extreme weather events

The frequency and intensity of flood events are rising globally, with many experts linking this trend to the effects of climate change. Climate models suggest that as global temperatures rise, rainfall patterns will become more erratic, leading to an increased likelihood of intense rainfall and flooding (Commonwealth Scientific and Industrial Research Organisation (CSIRO) and Bureau of Meteorology 2015)9. This change is particularly concerning for regions that are already prone to extreme weather, as even small shifts in precipitation patterns can have a significant impact on river systems and floodplains.

In areas experiencing more frequent high-intensity storms, bridges that were previously exposed to only occasional flooding are now subjected to repeated high-water events. This intensification of flood frequency increases the hydraulic loads on bridge structures, accelerating degradation and increasing the risk of structural failure. Flood-prone areas in New South Wales, Queensland and parts of Victoria are likely to experience more frequent and extreme floods, placing significant strain on existing bridge infrastructure. The implications for bridge management are profound: as these events become more common, the resilience of infrastructure must be a central focus in design, construction and maintenance practices (Intergovernmental Panel on Climate Change (IPCC) 2021)10.

## Need for resilient design

To counter the growing risk posed by recurring extreme weather events, there is an urgent need to incorporate resilience into new bridge designs and when retrofitting existing bridge crossings. Resilience strategies should focus on reducing the cumulative impact of floods, ensuring that bridges can withstand repeated exposure without significant degradation. Key strategies include:

* Elevated deck design: One of the key engineering solutions is to design bridges with elevated decks, allowing them to remain operational even during high-water events. By raising the bridge deck above predicted flood levels, designers can reduce the likelihood of water flowing over the structure. This minimises the potential for deck displacement and protects critical components from debris impact and hydraulic forces. Elevated decks are particularly important in regions where flash flooding is common, as they provide an additional safety buffer against sudden increases in water levels (Austroads 2019)1.
* Increased depth of foundations: Embedding foundations deeper than the minimum required for scour design is an effective resilience measure in flood-prone areas. This additional depth provides an additional factor of safety, improving stability against flood-induced scour, particularly in non-cohesive soils which are more susceptible to erosion. Deeper foundations protect against destabilisation from high-flow events, reducing the risk of structural failure and minimising the need for frequent, costly repairs. This approach not only fortifies bridges against immediate flood impacts but also contributes to the longevity and durability of the structure, as deeper foundations are less prone to exposure and damage over time.
* Scour countermeasures: Incorporating scour countermeasures is essential for protecting the foundations of bridges from erosion. These measures include the use of riprap, gabions and concrete collars around piers and abutments to prevent the hydraulic forces from eroding the supporting soil. For existing bridges, retrofitting with these countermeasures can extend the life of the structure and prevent cumulative scour from undermining its foundation (Melville & Coleman 2000)8. Proactive scour management, combined with regular inspections during and after flood events, can significantly reduce the risk of collapse. Scour countermeasures can be reinforced to improve their robustness and tailored to account for specific flow behaviour and morphology of the waterway during flood events.

Incorporating resilience into bridge design and maintenance is not just a reactive measure but a proactive strategy to address the increasing threat of extreme weather events. By adopting these engineering solutions, infrastructure managers can mitigate the cumulative effects of repeated floods and ensure the long-term viability of critical transport routes.

# Scour risk assessment

## Identification of scour susceptible sites

To effectively manage scour risk, comprehensive pre-flood assessments of bridge sites are necessary to identify potential vulnerabilities and facilitate timely interventions:

* Review historical flood data and previous scour incidents: Historical data on floods and previous scour behaviour provides valuable insight into the patterns of water flow, sediment transport and associated damages. This analysis should include records of past flood events, peak flow velocities and prior scour assessments, allowing engineers to identify trends and assess the likelihood of future scour occurrences at specific sites.
* Site inspections: Conducting thorough site inspections focusing on critical components such as foundations, piers, abutments and waterway conditions is essential. Inspections should identify signs of previous erosion, sediment deposits and the condition of any existing scour protection measures.
* Use of GIS and hydrological models: Geographic Information Systems (GIS) and hydrological models are useful tools for mapping and analysing scour risk across different sites. These technologies can help visualise areas that are susceptible to high flow velocities or erosion based on topography, land use and hydrological characteristics.

