# Identifying corridors of river recovery in coastal NSW for use in decision support and prioritisation systems.

Danelle Agnew [1], Kirstie Fryirs [1]

1. *Department of Earth and Environmental Sciences, Macquarie University, North Ryde, NSW, 2109, Australia. Email: danelle.agnew@hdr.mq.edu.au*

**Key Points**

- NSW River Styles database contains comprehensive information on geomorphic river condition and recovery potential.
- The database can be used to systematically analyse where corridors of river recovery could be created via conservation or rehabilitation.
- Combined with local on-ground knowledge, this information forms an important input to decision making when prioritising and developing river management strategies.
- By connecting corridors of river recovery, we can build resilience into river systems to mitigate against future floods and droughts driven by anthropogenic disturbance or climate extremes.

## Abstract

Geomorphic river recovery has been happening for several decades in coastal valleys of NSW (Fryirs et al., 2018). In a recovery enhancement approach to management, it is important to know where in a catchment (or region) to focus efforts and resources. River management strategies which trigger and enhance recovery can generate positive rehabilitation outcomes with less physical intervention and at lower cost. It could be argued that prospects for further improvement are finely balanced, as river management authorities consider the challenges of climate change and landuse pressures on riverine environments. Building corridors of river recovery will help build resilience into the landscape and help ameliorate impacts of floods, droughts, and anthropogenic disturbance on our rivers. But where are the corridors of river recovery, and where is there potential to build corridors in coastal catchments of NSW? Identifying existing and potential corridors can be used in prioritisation and decision-support systems to select appropriate conservation, maintenance and rehabilitation zones at sub-catchment, catchment, or regional scales.

The Open-Source NSW River Styles database contains comprehensive information on geomorphic river condition, recovery potential and relative catchment position, enabling systematic identification and analysis of corridors of river recovery. Corridor analysis can identify where hotspots of geomorphic river recovery occur, and where opportunities exist to establish and connect new corridors at the landscape scale, providing the basis to inform cost:benefit decision-making. If successful, this process can be undertaken at scale, providing practitioners with nature-based solutions for river management.

## Keywords

River management, NSW River Styles database, corridor analysis, cost: benefit analysis, investment prioritisation, building resilience.

## Introduction

### *Principles of the recovery-enhancement approach to river management*

Globally, river management philosophy has shifted to more sustainable nature-based solutions, with preferred rehabilitation strategies that are process-based, self-healing, and recovery-based (Environment Agency, 2017; Fryirs et al., 2018; Kondolf, 2011; Lane, 2017). These approaches, which seek to enhance existing recovery, can generate positive rehabilitation outcomes through reduced intervention (Fryirs et al., 2018).

River management authorities would ideally place their rehabilitation programmes within a broad framework or overall vision for their catchments, with optimal (often cumulative) ecosystem benefits accruing from coherent, rather than piecemeal, interventions (Gilvear et al., 2013). However, within catchments, river managers have spatial-temporal options in the practical application of the recovery-enhancement approach to river management.

The River Styles Framework embraces the philosophy of working with recovery, setting rivers in the context of their landscape position and geomorphic processes, and further characterising them according to their geomorphic condition and recovery potential. The Framework identifies a gradient of recovery potential from Conservation to Low Recovery Potential (LRP), explained in Fig 1a. (Brierley and Fryirs, 2005). Within this gradient, reaches characterised as Strategic and Rapid Recovery Potential (RRP) are of most interest to river management authorities. Strategic reaches contain threatening geomorphic processes that may have off-site consequences in terms of Conservation or High Recovery Potential (HRP) reaches that occur upstream or downstream (Brierley and Fryirs, 2005). Therefore, these reaches require intervention for rehabilitation if the integrity of the system is to be maintained. RRP reaches are generally in good geomorphic condition and may already be connected to other reaches in good condition with HRP, thereby presenting excellent opportunities to enhance recovery along a corridor (Fryirs and Brierley, 2016). In a rehabilitation context, these reaches tend to require minimal intervention (e.g. weed management) or no intervention at all (called the opt-out and leave it alone and monitor it approach by Fryirs et al. (2018)). This presents opportunities for sustainable environmental improvement at lower investment cost. Continuing along the gradient of recovery potential, Moderate Recovery Potential (MRP) and LRP reaches are of less interest for rehabilitation due to lower capacity for improvement in geomorphic condition. Geomorphic characteristics of Strategic and RRP reaches are described in Table 1.

