# River avulsion as an under-recognised floodplain hazard in Australia: Insights from the Lower Burdekin Delta

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**Key points**

- Avulsions are a fundamental process of river adjustment across Australian floodplains, alluvial fans and deltas.
- Avulsion controls vary systematically downstream from superelevation-dominated upper floodplains to gradient-controlled deltaic systems.
- Climate change may increase avulsion susceptibility through increased flooding, landslides, sediment delivery and sea-level rise.
- Hydraulic and geomorphic assessment indicates the probability of an imminent avulsion on the Lower Burdekin Delta is currently low.
- Avulsion hazard assessment should be incorporated into future floodplain and coastal hazard adaptation frameworks

## Abstract

River avulsion is a fundamental mechanism of channel adjustment across fluvial landscapes, occurring not only on low-gradient deltas but also across upper floodplains and alluvial fan systems where rapid sedimentation and gradient shifts promote channel instability. Under a changing climate, the frequency and magnitude of avulsion-triggering conditions may intensify, yet quantitative assessments of avulsion likelihood in Australia remain limited and is rarely assessed in flood studies and floodplain management plans. This paper synthesises contemporary avulsion theory with Australian examples and a case study from the Lower Burdekin River, north Queensland. The paper also advocates for more quantitative avulsion hazard assessments across Australia's coastal floodplains given the potential catastrophic economic, social and environmental consequences.

## Keywords

River avulsion, floodplain geomorphology, Burdekin River, delta evolution, climate change, sediment transport, adaptive floodplain management

## Introduction

River avulsion is the abrupt diversion of flow from an established channel to a new course across an adjacent floodplain or delta plain. Unlike ordinary flooding, avulsions permanently reorganise river planform, sediment transport pathways and floodplain connectivity, with potentially significant consequences for flooding, infrastructure, agriculture and ecosystems. Despite these impacts, avulsion hazard is rarely considered within flood risk assessments or river management frameworks in Australia.

Evidence of repeated avulsions is widespread across Australian floodplains, as demonstrated by abundant palaeochannels and distributary systems. Avulsive landscapes are particularly evident within the distributive fluvial systems of the Murray–Darling Basin and Lake Eyre Basin, and on large coastal deltas such as the Burdekin River. Other documented Australian examples include the Snowy, Thomson, Ovens, King, Clarence and Blackfellow Creek systems, demonstrating that avulsions occur across a broad range of geomorphic settings.

River avulsion is rarely an isolated event but instead represents one phase within longer-term geomorphic adjustment. Progressive changes in channel morphology, sediment transport, vegetation and hydraulic efficiency can gradually reduce channel capacity and increase overbank flow until a new channel develops. Graves et al. (2024) demonstrated this process in a semi-arid Australian dryland river, where channel contraction, floodout development and upstream migration of headcuts progressively increased avulsion susceptibility. Recent research has also shown that the dominant controls on avulsion susceptibility vary systematically along source-to-sink systems. Gearon et al. (2024) identified channel superelevation as the dominant control in proximal alluvial settings, whereas gradient advantage becomes increasingly important in distal floodplain and deltaic environments. These metrics provide a valuable first-order framework for assessing avulsion susceptibility but reflect the cumulative influence of longer-term geomorphic processes, including sediment supply, flood magnitude, vegetation dynamics, floodplain topography and pre-existing channels. Accordingly, avulsion assessments should integrate both geomorphic processes and hydraulic indicators.

Climate change has the potential to alter avulsion susceptibility through increases in extreme flooding, sediment delivery from hillslope erosion and landslides, and sea-level rise, although the relative importance of these processes will vary between catchments. Despite these emerging pressures, avulsion hazard remains largely absent from Australian floodplain planning and climate adaptation frameworks.

This paper:

- reviews river avulsion as a fundamental process of geomorphic adjustment across Australian landscapes;
- summarises recent advances in understanding avulsion controls;
- evaluates avulsion susceptibility in the Lower Burdekin River delta; and
- examines how climate change may influence future avulsion hazard in Australian coastal rivers.