## Hydrological and hydraulic models

Hydrological and hydraulic models play a central role in predicting flow conditions that contribute to scour at specific bridge sites. These models simulate the movement of water under various flood scenarios, helping engineers identify zones where scour risks are elevated. The following key considerations play a critical role in identifying scour risks:

* Flow velocity and depth: Scour is highly influenced by the velocity and depth of water, particularly during high-flow events. As water velocities increase, the hydraulic forces acting on the sediment around bridge foundations become more intense, dislodging particles and eroding the soil. Deeper flows, especially in flood conditions, exacerbate the risk of scour by increasing the pressure on piers and abutments. Tools such as 2-D flood hydraulic modelling packages such as HEC-RAS (Hydrologic Engineering Center’s River Analysis System), MIKE Flood and TuFlow provide detailed simulations of these flow dynamics, allowing engineers to predict how water will interact with the structure during extreme events.
* Channel and flow modelling: Hydraulic models are essential for simulating the behaviour of rivers and streams, particularly where changes in flow patterns may increase scour risks. These models allow engineers to assess how factors like flow constriction under bridges or the presence of obstacles in the waterway affect flow velocity and turbulence. By running simulations for various flood scenarios, high risk scour zones can be identified, enabling preventive action.

For further guidance on the appropriate use of modelling techniques, refer to Australian Rainfall and Runoff (Ball et al. 2019)2.

## Scour depth prediction methods

Predicting potential scour depths is a key aspect of risk assessment. Engineers use a combination of empirical formulas and site-specific calculations to estimate the depth of scour that may develop around bridge piers and abutments, including:

* Empirical formulas: One of the most widely used approaches is the application of empirical scour depth prediction equations, such as those provided in HEC-18: Evaluating Scour at Bridges (Arneson et al. 2012)5 and Transport for NSW (TfNSW) Scour Estimation Report, (Melville et al. 2022)11. These equations are based on historical data and have been calibrated to reflect the relationship between hydraulic forces and erosion at typical bridge sites. While empirical formulas provide useful estimates, validation with site-specific data is needed to ensure reliability.
* Local scour: Local scour refers to the erosion that occurs directly around individual bridge piers or abutments due to high-velocity flows. This type of scour is influenced by the geometry of the structure, the direction and speed of the water and the characteristics of the riverbed material. Local scour depth is calculated based on hydraulic conditions at the site, including flow intensity, pier shape and sediment properties.
* Contraction scour: Contraction scour occurs when the waterway is constricted beneath a bridge deck or between piers, causing the flow to accelerate and erode the bed material. Predicting contraction scour involves modelling how flow velocities increase through narrow sections of the bridge opening, using site-specific flow data and sediment characteristics to estimate the expected scour depth.

Observation of previous scour depths is a key indicator for future risk assessments. Historical records and anecdotal evidence from observed flood events provide valuable insights into scour behaviour at specific sites. Incorporating these observations aids the accuracy of predictions and helps identify areas that may be more vulnerable to scour during extreme events.

## Risk assessment framework

The first step is to conduct baseline assessments to identify bridges vulnerable to scour. This involves collecting and analysing historical flood data, including records of past flood events and scour incidents, to identify patterns of erosion and hydraulic behaviour at specific sites. Engineers should carry out visual inspections of piers, abutments, the waterway and its embankments, and protective measures to detect early signs of erosion, slumping or displacement. In parallel, hydraulic modelling tools like HEC-RAS or MIKE Flood can simulate water flow conditions and identify locations where high flow velocities and turbulence increase the potential for scour. These assessments provide a foundation for future monitoring and risk management.

