



Darling Baaka River Health Project 2023 to 2025

Chapter 3 Geomorphic condition

Department of Climate Change,
Energy, the Environment and Water



Acknowledgement of Country

Department of Climate Change, Energy, the Environment and Water acknowledges the Traditional Custodians of the lands where we work and live.

We pay our respects to Elders past, present and emerging.

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Artist and designer Nikita Ridgeway from Aboriginal design agency Boss Lady Creative Designs created the People and Community symbol.

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3. Geomorphic condition

3.1 What is geomorphic condition?

Geomorphic condition refers to the degree of departure from the expected physical forms and processes of a river, given the environmental and landscape setting in which it is found.

Fluvial geomorphology is the study of the physical forms of rivers and the processes responsible for creating, reworking and destroying geomorphic units. Assessment and interpretation of geomorphic forms and processes provides an understanding of how a river works, and whether the expected features are present for that river type. A river in good geomorphic condition has appropriate forms and processes that, under the right hydrological conditions, can provide a diversity of habitats critical for aquatic and semi-aquatic biota.

Rivers display a wide range of variability in terms of their physical character and behaviour. This is influenced by many factors including their position in the landscape, geology, historical and current land use, hydrology, sediment type and amount, and vegetation (Fryirs and Brierley 2005). The physical character of a river provides evidence of the key processes occurring there, such as channel bank erosion or in-channel and floodplain sedimentation, and is fundamentally related to the interplay between water, sediment and vegetation.

Many anthropogenic factors, such as land clearing, removal of logs and vegetation (de-snagging), stock trampling of riverbanks, streamflow regulation, and modifications to banks and weirs, can cause declines in river geomorphic condition. These factors can affect the balance between water, sediment and vegetation, impacting river health. For example, widespread land clearing and land use change following European settlement caused extensive erosion and significantly increased inputs of sediment into Australian rivers (Cook 2019). In some parts of the landscape, this manifests as extensive gullies and channels where previously intact valleys or floodplains occurred. In downstream river reaches, excess sediment caused by this erosion can sit in the channel in newly formed depositional geomorphic units, like bars and benches, while in the worst cases, sediment smothers riverbeds and benthic animals, slowly propagating downstream as a sediment 'slug'.

3.2 Why use geomorphic condition in river health?

Geomorphic condition is a critical component of assessment of river health because river character and behaviour strongly influence a range of biotic and abiotic factors. For example, rivers in good geomorphic condition are associated with high habitat diversity which is critical for instream and floodplain ecological diversity (Fryirs and Brierley 2005; Chessman et al. 2006; DPE 2023a). Conversely, rivers in poor geomorphic condition may experience excessive riverbank erosion relating to loss of riparian

vegetation for grazing, which contributes to poor water quality and excess sediment loads in rivers (Figure 1).

Healthy floodplains, river channels and groundwater systems are strongly interconnected. In contrast, rivers in poor condition often display weakened connections with their floodplains and/or groundwater. Such degraded geomorphic conditions are indicative of stressed catchments, which typically lack geomorphic diversity and are therefore less favourable to aquatic biodiversity.

