Considering geomorphology for management of the Great Cumbung Swamp, Lachlan River, NSW

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Key points

- Downstream declines in stream flow and energy drive channel breakdown and wetland formation in lowland rivers and wetlands, including the Lachlan River and Great Cumbung Swamp.
- Clusters of bank breaches, breakaway points and subtle floodplain topography influence flow dispersal pathways through the reed bed onto the broader floodplain.
- Palaeochannels and gilgai depressions influence areas of standing water on the floodplain, and steeper return channels allow water to exit the wetlands, sometimes coinciding with areas of erosion.
- Understanding geomorphic controls on sedimentation, erosion and inundation can support wetland conservation and water management.

Abstract

Most inland rivers on the alluvial plains of eastern Australia decline in size downstream due to inherent reductions in trunk stream discharge and stream power. Water leaving the main channel/s inundates the floodplain and sustains seasonal, intermittent and/or ephemeral wetlands that are biodiversity and cultural hotspots. The Great Cumbung Swamp (GCS) are Holocene-age wetlands on the lower reaches of the Lachlan River in south-western New South Wales (NSW), occurring just before the Lachlan meets the Murrumbidgee River during floods. The GCS hosts ~12.5 km^2 of Phragmites reed beds; some of the largest in the Murray-Darling Basin. Geomorphic mapping and topographic analysis of high-resolution digital elevation data reveal pronounced features along the lower Lachlan River associated with channel breakdown and reformation in the GCS. The meandering single channel entering the swamp has numerous breakaway points that allow water to exit before bankfull flow stage is reached. The channel is straighter near the centre of the swamp, upstream of the terminus, where water is lost through breakaways and through vegetated channel banks, spilling across the low alluvial ridge into nearby depressions and lakes. Overland and flood out flows dominate in the unchanneled swamp downstream of the terminus. A series of return channels occur at the downstream margin of the swamp, providing a pathway for water to join the Murrumbidgee River. Sedimentation processes dominate in the central swamp, while erosion processes dominate in the outflowing channels, leading to topographic gradients that influence inundation. The modern wetlands overlie a palimpsest of palaeochannels, many of which provide subtle but important impediments or conduits to flow, while coalescing gilgai depressions tend to funnel water to low points. Understanding the landforms and geomorphic processes that characterise the GCS can support water management and wetland conservation.

Keywords

Aquatic ecosystems, avulsion, channel breakdown, floodplain, gilgai, water, wetlands

Introduction

Understanding the factors that create landscapes, and the processes that shape landforms including rivers, floodplains and wetlands, is critical for environmental conservation and management. The geomorphology of lowland rivers can help to explain how water, sediment and organic matter move and accumulate over time. This is because processes such as erosion, sediment deposition and channel adjustment influence the hydrological, geomorphological and ecological structure and function of river and wetland systems. This is particularly important in inland Australia where many rivers are non-perennial and have complex interactions between hydrology, geomorphology, ecology and anthropogenic processes (Shanafield et al., 2024). Inland rivers that decline in size and stream power downstream as they spread water into secondary channels, onto the floodplain and into extensive wetlands, are strongly influenced by subtle topography and patterns and rates of erosion and sedimentation (Ralph and Hesse, 2010; Yonge and Hesse, 2009).

Floodplain wetlands such as the Great Cumbung Swamp (GCS) on the lower Lachlan River, south-western NSW (Figure 1) are dynamic systems that evolve over time through interactions between hydrology, vegetation, sediment movement and channel processes (O'Brien and Burne, 1994). Covering an area of ~160 km^2, the GCS supports some of the largest stands of common reed (*Phragmites australis*) and river red gum (*Eucalyptus camaldulensis*) in NSW (DPIE, 2020). The GCS also provides habitat for many species of fish, frogs and waterbirds, some of which are threatened or endangered, including migratory waterbirds recognised under international agreements. The lowland section of the Lachlan River is listed as an endangered ecological community under the NSW *Fisheries Management Act 1994*, largely due to pressure on the aquatic ecosystems from alterations to the flow and inundation regimes (MDBA, 2012). The region also supports a range of agricultural activities that rely on water from upstream as well as maintenance of the environmental health of the river and wetlands for ongoing productivity.

In the context of biodiversity conservation, the lower Lachlan River and GCS have for many years been the focus of water and wetland management efforts. This paper explores how understanding and considering geomorphology can support and enhance these ongoing efforts, for example, by helping to explain how water and sediment may move and be stored in wetlands, why inundation patterns may change, and why some parts of the wetlands receive more frequent or longer-lasting flows than others, in turn, influencing habitat condition.