This paper argues that river avulsion remains an under-recognised floodplain hazard in Australia and that quantitative avulsion hazard assessments should become a routine component of floodplain planning, river management and climate adaptation strategies.

## River avulsions as a fundamental mechanism of geomorphic adjustment

### *What is an avulsion?*

River avulsion is the process by which flow shifts from an established channel to a new pathway across the floodplain or delta plain. Unlike ordinary flooding, avulsions involve long-term or permanent channel relocation and reorganisation of sediment and floodplain connectivity. Avulsions are typically triggered by a flood event; however, long-term geomorphic preconditioning commonly occurs beforehand, progressively moving the system towards critical thresholds prior to the instigating flood(s). Key processes which contribute to this pre-conditioning include:

- Channel aggradation which may have been exacerbated by either increased sediment supply or reduced transport capacity (due to reduction flow and/or hydraulic gradient, or increased hydraulic roughness)
- Levee and alluvial ridge development which increases the differences in floodplain elevation
- deposition and/or erosion

These processes progressively modify channel and floodplain morphology, creating conditions where floodwaters may exploit shorter, steeper or more hydraulically favourable flow paths across the floodplain. During sufficiently large floods, if floodplain flow has adequate erosive capacity, these preferential flow paths may be scoured and progressively enlarged, ultimately establishing a new river course.

Avulsions are therefore rarely random events but threshold responses that emerge from long-term geomorphic preconditioning, including sediment accumulation, changes in channel capacity, vegetation dynamics and floodplain evolution. Although often triggered by individual flood events, the likelihood and location of avulsion are largely determined by these antecedent processes. Avulsions are a natural component of alluvial river evolution and represent an important mechanism of channel and floodplain adjustment, redistributing water and sediment and establishing more hydraulically efficient flow paths across floodplains and deltas. Some key avulsion examples and/or considerations from studies along Australia's east coast are described below. The economic impacts of the avulsions are also highlighted.

### *Blackfellow Creek, Lockyer Valley, Queensland*

A catastrophic flood-driven avulsion occurred within a steep partly confined gravel-bed valley in southeast Queensland during the 2013 flood. Some key preconditioning processes for the Blackfellow Creek reach included increased coarse sediment supply, reduction in sediment transport capacity due to road culverts and cleared floodplains (Ivezich et al, 2013). These processes lead to the channel becoming super-elevated during the 2013 flood events and the preferential floodplain flow path being scoured creating a new river channel which resulted in major impacts to roads, culverts and agricultural land.

### *Thomson River, West Gippsland, Victoria*

An avulsion of the lower Thomspon River occurring during the 1952 flood which formed the Rainbow Creek avulsion alignment. Brizga and Finlayson (1990) described key pre-conditioning processes as aggradation which elevated the riverbed and alluvial ridge. Ongoing loss of channel capacity, associated with the development of a tortuous meandering planform and vegetation (willows) and snags within channel resulted in floodwaters increasingly escaping to lower areas of the floodplain. This process resulted in the development of preferential flow path at the lowest point of the floodplain which was eventually scoured and incised during the 1952 flood to form a new river channel. The avulsion has resulted in loss of agricultural land, bridge instability and damage risks, and the need for engineering intervention to manage irrigation water down both the new and old channels.

### *Lower Snowy River East Gippsland, Victoria*

The lower Snowy River contains avulsion prone-pathways (known locally as 'gulches') that became a major management concern during river rehabilitation works (Glendining et. al. ,2009). In the past large structures have been built across these 'gulches' to stop avulsions. The lower Snowy River has experienced significant flow reduction resulting from river regulation. This process has resulted in channel contraction/aggradation, vegetation encroachment on benches and low flow channel development. Accelerating these processes has been a key river management goal with the aim of establishing a self-formed low flow channel which is more appropriate for the modified flow regime. However, it has been noted that these processes may increase avulsion risk in major floods due to the reduction in channel capacity over time. As a result river rehabilitation works aimed at accelerating channel recovery need to be considered spatially and longitudinally along the river to reduce avulsion risks and associated economic impacts to agriculture and adjacent infrastructure.