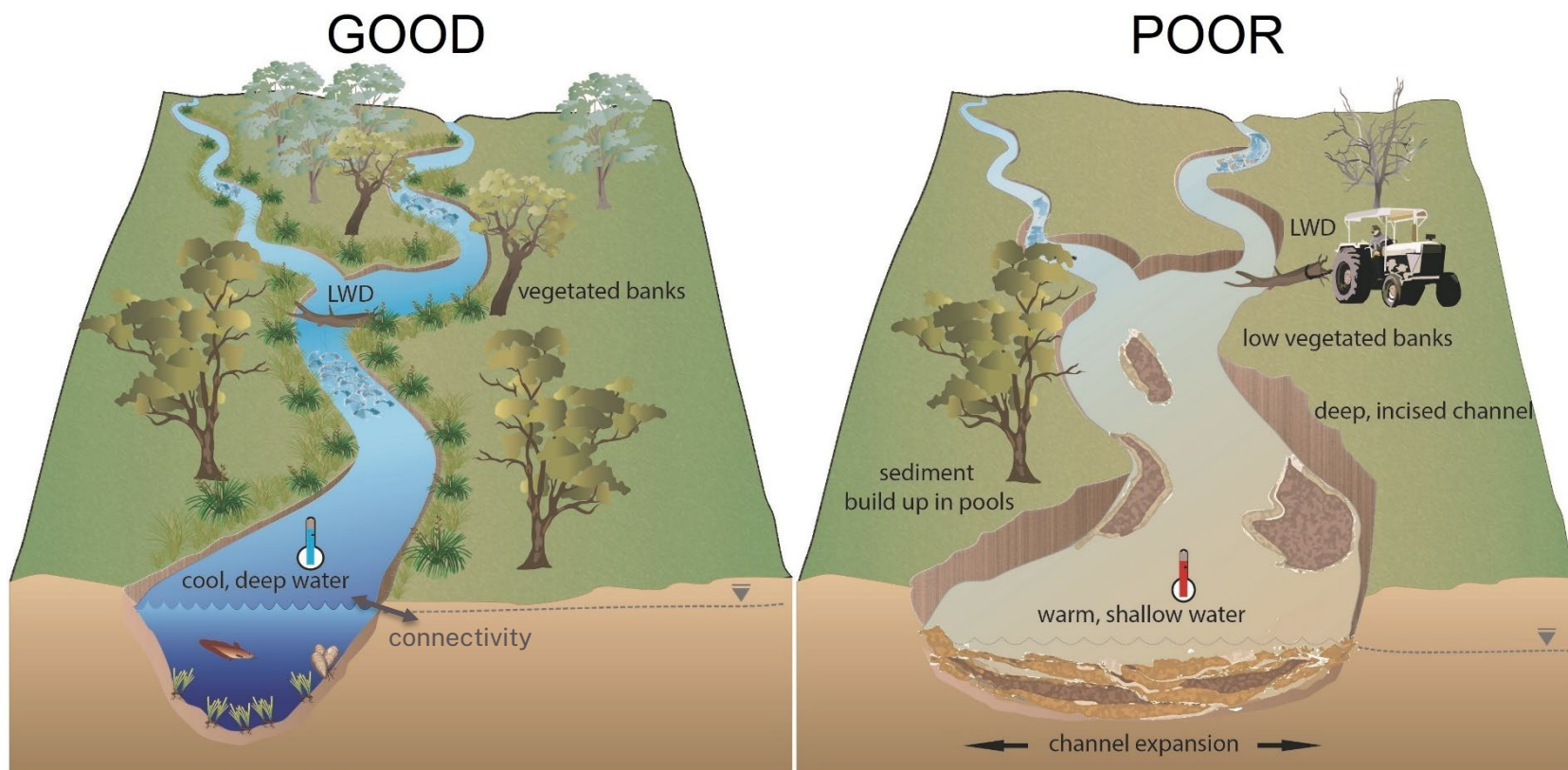


Figure 1 Good versus poor river geomorphic condition (Source: DPE 2023a)

Left: Good geomorphic condition, with large woody debris (LWD) present, strong connection between healthy floodplain, channel and groundwater. Right: Poor geomorphic condition, with large woody debris absent, loss of groundwater and floodplain connection as channel incises into its bed

3.3 River Styles and assessing geomorphic condition

For large-scale analyses, geomorphic condition is often assessed using the River Styles Framework. River Styles is a procedure to interpret river character, behaviour, condition and recovery potential. It includes assessment of a river's capacity to adjust, how sensitive it is to disturbances, and the key pressures affecting its geomorphic condition (Fryirs and Brierley 2005).

An initial River Styles analysis for the Darling Baaka River corridor, including major anabranches between Wilcannia and Wentworth, was completed by GHD consultants in 2011 using a rapid assessment approach. The results from this mapping were used in the statewide 2023 River Condition Index (RCI) assessment of geomorphic condition in alignment with the *River Condition Index: Method Report* (DPE 2023a). The 2011 GHD assessment relied solely on remotely sensed satellite and aerial imagery, without any field verification. The absence of field verification in the River Styles and geomorphic condition assessments is a major limitation of the pre-existing River Styles data for the lower Darling Baaka River.

The 2023 floods represented a major hydrological event that likely influenced the geomorphic condition of the lower Darling Baaka River. While a full assessment of these impacts is pending, floodwaters likely contributed to localised erosion, sediment redistribution and changes in channel morphology. Geomorphic adjustment of the lower Darling Baaka River occurs very slowly. The very low rates of lateral migration are associated with low stream power, limiting the river's sediment transport capacity (Pearson et al. 2024). The long-duration flooding in 2022–23 likely caused erosion on outside bank bends and scouring of meander bend waterholes, which are critically important refugial habitats during low flows, as well as incision of floodplain gullies and floodplain sedimentation. Due to these likely adjustments, an updated assessment of geomorphic condition was warranted.

