River Management on a Reach Basis Highlights Lagged Channel Responses to Multiple Catchment Disturbances: Yea and Murrindindi rivers, Victoria

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Key Points

- Accelerated sand supply was caused by multiple catchment disturbances up to 1944
- Sand aggradation rapidly formed elevated alluvial ridges on the main channels
- Avulsions occurred when alluvial ridges were breached and the channel flowed into connected floodplain depressions
- The new and the old channels only functioned simultaneously for short periods of time before the new channel dominated
- The avulsion cycle is initiated again by rapid sanding and alluvial ridge development on the new channel
- Sand supply has now declined despite recent conflagrations and the rate of avulsion development has consequently declined

Abstract

The Yea River and its major tributary, Murrindindi River, flow into the Goulburn River, Victoria. Each river was classified into geomorphologically homogeneous river reaches, with six on the Yea and four on the Murrindindi. Each reach has been used as the basis for identifying river management issues. Historically, avulsions have been the most significant river management issue. The lowermost reach on the Murrindindi River (Turnbull Avulsive Straight Reach) received large amounts of coarse granitic sand after European settlement from a combination of gold mining by shafts and sluicing (1850-1920), catchment erosion due to forest clearing (1850-1890) and a rabbit plague (1890-1950), and salvage logging following the 1939 conflagration (1939-1944). The sand has now been largely exhausted. River response to sanding was multiple avulsions and the supply of large amounts of sand to the Yea River downstream of the junction (Cheviot Avulsive Meandering Reach). Avulsions occurred due to bed aggradation with sand and the formation of an elevated alluvial ridge above the floodplain. When the channel avulsed off the alluvial ridge into a connected floodplain depression, the main channel rapidly switched from the original to the new channel and the two channels only functioned simultaneously for a short period of time. Recent decreases in sand supply have reduced the frequency of avulsions. River reaches are the logical basis of river management because they highlight connectivity, sensitivity and singularity.

Keywords

Avulsions; aggradation; alluvial ridges; sanding; connected floodplain depressions

Introduction

Formation of catchment management authorities has led to more focussed river management in Australia. We have undertaken two major studies in the Goulburn River valley over the last 20 years, using geomorphology as the basis to understand river management problems and recommend actions for future works (Erskine *et al.*, 1993; Ladson *et al.*, 2013). We undertook the work reported in this paper for the Goulburn Broken Catchment Management Authority to re-examine biogeomorphic issues in the Yea River catchment and to include biogeomorphic processes in the development of river management decisions and strategies. Our work was based on homogeneous river reaches defined on geomorphic criteria.

River Reaches

The approach adopted to identify, name and describe river reaches on the Yea and Murrindindi rivers follows Erskine (2005) and Saynor and Erskine (2013). River reaches are homogeneous lengths of channel within which hydrologic, geologic and adjacent catchment conditions are sufficiently constant so that a uniform river morphology (Kellerhals *et al.*, 1976) or a consistent pattern of alternating river morphologies is produced (Erskine *et al.*, 2001). While it is relatively easy to identify the core length of a reach it is more difficult to define precisely the boundaries of a reach because of their transitional nature. Floodplains should be included in the classification because they are important as potential sediment sources and sinks, and dissipate flood energy. We first proposed provisional reach boundaries and then checked their appropriateness based on further field work and interpretation of maps, air photographs and digital elevation models.

Formal names have been given to reaches and comprise at least three terms. The first term is a geographic name for a location or feature within or near the reach. The second term or phrase is a geomorphological descriptor for one or more of the dominant characteristics of the reach. The terms used here are explained by Erskine *et al.* (2005; 2006). The third term reach. An example is the *Yea Meandering Reach* on the Yea River at and downstream of Yea. Yea is the town at the upstream end of this reach. The sinuosity (ratio of channel length to valley length and used as an index of the degree of meandering) is 2.1 which is very high indicating a highly meandering river.

We allocate each identified river reach to the river classification schemes of Rosgen (1994), Brierley and Fryirs (2005) and Erskine *et al.* (2005). However, we do not necessarily believe that each reach of the same river type has progressed through the same evolutionary pathway. Therefore, each reach of the same river type may not behave identically in future. It is for this reason that individual names for reaches are required.

