Mapping geomorphic floodplain wetlands as assets for consideration in delivering natural flood management (NFM) across coastal catchments of New South Wales (NSW), Australia

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Key points

- Floodplain wetlands play an important role in Natural Flood Management (NFM) by slowing floodwater and reducing peak flood levels through natural hydrological and geomorphic processes.
- The 2021–2022 eastern Australia floods and inquiry that followed emphasized the need to better access and use floodplain wetlands as "assets" for flood mitigation across NSW coastal catchments.
- The study developed a protocol to identify four wetland types, including cutoffs, palaeochannels, backswamps, and lagoons, using satellite data, DEM-derived terrain metrics, and Random Forest algorithm.
- Over 21,000 wetlands (total area ~594 km^2) were mapped across 18 catchments, varying in number, size, mean DEM-derived depth, and valley-bottom position; backswamps dominate in both extent and abundance, lagoons are also widespread, while cutoffs and palaeochannels together comprise nearly half of all wetlands but account for only 17% of the total area.
- These findings provide a geomorphic baseline and database of floodplain wetlands that can now be used to determine their functional role and potential for integration into NFM strategies and flood resilience planning in coastal catchments of NSW.

Abstract

Floodplain wetlands are often under considered as key assets for Natural Flood Management (NFM), a nature-based flood mitigation option that harnesses hydrological and geomorphic processes to slow flood flows and attenuate flood levels. The catastrophic 2021–2022 floods in eastern Australia underscored the urgent need to assess the geomorphic capacity for NFM across the coastal catchments of New South Wales (NSW).

This study establishes a protocol for identifying and mapping four geomorphic floodplain wetland types: cutoffs, palaeochannels, backswamps, and lagoons using readily available remote sensing data. A GIS database of geomorphic floodplain wetlands was created, comprising over 21,000 wetlands delineated across 18 coastal catchments of NSW, covering 129,947 km^2, using satellite data, Digital Elevation Model-derived terrain metrics, and an integrated approach incorporating the Random Forest method. The distribution of floodplain wetlands allows quantification of total number, area, mean DEM-derived depth, and position on the valley bottom. Overall, floodplain wetlands occupy 594 km^2. Backswamps, occurring on low-gradient floodplains, dominate in both abundance and area, while lagoons, found in similar positions but containing persistent standing water, are also prevalent. Combined, cutoffs and palaeochannels comprise nearly half of all wetlands but account for only 17% of total wetland area. The distribution and valley-bottom position (distal or proximal) of wetlands vary with valley setting.

These findings provide a geomorphic baseline and database of floodplain wetlands that can now be used to determine their functional role and potential for integration into NFM strategies and flood resilience planning in coastal catchments of NSW.

Keywords

Natural flood management, floodplain assets, geomorphic floodplain wetlands, floodplain wetland mapping

Introduction

Natural Flood Management (NFM) uses nature-based solutions to attenuate flood flows, reduce erosive forces, and minimize flood risk (Dadson et al., 2017; Fryirs, 2026; Lane, 2017; McLean et al., 2013). A range of techniques can be applied to achieve NFM, including increasing channel and riparian roughness, reafforestation to desynchronise flood peaks, and installing runoff attenuation features such as leaky weirs in headwater systems (Collentine & Futter, 2018; Quinn et al., 2022; Stratford et al., 2017). While these measures can be effective at local scales, particularly in small catchments, their impact is often limited in medium to large systems. In such contexts, NFM requires an integrated, cross-scalar approach that also incorporates the role of floodplains and associated wetlands as key zones of water storage, detention, and energy dissipation (Ellis et al., 2021; Hartmann et al., 2019; Nesshöver et al., 2017; Schanze, 2017).

The 2021–2022 floods in eastern Australia highlighted both the vulnerability of existing flood management approaches and the potential for NFM in coastal catchments of New South Wales (NSW) (Fryirs et al., 2023). These catchments are characterised by large spatial scales and high flow variability (Rustomji et al., 2009), meaning that effective flood mitigation must consider processes operating at (sub)catchment scales. In response, the NSW Government inquiry advocated for nature-based approaches, including “using floodplains as assets” and allowing rivers to function more naturally, alongside reconsideration of floodplain land use (Fryirs, 2026; O’Kane & Fuller, 2022).