### *Lower Burdekin River, Queensland*

The Lower Burdekin River forms one of Australia's largest actively prograding tropical deltas and has a long history of episodic river avulsions. Fielding et al. (2006) identified at least 10 different delta lobes since the mid Holocene period. In the past 3,000 years there have been at least three avulsions, and these avulsions have each moved south and tended to be shorter than previous avulsions. This highlights a process of delta lobe development which increases channel length and decreases the channel slope. This helps create situations where the shorter and steeper flow path across the floodplain becomes a preferential flow path and avulsion occurs. While there has been no avulsion since European settlement, Wolanski and Hopper (2022) suggest that post-European land clearing and increased sediment supply have accelerated channel aggradation and increased the probability of a future avulsion within the Lower Burdekin Delta. An avulsion on the Lower Burdekin Delta would have major impacts on the Bruce Highway, flooding dynamics in Ayr, agricultural land, coastal erosion and associated risks to Ramsar wetlands and fisheries habitat.

The risk of an avulsion in the Lower Burdekin River is further considered in the case study below.

## Geomorphic controls on avulsion: A global perspective

The key factors that impact the likelihood of an avulsion were outlined in Gearon et al. (2024). These controls vary systematically along the source-to-sink continuum, from steep alluvial fan and upper floodplain systems through to low-gradient coastal deltas. As a result, the dominant mechanisms controlling avulsion differ between confined valleys, inland floodplains and deltaic environments. The key factors include:

1. **Superelevation (β)**: This occurs when the riverbed aggrades to be level with the floodplain, making the channel superelevated relative to the adjacent floodplain (see Figure 1). The riverbed can aggrade because the banks of the river also rise as natural levees are deposited producing an alluvial ridge. The superelevation (β) is the ratio of the channel height to the alluvial ridge height (measured from the ridge crest to the floodplain surface). The superelevation (β) can be impacted by channel aggradation over time. Avulsions are more likely because the flow in the river is perched above the floodplain. Where the bed of the river is level with the average elevation of the floodplain (i.e. a β of 1), an avulsion is more likely. Whilst a β of 1 is the global average for avulsions to take place on rivers, avulsions on deltas tend to occur at values of β less than 1, with an average of 0.4. That is, the height of the alluvial ridge is just 0.4 of the depth of the river. Superelevation is generally considered the dominant avulsion control within upper floodplain, distributive fluvial and alluvial fan environments where rapid aggradation and coarse sediment deposition elevate the channel above adjacent floodplain surfaces.
2. **Gradient Advantage (γ)**: This is when the topographic slope perpendicular to the river exceeds the channel slope, making the alternative river path steeper. This commonly occurs where floodwaters are able to exploit lower floodplain surfaces, palaeochannels, distributary pathways or floodplain depressions during large overbank floods. The gradient advantage (γ) is the ratio of the gradient of the alternative river path relative to the river gradient. Models suggest that γ values greater than 3-10 make a river prone to avulsion-inducing overbank flows (i.e. the slope of the floodplain next to the river is 3 to 10 times steeper than the slope of the adjacent riverbed). Gearon et al. (2024) also concluded that the slope advantage for deltas needed to be higher than for upper floodplain avulsions – finding an average of 8 for global deltas. In partly confined valleys and inland floodplains, lower gradient advantages may still produce avulsion where local channel constrictions, sediment plugs, floodplain stripping or floodplain breakout processes concentrate flow onto alternative pathways.
3. **Shear stress advantage:** This is the ratio of the shear stress exerted by water flowing down the alluvial ridge flank to the shear stress acting on the bed of the main channel. In deltaic environments, Gearon et al. (2024) found that avulsion commonly occurs when shear stress along the alluvial ridge flank is approximately twice that within the main channel. Although closely related to channel superelevation and gradient advantage, shear stress advantage provides a hydraulic measure of the erosive potential of floodplain flow during avulsion and therefore complements these geomorphic metrics in assessing avulsion susceptibility.

Gearon et al. (2024) examined 174 global avulsions and found that, on deltaic streams, gradient advantage (i.e. the ratio of the levee slope to the river slope) increases relatively faster than the superelevation, meaning that it contributes relatively more to shear stress increase. Thus, higher gradient advantage is required for avulsion in river deltas compared to other geomorphic settings due to the low gradients of the river. Conversely in upper floodplain or alluvial fans section, channel superelevation and local breakout processes are the greater predictor of avulsion risk due to higher gradients and the potential for rapid sedimentation.