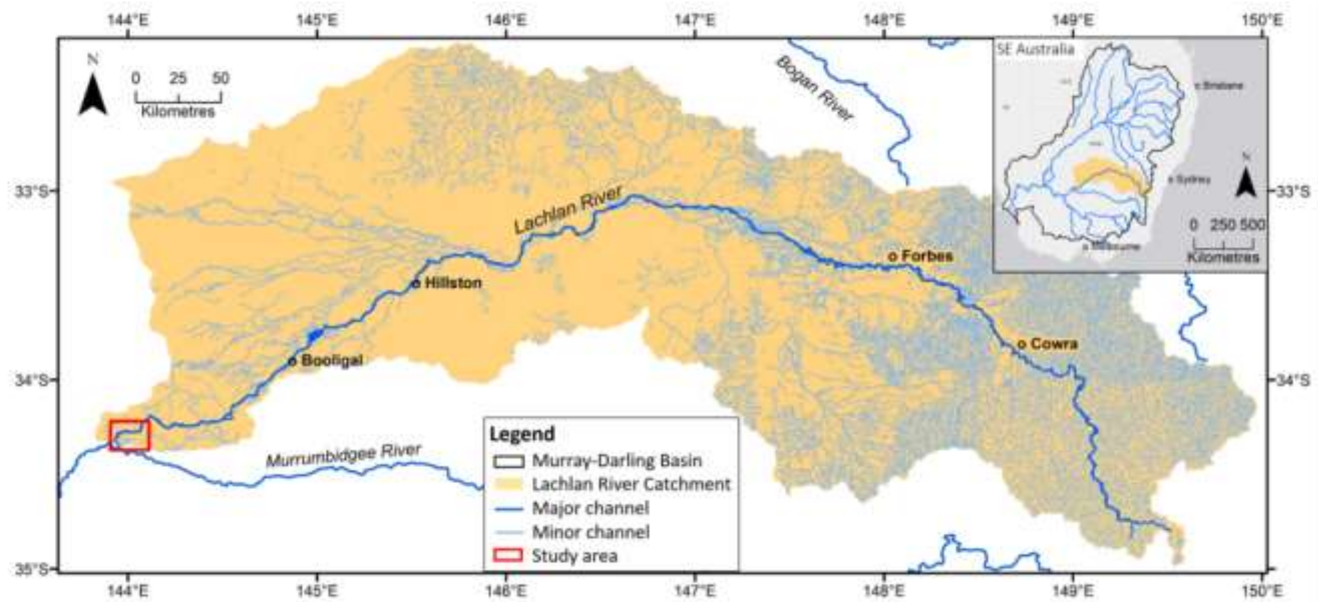

Figure 1 Lachlan River catchment map and the Great Cumbung Swamp (GCS) study area (red box). Catchment and river layers modified from NSW hydrography data (NSW Spatial Services, 2026)

Sites and methods

The Lachlan River branches into secondary channels on its alluvial plain downstream of Wallanthery, upstream of Hillston, and the meandering trunk stream is maintained until it disappears in the GCS (Figures 1 and 2). The Lachlan only flows through the GCS to join the Murrumbidgee River during major flood events (O'Brien and Burne, 1994). The modern river and floodplain wetlands sit at the southern edge of the alluvial plain, the plain having been formed by sediment deposition and reworking over thousands of years by a succession of ancient rivers, now preserved as palaeochannels (Kemp, 2004; 2010; Kemp and Spooner, 2007; Kemp and Rhodes, 2010; Kemp et al., 2017). Gilgai mounds and swales (depressions) created from shrinking and expansion of clay soils dominate the modern floodplain, together with shallow, reticulate channels that act to disperse water through and around the wetlands in times of flood.

Geomorphic features were identified and mapped from satellite imagery and a 1 m LiDAR-derived digital elevation model (DEM) with vertical accuracy of ±0.3 m and horizontal accuracy of ±0.8 m (NSW Government and Geoscience Australia, 2009). The mapping provides insight into fluvial landforms that underly inundation and flow patterns in the system. The LiDAR-derived DEM was used to produce a longitudinal profile and cross sections, enabling analysis of topography and landforms in the study area. Oblique aerial photography from a reconnaissance flight in 2021 and on-ground observations from field visits in 2022 and 2024 were used to assist with interpretation of the geomorphic features. We also refer to river reach codes established by O'Brien and Burne (1994), as shown in later figures (e.g. Figure 5).

