Rivers, channel breakdown and floodplains: Resolving a regulatory dilemma on lowland rivers in NSW

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Key points

- Regulatory overlap between floodplain harvesting and unregulated river licensing in NSW creates uncertainty in water extraction in lowland rivers.
- Channel breakdown complicates distinctions between river channels and floodplain features under current policy frameworks.
- A geomorphic classification approach provides a practical method to define rivers and support protection of flow continuity in lowland systems.

Abstract

Protection of unregulated river flows is a difficult decision-making area under New South Wales (NSW) water law. One area of contention, the definition of a river, has not been adequately resolved in all instances in NSW. The NSW Floodplain Harvesting Policy aims to regulate landholder capture and use of floodplain runoff. It has unintentionally created a regulatory overlap with unregulated river access licensing under the NSW *Water Management Act 2000* in cases of lowland rivers that undergo channel breakdown. Channel breakdown usually occurs in the lower reaches of inland rivers, where a watercourse loses its primary form (i.e. well-defined bed and banks) and either splits into multiple shallow floodplain channels, or terminates on the floodplain or in a wetland. In some cases, as in the Macquarie Marshes, the trunk stream and its branches dissipate into wetlands, before channels reform further downstream. This is important for water law because prohibition of increased unregulated river extraction may be side-stepped if parts of the river channel network are treated as floodplain features.

The identity of a river is starkly different in upland, escarpment, mid catchment slope and lowland settings. A robust method applying geomorphic techniques and diagnostic attributes is required to define what is, and is not, a river in lowland river networks that experience channel breakdown across NSW. A method has been applied using classification of channel breakdown classes in the lower Macquarie catchment. This will assist in defining rivers in lowland settings that experience channel breakdown, in order to better understand and protect flow continuity.

Keywords

river type, channel breakdown, floodplain wetlands, water regulation

Introduction

Twenty five years since the NSW *Water Management Act 2000* came into force, a number of key questions remain. One of these questions is the distinction between rivers and floodplains in lowland, low profile settings. The differences in river form and behaviour between northwestern Europe, from which the legal definition of a river is derived and Australia is well documented (Taylor and Stokes 2005, Williams and Fryirs 2020). Therefore, applying the very different channel patterns and hydrology of lowland rivers in inland NSW to existing policy has proven difficult.

One such difference is the frequency of channel breakdown in Australian lowland rivers. Channel breakdown refers to river channels that divide into networks of finer channels, fans or floodouts due to loss of stream energy as channel profiles reduce and sedimentary deposition occurs within the channel network (Yonge and Hesse 2009, Ralph and Hesse 2010, Larkin et. al. 2020a, Grave et. al. 2024).

The lack of an effective definition of rivers that includes watercourses that experience channel breakdown impairs defensible, consistent decision making. It also places greater threats of disruption and interception of flow in river networks across inland NSW. The threat of greater channel disconnection is more apparent as the range of river channel breakdown scale goes from 1st and 2nd Strahler order streams up to some of the largest rivers in the NSW Murray Darling Basin, including the Gwydir, Macquarie Wambuul and Lachlan Rivers.

This paper outlines problems of policy gaps in regulatory frameworks in NSW law, discusses applying scientific knowledge of unusual river forms to water policy, and establishes a method to identify and protect discontinuous rivers across NSW.

Water regulation policy and practice

The NSW Floodplain Harvesting Policy was introduced in 2013. It was developed to regulate overland flow harvesting works constructed on floodplains in the NSW Murray-Darling Basin prior to 2008. It requires licensing works that intercept overbank floodplain flows to regulate the indirect take of water that may otherwise form part of river flows. NSW Floodplain Harvesting Licensing procedures prohibit new authorisation of floodplain harvesting works in Zones A (floodways) or D (ecological assets) of relevant Floodplain Management Plans, such as the *Floodplain Management Plan for the Macquarie Valley Floodplain 2021* (Figure 1). If not enforced, this would permit the take of many additional gigalitres of river flow every year, leading to a potential breach of the Murray-Darling Basin Cap.