These findings suggest that avulsion susceptibility should be assessed within the broader geomorphic context of the river system, with different controls in confined valleys, alluvial fans and low-gradient coastal deltas.

Prasojo et al. (2024) also looked at factors that drive river avulsions in deltaic environments and highlighted these factors which can also contribute to the variables outlined above:

- Increased sediment loads from the catchment lead to higher aggradation rates within the channel, which reduces channel capacity and channel slope which in turn promotes more frequent avulsions
- Higher bankfull depth (due to deposition of an alluvial ridge) results in higher channel capacities and requires more sediment to fill the channel to induce avulsion.

Prasojo et al. (2024) also found the location of avulsions in deltaic environments has a strong correlation with the backwater length. The backwater length is the distance from the shoreline to the point where the river's flow velocity is significantly reduced due to the influence of the sea level. Avulsions often occur near the upstream limit of the backwater zone.

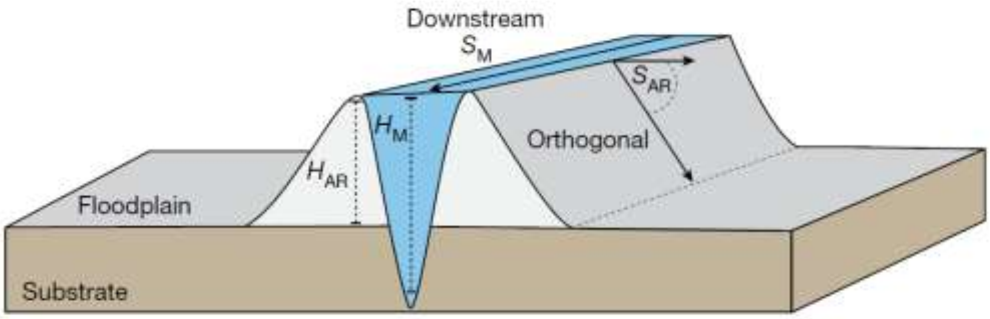


**Figure 1 The variable used to calculate both Superelevation ($\beta = H_{AR}/H_M$) and Gradient Advantage ($\gamma = S_{AR}/S_M$) from Gearon et al. (2024). $H_{AR}$ is the vertical distance from the ridge crest to the floodplain surface. $S_{AR}$ is measured perpendicular to flow direction from the ridge crest to the floodplain and $S_M$ is measured along the levee crest following the channel**

## Case study- Avulsion risk assessment of the Burdekin River

### *Background*

Wolanski and Hopper (2022) argued that reduced sediment transport efficiency, combined with sea-level rise and coastal backwater effects, may be promoting increased floodplain instability and avulsion susceptibility to the Lower Burdekin River. Wolanski and Hopper (2022) highlighted the potential ecological and floodplain consequences associated with an avulsion and the associated coastal erosion including risks to Ramsar wetlands, fisheries habitat and agricultural land.

Alluvium Consulting were engaged by the Queensland Government to assess the risk of an avulsion on the Burdekin River delta. To assess avulsion thresholds, two-dimensional hydraulic and sediment transport modelling and LiDAR-derived morphology analysis were used to evaluate channel and floodplain morphology; floodplain engagement during large floods; potential avulsion pathways; and hydraulic thresholds for floodplain scour. The assessment considered the avulsion metrics proposed by Gearon et al. (2024) described above, including channel superelevation (β); floodplain gradient advantage (γ); and shear stress advantage.

### *Channel and floodplain morphology*

Cross-sections across the Lower Burdekin River indicate superelevation ratios (β) generally between 0.4 and 0.7 (Figure 2). While these values are below the classical avulsion threshold of β ≈ 1, they fall within the range identified by Gearon et al. (2024) for deltaic avulsions. These results indicate that several potential avulsion pathways exist on the Burdekin Delta if superelevation alone is considered.