Yea River

The Yea River was called 'Muddy Creek' by Hume and Hovell during their explorations of 1824-25 because of the muddy banks in the vicinity of present-day Yea (Blanks 1973). Muddy Creek A and Muddy Creek B were 6,000 and 10,000 acres licences, respectively, during the squatting period issued to the first settlers and maintained their original names until about 1850 (Blanks 1973). Muddy Creek retained its name until 1879 when it was changed to Yea River by Governor-in-Council (Blanks 1973). Surveyor Pinniger named the township, Yea, on 14 November 1855 (Blanks 1973).

The six river reaches are defined and their dominant biogeomorphic processes and associated river management issues are outlined in Table 1. Figure 1 shows the spatial distribution of the reaches. While a range of biogeomorphic processes and river management issues are mentioned in Table 1, the most significant issue was river avulsions in Reaches 2 and 3. Furthermore, avulsions and anabranching rivers are poorly accommodated by both classifications of Rosgen (1994) and Brierley and Fryirs (2005). Additional work is required to more accurately classify avulsive rivers.

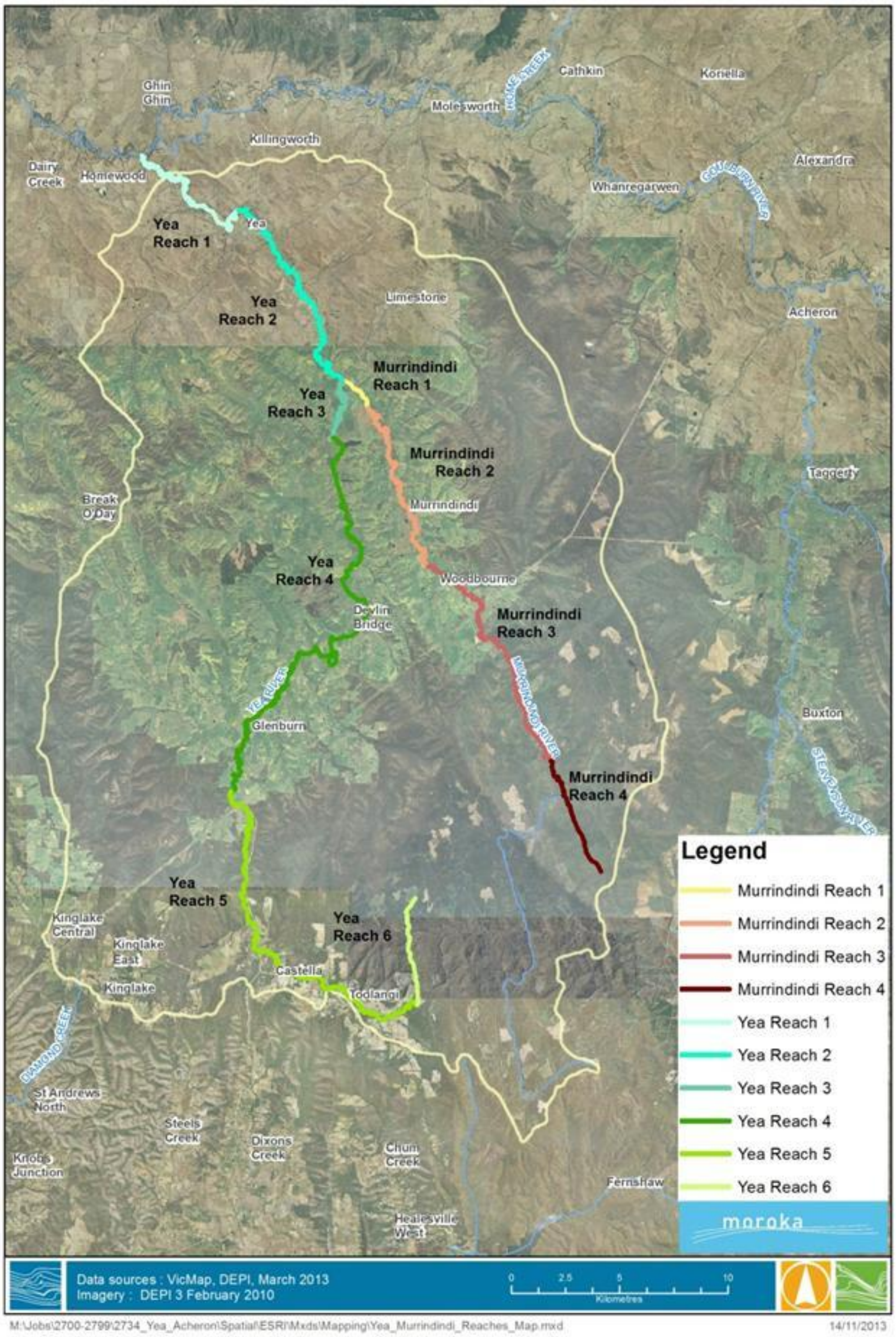

Figure 1. Geomorphic river reaches on the Yea and Murrindindi rivers, Victoria

Murrindindi River

The four river reaches are shown in Figure 1, and defined and explained in Table 2. Again while a range of biogeomorphic processes and river management issues are mentioned in Table 2, the most significant issue was undoubtedly river avulsions in reach 1.

Table 1. River reaches on the Yea River showing their geomorphic characteristics and river types.

River Reach	Geomorphic Characteristics	River Management Issues	River Type (after Rosgen, 1994)	River Style (after Brierley & Fryirs 2005)
Yea River Reach 1 - Yea Meandering Reach (Goulburn confluence to Yea) 0-13.1 km	Low slope (0.72 m/km), laterally migrating, unconfined, sand-bed, muddy banks meandering (sinuosity of 2.1) river flanked by continuous floodplain. Short sections of straight channel sandwiched between highly meandering sections. Well vegetated point bars and banks, and a reasonable load of in-channel large wood. Many historical and prehistorical cutoffs.	Lateral migration occurring. Flood scour channels developing. Historical desnagging and vegetation clearing have been completed. Bank planting and fencing have been carried out in more recent years. Post-settlement influx of sand and channel straightening by cutoffs.	E5/E6	Meandering sand bed
Yea River Reach 2 - Cheviot Avulsive Meandering Reach (Yea to Murrindindi confluence) 13.1–29.0 km	Moderate slope (1.2 m/km) sand-bed, muddy banks meandering (sinuosity of at least 1.6) river flanked by continuous floodplain. Active multiple avulsions both before and after European settlement. Well vegetated point bars and banks. Many historical and prehistorical cutoffs	Block banks and excavations carried out at various times and locations to hasten and/or prevent avulsions. Limited bank protection works have been constructed. Desnagging and vegetation clearing completed. Historical avulsions have been common. Floodplain scour common.	E5/E6 but with avulsions	No Category