Secondly appropriate risk levels need to be assigned to individual bridges to allow asset managers to develop targeted intervention strategies. Risk levels should be based on:

* Water flow and velocity: The level of risk depends on both the speed of the water and the direction of flow relative to the structure.
* Foundation depth and type: Shallow foundations are more vulnerable to scour-induced failure compared to deep pile foundations.
* Geotechnical characteristics of the riverbed: The composition and stability of sediment or soil surrounding bridge foundations influence scour vulnerability. Sandy or loose, unconsolidated soils are more prone to erosion, increasing the scour risk, while dense, cohesive soils may provide greater resistance.
* Presence of protective measures: Structures with riprap, gabions or other erosion control measures may have a reduced risk, but the effectiveness of these defences must be regularly assessed.

Bridges can be categorised as low, moderate or high risk, with high-risk structures requiring immediate attention or more frequent monitoring.

Thirdly, after risk levels has been assigned, the framework prioritises high-risk bridges for further assessment or intervention. For bridges identified as critical to the transport network – such as those on major highways or emergency routes – interventions may include temporary closures, installation of additional scour protection or real-time monitoring during floods. This prioritisation ensures that resources are allocated to structures most at risk of failure, minimising potential disruptions to the network.

# Bridge management for flood events

## Operational management pre-flood

Flood preparedness involves a combination of preventive measures, inspections and data analysis to minimise risks and ensure that bridges can withstand flood events. Critical steps include:

* Pre-flood inspections focusing on vulnerabilities and areas prone to scour
* Preventive maintenance such as clearing drainage systems to prevent blockages, removing vegetation that could obstruct water channels and reinforcing protective measures like riprap or gabions.
* Review of hydrological data to assess the likelihood and impact of future flood events. Engineers and asset managers should analyse peak flow records and recurrence intervals for the area, identifying trends in flood frequency and severity.

Categorising bridges based on risk is essential as not all bridges are equally vulnerable to flood damage. Risk-based categorisation prioritises vulnerable structures, ensuring that resources are allocated efficiently. Factors for risk-based categorisation may include:

* Age and condition of the bridge.
* Historical flood damage or vulnerabilities.
* Location relative to critical transport corridors and communities

Using these factors, engineers can assign risk categories (e.g. low, medium, high) to each bridge. High-risk bridges should be prioritised for detailed inspections, preventive maintenance and the development of contingency plans.

Operational readiness ensures that all necessary resources, protocols and personnel are in place before flood events occur. It includes detailed planning for the roles and responsibilities of engineering teams, transport managers and emergency response units. The following outlines possible approaches to operational readiness for consideration:

* Developing flood response protocols: Pre-flood planning should involve the development of protocols for closing, monitoring and reopening of bridges. These protocols specify the conditions under which a bridge must be closed (e.g. when water levels exceed critical thresholds) and the procedures for monitoring structural integrity during the event. Regular communication with transport managers and emergency services ensures a coordinated response when closures are necessary.
* Access to real-time hydrological data: Ensuring access to real-time hydrological data is critical for flood forecasting and risk management. Bridges in flood-prone areas should be linked to early warning systems that provide data on water levels, flow velocities and rainfall. Access to such data allows engineers to anticipate potential risks and take preventive actions, such as closing a bridge before conditions become hazardous.
* Securing equipment for emergency inspections and flood response: Operational readiness also involves securing equipment and personnel for emergency inspections and repairs. Teams should have access to scour sensors, sonar equipment, drones and other tools for monitoring bridge conditions during floods. Emergency materials, such as riprap or temporary barriers, should be available for rapid deployment if needed to stabilise structures. Pre-positioning critical equipment near high-risk bridges ensures a swift response to unexpected issues.

By following these operational management strategies before floods occur, engineers and asset managers can reduce the risk of structural failure, maintain critical transport links and protect public safety. Proactive inspections, preventive maintenance and the use of predictive data ensure that bridges are prepared to handle extreme weather events. Risk-based categorisation further enhances the effectiveness of flood management efforts, while operational readiness plans provide the foundation for a coordinated and timely response during emergencies.