3.3.1 Data used to assess geomorphic condition for the Darling Baaka River

Using the 2023 RCI methodology, the Geomorphic Condition Index was calculated using the River Styles Framework and an updated River Styles assessment of the lower Darling Baaka River was completed for the study area in 2024–25.

An analysis of various remotely sensed products, including recent 2019 and 2020 1-m light detection and ranging (LiDAR) digital elevation models (DEMs) and high-resolution aerial and satellite imagery was completed, providing high-resolution information on the river's shape and form. Importantly, the 2025 Darling Baaka RCI, River Styles condition assessment incorporated field verification and data collection to ensure robust and reliable evaluations of geomorphic condition and recovery potential. Due to the differences in methodologies, comparing the results for the 2023 RCI and 2025 Darling Baaka RCI is not a true indication of changes to geomorphic condition over time. It is important to understand the differences between the 2023 RCI and the 2025 Darling Baaka RCI presented in this report (see Chapter 9).

The final calculations of the River Styles indicator and the overall scoring grades (A to E) remained consistent with the 2023 RCI methodologies. Detailed methods are provided section 3.4.

3.4 Methods

3.4.1 River Styles Framework

The River Styles Framework was developed to classify the physical characteristics of rivers and assess their geomorphic condition (Fryirs and Brierley 2018). Importantly, it also incorporates assessment of the river's sensitivity to future disturbance and the likelihood of future geomorphic condition recovery.

There are 4 key stages of the River Styles Framework:

- **Stage 1:** Identify and classify river types by interpreting the forms and processes responsible for driving adjustment or change within the river.
- **Stage 2:** Determine geomorphic condition by considering the extent to which a river has been altered from a reference condition. This is conducted by comparing the observed geomorphic units and features with those that would be expected for that particular river type, given its landscape position, hydrology and climate.
- **Stage 3:** Assess each river reach within a catchment context to determine the potential or likelihood of a river to improve its geomorphic condition over a reasonable timeframe, typically decades.
- **Stage 4:** Based on geomorphic condition and recovery potential, identify priorities for conservation or management efforts.

Desktop analysis and mapping

Prior to assessing the geomorphic condition and recovery potential of a reach, the River Styles Framework incorporates classification of the river type depending on dominant geomorphic processes and drivers of geomorphic character. The hierarchy of characteristics listed in the typical river type classification range from the broad-scale valley setting and how much structural control the valley imparts on the geomorphic character of the river, through the planform and number of channels, to the bed substrate as the finest scale of river type differentiation (Fryirs and Brierley 2005).

Key to the geomorphic condition assessment for this project are 2 indicators, **geomorphic condition** and **recovery potential**, which are measured following standard River Styles Framework protocols (Fryirs and Brierley 2005; DPE 2023b). Desktop assessment of River Styles, geomorphic condition and recovery potential for the project was reliant on a range of remotely sensed datasets, including LiDAR DEMs and available high-resolution aerial and satellite imagery, both historical and current. Reaches were not classified by a set length; instead, their length was dependent on variations in river style, condition or fragility. The entire river length including major anabranches was scanned in detail to identify 3 geo-attributes:

- channel features – channel size and shape, bank form, instream and floodplain geomorphic units and vegetation
- channel planform – number of channels, channel sinuosity and degree of lateral stability
- bed character – type of bed sediment, that is, fine-grained, sand-sized sediment, gravel, cobbles, boulders.

Field verification at sites informs these interpretations, particularly in the assessment of bed character as this is often difficult or impossible to ascertain using satellite imagery alone (see section ‘Field verification methods’).

Each unique river style has its own suite of geo-attributes, and the process of determining geomorphic condition and recovery potential requires expert qualitative interpretation of the geo-attributes present in a reach of a river and the degree of departure, or not, from an intact reach. Reaches that are considered intact with all geo-attributes, indicating no significant evidence of disturbance to river character and behaviour, are given a geomorphic condition score of good. Reaches that show evidence of localised areas of degradation, for example reduced effective riparian vegetation or modified assemblages of geomorphic units, are given a condition score of moderate. Poor condition reaches have accelerated degrading processes and lack expected geomorphic units with poor vegetation coverage.