Yea River Reach 3 - Murrindindi Station Meandering Reach (Murrindindi confluence to Tea Tree Creek confluence) 29.0-34.6 km	Muddy meandering river (sinuosity of 2.0) with well-developed natural levees and flanked by a continuous floodplain. Well vegetated banks and a reasonable load of large wood. Developing, eroding flood channels present on both sides of the floodplain. High potential for channel avulsion. Prehistorical and historical cutoffs present and highly impacted by historical high sand loads from, and repeated historical avulsions on, the lower Murrindindi River. Low slope of 0.87 m/km.	Lateral migration active. Recent river works (artificial cutoffs, rock chute construction, artificial levees built, channel excavated, desnagging and vegetation clearing, bank fencing/stock exclusion installed) and floodplain drainage works have been undertaken to prevent avulsions. Reach is very sensitive to avulsions. Potential erosion at overflow outflow and overbank flow re-entry points needs to be targeted.	E6 but with avulsions	Meandering fine grained but with avulsions
Yea River Reach 4 – Devlin's Alternating Straight and Sinuous Reach (Tea Tree Creek confluence to Glenburn) 34.6-66.3 km	Alternating straight bedrock-confined and -constrained channels separated by sections of sinuous channel with macrophytes in the bed flanked by pocket floodplains. The straight sections are much narrower than the sinuous sections. The repetitive pattern of narrow and wide floodplains is the characteristic feature of this reach. Overall bed slope of 2.1 m/km.	High stream power makes straight sections vulnerable to erosion. Need to limit artificial levees because floodplain is important for dissipation of flood power. Riparian vegetation important for large wood recruitment and bank protection against erosion.	Alternating B3/B4 and E6	Alternating floodplain pockets and low-moderate sinuosity sand bed
Yea River Reach 5 – Toolangi Meandering Reach (Glenburn to Toolangi) 66.3-92.0 km	Small sinuous (sinuosity of 1.5), steep (9.3 m/km) channel with gravel riffles and silt-floored pools flowing through a densely forested floodplain. Trees, tree roots, large wood and fine bank sediment contribute to lateral stability but also to island formation. Islands are common.	Desnagging carried out in the past. Artificial constrictions could destabilise channel. Strawberries grown in catchment on krasnozemic/ferrosolic soils developed on Devonian and Silurian mudstones at Toolangi and Castella. Issue of high soil erosion rates on strawberry fields..	E6	Meandering fine grained
Yea River Reach 6 – Mount Tanglefoot Straight Headwater Reach (Upstream of Toolangi) 92.0-97.7 km	Small, steep (38 m/km), straight, headwater bedrock channel on resistant Upper Devonian hornfels in rainforest.	Catchment currently being harvested of old growth *Eucalyptus regnans*. No known issues, except forestry.	A1, A2, A3	Steep Headwater