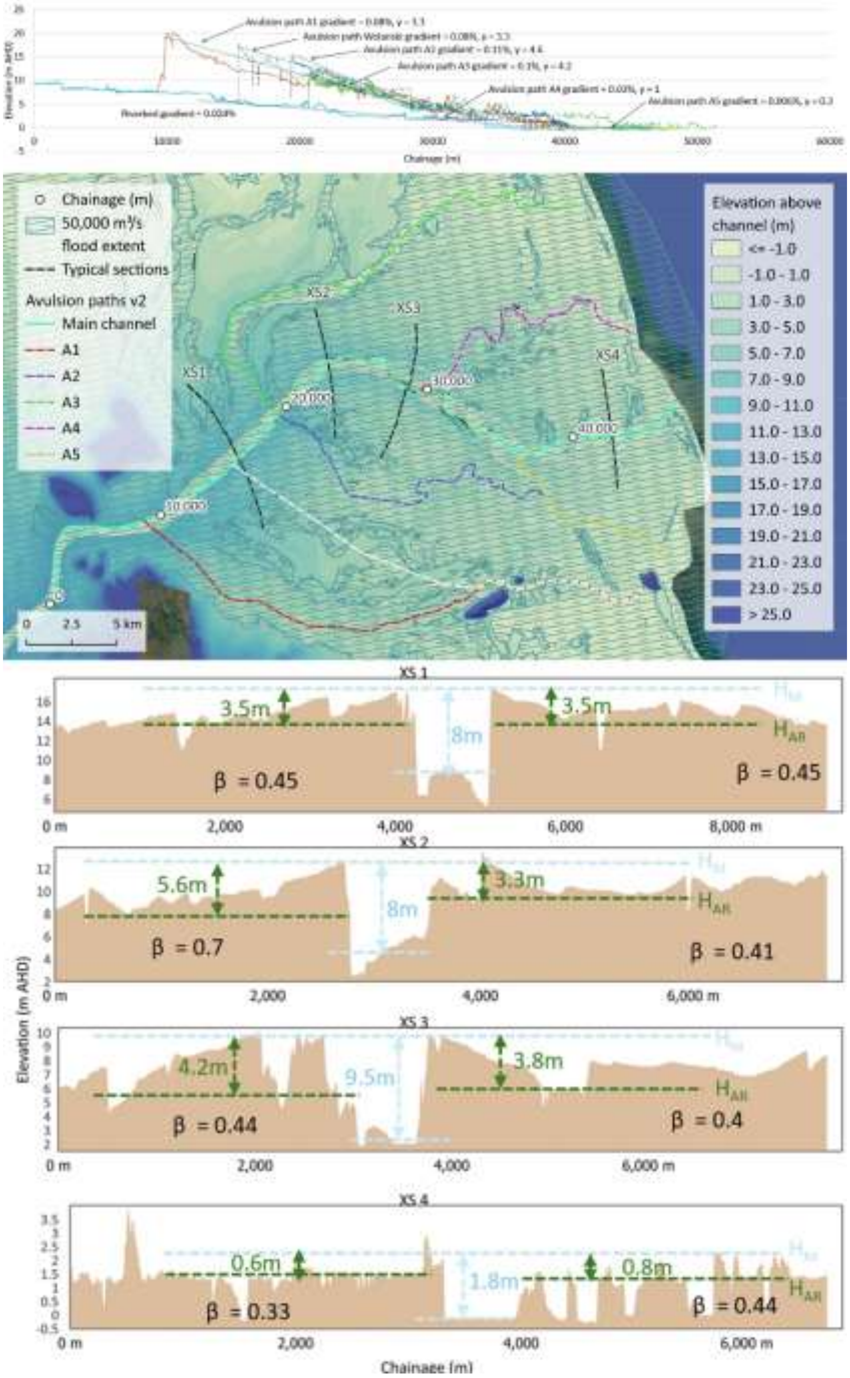


**Figure 2 The Burdekin River delta showing potential avulsion paths and the extent of a large flood (middle), assessment of gradient advantage for potential avulsion paths (top) and assessment of superelevation (bottom)**

### *Channel floodplain connections*

Hydraulic modelling of floods demonstrated that the Lower Burdekin floodplain is only engaged during very large floods. The very high channel capacity of the Lower Burdekin means that avulsions are likely restricted to rare, high-magnitude floods which may only occur once every 20-50 years.