**Table 1. Geomorphic features characteristic of Strategic and RRP reaches (adapted from Fryirs and Brierley (2016).**

| Reach | Geomorphic feature | Form of adjustment |
|---|---|---|
| **Strategic** | Sediment slug | Translating downstream |
| | Headcut | Potential to migrate upstream |
| **RRP** | Bench formation | Narrows incised and widened channels |
| | Pool re-emergence | Indicates recovery of bed heterogeneity post degraded bed condition (e.g. sand sheet) |
| | Low flow channel redefinition | Indicates recovery post sand slug passing downstream |
| | Discontinuous watercourse/swamp reformation | Indicates recovery after incision |
| | Floodplain reconnection and reoccupation of cutoffs | Indicates recovery after incision or straightening |

*Identifying corridors of river recovery for decision-making and prioritisation*

Catchment position can inform the prioritisation of conservation and rehabilitation activities. Several approaches can be used. For example, working from upstream to downstream. Upstream reaches can be rehabilitated through measures including stock and weed management, revegetation, and instream wood installation, thus enhancing positive off-site impacts and connectivity to downstream good condition reaches (Fryirs et al., 2018; Gilvear et al., 2013). Alternatively, rehabilitation can be undertaken by working out from loci within the catchment, for example, treatment of stream incision in a Strategic reach, or working outwards from good condition or High Recovery Potential (HRP) reaches to trigger geomorphic recovery in adjacent reaches (Brooks et al., 2004; Fryirs et al., 2018) (Fig 1a). The timing of these interventions may also be informed by the position of the reach in a catchment. For example, a decision could be made to postpone intervention in a Low Recovery Potential (LRP) reach until the off-site consequences of intervention elsewhere trigger signs of recovery along the LRP reach (Rutherfurd et al., 1999).

## *The potential for Corridor analysis using the NSW River Styles database*

With extensive catchment systems and resource allocation limits, one challenge practitioners and decision-makers face is how to identify the most suitable reaches systematically and efficiently for rehabilitation. Corridor analysis can be used for this identification by running various algorithms to identify patterns and sequences in a database (Betz et al., 2020; Piégay et al., 2020). If geomorphic baseline information such as river diversity, condition and recovery potential are available we can use Geographical Information Systems (GIS) to interrogate the data and produce evidence-based results. In NSW we have the opportunity to perform such analyses using the NSW River Styles database (NSW DPIE, 2019). The NSW River Styles database was developed by the NSW Department of Planning, Industry and Environment (DPIE), in collaboration with Macquarie University. It provides comprehensive geomorphic information for over 216,000 km of stream length in NSW. This Open Access database characterises NSW coastal and inland streams by multiple River Styles Framework attributes, including river diversity, geomorphic condition, and recovery potential, plus DPIE-developed characterisations of fragility, condition change, threatening processes and refugia. It can be systematically analysed at a variety of scales for a range of different purposes and uses (Fryirs et al., 2021). The geomorphic recovery potential layer for NSW coastal catchments is shown in Fig 1b. This paper presents a pilot study to test the usefulness of the database for undertaking corridor analysis. A full analysis is currently being undertaken by the lead author as part of her PhD.