Table 2. River reaches on the Murrindindi River showing their geomorphic characteristics and river types.

River Reach	Geomorphic Characteristics	River Management Issues	River Type (after Rosgen, 1994)	River Style (after Brierley and Fryirs, 2005)
Murrindindi River Reach 1 – Turnbull Straight Avulsive Reach (Yea River confluence to 2 km downstream of Creeds Road) 0-2.1 km	Low sinuosity (sinuosity of 1.3), low slope (1.6 m/km) sand-bed channel with a continuous floodplain and discontinuously lined by vegetation. Sinuosity should develop slowly over time. Mulitple avulsions on left bank floodplain since European settlement.	Vegetation clearing at multiple times but vegetation will be required to control developing lateral migration. Current avulsion risk is low.	No Category	No Category
Murrindindi River Reach 2 – Murrindindi Sinuous Reach (2 km downstream of Creeds Road to about 4 km upstream of Cummins Road) 2.1-15.1 km	Moderately steep (3.6 m/km), alternating meandering and straight channel (overall sinuosity of 1.6) with discontinuously well vegetated banks. Continuous but narrow floodplain. Right bank tributaries have eroded and contributed sand to main stream.	Risk of rare cutoffs and need for more riparian vegetation. Monitoring of right bank tributaries needed to determine whether increased meandering will occur after post-European settlement straightening.	E4	Meandering gravel bed
Murrindindi River Reach 3 – Woodbourne Bedrock-Confined Reach (essentially downstream of Black Range State Forest) 15.1-31.3 km	Steep (5.7 m/km) bedrock-confined channel with discontinuous floodplain. Minor bank erosion risk.	Willows at Myles Road bridge are a potential source of downstream invasion. Management of riparian vegetation will control minor bank erosion risk	C4	Meandering planform-controlled discontinuous floodplain
Murrindindi River Reach 4 – Wilhelmina Falls Reach (first 7 km of headwaters) 31.3-38.3 km	Very steep (48.3 m/km), bedrock (granodiorite) channel with waterfalls, bedrock steps, cascades, boulder steps and rapids. Little floodplain development.	Sand input following conflagrations	A1, A2, A3	Bedrock-controlled discontinuous floodplain with occasional floodplain pockets