In addition to assessing geomorphic condition, the River Styles Framework incorporates an assessment of the recovery potential of reaches (Table 1). This requires estimating the likelihood that a reach will improve its geomorphic condition over a management relevant timeline, typically decades (DPE 2023b). Again, this requires expert interpretation of the degree of degradation of geomorphic condition as well as acknowledgement of the key threatening or degrading processes responsible for declines in geomorphic conditions and the likelihood of recovery if these pressures are eased or removed (DPE 2023b).

Table 1 Recovery potential categories (Source: DPE 2023b)

Recovery potential	Rate of recovery
Intact	No recovery required. The reach has not been recently disturbed or has fully recovered from past disturbances.
High	Geomorphic condition may improve quickly if existing pressures are removed and the river is connected (or reconnected) to good condition upstream reaches; or may improve at a moderate rate if disconnected to good condition upstream reaches.
Moderate	Condition may improve at a slow to moderate rate if existing pressures are removed. Some recovery may already be occurring.
Low	Very slow rate of recovery or not at all. Degradation may still be occurring.

Alluvial gully mapping

The locations of alluvial gullies identified in the high-resolution 1-m LiDAR DEM were mapped along the mainstem of the lower Darling Baaka River in the study area. Gullies were mapped at a scale of 1:5,000 in line with mapping undertaken by Pearson et al. (2024). The total count of gullies in each subcatchment provides an estimate of gully frequency per kilometre of river length. These data were collected in addition to routine River Styles mapping but contributed to assessments of geomorphic condition and recovery potential.

Field verification methods

Field verification of River Styles classifications and geomorphic condition assessments are an important component of the River Styles assessment. Field verification involves identifying instream and floodplain geomorphic units and interpreting river behaviour during different flow stages. Depending on the river style and boundary conditions (that is, valley setting, sediment load, hydrology), the presence or absence of expected geomorphic units informs assessment of geomorphic condition. Where geomorphic units are present that indicate processes beyond those typical for a given river type (such as deeply eroded bank gullies), the geomorphic condition will be rated moderate or poor, depending on the scale of impairment to expected functioning.

Twenty-one sites were assessed in the field (Table 2). At each site, qualitative data were collected on channel size and shape, observed geomorphic units within the channel and floodplain, and river behaviour (see Appendix A; DPE 2023b). Additionally, gullies and large woody debris were mapped to ground-truth satellite imagery and ensure accuracy of broader-scale assessments of feature density.

The geomorphic condition assessments and field verification process allowed the identification of key, long-term geomorphic threats to the lower Darling Baaka River. Due to logistical constraints (mainly weather and access), field verification could not be undertaken at all river reaches across the study area, rather they were targeted to key locations identified in preliminary desktop mapping. In this project, a key focus was on assessing the condition of major anabranches, as well as reaches of the lower Darling Baaka River impacted by weirs, for example the Menindee weir pool and Lake Wetherell.

Table 2 Field verification site details for Geomorphic Condition Index (GCI) calculations

Sub-catchment name	Sub-catchment number	GCI site	River/creek	Longitude	Latitude	Date	Key observations
Darling Baaka River subcatchments							
Lake Woytchugga	3254	A	Darling Baaka	143.401	-31.553	24/09/24	Wilcannia weir pool, alluvial gullies
Wilcannia Downstream	3249	C	10 Mile Creek	143.282	-31.77	24/09/24	Broad shallow flow path with indistinct banks, coolibah (<i>Eucalyptus coolabah</i>) and lignum (<i>Duma florulenta</i>) riparian vegetation
Wilcannia Downstream	3249	D	Darling Baaka	143.124	-31.862	24/09/24	Within-channel benches and point bars, 10 Mile Creek re-entry eroded and widening
Wilcannia Downstream	3249	E	Booligal Creek	143.061	-31.928	24/09/24	Shallow indistinct flow path with no defined channel
Wilcannia Downstream	3249	F	Darling Baaka	142.783	-32.17	24/09/24	Over-widened, upstream extent of Lake Wetherell
Lake Wetherell	1483	H	Darling Baaka	142.58	-32.318	24/09/24	Lake Wetherell, largely slack water conditions, semi-permanent floodplain inundation
Lake Wetherell	1483	L	Talyawalka Creek	142.416	-32.458	25/09/24	Broad benches within infilling palaeochannel, small inset channel
Upstream Pooncarie	1484	N	Darling Baaka	142.563	-32.38	25/09/24	Point bar bench and low-level bench with dense coverage of macrophytes