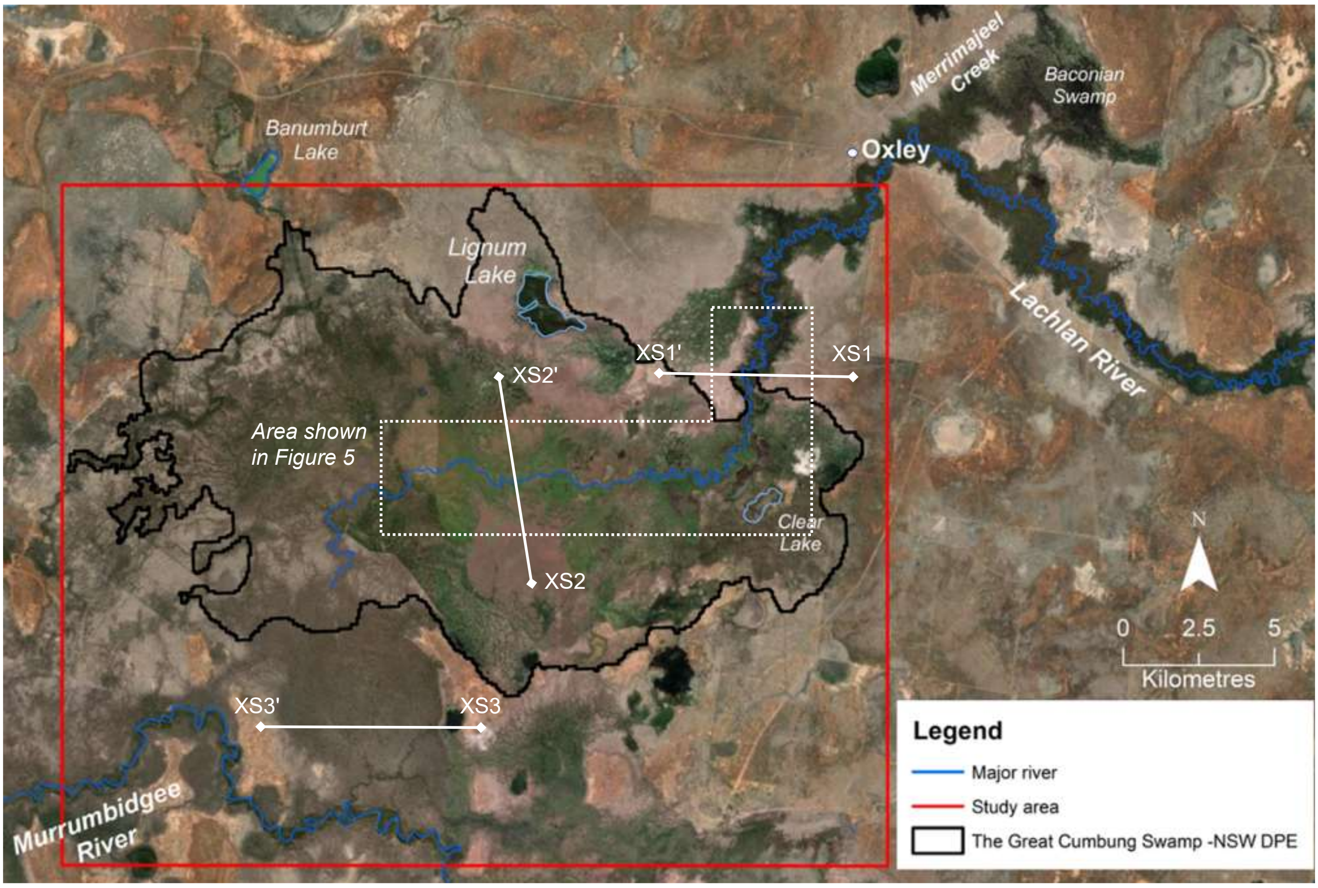

Figure 2 The Great Cumbung Swamp study area. The black line shows the extent of the swamp in the NSW wetlands layer (DPE, 2010), overlain on ESRI basemap satellite imagery. The white lines show the locations of three DEM transects upstream (XS1—XS1'), within (XS2—XS2'), and downstream (XS3—XS3') of the core wetlands. The dashed box indicates the area shown in Figure 5

Results and discussion

Channel and floodplain morphology

Along the lower Lachlan River, water progressively spreads from a sinuous, single-thread trunk stream within a narrow meander belt into the broader wetlands of the GCS through numerous breakaway points, floodouts and seepage through vegetated banks (Figure 2). This transition promotes inundation across the reed beds, lakes and shallow depressions, where diffuse overland flow and ponding dominate. Further downstream, however, water begins to concentrate into returning channels that provide pathways out of the GCS toward the Murrumbidgee River. These downstream channels are more prone to erosion, contrasting with the sedimentation that characterises the central swamp. Together, the downstream dispersal and reconvergence of flows are key controls on inundation patterns, sediment movement and wetland connectivity within the system.