Channel Avulsions

Large-scale, historical channel changes started in the Turnbull Straight Avulsive Reach on the lower Murrindindi River (figure 1). Figure 2A shows the lower Murrindindi River in 1888 (Murrindindi Parish Plan) as a sinuous channel which alternates from one side of the floodplain to the other. Figure 2B shows that at an earlier time this course was even more sinuous and is now preserved as an alluvial ridge on the floodplain. At the time of first settlement we believe that the junction of the Murrindindi and Yea Rivers was located upstream of its present location where river management works were constructed on the Yea River in the Murrindindi Station Meandering Reach (Table 1). We also believe that the sinuosity of the lower Murrindindi River was more sinuous than in 1888 when it had started to straighten because of the influx of large quantities of sand. The 1918 Murrindindi Parish Plan shows a straight anabranch developing on the right floodplain where the present course is now located. However, Parish Plans do not show channel location at the time that the map was produced but depict the survey information when the map was last changed. This means that the channel location could be 20-100 years out-of-date. However, State Rivers and Water Supply Commission photos show the Murrindindi River cutting a new course in the area of the anabranch in 1947. A 1960 topographic map shows the current course, indicating that the avulsion occurred from at least 1947 onwards. The avulsion has been associated with a significant reduction in sinuosity (Figure 2B). Increases in sand load since European settlement have caused the straightening of many Australian rivers and agree with geomorphic theory that increased bedload requires a steeper slope for its transport.

Another historical avulsion occurred on the Yea River immediately downstream of the Murrindindi River junction (Figure 3) in the Cheviot Avulsive Meandering Reach (Figure 1). The historical sand influx from the Murrindindi River also caused a straightening of the Yea River. Figures 3A and 3B show the location of the Yea River at the time of first survey next to the right edge of the floodplain near the junction of Frog Ponds, Langs

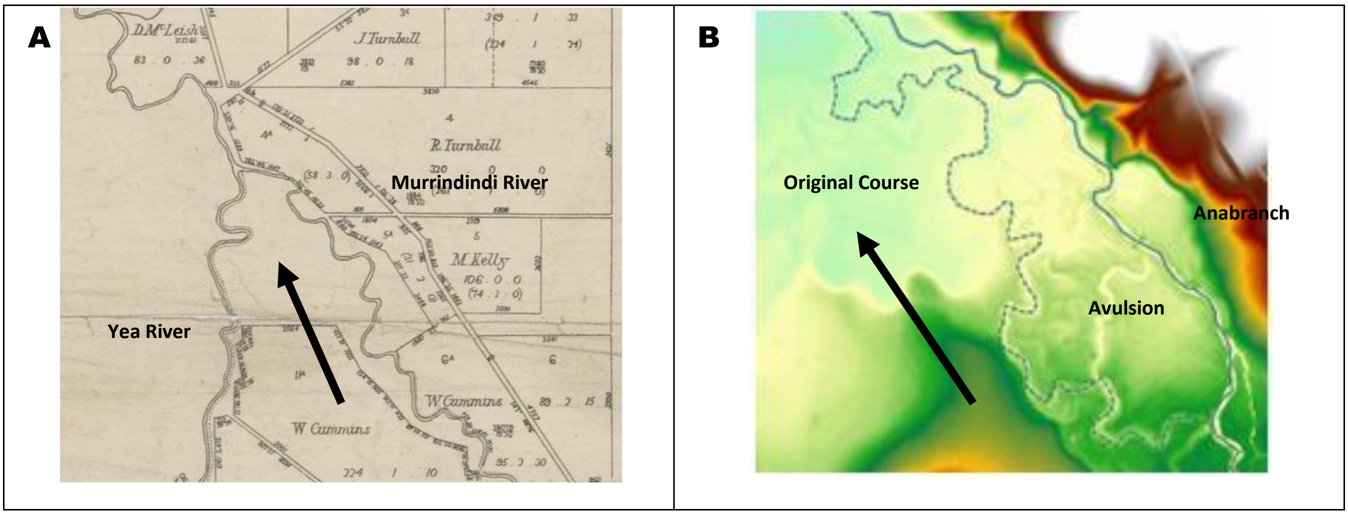

Figure 2. (A) Murrindindi Parish Plan of 1888 showing the sinuous pattern of the lower Murrindindi River. (B) The current pattern of the lower Murrindindi River shown as a solid line and a pre-European settlement course shown as a dashed line on the DEM. This sinuous alluvial ridge has a different pattern to that shown in (A). Flow direction shown by arrows.