Differentiating between channel flow that is connected to rivers and rainfall runoff that enters floodplain features but does not connect to rivers requires detailed spatial and hydrological data. Spatial mapping has improved substantially across inland NSW over the past 15 years, including high resolution visual and multi-spectral LiDAR generated Digital Elevation Models (DEM) used to map channel breakdown (Ralph et al., 2021). On the other hand, hydrologic modelling relies on extrapolation from widely spaced flow gauges and/or pluviometers (Xu, 2021).

Effective regulatory decision making is needed that protects environmental flows to and through floodplain wetlands yet recognises legitimate landholder rights to irrigate defined floodplain areas. Floodplain harvesting regulation applies largely in lowland river environments where extended floodplains have multiple structures that intercept or redirect flows. Lowland river environments may have complex multiple channels, including anabranches and anastomosing channel networks (Riley and Taylor, 1978; Ralph et.al., 2021). This requires a definition of watercourses that includes those that undergo channel breakdown.

Case study: Macquarie Wambuul River and Macquarie Marshes

A decision framework has been developed to aid the authorisation of floodplain harvesting works and issue orders to remove or modify works that interfere with watercourses that transmit flows between rivers and floodplain wetlands. We present a case study with examples from the lower Macquarie Wambuul and Macquarie Marshes to demonstrate the capacity for improved identification of rivers and floodplain features through the use of more nuanced channel classification schemes.

The lower Macquarie Wambuul River enters a low-gradient inland floodplain where the main channel progressively breaks down into a complex anastomosing and distributary network (Larkin et. al. 2020a). In the Macquarie Marshes, flow is redistributed through channels, lagoons, reed beds, water couch grasslands, river red gum woodlands and intermittently inundated floodplain wetlands. The lower Macquarie Wambuul River and its branches in the southern Macquarie Marshes are especially dynamic, with avulsion, channel enlargement, sedimentation and channel abandonment that have shifted the focus of inundation over time (Ralph et al., 2016). Hydrologically, the system is strongly flood-dependent, with wetland extent and condition controlled by variable river flows, overbank flooding, channel connectivity and, more recently, flow regulation and water extraction upstream (Ralph and Hesse, 2010).

Back Swamp is an extension to Marebone Break, an offshoot of the regulated Macquarie Wambuul River, ~42 km north of Warren, NSW. It was cut off as part of an extension to Marebone Break to connect Bulgeraga Creek to the regulated Macquarie River in 1975. Bulgeraga Creek directs regulated river flow, including environmental flows, to the southern Macquarie Marshes and the eastern wetlands along Gum Cowal. Back Swamp remains but has been cut by three irrigation channels supplying water from Marebone Break and Bulgeraga Creek to irrigated cropping land to the east of Back Swamp (Figure 2).

Back Swamp catchment position and relationship to the Macquarie River is shown in Figure 1.