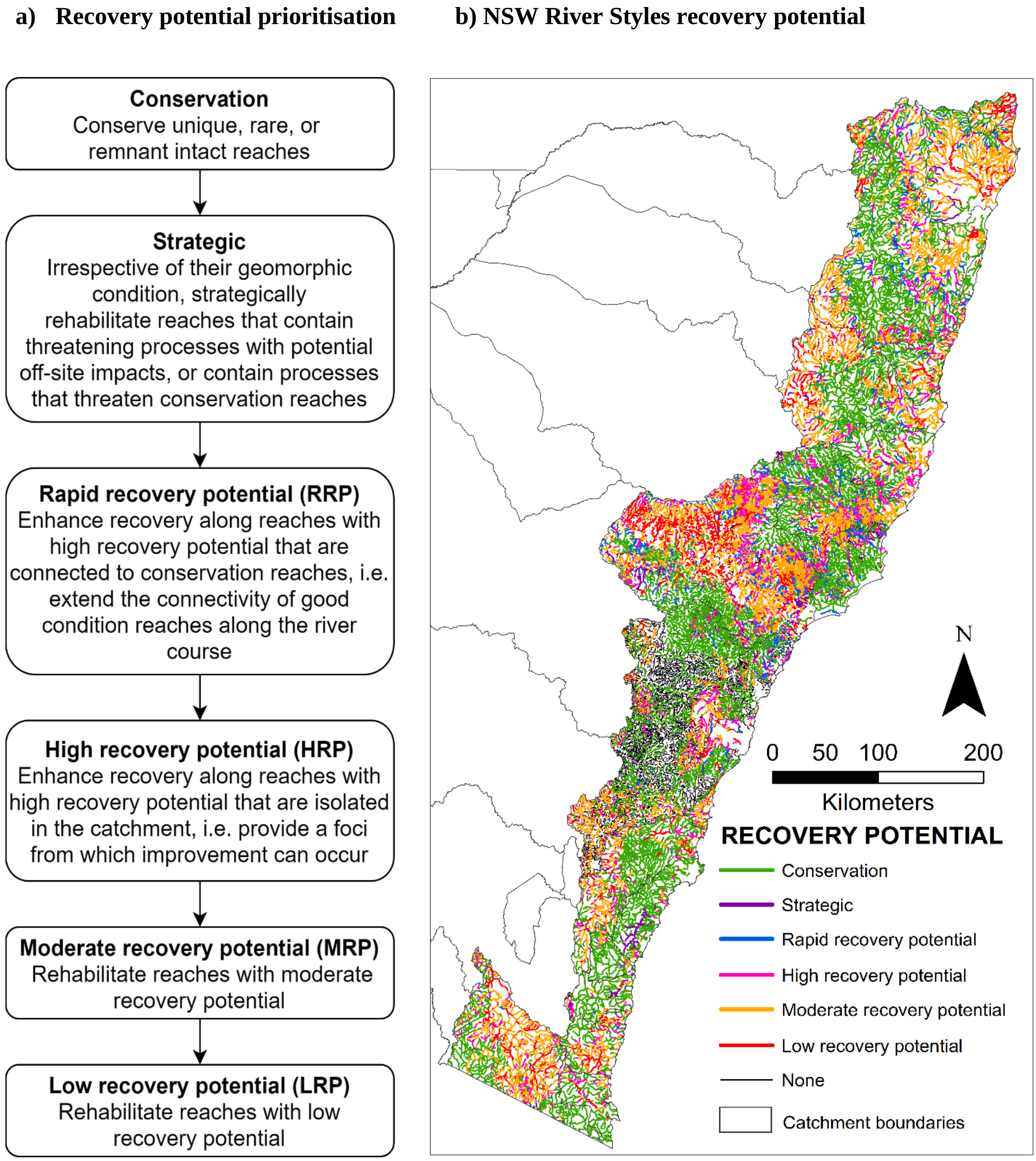



**Figure 1. a) Prioritisation protocol of river reaches based on recovery potential. Adapted from Stage Four of the River Styles Framework, page 353 (Brierley and Fryirs, 2005), b) Geomorphic recovery potential prioritisation across NSW coastal catchments using the NSW River Styles database.**

## Methods

In this preliminary work, the database was analysed using ArcMap to identify, within NSW coastal catchments, Strategic reaches located either upstream or downstream of Good reaches (Strategic-Good), and RRP reaches located between two Good condition reaches (Good-RRP-Good). These connections ranged from simple connections of reaches along a single stream, to more complex connections of streams and their tributaries. In the database, reach length ranges from <1 m to ~100 km, averaging 721 m. To reduce processing time for this pilot study, where Strategic and RRP recovery characteristics are connected end to end, and if applicable, connected to tributaries with identical characteristics, they have been combined, creating reaches up to ~47 km and ~16 km long, respectively.

## Preliminary results

In coastal catchments of NSW there are 87,730 km of stream length in an area of 129,222 km$^2$. Strategic and RRP reaches occur along 1,837 and 4,492 km of stream length, respectively. Across the coastal catchments, 926 km (50%) of Strategic reaches have a one- or two-way connection to Good condition reaches (Strategic-Good). 726 kms (16%) of RRP reaches are located between two Good reaches (Good-RRP-Good). Strategic-Good reaches ranged in length from <1 km to 48 km, averaging 4.7 km. Good-RRP-Good reaches ranged in length from <1 km to 16 km, averaging 1.4 km. Fig 2 shows stream length and percentage breakdown, by catchment, of Strategic-Good and Good-RRP-Good reaches.