Sub-catchment name	Sub-catchment number	GCI site	River/creek	Longitude	Latitude	Date	Key observations
Downstream Pooncarie	1475	O	Darling Baaka	142.396	-33.674	25/09/24	Vertical outside bank, deep pool and inside bend point bar bench, narrow riparian zone
Downstream Pooncarie	1475	P	Darling Baaka	142.396	-32.674	25/09/24	Symmetrical channel, point bar and bench on inside bend, narrow riparian zone
Great Darling Anabranh subcatchments							
Cawndilla	1477	I	Darling Baaka	142.373	-32.46	25/09/24	In-channel benches and point bars, numerous alluvial gullies/knickpoints
Cawndilla	1477	U	Great Darling Anabranh	142.094	-32.714	26/09/24	Large scour pool downstream Packers Crossing, semi-permanent inundation upstream of weir
Anabranh North Lakes	1474	T	Great Darling Anabranh	142.009	-33.075	26/09/24	Shallow angled benches, inset pool ~1.5 m deep
Anabranh North	1473	S	Great Darling Anabranh	141.793	-33.267	26/09/24	Broad benches on inside and outside bend
Warrawenia Lake	1467	R	Great Darling Anabranh	141.75	-33.58	26/09/24	Broad benches on both sides of channel as palaeochannel infills, sediment lobe deposits at base of small gullies, juvenile river red gums (<i>Eucalyptus camaldulensis</i>)
Lower Anabranh	1521	Q	Great Darling Anabranh	141.836	-33.975	26/09/24	Broad benches on both sides of channel as palaeochannel infills

Sub-catchment name	Sub-catchment number	GCI site	River/creek	Longitude	Latitude	Date	Key observations
Talyawalka Creek subcatchments							
Upper Talyawalka Creek	3251	B	Talyawalka Creek	143.429	-31.651	24/09/24	Broad shallow palaeochannel with small inset flow path
Middle Talyawalka Creek	3248	G	3 Mile Creek	142.613	-32.309	24/09/24	1-2 broad, shallow anabranching channels
Lower 3 Mile Creek	1531	J	3 Mile Creek	142.474	-32.419	25/09/24	Scour pool downstream of road, broad macro channel with <10 m wide inset channel
Lower Talyawalka Creek	1530	K	Talyawalka Creek	142.523	-32.445	25/09/24	Scour pool downstream of road crossing, broad shallow infilling palaeochannel, adjacent alluvial gullies depositing sand in channel bed
Charlie Stones Creek	1482	M	Charlie Stones Creek	142.426	-32.492	25/09/24	In-channel point bars and benches indicate good geomorphic diversity

3.4.2 River Styles Geomorphic Condition Index calculation

To calculate River Styles Geomorphic Condition Index scores for all subcatchments within the study area a combination of the two indicators, geomorphic condition and recovery potential, provided 5 condition categories (Table 3). The inclusion of recovery potential in assessing geomorphic condition allows consideration of the likelihood of condition improvement into the future as well as current geomorphic condition.

Table 3 Geomorphic condition matrix condition categories

Geomorphic condition				
Recovery potential		Good	Moderate	Poor
	Intact	Very good	–	–
	High	–	Good	–
	Moderate	–	Moderate	Poor
	Low	–	Moderate	Very poor

The River Styles Geomorphic Condition Index score was calculated by assessing the proportion of river length, within each subcatchment, that fall into the 5 different condition categories using Equation 1.

Equation 1:

$$\text{River Styles Geomorphic Condition Index} = \frac{((\%Very\ good * 1) + (\%Good * 0.75) + (\%Moderate * 0.5) + (\%Poor * 0.25) + (\%Very\ poor * 0))}{100}$$

The final River Styles geomorphic condition score was a value between 0 (zero) and 1, split into the 5 RCI condition grades (Table 4). The condition classes directly translate into Darling Baaka RCI Geomorphic Condition Index (GCI) health scores.