The first cross-section (XS1—XS1') shows the Lachlan River trunk stream sited within a narrow (~1.9 km-wide) meander belt upstream of the swamp (Figure 3A). The slightly lower elevation meander belt constrains accretion processes and limits flow retention, promoting downstream transfer in the near-channel zone. Ephemeral wetlands on the surrounding floodplain have pronounced gilgai (mounds and swales) formed through post-depositional shrink-swell processes and act to filter sediment from water during overbank flood events. The surrounding alluvial 'red soil' plain is rarely inundated and suffers scalding and wind deflation at times, leading to a relatively flat surface with minimal surface expression of gilgai.

The second cross-section (XS2—XS2') shows the trunk stream perched on an alluvial ridge near the centre of the swamp (Figure 3B). The formation of an alluvial ridge indicates a dominance of in- and near-channel vertical accretion, creating lateral floodplain gradients that exceed the longitudinal gradient of the river. The convex, or humped, morphology influences lateral flow dispersal which occurs through many breakaway points and small, shallow distributary and reticulate channels on the proximal and medial floodplain. Most of the reticulate channels follow the swales of gilgai. In places, broad, shallow lagoons occur in floodplain depressions, and in some places buried palaeochannels constrain or impede the movement of water on the medial and distal floodplain, and at the margins of the wetlands.

The third cross-section (XS3—XS3') shows a basin or depression with multiple floodplain return channels downstream of the swamp (Figure 3C). There is a dominance of erosion in the return channels, where flows gather volume and energy as they drop towards the Murrumbidgee River. The concave morphology in this area leads to flow convergence where the surrounding alluvial plain acts as a barrier to divergent flow.

Overall, there is a marked contrast between the dominance of sedimentation, topographic growth and flow dispersal away from the trunk stream in the upper reaches compared to the dominance of erosion, topographic degradation and flow convergence in returning channels in the lower reaches. This is important to recognize for water and wetland management because these reaches inherently behave differently under a range of flow conditions.