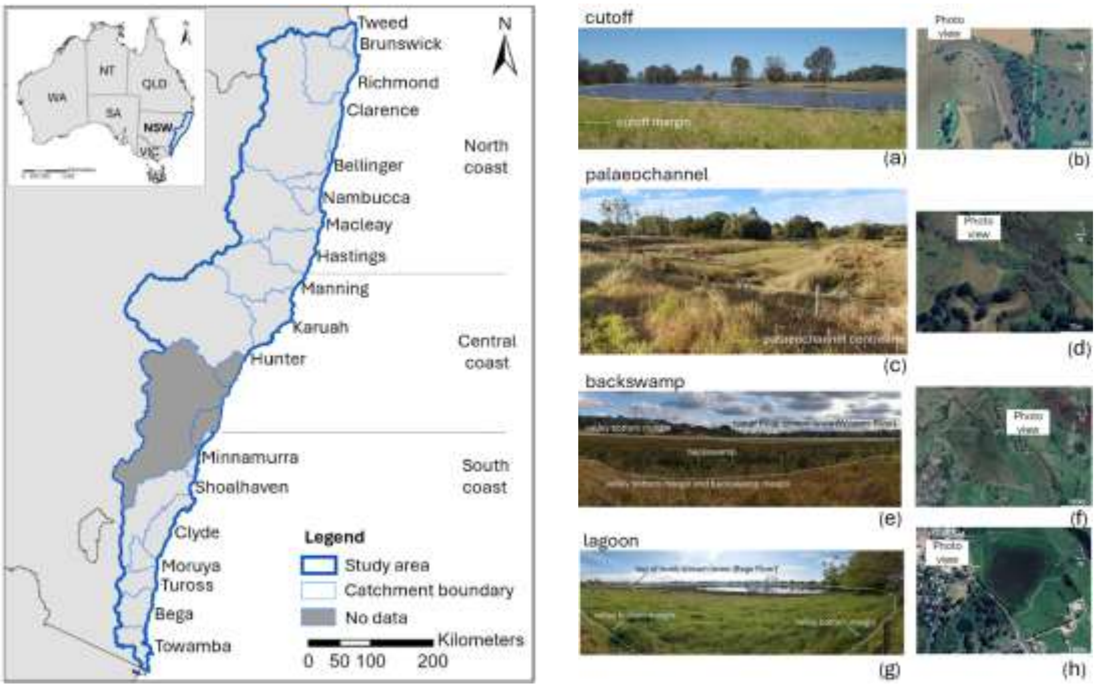

Figure 1 18 study catchments (left) and types of floodplain wetland found in coastal catchments of NSW, Australia (right). (a-b) cutoff. Example from the Richmond River near Coraki, North Coast, NSW; (c-d) paleochannel. Example from near Coopers Creek in the Richmond catchment, North Coast, NSW; (e-f) backswamp. Example from the Wilsons River in the Richmond catchment, North Coast, NSW; (g-h) lagoon. Example from the Bega River, South Coast, NSW. Source Wang et al., (subm.)

Floodplain wetlands, including cutoffs, palaeochannels, backswamps, and lagoons are key geomorphic units that can act as natural floodplain assets (Brierley & Fryirs, 2005; Lewin & Ashworth, 2014; Lisenby et al., 2019; Singh & Sinha, 2020). Their capacity to store and delay floodwaters depends on their size, morphology, sedimentary characteristics, and position on the valley bottom (proximal or distal) (Åhlén et al., 2022; Ferreira et al., 2023; Wu et al., 2020). However, across coastal NSW, there is currently no consistent, region-wide dataset describing the type, distribution, and characteristics of these wetlands. This lack of baseline information limits the ability to understand their function and their consideration in flood mitigation planning.