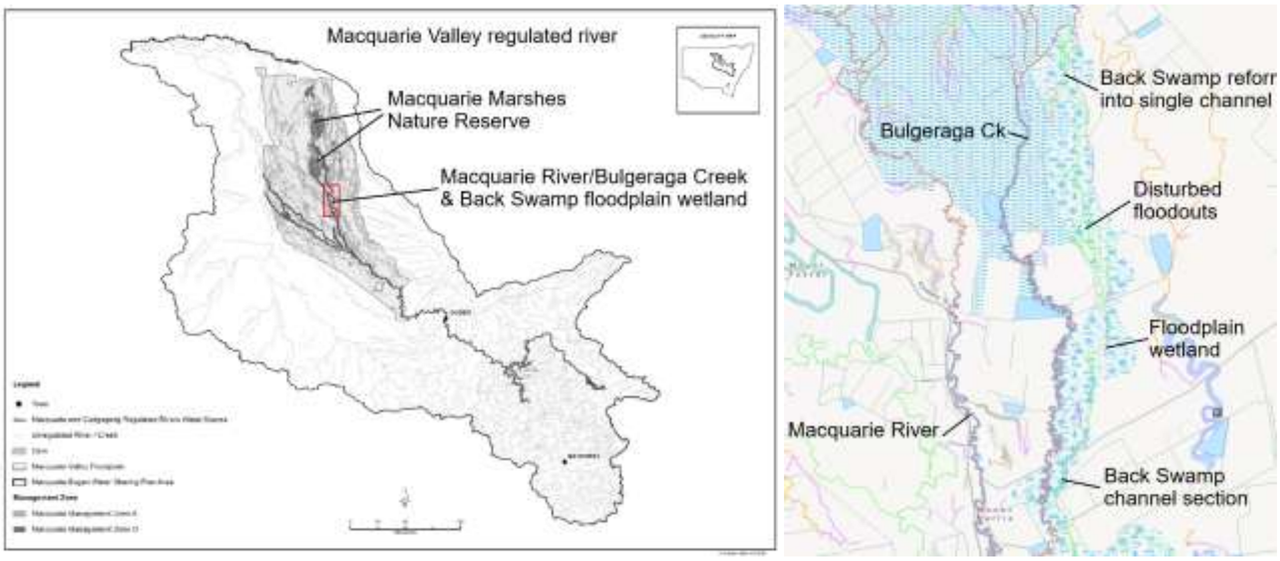

Figure 1 A. Macquarie catchment indicating catchment position of Bulgeraga Creek/Back Swamp. Source NSW Water Sharing Plan for Macquarie Regulated River 2016. B. Bulgerara Creek and Back Swamp showing Strahler stream order. Source: NSW Water Spatial Viewer VertiGIS Studio Web Version: 5.39.0