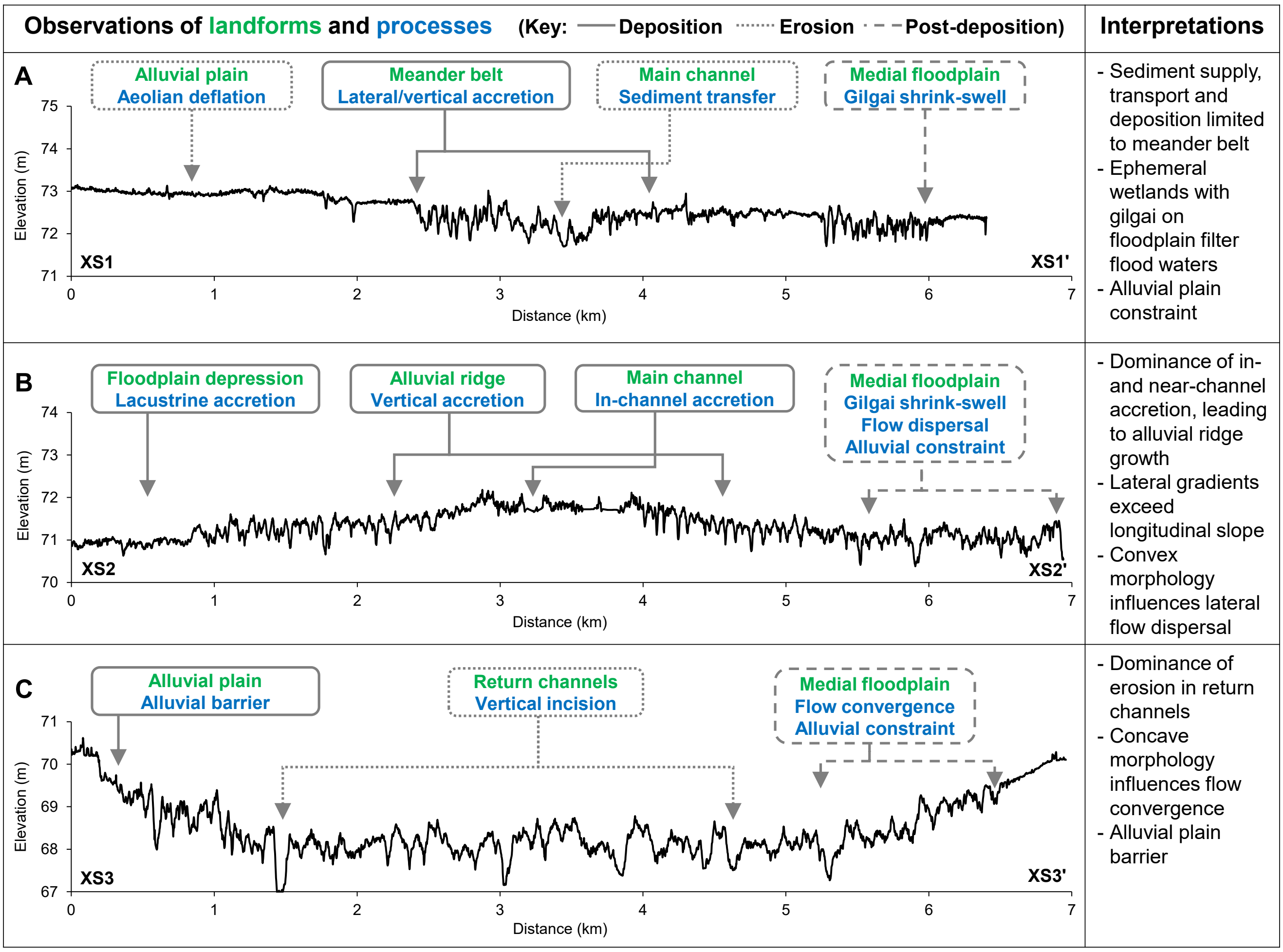

Figure 3 Observations and interpretations of geomorphology at three DEM cross-sections in the Great Cumbung Swamp. A) Lachlan River meander belt upstream of the swamp (XS1—XS1'). B) Alluvial ridge and wetlands within the swamp (XS2—XS2'). C) Floodplain return channels downstream of the swamp (XS3—XS3') near the Murrumbidgee River

Breakaway points and downstream change

Breakaway points are important geomorphic features in the GCS because they provide pathways for water to leave the main channel and spread into the wetlands either before or when bankfull stage is reached (Figure 4). Along the lower Lachlan River, the increasing number of breakaway points corresponds with the downstream transition from a single-thread river to a more diffuse wetland system (Figure 5A). As discharge and stream power decline downstream, the capacity of the main channel to contain and efficiently convey flow is reduced, allowing water to progressively escape through channel margins and distributary flow paths. These breakaways promote lateral connectivity between the river and floodplain, sustaining inundation of reed beds, lakes and shallow wetland depressions within the GCS. Their distribution and activity therefore strongly influence how water is retained, redistributed and stored within the system.

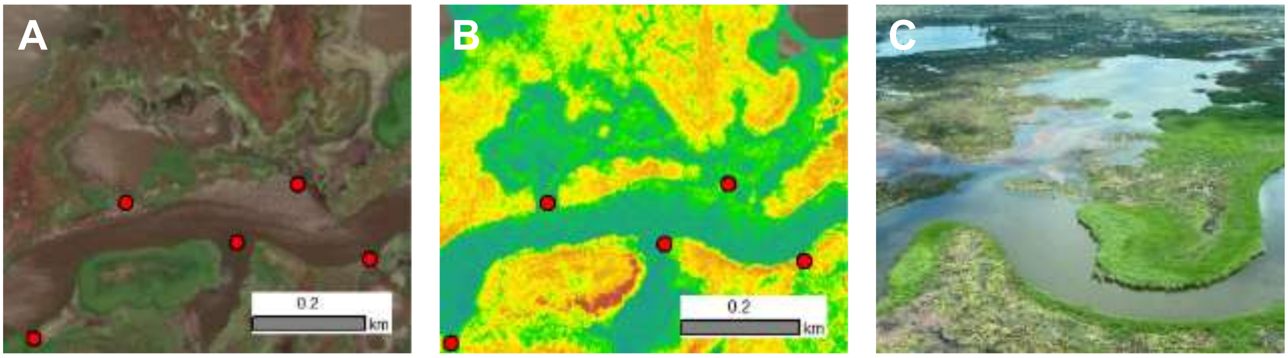

Figure 4 Examples of breakaway points (red dots) on the lower Lachlan River in the Great Cumbung Swamp. A) Shown on ESRI satellite imagery. B) Shown on DEM. C) Oblique aerial photo