**a) Strategic-Good** **b) Good-RRP-Good**

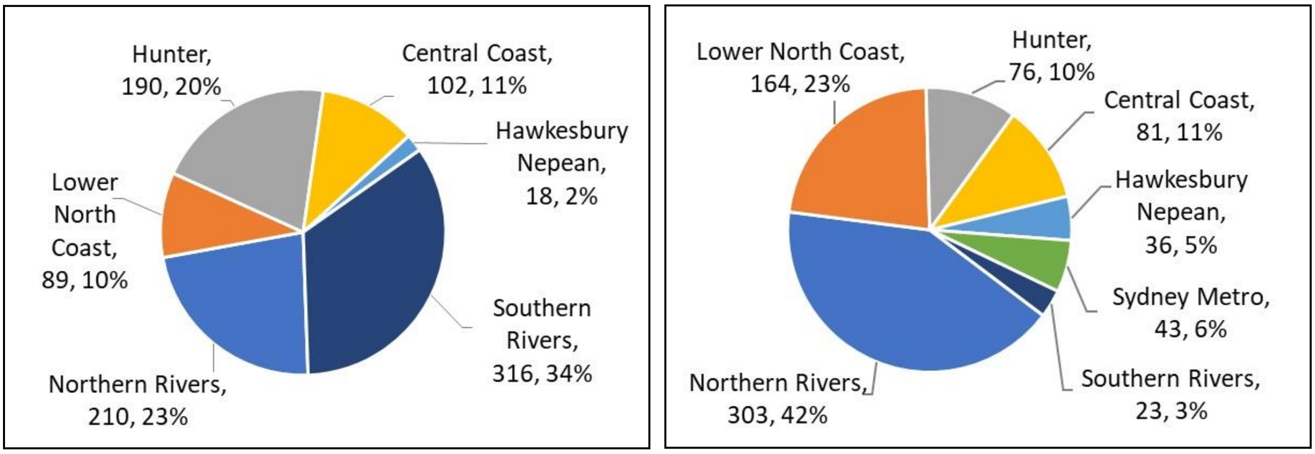



**Figure 2. a) Strategic-Good stream length in km, and % of total Strategic-Good stream length, b) Good-RRP-Good stream length in km, and % of total Good-RRP-Good stream length.**

The NSW River Styles regions of Northern Rivers, Lower North Coast and Hunter cover an area of 82,896 km$^2$ and contain 52,603 km of stream length, with 1,277 km of Strategic reaches and 3,806 km of RRP reaches (Fig 3). The Manning and Karuah catchments located on mid North Coast (NSW DPIE, 2021a; NSW DPIE, 2021b) are representative examples. These catchments cover an area of 12,900 km$^2$ and together contain 9,725 km of stream length, with 136 km of Strategic reaches and 1,006 km of RRP reaches. 89 km (65%) of Strategic reaches have a one- or two-way connection to Good condition reaches (Strategic-Good). 164 kms (16%) of Lower North Coast RRP reaches are located between two Good reaches (Good-RRP-Good) (Fig 3).

A variety of Strategic-Good and Good-RRP-Good reaches were identified. They range in complexity from a single Strategic-Good or Good-RRP-Good reach on one stream to a network of multiple Strategic-Good or Good-RRP-Good reaches on adjoining streams and tributaries and vary in length from 16 m to ~30 km for Strategic-Good, and 39 m to ~16 km for Good-RRP-Good, averaging 4.9 km and 1.5 km, respectively. For example, Split Yard Creek, located low in the south of the Karuah catchment, flowing via Jacks Creek into the Nerong River, contains a Strategic-Good connected reach of 1.5 km (Fig 4a). Kalang River, in the Bellinger catchment, is a sandslug-filled 16 km Strategic-Good reach (Fig 4a). Wollombi Brook, in the south of the Hunter catchment, is a sandslug-filled 8.5 km long Strategic-Good reach (Fig 4a). Lewis Creek, in the headwaters of The Branch River sub-catchment of the Karuah catchment, contains a single Good-RRP-Good connected reach of 670 m (Fig 4b). Located in the Karuah catchment, Washpool Creek is an example of a more extensive, complex Good-RRP-Good connected set of reach plus tributaries, with a combined RRP stream length of 8.9 km (Fig 4b). Likewise, the Tirrill sub-catchment, comprising Tirrill, Wild Cattle and Little Creeks, located in the headwaters in the north of the Manning catchment, is another example of a more complex arrangement of Good-RRP-Good reaches and tributaries, with a combined RRP stream length of 16.6 km (Fig 4b).