## Operational management during floods

Real-time monitoring provides engineers and asset managers with essential information about flood conditions and potential structural risks. Continuous data collection ensures that decisions, such as bridge closures, are based on current conditions, reducing the likelihood of accidents or failures. The following outlines technology available to assist in the real-time monitoring of structures:

* Hydrological sensors: Water level sensors and flow measurement devices installed around bridge sites track flood conditions in real time. These sensors monitor rising water levels and flow velocities, providing critical data to assess whether a bridge is at risk of overtopping or structural compromise. Alerts from hydrological systems linked to early warning networks allow engineers to prepare for emergency actions.
* Scour monitoring systems: Scour monitoring instruments provide valuable information on the progression of erosion around piers and abutments during a flood. These systems use sensors embedded in foundations to detect changes in sediment levels. Real-time data from scour monitoring systems enables engineers to intervene if erosion becomes critical, reducing the chance of bridge collapse.
* Drones and remote sensing: Drones, specifically water-resistant models, equipped with cameras and infrared sensors are essential tools for conducting aerial inspections of bridges during floods, especially when access to the site is dangerous or restricted. Drones provide a comprehensive view of the bridge and surrounding area, capturing images of debris accumulation or signs of structural distress, such as tilting piers or displaced elements. Remote sensing technologies complement on-the-ground inspections, enhancing safety and efficiency during flood events.

A structured decision-making framework ensures that closures occur promptly to protect the public and prevent structural failures. Engineers must rely on real-time data, predictive models and historical insights to determine when bridges should be closed. Defining specific thresholds for decision-making during flood events allows for timely and effective responses based on real-time data. The below provide guidance on three areas of focus for decision-making:

* Water level and flow rate thresholds: It is crucial to establish critical water levels and flow rates for each bridge. These thresholds should be determined based on engineering assessments, historical flood data and structural design limits. Bridges must be closed if water levels rise to a critical threshold. Thresholds for closures should be defined in advance, based on historical flood levels and predictive modelling. By integrating predictive models, engineers can forecast when water levels may exceed these thresholds, triggering actions such as traffic closures or detours. Real-time monitoring of water levels, through hydrological sensors, provides accurate data to ensure proactive decision-making.
* Scour depth indicators: Scour poses a significant risk to bridge stability; thus, establishing a critical scour depth is essential. Real-time data from scour monitoring systems, combined with historical information, can provide valuable insights for decision-making. While it may not always be feasible to detect significant erosion in real time, monitoring devices can alert engineers to abnormal foundation movements or changes in stability. When these indicators suggest a heightened risk of structural compromise, bridges may be closed as a precautionary measure and detailed inspections conducted to confirm the extent of the damage.
* Structural deformation and safety: Monitoring for signs of structural deformation, such as excessive deflection, settlement or visible damage to piers and abutments, is critical. Establishing criteria for closure based on deformation measurements ensures that bridges are only opened when they meet safety standards.
* Debris impact potential: High flow velocities increase the likelihood of debris impact, which can weaken bridge elements and obstruct water flow. If debris accumulates against piers, it creates additional hydraulic pressure, raising the risk of scour and structural instability. When velocities exceed safe limits or debris poses a threat, temporary closures may be necessary until conditions stabilise.

## Operational management post floods

Once floodwaters recede, bridge infrastructure must be inspected, assessed and repaired to ensure public safety and restore normal transport operations. Post-flood operational management focuses on immediate inspections, prioritised repair work, structural integrity assessments and temporary solutions to maintain service continuity during the recovery phase.

Decision-making must be informed by experience in risk management to balance the urgent need to restore access with safety considerations. Engineers must carefully evaluate the trade-offs involved, weighing the importance of re-establishing connectivity against the risks of allowing public access to potentially compromised structures. For high-priority routes, such as those serving emergency services or essential supply chains, reopening may be considered sooner, but only with a clearly defined approach to ensure safety.

In some cases, authorities may impose vehicle load restrictions as an interim measure to mitigate potential strain on the structure until a more comprehensive inspection can be conducted. Limiting bridge access to light vehicles or emergency responders reduces loading stress and prevents further structural degradation, allowing essential traffic to proceed while safeguarding public safety.