Despite their importance, most wetland mapping approaches rely on ecological or vegetation, and do not explicitly account for geomorphic form or valley-bottom position. As a result, these datasets are poorly suited to analyzing floodplain function and flood attenuation potential. Recent advances in remote sensing, cloud computing, and machine learning provide new opportunities to address this gap.

In this study, we combine open-access satellite imagery and Digital Elevation Model (DEM)-derived terrain metrics with Random Forest method to systematically identify and map key geomorphic floodplain wetland types, including cutoffs, palaeochannels, backswamps, and lagoons, across 18 coastal catchments of NSW (Figure 1). We quantify their geomorphic characteristics and analyze their spatial distribution in relation to valley setting and valley-bottom position. The resulting geospatial database provides a consistent baseline and establishes a foundation for developing a floodplain "assets register", supporting future assessment of the role of wetlands in flood attenuation and NFM implementation (Wang et al., subm.).

Methods

Data sources include Satellite data and DEM-derived Data. Sentinel-1, Sentinel-2 and Landsat 8 images from January 1st 2020 to December 31st 2024, were acquired from Google Earth Engine (GEE). The 5 m DEM of coastal catchments in NSW were sourced from Australian Government Elevation and Depth Foundation Spatial Data (ELVIS) (http://elevation.fsdf.org.au/).

We developed a workflow to delineate and map floodplain wetlands using the Random Forest machine-learning method (see Wang et al., subm. for details). The workflow was implemented using Google Earth Engine and ArcGIS Pro 3.2. Four key layers (Thermal from Landsat 8, mean DEM-derived depth, NDVI from Sentinel-2, and VH from Sentinel-1) were selected for the Random Forest (RF) classifier in GEE. Wetlands affected by marine or tidal influence were excluded from the analysis by expert geomorphic interpretation. The RF classifier of floodplain wetlands across the 18 coastal catchments exhibited strong performance, based on both overall accuracy (OA) and Kappa statistics. OA ranged from 0.84 to 0.98, and Kappa values ranged from 0.78 to 0.97, indicating good agreement between prediction and validation data. Using the distribution of confined valley setting (CVS), partly confined valley setting (PCVS) and laterally unconfined valley setting (LUVS) of study catchments are extracted from the State-wide NSW River Styles database (Fryirs et al., 2021), analyses of floodplain wetlands were conducted at subregion, catchment, and valley scales to map and analyze the spatial extent and distribution of the four geomorphic wetland types (Figure 1).

Results

Floodplain wetlands in coastal catchments of NSW

Across the study area (Figure 1), we identified 21,413 floodplain wetlands, covering a total area of ~594 km^2 (Table 1). Some representative examples are shown for the Richmond, Hunter and Bega catchments in Figure 2d-f. Each of the four geomorphic wetland types (cutoffs, palaeochannels, backswamps, and lagoons), have distinct spatial and morphological characteristics.

Table 1 Number, area and mean depth for each floodplain wetland type across study area (Source Wang et al.(subm.))

Wetland Type	Total Number	Total Area (km^2)	Mean DEM-depth (m)*
Cutoff	4,479	46	0.63
Palaeochannel	5,844	52	0.64
Backswamp	6,573	340	0.61
Lagoon	4,517	156	0.50
Total	21,413	594	—

* Mean depth is the mean DEM-derived depth that reflects depression in the DEM, not true bathymetric or water depth.

Backswamps dominate in terms of area, accounting for ~57% of total wetland extent and nearly one-third of all wetlands, with a moderate mean DEM-depth of ~0.61 m. Lagoons are less abundant but represent the second largest contributor to total area (~26%), with a mean DEM-depth of ~0.5 m. In contrast, cutoffs and palaeochannels are numerically dominant, with over 10,000 features combined, but together occupy only ~17% of total wetland area. These features tend to be more linear and elongate, with moderate to relatively high mean DEM-depths (~0.63–0.64 m). Overall, these results highlight clear differences in the abundance, morphology, and storage potential of floodplain wetland types across coastal catchments of NSW.