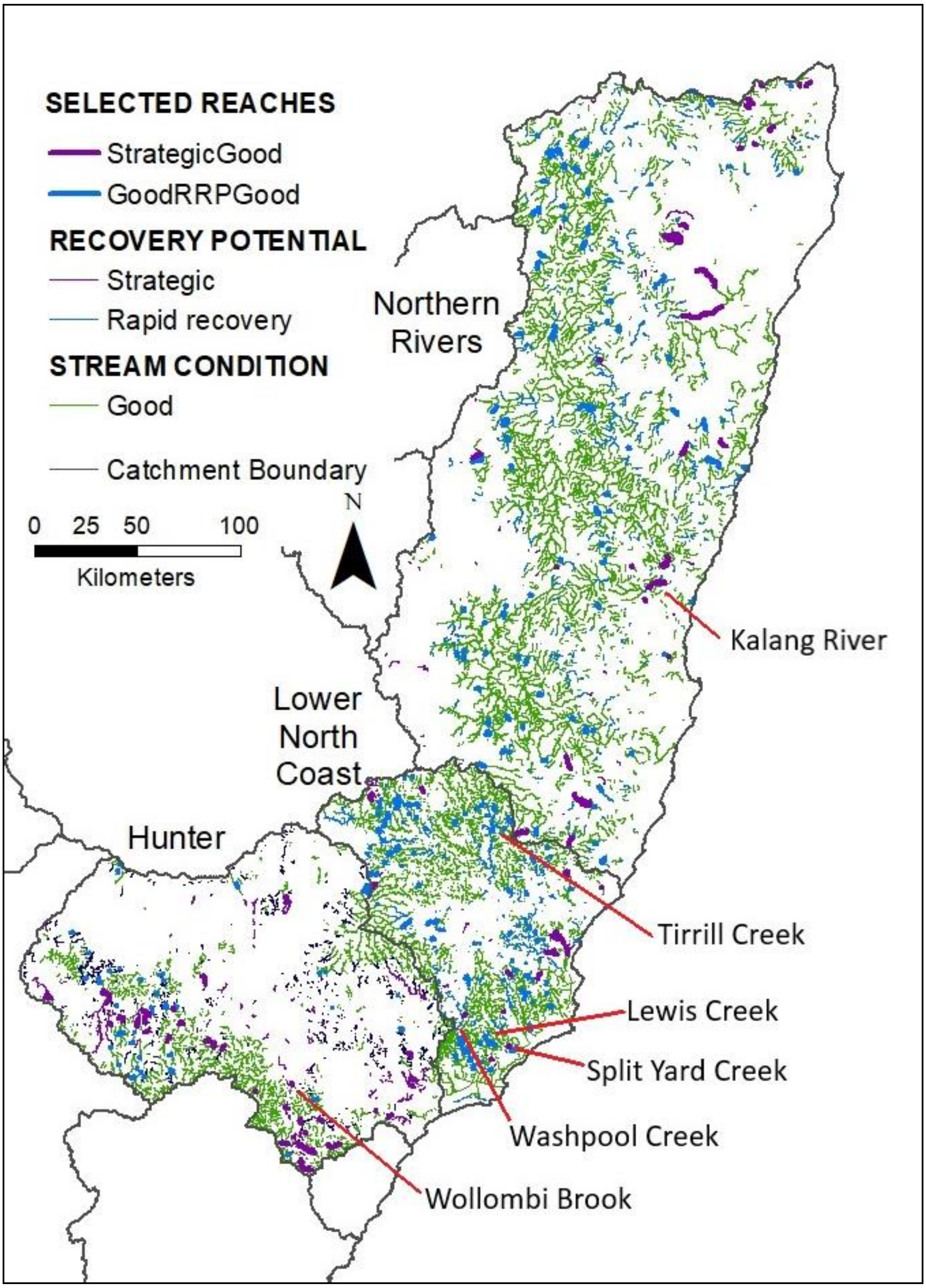