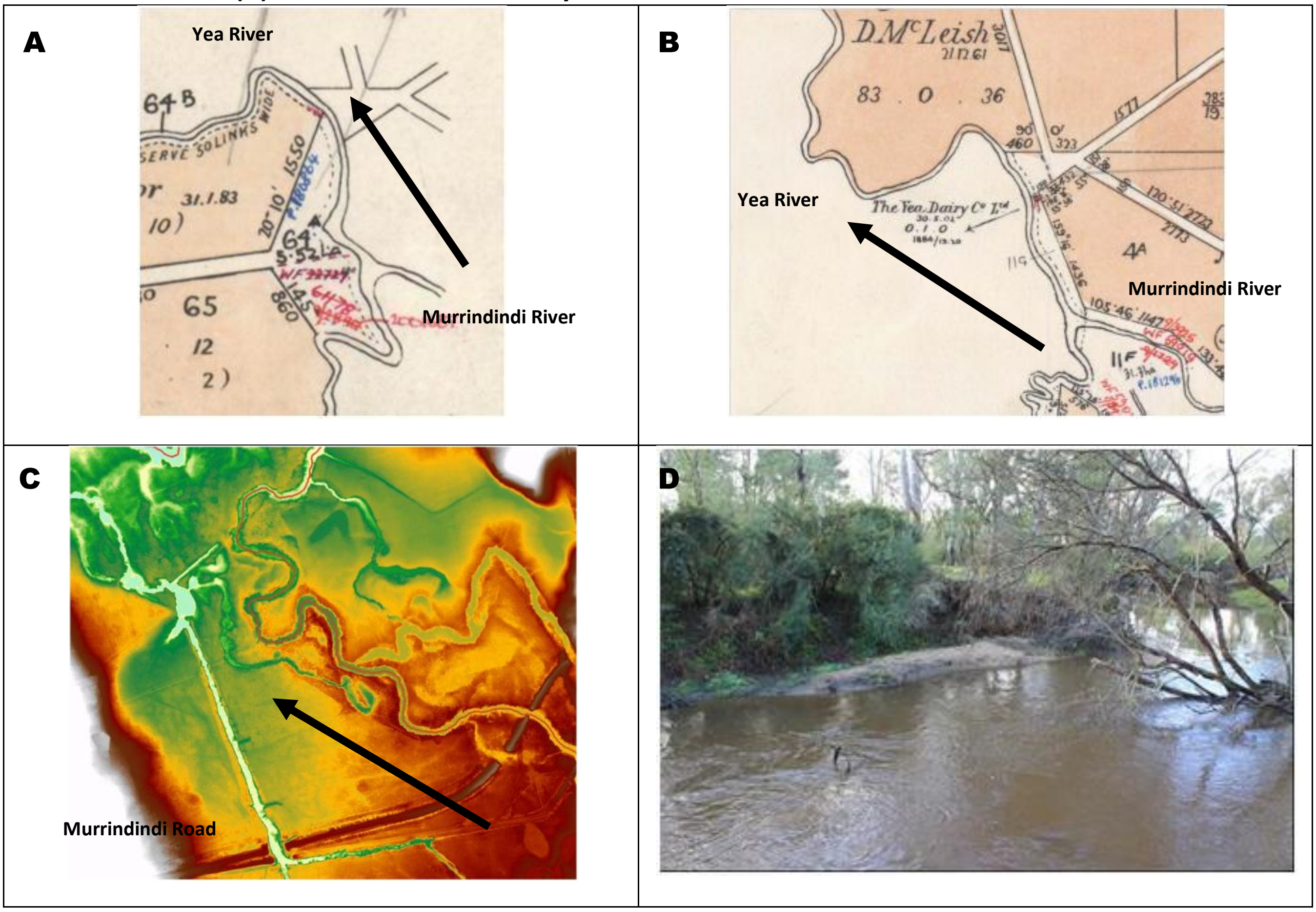

Figure 3. (A)Yea Parish Plan showing the original location of the Yea River against the right floodplain edge. (B) Murrindindi Parish Plan of 1888 showing the Yea River located against the right edge of the floodplain. (C) DEM showing Murrindindi Road crossing the Yea River floodplain and the avulsion. The present course is located closer to the bend in the road. (D) Sand bar on right bank of Yea River immediately downstream of Murrindindi River junction in 2013.

and Murrindindi Roads. Before 1900 an avulsion occurred some 230 m to the west (Figure 3C).