Table 4 River Styles Geomorphic Condition Index (GCI) score and associated River Condition Index (RCI) condition grade

GCI score	RCI condition grade
0.0 to <0.2	Very poor
0.2 to <0.4	Poor
0.4 to <0.6	Moderate
0.6 to <0.8	Good
0.8 to 1.0	Very good

3.5 Results and discussion

3.5.1 Darling Baaka River Styles

The lower Darling Baaka River is dominated by the laterally unconfined, continuous, meandering, fine-grained river style. Some anabranches or sections of the main channel are low sinuosity rather than meandering and, in some places, dunes or terraces partly confine adjustment of the river. However, these river types are less common. The major anabranches of the lower Darling Baaka River, Talyawalka Creek and the Great Darling Anabranch, are classified in the same river type as the mainstem of the lower Darling Baaka River, that is, laterally unconfined, continuous, meandering, fine-grained bed. However, consideration of their geomorphic condition and functioning require acknowledgement of the fundamental differences between these anabranches and the modern course of the Darling Baaka.

Talyawalka Creek and the Great Darling Anabranch are palaeochannels, or ancient courses of the Darling Baaka, which are slowly infilling with sediment after they were abandoned, and the modern course of the river established. The width of these anabranch channels, and the wavelength and amplitude of the meanders are significantly larger than the geometry of the modern Darling Baaka, indicating consistently higher average or peak flow during the period that they were active (Hesse et al. 2018). In the modern system, these channels are broad, shallow depressions and flow paths, that are not actively migrating and are not characterised by the deep scoured waterholes that occur along the bed of the modern Darling Baaka River.

Flow along the Great Darling Anabranch is regulated by the Menindee Lakes Storage Scheme, thus it currently flows far more frequently than it would have under natural conditions. Earth dams were removed from the Anabranch channel when the Anabranch Pipeline was installed to provide stock and domestic water to landholders in the period 2006-10. Prior to river regulation, the natural hydrology of the Anabranch would likely reflect that of Talyawalka Creek which flows approximately every 5 to 10 years only during large floods. These differences have implications for ecosystem functioning, food webs and drought refugia between the palaeo- and modern Darling Baaka River.

3.5.2 General observations and geomorphic threats

Geomorphic assessments of the lower Darling Baaka River indicated the following persistent geomorphic threats to the river:

- increased local sediment supply from alluvial floodplain gullies
- lack of river red gum (*Eucalyptus camaldulensis*) recruitment in some riparian areas
- river regulation with compounding impacts from catchment-scale water extraction and the backwater impacts of weirs, particularly during low flows.

Alluvial floodplain gullies

Alluvial floodplain gullies are abundant throughout the study area, and their density and size vary significantly. Field assessments of gully locations confirmed the accuracy of

the LiDAR gully mapping for gullies deeper than ~1 m (100% reliably identified in LiDAR). Gullies identified in the field that were smaller than this were not reliably mapped using the 1-m resolution LiDAR DEM (Figure 2). Mapping of alluvial gullies along the mainstem of the lower Darling Baaka River using 1-m LiDAR digital elevation data highlighted that gullies are significantly more prevalent between Wilcannia and Menindee than reaches further downstream.