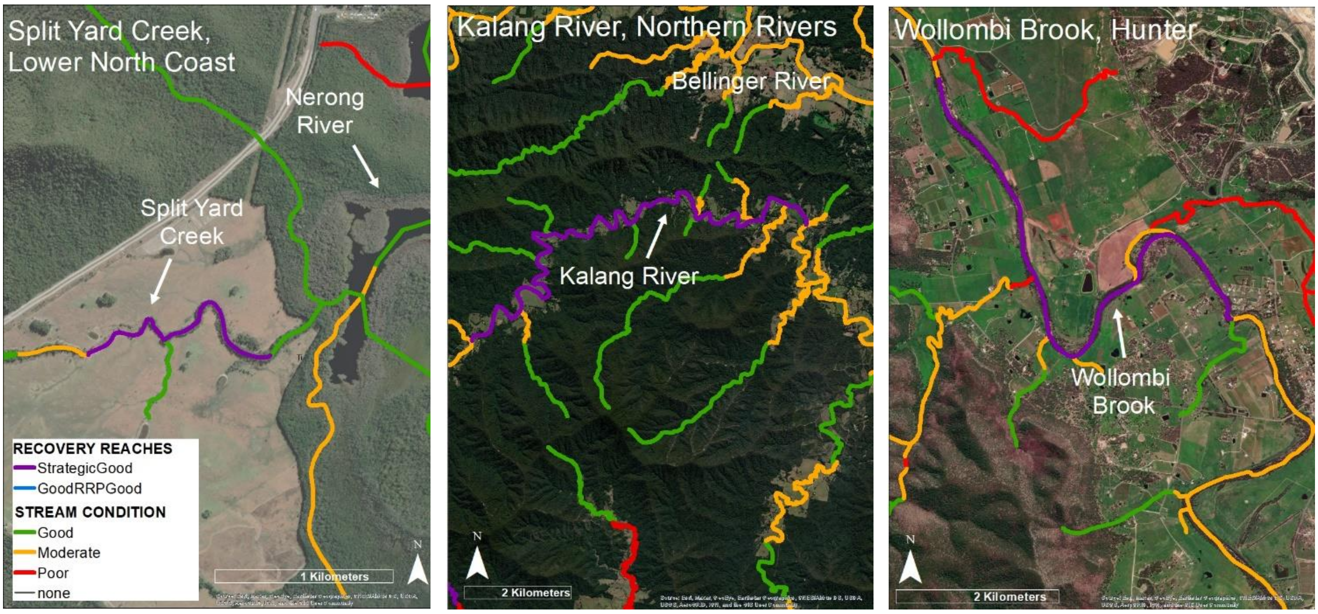