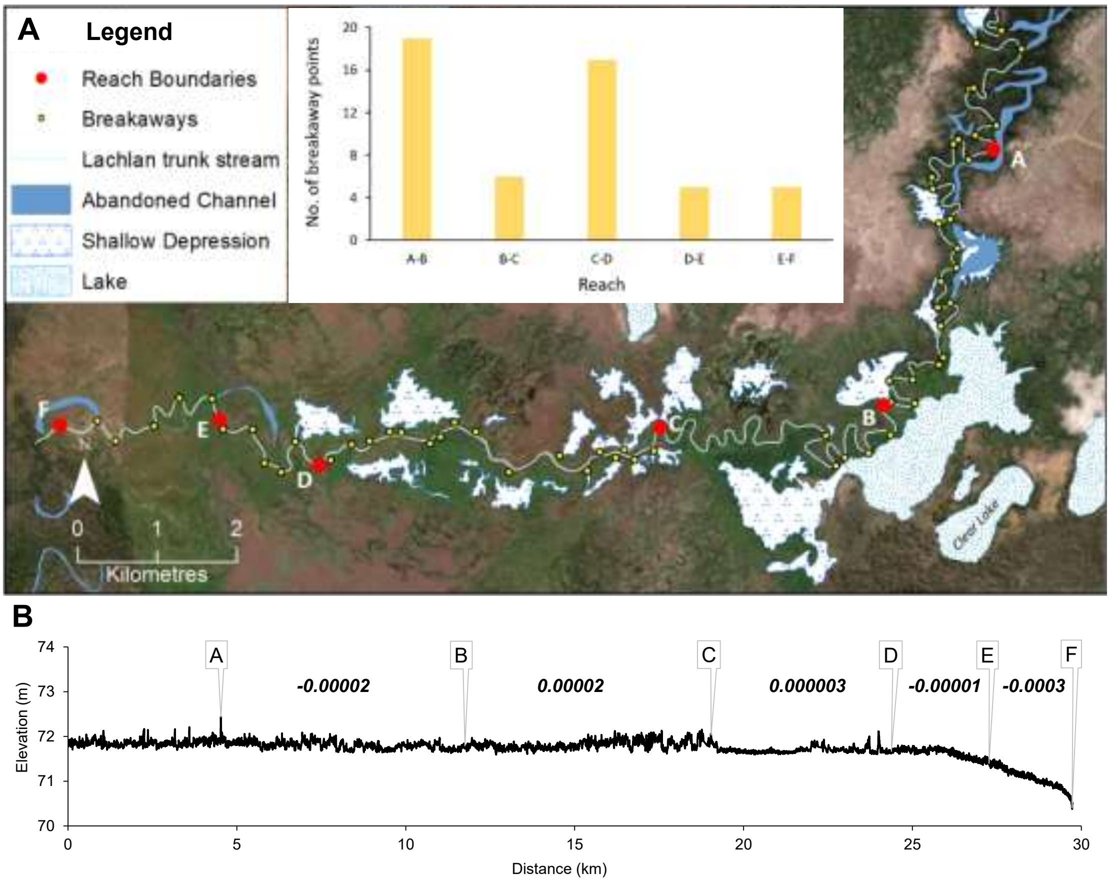

Figure 5 The main Lachlan River channel in the Great Cumbung Swamp, and its breakaway points. A) Geomorphic map, location and count of breakaway points. B) DEM-derived long profile showing channel gradient in reaches A-B, B-C, C-D, D-E and E-F identified by O'Brien and Burne (1994)

A DEM-derived long profile of the Lachlan River through the GCS shows a slight negative (downhill) gradient in the sinuous reach A-B, and a slight positive (uphill) gradient in sinuous reach B-C, before the main channel becomes less sinuous in reach C-D within the core wetlands (Figure 5B). Reach C-D has, on average, a slightly positive (uphill) gradient, while reaches D-E and E-F have negative (downhill) gradient downstream of the core wetlands, where the trunk stream appears to occupy a segment of a paleochannel.

Downstream changes in channel size, shape, sinuosity and gradient reflect the progressive decline in discharge, stream power and channel efficiency as flow is lost through breakaway points leading to channel breakdown in the swamp. Upstream reaches maintain a more continuous and sinuous channel, but further downstream the river increasingly loses water through breakaway points, vegetated banks and floodouts. The downstream pattern represents a fundamental geomorphic and hydrological transition from channelised flow to diffuse wetland inundation, which underpins the ecological function of the system.

Returning channels at the downstream margin of the swamp are important because they provide pathways for water to reconcentrate and exit toward the Murrumbidgee River. Unlike the upstream reaches where flows are dispersed, these downstream channels locally concentrate flow and energy as water is funnelled back into defined pathways. As a result, they are more prone to erosion and channel enlargement, which creates an apparent imbalance within the system, since sediment deposition dominates in the central part of the swamp. Changes in the size, efficiency or position of the returning channels may alter water levels, inundation patterns and duration, and connectivity in the wetlands. Consequently, both the dispersal of flows through breakaways and the reconcentration of flows into downstream channels are critical controls on wetland behaviour, sediment movement and long-term geomorphic adjustment in the GCS.