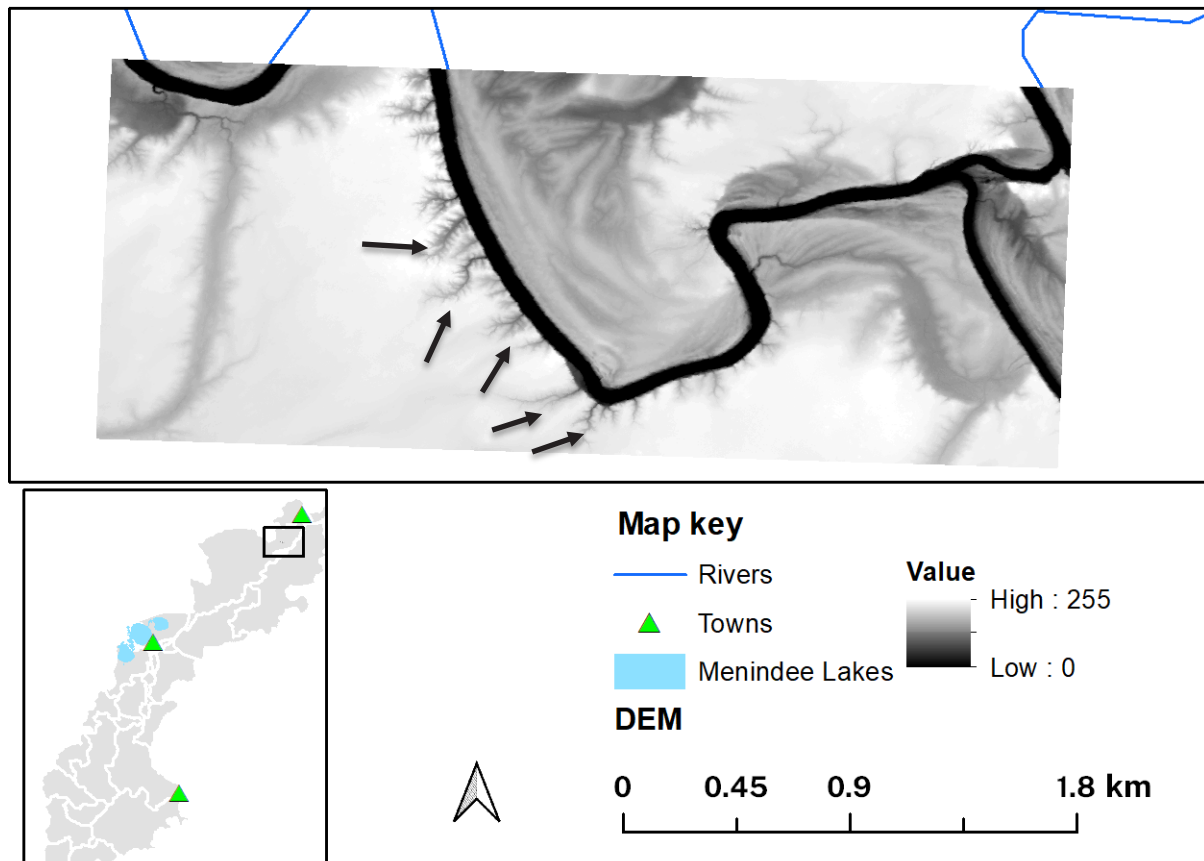


Figure 2 Example of alluvial gullies in the 1-m light detection and ranging digital elevation model (DEM) downstream of Wilcannia. Arrows indicate the location of some of the larger gullies, though note that not all gullies have been marked by an arrow

In the RCI subcatchments downstream of Wilcannia on the Darling Baaka River to just downstream of Weir 32, alluvial gully densities range from ~3.2 to 7 gullies/km of river. The downstream reaches of the Darling Baaka River have substantially lower alluvial gully densities ranging from ~0.8 to 1.5 gullies/km river length (Table 5).

Table 5 Alluvial gully frequency along the mainstem of the Darling Baaka between Wilcannia and Wentworth (subcatchments listed in downstream order)

Subcatchment name	Sub-catchment number	Number of alluvial gullies	Darling Baaka stream length (km)	Number of alluvial gullies/km stream length
Lower Paroo	3411	525	91.22	5.76
Lake Woytchugga	3254	108	15.29	7.06
Wilcannia downstream	3249	1131	246.81	4.58
Middle Talyawalka Creek	3248	4	1.92	2.08
Lake Wetherell	1483	138	65.77	2.10
Cawndilla	1477	105	21.91	4.79
Downstream Weir 32	1518	44	13.57	3.24
Lower Yampoola Creek	1515	95	62.71	1.51
Cuthero Creek	1514	55	38.18	1.44
Upstream Pooncarie	1484	103	131.39	0.78
Downstream Pooncarie	1475	92	108.28	0.85
Palinyewah	1504	75	61.40	1.22
Lower Darling	1512	63	56.29	1.12

There is significant variation between different types of gullies and their potential impact on river functioning. Gullies formed in the black clay floodplains are generally associated with the waning stages of flooding and return flows to the river. Whereas gullies that extend from higher elevated red, sandy soil are caused by relatively high energy runoff during localised storms (Figure 3).

Gullies have a distinct impact on sediment transport and river condition (Wethered et al. 2015). The impacts of alluvial floodplain gullies in the study area are less well known than in the northern Murray–Darling Basin. However, in the adjacent upstream section of the Barwon–Darling system these features are estimated to have contributed approximately 168 million cubic metres (m³) of sediment to the river between Mungindi and Wilcannia (Pearson et al. 2024). Since the 1940s, gully formation and expansion has been rapid (around 40% increase) and is thought to be linked to human activities such as livestock grazing (Pearson et al. 2024).