We discuss further historical avulsions in the Cheviot Avulsive Meandering Reach at Beer's and Yea in Ladson *et al.* (2013). As documented by Erskine (2013) for a number of historical avulsions in NSW, we found that sand aggradation of the channel and sedimentation of the whole alluvial ridge was important for elevating the channel above connected straight floodplain scour channels (Figure 4). When the alluvial ridge is breached by overbank flow, upstream progressing erosion along the connected floodplain scour channel (Judd *et al.*, 2007) eventually erodes a new channel along a shorter, steeper course. As bedload is transported through the new channel, the avulsion cycle starts over again (Figure 4).

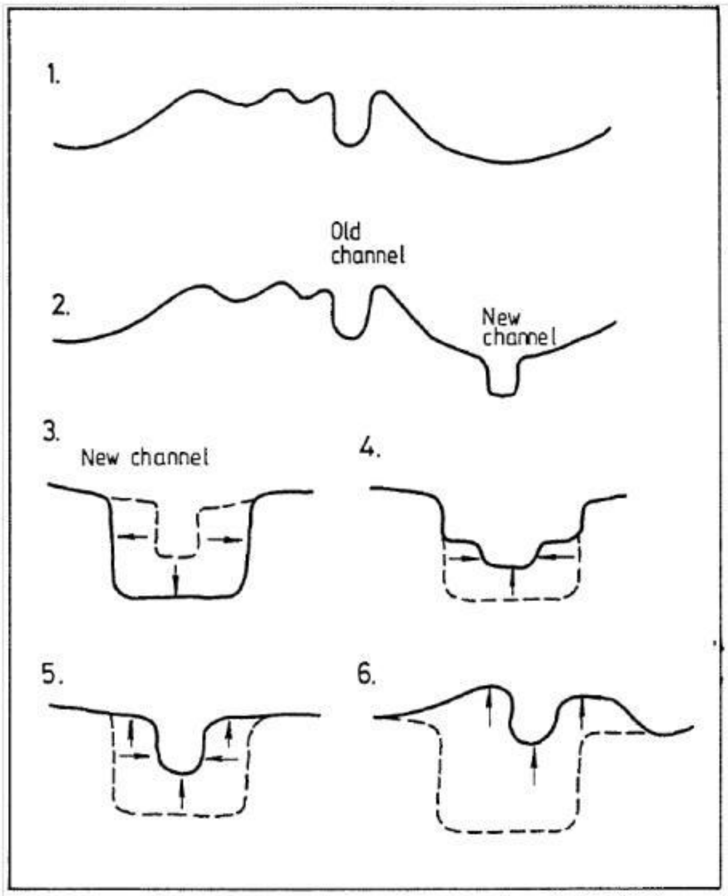

Figure 4. Evolutionary stages of avulsion development following Erskine et al. (1990).

There has been a lagged avulsive response. Avulsions are still active in the downstream part of the Cheviot Avulsive Meandering Reach (Yea and Beer's) whereas avulsions have ceased to be active in the upstream part of the Cheviot Avulsive Meandering Reach and in the Turnbull Avulsive Straight Reach. The reason for lagged response is the time needed for sand to be transported through and stored in the channel network.

The trigger for avulsions on the Murrindindi and Yea Rivers was the influx of large volumes of sand after European settlement. The source of this sand was a combination of gold mining by shafts and sluicing (1850-1920), catchment erosion due to forest clearing (1850-1890) and a rabbit plague (1890-1950), and salvage logging following the 1939 conflagration (1939-1944). This sand was only found in any quantity on the Murrindindi River and the Yea River further downstream in the Cheviot Avulsive Meandering Reach and the Yea Meandering Reach (Table 1).

Conclusions

The Yea River and its major tributary, Murrindindi River, were classified into geomorphologically homogeneous reaches which were used to deduce the dominant biogeomorphic processes and to determine the main river management issues. Channel avulsions were the major geomorphic process of concern to local land owners and river managers. Historical avulsions were restricted to the lowest reach of the Murrindindi River and the next reach downstream on the Yea River. Avulsions were caused by the influx of sand since European settlement and were restricted to reaches immediately downstream of the sand input. Avulsions lagged behind the input of sand because of the time needed for the sand to be transported downstream.

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