Geomorphology and wetland management

Overall, features such as palaeochannels, levees, breakaways, floodouts and gilgai depressions strongly influence how water moves through the GCS, as in other inland floodplain wetlands in NSW (Ralph and Hesse, 2010; Yonge and Hesse, 2009). In low-gradient systems, even subtle variations in topography can redirect flows, promote ponding, or create preferential pathways. Palaeochannels may continue to act as conduits for surface flow and/or shallow groundwater flow long after abandonment by the main river, while levees and alluvial ridges can impede or redistribute inundation (Hesse et al., 2018). On the main channel upstream of the GCS, the Lachlan River responds to large floods by distributing flows across its palaeochannel network, turning what is primarily a single channel system into an anabranching and distributary network (Kemp, 2004). Similarly, at a smaller scale in the GCS, these landforms and processes contribute to the transition from a defined river channel to diffuse overland and flood out flow within the wetlands.

These broader geomorphic controls are important because they influence inundation depth, duration and connectivity, which underpin wetland vegetation, habitat availability and other ecological processes (Ralph et al., 2011; Ralph et al., 2016). Changes in channel form, sedimentation or erosion patterns and rates may alter the way water, including environmental flows, spread through the system, in turn affecting wetland extent and persistence over time. Erosion that cuts down, widens and causes headward retreat of knickpoints in returning channels may lead to wetland disconnection from essential overbank inundation (Oyston et al., 2014). Geomorphological assessment therefore provides an important basis for water and wetland management by identifying the landforms and flow pathways that control floodplain inundation and ecological function.

Management of the GCS is closely linked to understanding how water moves through the reed beds, floodouts and distributary flow paths that characterise the lower Lachlan system. Historical and recent inundation patterns and vegetation indicate that parts of the core reed beds that previously experienced frequent inundation have received substantially less water in recent decades, even during environmental flow events and large floods. Water and wetland management plans have considered how natural and anthropogenic changes to channels, levees, banks and control structures have altered the distribution of flows across the swamp, diverting water away from historically inundated reed bed areas toward other parts of the floodplain. These changes appear to have reduced the persistence and extent of Phragmites reed beds in some areas and altered inundation pathways through the wetland system.

A key management focus is therefore improving or maintaining hydrological connectivity between the lower Lachlan River and the core wetland areas within the GCS (DPIE, 2020). Proposed actions include detailed analysis of historical inundation patterns and LiDAR data to better understand flow pathways, assessment of banks and regulators that influence water distribution, hydrological and hydrodynamic modelling of a range of flow scenarios, and targeted environmental actions (e.g. nature-based rehabilitation works) to direct flows back toward priority wetland areas. It is also important to understand how artificial structures, channel modifications and ongoing erosion and sedimentation processes interact to influence flow and inundation in the swamp.

Community engagement and consultation are also critical components of wetland and conservation management because the GCS and other inland wetlands are influenced by a long history of land use, water management and local knowledge. Landholders, Traditional Owners, environmental water managers, environmental scientists, and local communities often have detailed observations of changing flow patterns, vegetation conditions and wetland health that may not be captured through short-term scientific monitoring or assessments. Incorporating these perspectives can improve understanding of how wetlands function and respond to both natural variability and management interventions. With all stakeholders on board, a combined geomorphological, hydrological and socio-ecological approach to water and wetland management can consider both natural floodplain processes and the long-term effects of infrastructure and water management interventions.

Conclusions

The Great Cumbung Swamp is a geomorphologically complex wetland system where subtle variations in topography, channel form and floodplain connectivity strongly influence inundation, habitats, and ecological processes. Understanding how water moves through breakaways, into wetlands, and reconcentrates at downstream return channels is important for interpreting wetland character and behaviour and for managing water. Integration of geomorphic assessment with hydrological analysis and modelling, inundation and vegetation mapping, and local community knowledge can support more effective conservation and management in the lower Lachlan River and GCS.

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References

Department of Planning, Industry and Environment (2020). Lachlan Long-Term Water Plan Part A: Lachlan catchment. Available online: https://www.environment.nsw.gov.au/sites/default/files/lachlan-long-term-water-plan-part-a-catchment-200092.pdf, last accessed 20/5/2026.