The modelling identified five potential avulsion pathways (see Figure 2). The most downstream pathways near Rita Island coincide with a sharp reduction in flood velocity associated with the upper extent of the backwater zone identified by Prasojo et al. (2024). This location also aligns with the most recent historical avulsions, suggesting it remains one of the most probable future avulsion zones. Several upstream pathways near the delta apex are also activated during larger floods once discharge exceeds approximately 21,500 $m^3/s$ (i.e. greater than 5% AEP).

### *Gradient advantage*

The assessment of the five potential avulsion pathways showed that none possessed a strong gradient advantage relative to the existing river channel (Figure 2). Gradient advantage ratios ranged from 0.3 to 4.6, which is generally at the lower end of the range associated with active deltaic avulsions globally.

The pathway proposed by Wolanski and Hopper (2022) corresponds most closely with Path A1. However, flood modelling indicates this is not a strongly preferred hydraulic pathway, even during extreme floods. In addition, exposed granitoid bedrock adjacent to this pathway may locally limit floodplain scour. Overall, the modelling suggests that while several potential avulsion pathways exist, none currently possess a substantial slope advantage over the main river channel.

### *Shear stress assessment*

Total shear stress modelling was undertaken for a range of flood events. Results indicate that shear stresses within the main river channel are substantially higher than those along the floodplain avulsion pathways. None of the identified pathways achieved the shear stress advantage proposed by Gearon et al. (2024) for active avulsions.

The highest relative shear stress values occurred along pathways A2 and A4, suggesting these are the most probable future avulsion corridors. Floodplain vegetation (grass, sugarcane) also increases erosion resistance across much of the upper delta and likely reduces the probability of rapid floodplain scour during moderate floods.

### *Summary of avulsion risk on the Burdekin River Delta*

The Lower Burdekin River has a long history of avulsions, consistent with the natural evolution of large river deltas. However, the probability of an imminent avulsion is considered low because:

- Very large floods are required to engage floodplain pathways;
- The river is not strongly superelevated relative to the floodplain;
- Potential avulsion pathways have limited gradient advantage;
- Main-channel shear stresses remain substantially higher than floodplain flow paths; and
- Floodplain vegetation increases substrate resistance.

European land clearing substantially increased sediment loads to the Burdekin prior to construction of Burdekin Falls Dam, likely increasing historical avulsion susceptibility. However, sediment trapping by the dam has reduced rates of channel aggradation and delta-lobe growth relative to post-European pre-dam conditions (Lewis et al., 2021). The Burdekin River will likely avulse again over longer timescales (i.e. hundreds to thousands of years), but current hydraulic and geomorphic conditions suggest that the probability of an imminent avulsion remains low. Of the identified pathways, A2 and A4 appear the most probable under future extreme flood scenarios (Figure 2).

## **Changes to avulsion hazard due to climate changes**

There is significant potential for climate change to alter the key avulsion indicators described above through increases in extreme rainfall, flooding and sea-level rise. Recent studies have identified that intense rainfall events have triggered widespread landslides across upper catchment areas in Northern NSW and Far North Queensland, resulting in substantial sediment and debris inputs to stream networks (Griffith, 2025; Alluvium, 2025). If landslide frequency and coarse sediment delivery increase across the Great Dividing Range under more intense rainfall regimes, larger sediment pulses may accelerate channel aggradation and superelevation, floodplain stripping, and thereby increasing avulsion susceptibility across upper floodplains.

Within lower floodplains and deltas, sea-level rise is likely to reduce effective channel slopes and promote upstream migration of the backwater zone. This may alter zones of sediment aggradation, floodplain connectivity and distributary flow pathways, potentially shifting the locations where Prasojo et al. (2024) identified delta avulsions are most likely to occur and increases gradient advantage in some areas.