Immediate post-flood Inspections are essential as floodwaters are receding to identify potential damage caused by scour, hydraulic forces and debris impact. The following provides guidance on the conduct of post-flood inspections, including potential technology:

* Inspecting bridge foundations for scour damage: A primary post-flood concern is identifying scour damage. Engineers should inspect piers and abutments for settlement or exposure of foundations caused by erosion. Particular attention should be given to areas with known scour history or where protective measures such as riprap have been displaced. Inspection of the embankments for overall stability should also be carried out during these inspections for signs of possible slumping.
* Checking for structural damage to piers, abutments and decks: Structural components must be assessed for damage caused by debris impact and hydraulic forces. Floodwaters often carry large debris such as logs, rocks or vehicles, which can strike bridge piers and abutments, causing cracks or displacement. Engineers should also inspect the bridge deck for signs of buckling, dislodged elements or impact damage. Past inspection reports should be referenced to assist in identifying the magnitude of damage and/or if the defects identified were already in existence.
* Use of advanced inspection techniques: In addition to visual inspections, advanced tools such as sonar and ground-penetrating radar (GPR) may be used to detect underwater scour or hidden damage within foundations.

Where the above has identified defects that may impact the structural integrity of the bridge, an experienced structural engineer should assess the structure. They should determine whether it is safe to reopen to traffic or if repair and/or further investigations are required before reopening to traffic.

Structural integrity testing of a bridge after a flood event may be required to ensure it is safe for use. This process involves detailed testing and analysis to evaluate the bridge’s ability to bear loads and withstand future stresses. Static or dynamic load-bearing capacity tests may be performed.

In the aftermath of a flood event, repairing and restoring bridge functionality is often a top priority, but limited resources mean that decisions must be made about which bridges to repair first. This prioritisation typically depends on several factors, including the community’s reliance on the bridge and the broader regional or national transport network that the bridge supports.

Decisions about repair often involve a multi-agency approach, involving local, state and national authorities, along with transport engineers and infrastructure managers. The goal is to balance the needs of isolated communities with the importance of restoring larger transport networks that benefit the broader population.

# Conclusion

To strengthen the flood resilience of an asset and its safety, the draft guideline proposes that Austroads and its members should adopt scour risk assessments as part of the routine bridge management process, especially in high-flow or flood-prone areas. Integrating scour monitoring and identifying potential scour protection upgrades (if required) into annual inspections and equipping high-risk bridges with permanent monitoring systems enables early detection of vulnerabilities. Proactive monitoring helps prevent costly damage and supports timely interventions during flood events.

A consistent decision-making framework is proposed to standardise operational responses across jurisdictions. This framework should define operational thresholds, such as maximum allowable water levels, scour depths and structural deformation limits, that determine when to close and/or reopen a bridge. With a structured framework, field engineers and decision-makers can ensure uniform, safe and coordinated responses during flood events, enhancing public safety and infrastructure integrity.

In regions with known scour risks, establishing a protocol for temporary scour mitigation measures – such as rapid riprap installation or temporary shoring – would add an important layer of resilience. Readily available emergency materials and trained response teams allow for quick deployment of protective measures, especially for bridges serving critical functions or at high risk of erosion.

A risk-based maintenance strategy is proposed, focusing on prioritising critical infrastructure such as bridges serving hospitals, emergency services and major transportation corridors. Assigning higher priority to these structures for enhanced inspections, timely maintenance and upgrades ensures their ongoing reliability. As new data becomes available, updating these priorities allows agencies to remain agile and responsive to changing conditions.

Finally, the guideline proposes Austroads facilitate collaboration and data-sharing among member agencies. A centralised data platform for hydrological data, bridge performance and flood forecasts would improve flood risk assessments and support consistent decision-making. Interagency collaboration will enable effective resource allocation and a quicker, coordinated response to emergencies, reinforcing resilience efforts.

The guideline drafted is proposed to be a living document and should undergo regular review and updates, incorporating stakeholder feedback, new research insights and technological advancements. This approach will ensure the guideline aligned with current best practices, ensuring that it remains a relevant and valuable resource for managing flood risks to bridge infrastructure

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