Hesse, P.P., Williams, R., Ralph, T.J., Fryirs, K.A., Larkin, Z.T., Westaway, K.E., & Farebrother, W. (2018). Palaeohydrology of lowland rivers in the Murray-Darling Basin, Australia. *Quaternary Science Reviews, 200*, 85-105. https://doi.org/10.1016/j.quascirev.2018.09.035

Kemp, J. (2004). Flood channel morphology of a quiet river, the Lachlan downstream from Cowra, southeastern Australia. *Geomorphology 60*, 171-190. https://doi.org/10.1016/j.geomorph.2003.07.007

Kemp, J. (2010). Downstream channel changes on a contracting, anabranching river: The Lachlan, southeastern Australia. *Geomorphology 121*, 231-244. https://doi.org/10.1016/j.geomorph.2010.04.018

Kemp, J., Pietsch, T., Gontz, A., & Olley, J. (2017). Lacustrine-fluvial interactions in Australia's Riverine Plains. *Quaternary Science Reviews 166*, 352-362. https://doi.org/10.1016/j.quascirev.2017.02.015

Kemp, J., & Rhodes, E.J. (2010). Episodic fluvial activity of inland rivers in southeastern Australia: Palaeochannel systems and terraces of the Lachlan River. *Quaternary Science Reviews 29*, 732-752. https://doi.org/10.1016/ j.quascirev.2009.12.001

Kemp, J., & Spooner, N.A. (2007). Evidence for regionally wet conditions before the LGM in southeast

Australia: OSL ages from a large palaeochannel in the Lachlan Valley. *Journal of Quaternary Science*, 22(5), 423-427. https://doi.org/10.1002/jqs.1125
Murray Darling Basin Authority (2012). Assessment of environmental water requirements for the proposed Basin Plan: Great Cumbung Swamp. MDBA Publication No: 36/12, ISBN: 978-1-922068-44-6. Available online: https://www.mdba.gov.au/sites/default/files/publications/EWR-Great-Cumbung-Swamp.pdf, last accessed 20/05/2026.
NSW Government and Geoscience Australia (2009). Digital elevation data – 1 m LiDAR-derived DEM. Available online: https://nsw-elvis.s3-ap-southeast-2.amazonaws.com/elevation/1m-dem/z55/Oxley202105/metadata/Oxley202105-LID1-AHD_2586194_55_0002_0002_1m.html, last accessed 07/12/2023.
NSW Spatial Services (2026). NSW Hydrography. Available online: https://data.nsw.gov.au/data/dataset/nsw-hydrography, last accessed 20/07/2026
O'Brien, P.E., & Burne, R.V. (1994). The Great Cumbung Swamp – terminus of the low-gradient Lachlan River, Eastern Australia, *Journal of Australian Geology and Geophysics*, *15* (2), 223-233.
Oyston, S.M., Ralph, T.J. & Hesse, P.P. (2014). Cutting down, back and out: assessment of channel erosion in a sensitive floodplain wetland. In Vietz, G., Rutherfurd, I.D. & Hughes, R. (editors), Proceedings of the 7th Australian Stream Management Conference, 27-30 July 2014, Townsville, Queensland, River Basin Management Society, pp. 143-149.
Ralph, T.J., & Hesse, P.P. (2010). Downstream hydrogeomorphic changes along the Macquarie River, southeastern Australia, leading to channel breakdown and floodplain wetlands. *Geomorphology, 118*, 48-64. https://doi.org/10.1016/j.geomorph.2009.12.007
Ralph, T.J., Hesse, P.P., & Kobayashi, T. (2016). Wandering wetlands: Spatial patterns of historical channel and floodplain change in the Ramsar-listed Macquarie Marshes, Australia. *Marine and Freshwater Research, 67,* 782-802. https://doi.org/10.1071/mf14251
Ralph, T.J., Kobayashi, T., García, A., Hesse, P.P., Yonge, D., Bleakley, N., & Ingleton, T. (2011). Paleoecological responses to avulsion and floodplain evolution in a semiarid Australian freshwater wetland. *Australian Journal of Earth Sciences, 58*, 75-91. https://doi.org/10.1080/08120099.2010.534818
Shanafield, M., Blanchette, M., Daly, E., Wells, N., Burrows, R. M., Korbel, K., Rau, G., Bourke, S., Wakelin-King, G., Holland, A., Ralph, T. J., McGrath, G., Robson, B., Fowler, K., Andersen, M. S., Yu, S., Jones, C. S., Waltham, N. J., Banks, E. W., ... & Duvert, C. (2024). Australian non-perennial rivers: global lessons and research opportunities. *Journal of Hydrology, 634*, 1-19. Article 130939. https://doi.org/10.1016/j.jhydrol.2024.130939
Yonge, D., & Hesse, P.P. (2009). Geomorphic environments, drainage breakdown, and channel and floodplain evolution on the lower Macquarie River, central-western New South Wales. *Australian Journal of Earth Sciences, 56*, S35-S53. https://doi.org/10.1080/08120090902870780