## Assessing avulsion hazard

In Australia there has been substantial advances in the assessment and management of coastal and flood-related hazards through structured risk-based planning frameworks. A good example is the Queensland Coastal Hazard Adaptation Strategy (CHAS) framework. The CHAS framework applies a risk-based approach to identifying, assessing and managing long-term coastal hazards (i.e. coastal erosion, tidal inundation, wave overtopping etc.) under changing climatic conditions. The CHAS process is organised into sequential phases that include: identifying current and future hazard exposure, mapping vulnerable assets, undertaking risk assessment, evaluating adaptation options, and implementing adaptive managements included planned retreat. There are similar hazard assessment methods for coastal areas and flood risk across Australia.

However, to date there have been limited river avulsion hazard assessments across Australia. Avulsions across many of Australia's coastal floodplains could have catastrophic economic, social and environmental consequences. Given the potential for climate change to alter river avulsions susceptibility through increased sediment supply, flooding and sea level risk there is strong case for incorporating avulsion assessment into future river, catchment and floodplain management frameworks. These approaches could align with the established approaches used in coastal hazard adaptation strategies and floodplain risk management frameworks across Australia. Avulsion susceptibility should be assessed through geomorphic assessments, hydraulic and sediment transport modelling and probabilistic risk analysis. Once the avulsion likelihood and consequences are understood adaptive management and mitigation options can be evaluated through established economic assessment approaches.

## Conclusions

River avulsion is a fundamental mechanism of geomorphic adjustment across Australian alluvial fans, floodplains and deltas, yet it remains poorly incorporated into floodplain management and climate adaptation frameworks. The Australian examples and Lower Burdekin case study demonstrate that avulsion susceptibility is controlled by interacting geomorphic, hydraulic and sediment transport processes that vary systematically downstream across fluvial systems. Under a changing climate, increases in extreme flooding, sediment delivery and sea-level rise may alter avulsion thresholds and floodplain connectivity, highlighting the need for integrated avulsion hazard assessment within future river and coastal management frameworks.

## Acknowledgements

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## References

Alluvium Consulting. (2025). *Burdekin Basin water plan – sediment transport assessment*. Report prepared for the Department of Local Government, Water and Volunteers (DLGWV).

Brizga, S. O., & Finlayson, B. L. (1990). Channel avulsion and river metamorphosis: The case of the Thomson River. *Earth Surface Processes and Landforms*, 15(5), 391–404

Gearon, J. H., Martin, H. K., DeLisle, C., Barefoot, E. A., Mohrig, D., Paola, C., & Edmonds, D. A. (2024). Rules of river avulsion change downstream. *Nature*, 634, 91–98. https://doi.org/10.1038/s41586-024-07964-2

Graves, R., Fryirs, K., Ralph, T.J. & Erskine, W.D. (2024). *Patterns and processes of channel and floodout adjustment in a discontinuous dryland river, semi-arid eastern Australia*. Geomorphology, 446, 108991.

Glendining, T., Pollino, C., & others. (2009). River restoration using simple decision support tools: Lower Snowy River rehabilitation works. In *Proceedings of MODSIM 2009 International Congress on Modelling and Simulation*, 4283–4289

Ivezich, M. J., Blackham, D., & Hardie, R. E. (2016). Analysis of catastrophic channel change in a high-energy gravel bed stream. In G. Constantinescu, M. Garcia, & D. Hanes (Eds.), *River Flow 2016: Proceedings of the International Conference on Fluvial Hydraulics*, St. Louis, USA, 11–14 July 2016 (pp. 1867–1874). CRC Press/Balkema. ISBN 978-1-138-02913-2.

Lewis, S., Bainbridge, Z. & Smithers, S. (2021). *A synthesis of the changing sources, transport and delivery of sand to the Burdekin River Delta: implications for the stability of the Bowling Green spit. Centre for Tropical Water and Aquatic Ecosystem Research (TropWATER) report 21/38, James Cook University, Townsville,* 27.

Wolanski, E., & Hopper, C. (2022). Dams and climate change accelerate channel avulsion and coastal erosion and threaten Ramsar-listed wetlands in the largest Great Barrier Reef watershed. *Ecohydrology & Hydrobiology*, 22(2), 197–212.