Floodplain wetlands across three subregions

Floodplain wetlands display pronounced spatial variation across three subregions (Figure 2a-c and Figure 3). The North Coast which extends from the Tweed to the Hastings catchments contains the greatest number and area of wetlands. The Central Coast which extends from the Manning to the Hunter catchments exhibits the deepest wetlands. The South Coast which extends from the Minnamurra to the Towamba catchments is characterized by fewer, shallower wetlands dominated by backswamps (Figure 3).

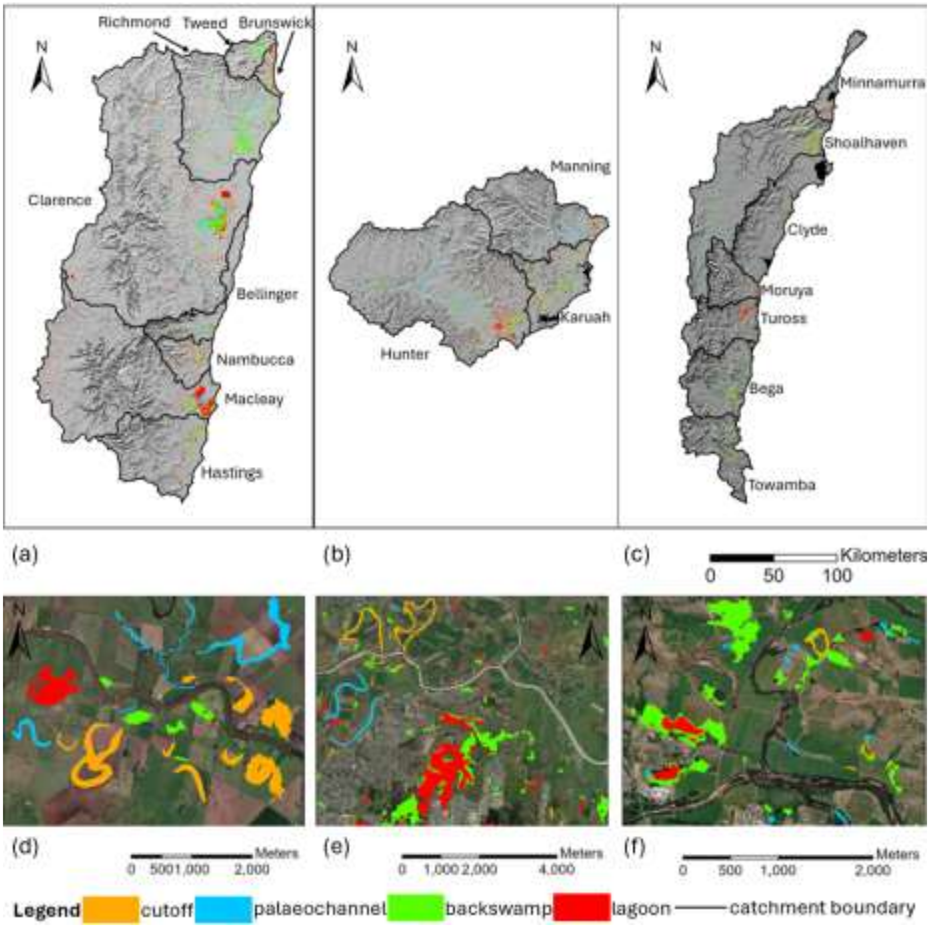

Figure 2 Spatial distribution of floodplain wetlands across 18 catchments: (a) North Coast (b) Central Coast (c) South Coast and three representative catchments: (d) Richmond (e) Hunter and (f) Bega. Source Wang et al. (subm.)