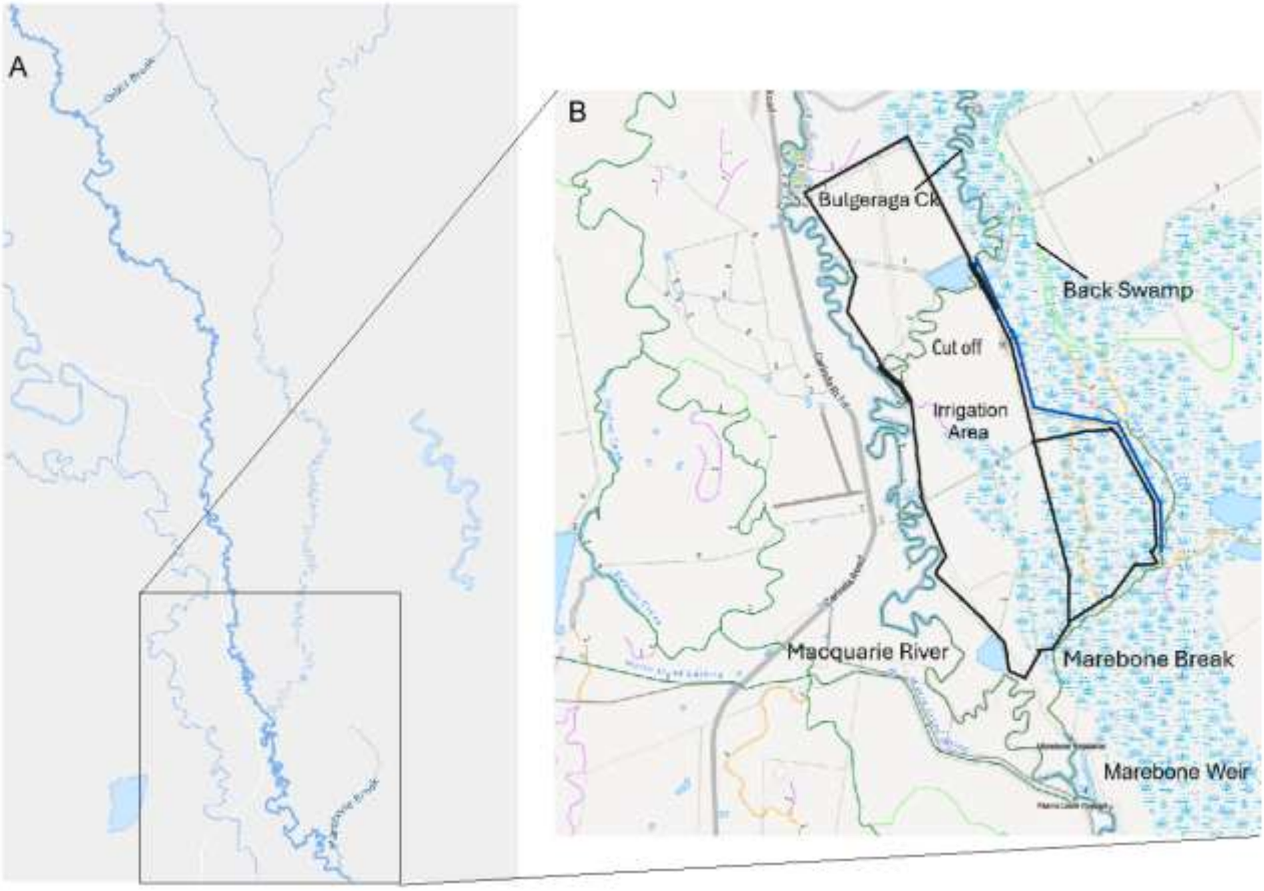

Figure 2 A. Hydroline map of Macquarie River and Bulgeraga Creek. Marebone Break channel and Back Swamp missing. B. Marebone Break, Bulgeraga Creek and Back Swamp

The regulated Macquarie River divides between the Macquarie River and Marebone Break at Marebone Weir. Regulated river flows are directed along both rivers to supply water to the western section of the Macquarie Marshes or through the centre of the wetlands from Marebone Break via Bulgeraga Creek (Figure 1). A further regulator redirects selected flows along Gum Cowal to the east of the Macquarie Marshes and to regulated water users near Carinda.

Back Swamp is a disrupted hydrologic link between Marebone Break and Gum Cowal. The single thread channel from upstream breaks down into three larger channels and smaller distributary marsh channels that maintain Back Swamp, a floodplain wetland that is isolated from regulated flows by bunds constructed along Marebone Break and Bulgeraga Creek (Figure 3). The inlet to Back Swamp has a mid-bank height outlet from Marebone Break that supplies flow to the floodplain wetland section downstream to downstream of Gradgery Lane. From there, the channel network has been disrupted by cropping activity until its lowest reaches where the dendritic channel network coalesces into a single thread channel that drains into Gum Cowal.