**Figure 3. Northern Rivers, Mid North Coast and Hunter regions of NSW RiverStyles database showing Good condition, Strategic and RRP reaches, Strategic-Good and Good-RRP-Good connections, and location of representative reaches.**

**a) Strategic-Good reaches**




**b) Good-RRP-Good reaches**

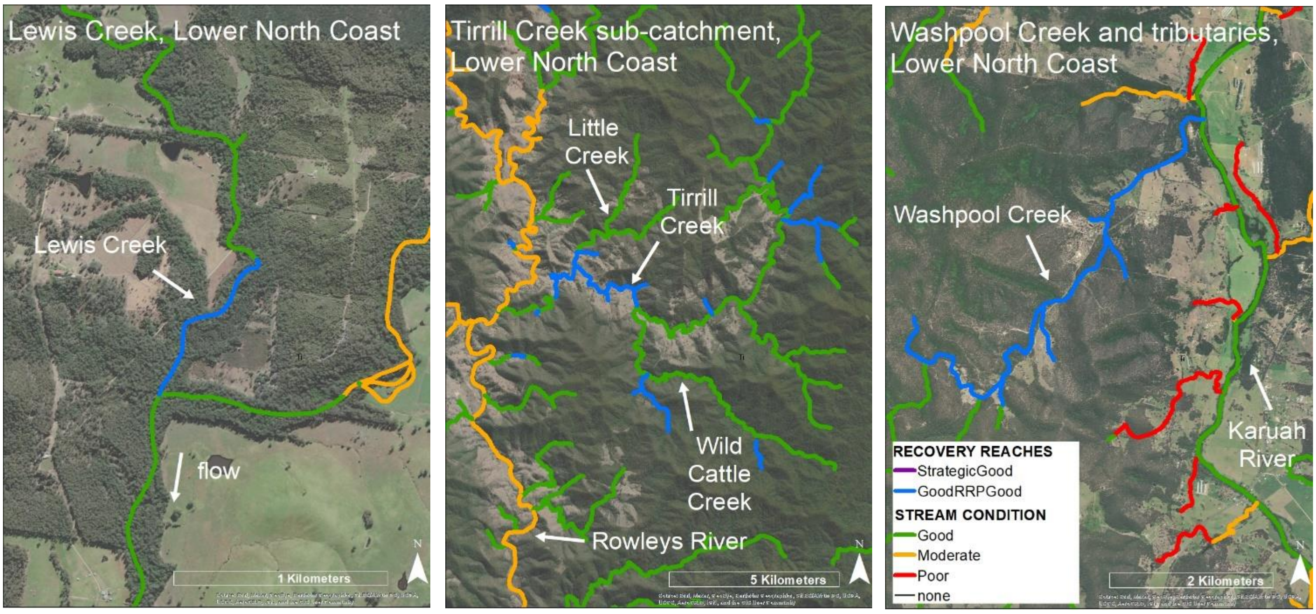



**Figure 4. Representative a) Strategic-Good and b) Good-RRP-Good reaches in the Northern Rivers, Lower North Coast and Hunter regions of the NSW River Styles database.**

## Discussion

The NSW River Styles database can be used to identify reaches that could be prioritised for rehabilitation to build corridors of river recovery. It can be used to identify where corridors of recovery can be extended (e.g., Lewis Creek) or established (e.g., Split Yard). It can detect opportunities for improvement in both single streams (e.g., Split Creek), and across networks of streams (e.g., Tirrill sub-catchment). Once identified, suitable reaches can be further analysed using the database's other layers, such as fragility, to better understand the processes threatening geomorphic recovery, thus informing decision-making of potential treatments.

The database also provides the ability to inform decision-making at varying scales. For example, compare Lewis Creek's RRP stream length of 670 m with the Tirrill sub-catchment combined RRP stream length of 16.6 km (Fig 4b). At the local/reach scale (Split Yard Creek, Lewis Creek, Wollombi Brook), identification of the most suitable reaches for rehabilitation allows local communities and individual property owners to 'know their river' better, and allow effective targeting and tailoring of localised management plans (Fryirs et al., 2021). For longer reaches or at sub-catchment and catchment scale (Kalang River, Tirrill sub-catchment), realistically achievable plans can be implemented over longer time frames. Catchment location is also an important consideration. Most Good-RRP-Good reaches are located either in headwaters or are tributaries of mid-catchment streams, with very few along trunk streams, and therefore it makes sense to rehabilitate upstream to downstream.

The integration of this geomorphic understanding with local on-ground knowledge is critical as it verifies the condition and recovery potential of identified reaches. Any recent on-ground physical changes not yet included in the database can then be considered and incorporated into decision making and prioritisation.

Connecting corridors of river recovery provides a method for prioritisation that considers strategic and efficient resource allocation. This potentially allows river managers, to shape their investment strategy to set realistic, achievable targets, by minimising waste in resource allocation, and maximising environmental outcomes.

Identifying and connecting corridors of river recovery provides a consistent method for prioritisation of river rehabilitation strategies. It identifies the corridors with the highest potential of improved geomorphic function. It highlights the varying scale of potential rehabilitation projects, from projects suitable for individual landowners, to large regional scale projects, and projects requiring shorter or longer time scales. It also provides a focus for community engagement, to compare alternative projects, and support identification of river management priorities and development of appropriate rehabilitation plans (Fryirs et al., 2021).

Decision makers, from local landowners to regional catchment authorities, can use the prioritised reaches as inputs to cost:benefit analysis and other decision-support tools. Rehabilitation of corridors with the highest recovery potential should reduce resource waste. By comparing the merits of prioritised projects at different scales, using both quantitative and quantitative factors, cost:benefit analysis identifies projects with the most valuable environmental outcomes with the available resources. River managers are then able to develop geomorphological-informed investment strategies, which minimise resource wastage, minimise financial outlays, and maximise river health. This prioritisation method could provide practitioners with tools for sustainable, robust, resilient river management. The plan from here is to test and roll out the prioritisation method across all coastal catchments of NSW.

## Conclusion

The NSW River Styles database can be used to identify existing and potential corridors of river recovery. This can be used by managers to prioritise suitable reaches for rehabilitation. The information is useful for local, sub-catchment, catchment, or regional scale decision-making. Connecting corridors of river recovery provides a method for prioritisation to enable strategic and efficient resource allocation. This potentially allows river managers to shape their investment strategy to set realistic, achievable targets, by minimising waste in resource allocation, and maximising environmental outcomes.

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