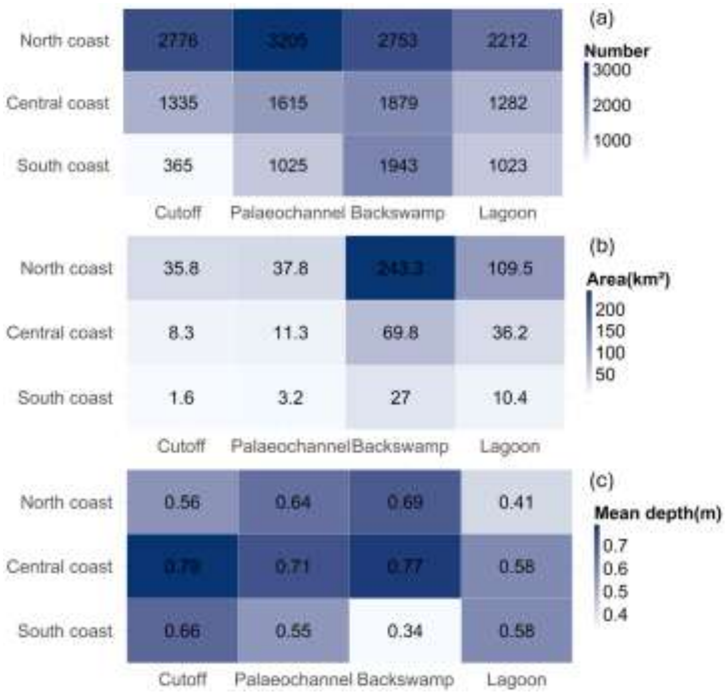

Figure 3 Distribution of floodplain wetland types across the North coast, Central coast and South coast: (a) number, (b) area, and (c) mean depth. Source Wang et al. (subm.)

The North Coast contains the largest extent, with 10,946 wetlands covering 426.4 km² (72% of total area). Backswamps dominate (57%, 243.3 km²) and have the greatest mean DEM-depth (0.69 m), while lagoons contribute 26% (109.5 km²) but are shallower (0.41 m). Cutoffs and palaeochannels are numerous but together account for only 17% of the area.

The Central Coast includes 6,111 wetlands over 125.6 km² (21%). Backswamps again dominate (56%, 69.8 km²), followed by lagoons (29%, 36.2 km²). Although smaller in area, cutoffs and palaeochannels show relatively high mean DEM-depths (0.79 m and 0.71 m).

The South Coast has the smallest extent, with 4,356 wetlands covering 42.2 km² (7%). Backswamps dominate (64%, 27.0 km²) but are notably shallow (0.34 m). Lagoons account for 25% (10.4 km²), while cutoffs and palaeochannels are limited, comprising only 11% of the area.

Floodplain wetlands across 18 catchments

Wetland dominance across the 18 catchments shows strong variation in both number, area and mean DEM- depth (Figure 4 and Figure 5). In terms of number, the Richmond catchment contains the highest number of wetlands, largely driven by palaeochannels and cutoffs, which together comprise 78% of all features. However, in terms of area, backswamps dominate (66.1 km²), exceeding cutoffs (17.6 km²) and palaeochannels (9.2 km²). Backswamps in Richmond also have the greatest mean DEM-depth (0.95 m), indicating a high capacity for water storage. In contrast, the Moruya catchment has the lowest wetland abundance (<250 features), with small lagoons and backswamps confined to isolated depressions on the lower floodplain.