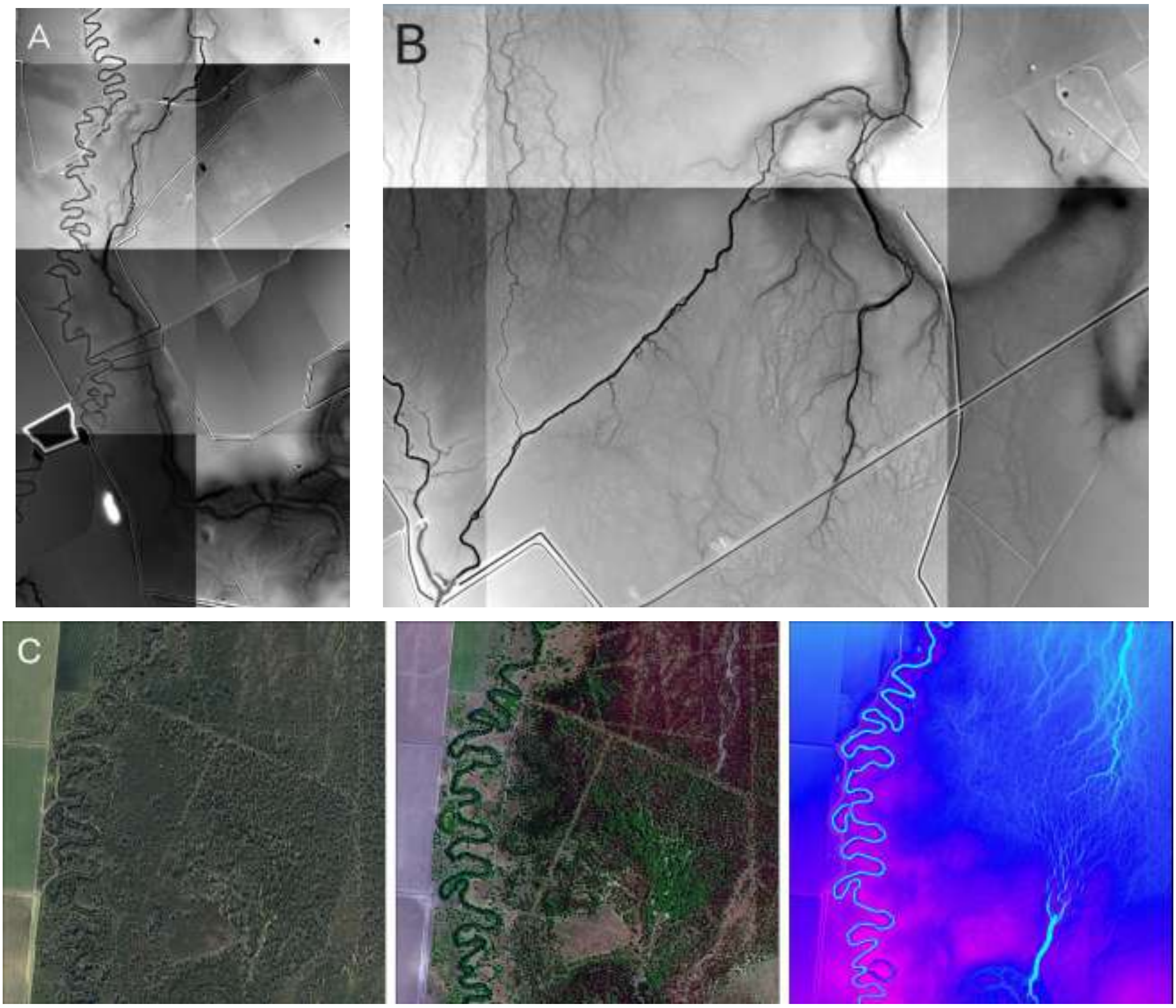

Figure 3 A. 1 metre DEM of upstream section of Back Swamp from Marebone Break to Gradgery Lane, beyond which the Back Swamp channel breaks down into a floodplain swamp. B. 1 m DEM of downstream Back Swamp swamp channels recombining to form a single thread channel to Gum Cowal junction (top). C. Multi-spectral 1 m DEM of Bulgeraga Creek (left side of images) and Back Swamp (right side) showing channel breakdown and coalescence

The inherent complexity of river and wetland channels in the Macquarie Marshes, and similar lowland river systems, means that channel mapping and identification is fraught with difficulty. To date, the NSW Hydroline Dataset forms the platform for river identification and position: https://www.water.dcceew.nsw.gov.au/our-work/licensing-and-approvals/controlled-activity-approvals/development-activities-waterfront-0

The NSW Hydroline dataset defines waterways primarily as centrelines of mapped watercourses and performs reasonably well in larger (5th Strahler order and larger) single-thread river systems. However, in lowland rivers of NSW that undergo channel breakdown, distributary flow and floodplain channelisation. Hydroline mapping commonly fails to capture the full extent of geomorphically active channels and associated floodplain features. In these settings, flow continuity may occur across multiple anabranching channels, flood runners and other floodplain features that are not consistently represented within the regulatory stream layer, despite functioning as components of the river system during moderate and high flows.