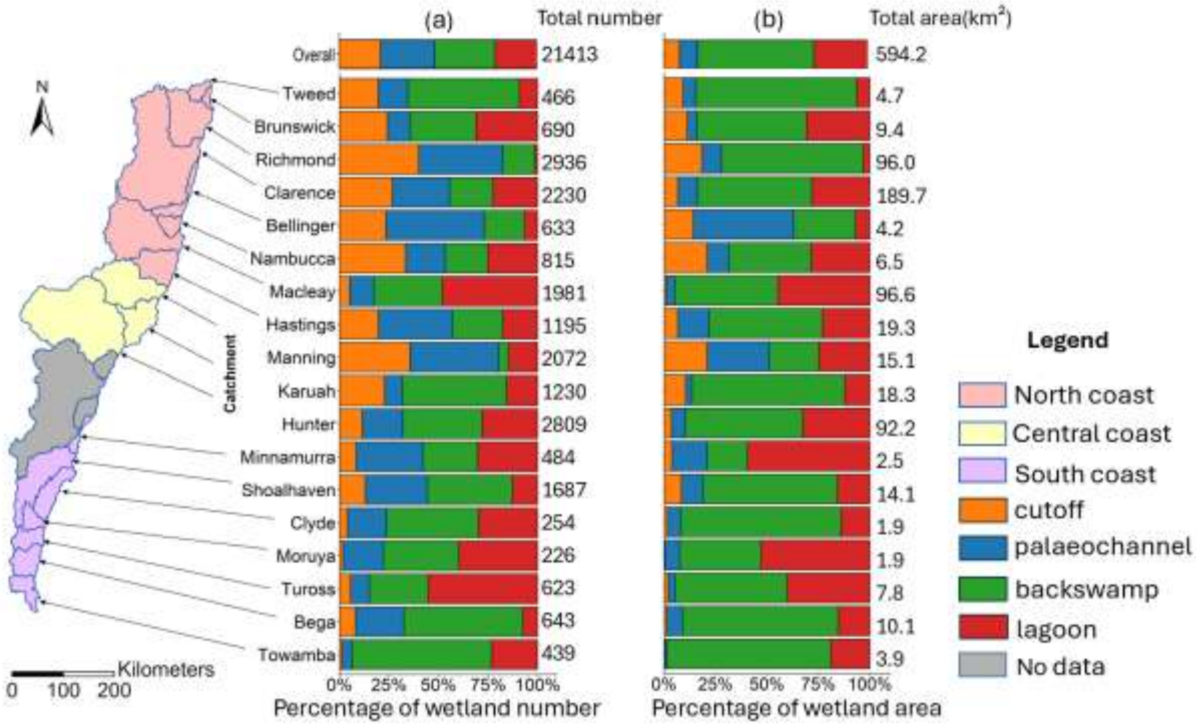

Figure 4 Percentage of floodplain wetlands by (a) number and (b) area within 18 study catchments. Source Wang et al. (subm.)

In terms of area, the Clarence catchment contains the largest total wetland area (189.7 km²), dominated by backswamps and lagoons, which together account for 85% of the total extent. Backswamps here also exhibit the greatest mean DEM-depth (1.37 m), suggesting substantial storage potential. Conversely, the Clyde catchment has the smallest wetland area (1.86 km²), primarily consisting of small, shallow backswamps and lagoons with mean depths <0.25 m.

In terms of mean DEM-depth, lagoons in the Bega catchment are the deepest across all study areas, with a mean DEM-depth of 1.73 m, indicating locally significant storage despite their limited extent (1.56 km^2). Floodplain wetlands in the Hunter catchment exhibit the greatest overall mean DEM-depth (1.04 m) across the region. Within the Hunter, cutoff channels are particularly deep (mean 1.35 m), while backswamps average 1.24 m, ranking as the second deepest among all 18 catchments.

Overall, these patterns highlight substantial spatial variability in wetland distribution, morphology, and storage potential across NSW coastal catchments.