This limitation has been identified in geomorphic studies of the lower Macquarie and other lowland systems, where channel breakdown produces transitions between clearly defined channels and diffuse floodplain flow networks (Ralph et. al. 2016, Hesse et. al. 2018). Reliance on Hydroline mapping therefore risks under-representing hydrological connectivity and river extent in lowland settings, particularly where policy and licensing decisions depend on distinctions between rivers and floodplain features.

Distinguishing rivers and floodplain features

Two general criteria are necessary to legally distinguish watercourses and rivers from floodplain features in lowland rivers. These criteria are hydrologic connection and geomorphic attributes, representing flow nature and geomorphological character to determine if a river exists or is only a floodplain feature that is not in connection to the hydrologic network below overbank flow stage.

Hydrologic connection

The *NSW Water Management Act 2000* dictionary definition of a river contains two key indicators to determine whether a river is present for decision making purposes. These are:

- a watercourse conveying perennial or intermittent flows, with a defined channel whether natural or artificially improved, and;
- a tributary, branch or other watercourse into or from which a watercourse above flows.

As the NSW *Water Management Act 2000* requires the hydrological context of watercourses to be established, breaks, cowals and branches must be assessed to determine if their commencement begins at a break from the antecedent river at, or below, bank height. River flows enter the distributary watercourse at below bankfull stage and commonly supply floodplain wetlands, terminal lakes or may connect to another watercourse downstream, while fluvial action may cause the positions or connections between these systems to change over time (Ralph and Hesse 2010, Ralph et al. 2016). Therefore, the flow stage at which connection between rivers from which flow is sourced or enters and distributary discontinuous watercourses must be established. This is important to distinguish between water that flows through discontinuous rivers and floodplain runoff that is intercepted by floodplain harvesting structures.

NSW water regulation case law (e.g. O'Keefe v Water Administration Ministerial Corporation [2010] NSW LEC 9) recognises channel discontinuity may be included in the definition of watercourse and rivers under the NSW *Water Management Act 2000*. Assessing patterns of flow continuity alongside geomorphically distinct channel features is essential to maintain hydrologic connectivity, downstream flow paths and ecological links between floodplain wetlands and watercourses.

Two NSW environmental law cases in 2023 and 2025 determined flow continuity along Back Swamp is to be protected alongside a prohibition on taking water flows along the discontinuous channel network that drains into the reformed channel to Gum Cowal. These cases, alongside previous cases involving discontinuous upland watercourses, provide a precedent and should guide future regulatory approaches involving channel breakdown in lowland NSW rivers.

Geomorphic attributes – classifying river networks

A large proportion of rivers throughout inland NSW, including the Macquarie Wambuul, are characterised by downstream decreasing channel size, reduction in stream power, and reduced sediment transport capacity (Ralph and Hesse, 2010; Larkin et al., 2020a). Several major lowland river tributaries to the Barwon-Darling Baaka River experience substantial loss of channel definition, undergoing channel breakdown due to sedimentary hydraulic damming upstream of river junctions, termed buffers (Fryirs et al., 2007; O'Brien and Burne. 1994).

In lowland rivers, channel breakdown occurs where rivers channels can no longer transport sediment downstream, depositing sediment both in channel, frequently forming depositionary fans and floodplain wetlands (Tooth, 1999; Larkin et al., 2020b). Sedimentary features infill the channel to form anastomosing multi-channel features, including floodouts and floodplain wetlands. These develop discontinuous river sections along the flow pathway, frequently with channelised sections separated by floodouts and/or floodplain wetlands.

The distinction between watercourses and paleochannels requires an assessment of flow continuity through channelised, multi-channel breakdown and floodplain wetlands (Graves et al., 2024). The continuity of watercourses that undergo channel breakdown does not, of itself, require a continuous channel but must have a flow that has a source and either a junction with another river or terminus in a lake or wetland.

We have applied a classification system applied to the river channel network in the Lower Macquarie catchment (Yonge and Hesse, 2009; Ralph and Hesse, 2010) to form a consistent and defensible method to determine whether a river is present under the definition in the NSW *Water Management Act 2000*. This imposes a restriction on volumetric licensing of floodplain harvesting to protect flow connectivity in channel networks across NSW.