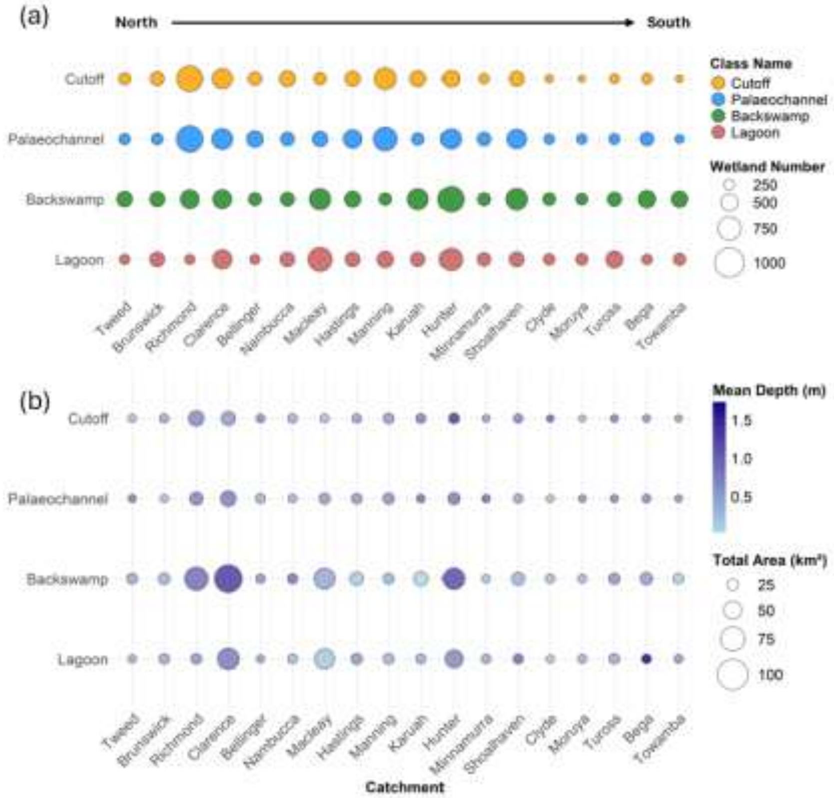

Figure 5 Floodplain wetland metrics across 18 catchments arranged from North(left) to South (right): (a)number; (b) area and mean depth. Source Wang et al. (subm.)

Distribution and position of floodplain wetlands on the valley bottom across different valley settings

In confined valley settings (CVS), wetlands are limited in extent, with 1,799 features covering 16.6 km^2 and a mean DEM-depth of 0.45 m (Table 2). Backswamps and cutoffs dominate numerically, while backswamps occupy the largest share of area. Cutoffs and palaeochannels are mainly located in proximal zones, whereas backswamps and lagoons occur in distal areas.

Table 2 Number, area, mean DEM-depth, and median distance of floodplain wetlands across three valley settings, confined (CVS), partly confined (PCVS) and laterally unconfined (LUVS). Source Wang et al. (subm.)

Valley setting	Wetland Type	Number	Area (km^2)	Mean DEM-depth (m)*	Median distance (m)	Distal or Proximal position
CVS	Cutoff	515	3.6	0.60	80	Proximal
	Palaeochannel	475	2.4	0.74	79	Proximal
	Backswamp	518	6.4	0.29	161	Distal
	Lagoon	291	4.2	0.17	132	Distal
PCVS	Cutoff	2087	17.0	0.61	106	Proximal
	Palaeochannel	2651	19.8	0.62	112	Proximal
	Backswamp	2307	43.6	0.43	172	Distal
	Lagoon	1645	25.3	0.37	246	Distal
LUVS	Cutoff	1877	25.2	0.67	152	Proximal
	Palaeochannel	2718	30.1	0.65	149	Proximal
	Backswamp	3748	290.0	0.76	359	Distal
	Lagoon	2581	126.6	0.62	437	Distal

* Mean DEM-depth is the DEM-derived depth that reflects depression in the DEM, not true bathymetric or water depth.

In partly confined valley settings (PCVS), both wetland number and area increase (8,690 wetlands; 105.6 km^2) with a mean DEM-depth of 0.51 m (Table 2). Backswamps remain dominant, followed by lagoons and palaeochannels. Cutoffs and palaeochannels have relatively higher mean DEM-depths (0.61–0.62 m) and are primarily proximal, while backswamps and lagoons are concentrated in distal zones.

The laterally unconfined valley settings (LUVS) contain the largest and deepest wetlands (10,924 features; 471.9 km^2; mean DEM-depth 0.68 m) (Table 2). Backswamps dominate in both number and area, reflecting extensive floodplain width, while deeper backswamps and lagoons indicate strong water storage potential. As in other settings, cutoffs and palaeochannels are mainly proximal, and backswamps and lagoons are distal.

Overall, distal wetlands dominate most catchments, particularly in PCVS and LUVS, while CVS shows a more balanced distribution (Table 2 and Figure 6). The increase in wetland extent, depth, and distance from the main channel from CVS to LUVS reflects decreasing valley confinement and increasing floodplain width.