A four-tier hierarchy of channel form (Yonge and Hesse, 2009) provides a guide to discriminating between channel types in lowland landscapes: gradational reduction in channel size, shape and changed sedimentary characteristics through channel breakdown from single thread rivers to floodplain wetlands (Ralph and Hesse, 2010). Channel breakdown creates both an intimate connection with floodplains and an anastomosing network of low sinuosity, interconnective channels. In terms of channel form, larger continuous river channels form tortuous meandering patterns compared to low sinuosity multiple channels.

The component waterway types are:

- Meandering trunk streams: meandering to tortuous continuous channels featuring channel capacities sufficient to convey significant flow before bankfull stage is reached. Vegetation is complex with large trees and dense understorey and large wood structures are frequent along the channel. Examples in the Mt Harris area upstream of the Macquarie Marshes include Macquarie River, Bulgeraga Creek, Ewenemar Creek and Marra Creek.
- Primary distributary channels: channels bifurcating from primary river channels with relatively large channel capacity but low sinuosity and may break down into floodplain wetlands. Channel vegetation is dominated by reeds that colonise narrow benches and back top. Examples in the area immediately upstream of the Southern Marshes include Gum Cowal, Umangla Cowal.
- Floodplain marsh channels: channels that possess variable channel shape, depending on fringing vegetation and sediment features such as swales, sediment plumes and fill surfaces as channel breakdown disperses flow energy through complex distributary channels. Examples in the Mt Harris area include Stewarts Creek, Back Swamp and McClunes Creek.
- Unchannelised marsh: channels have broken down into very shallow flow paths that may be indistinguishable to the eye before dissipating into intermittent floodplain wetlands or semi-permanent wetlands such as the Monkeygar Marsh, Mole Marsh or Northern Marshes of the Lower Macquarie Wambuul.

This hierarchy provides a defensible method to distinguish between primary, secondary and discontinuous tertiary channel and fans, floodouts and marsh flow paths. It may inform water regulatory decision making in rivers across inland NSW and provide a useful tool for community education in hydromorphic river character and flow connectivity. The hierarchy has demonstrated effectiveness in situations where flow connectivity to downstream watercourses exists. Examples of these four river types are shown below in Figure 4.

Figure 4 Images of four classes of channel systems in the Lower Macquarie catchment. A. Meandering trunk stream (Macquarie River, Oxley). B. Primary distributary channel (Marra Creek), C. Floodplain marsh channels (Back Swamp) D. Unchannelised marsh (Southern Macquarie Marshes, Monkeygar Ck outlet)

The key delineation of discontinuous channels forming part of continuous watercourses in the Lower Macquarie Valley provides a level of protection to other lowland rivers in NSW. Further work to determine how discontinuous channel patterns, such as floodouts and floodplain wetlands, should be assessed under NSW water law. This should utilise high resolution time series imagery and Digital Elevation Models (Ralph et al., 2021).

Conclusion

To date, the four scale hierarchy of river channel form has been used in several locations in the Lower Macquarie Valley to determine mitigation measures of floodplain works installed prior to 2008 and to prohibit new floodplain harvesting works. It is anticipated the method may be applied to channels in the near future in the Lower Lachlan and Murrumbidgee valleys and sections of the Gwydir Valley, Darling Baaka and elsewhere in the NSW Murray-Darling Basin. The inclusion of channel breakdown into floodplain harvesting regulation is a positive step to protect connective flows in lowland rivers in the northern NSW Murray-Darling Basin.

At this time, channel networks that terminate in wetlands have not been considered in the regulatory framework. Other river types, particularly those possessing no defined channel, such as chain of ponds, require separate evaluation. They may be assessed either as riverine types or lake/wetland types (NSW *Water Management Act 2000* dictionary). Further work in this area is required to define how geomorphological attributes may inform regulatory policy in NSW.

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