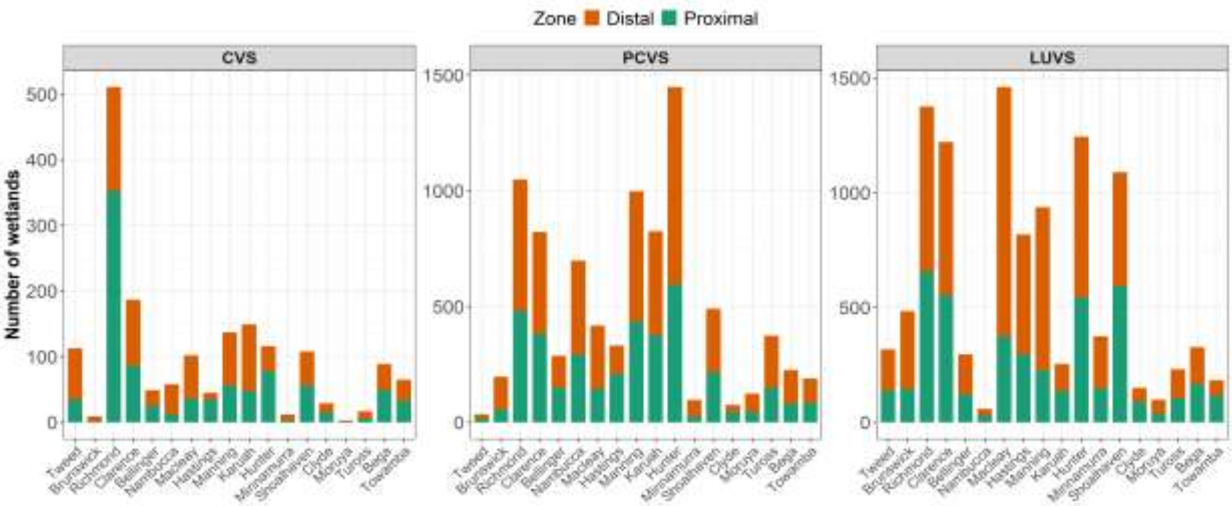

Figure 6 Distal and proximal wetland count across three valley settings in the 18 study catchments. Source Wang et al. (subm.)

Discussion

It is increasingly recognised that naturally occurring floodplain wetlands play a vital role in regulating flood morphodynamics. They are therefore ideal candidates for contributing to NFM by utilising their water storage, detention and release functions (Fryirs, 2026; Lane, 2017).

In Australia, following the major flooding events of 2022, Australian government agencies increasingly recognise floodplains as valuable natural assets that play a crucial role in flood mitigation (O'Kane & Fuller, 2022). This study provides the first comprehensive geomorphic inventory of floodplain wetlands across the coastal catchments of New South Wales, establishing a regional baseline for understanding their distribution and geomorphic characteristics. Given that the workflow and method run on open access remote sensing and DEM data, it is transferable to any place where such data is available (Wang et al., subm.).

The resulting inventory provides a practical framework for identifying geomorphic floodplain assets and supports the planning and implementation of NFM initiatives in coastal catchments of NSW. Now that this "assets register" is in place, future work is examining the processes and functional role these different types of floodplain wetlands play in flood hydrology, and the potential for them to contribute to flood mitigation.

Future research could also integrate field and laboratory analyses to characterise key sedimentological and hydrological properties of each wetland type, including grain size, hydraulic conductivity, porosity, and duration of water storage, to assess the ability of wetlands to retain water, reduce flow velocities, and attenuate flood peaks, providing a process-based understanding of wetland behaviour.

Conclusion

This study establishes a baseline database of geomorphic floodplain wetlands for the eastern coastal region of NSW. Their extent and distribution emphasise the potential for floodplain wetlands as assets for nature-based

flood management (NFM). The spatial characterization provided forms a foundation for undertaking the next stage of research which is investigating their hydrological function and flood mitigation potential.

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