Field observations on the lower Darling Baaka River highlighted numerous gully formations that extended into coarser grained aeolian red soil, which can result in the localised inputs of fine-medium grained sand into the river. These coarser sediment

inputs tend to be deposited in small fans or on benches. Erosion of gullies during the waning stages of floods may also be associated with the discharge of 'black water' to the main river as overland flows with high organic matter return to the channel. Gullies in red soil tend to transport coarser sediment to the river but will not always be associated with widescale riverine flooding. Further work on the lower Darling Baaka is required to better characterise the drivers of gully formation, their implications for ecological processes and the amount of excess sediment delivered to the river by active gully enlargement in the lower Darling Baaka.



Figure 3 Knickpoint at the base of an alluvial gully in the bank of the Darling Baaka River near Wilcannia. Photo credit: Zacc Larkin/DCCEEW 2024

River red gum recruitment

River red gums are a keystone species along the riparian zones of the lower Darling Baaka. They provide important habitat for a range of species and play an important role in stabilising riverbanks. Associated large woody debris located in the river channel also promotes hydraulic diversity and is often related to increases in in-channel habitat diversity. While there are well-established river red gums along most of the lower Darling Baaka River, many areas lack significant recruitment of saplings and juveniles (Figure 4; see Chapter 5). This lack of recruitment presents a long-term geomorphic threat given the importance of river red gums in stabilising banks and providing large amounts of woody debris to the river.



Figure 4 Well-established riparian river red gums on the lower Darling Baaka River near Pooncarie. At this site there is no evidence of successful recruitment of saplings or juvenile river red gums. Photo credit: Zacc Larkin/DCCEEW 2024

River regulation and in-channel structures

River regulation and associated structural works can alter river geomorphology. These works can directly straighten or deepen channels to improve water delivery (flow); or they can artificially inundate floodplains and channels, thus maintaining artificially stable, elevated water levels.

The compounding impacts of catchment-scale water extractions and weirs on river geomorphology can be difficult to quantify. Persistent low flows in the highly regulated Murray River cause erosion of in-channel benches (Lauchlan Arrowsmith et al. 2022). Further investigation is required to determine whether flow regulation associated with the Menindee Lakes Storage Scheme is having similar impacts in the lower Darling Baaka River. During drought, the extraction and storage of small flows throughout the Darling Baaka catchment increases the likelihood of extended cease-to-flow events in the lower Darling Baaka River (Mallen-Cooper and Zampatti 2020). This flow disruption causes a dominance of lentic (slack water) pools behind weirs, significantly altering the river's hydraulic characteristics, and impacting water quality and aquatic ecology. The shift from flowing (lotic) to still (lentic) water conditions can also elevate sedimentation rates in waterholes, particularly when combined with increased sediment loads

associated with catchment disturbances and localised inputs of sediment from alluvial floodplain gullies (Pearson et al. 2024).

3.5.3 Geomorphic indicators

The Geomorphic Condition Index is comprised of two indicators. Each are calculated at the subcatchment level. These subcatchments are detailed in Chapter 2, and for reporting purposes have been further categorised into river reach zones (refer Chapter 2, Figure 2).

Geomorphic condition indicator

Overall, the Darling Baaka River is in moderate geomorphic condition owing to historical legacy impacts of grazing, de-snagging and river regulation (Table 6). The magnitude of post-European geomorphic degradation in the lower Darling Baaka River is not as significant as in other rivers in Australia (Brierley et al. 1999; Fryirs et al. 2009). In particular, land clearing and intensive agriculture during the 19th and 20th centuries in coastal catchments with higher energy rivers has caused – in some places – irreversible geomorphic changes associated with catastrophic floodplain erosion, gullyng and the development of smothering sand sheets (Brierley et al. 1999; Fryirs et al. 2009).

The major anabranches in the study area, such as Talyawalka Creek and the Great Darling Anabranch, are assessed as being in good geomorphic condition. These anabranches tended to display the range of expected geomorphic features which indicate geomorphic processes are not significantly altered, despite changes to land use and flow regulation. This distinction between the Darling Baaka itself and its major anabranches in terms of geomorphic condition is relatively consistent throughout the study area. The exception to this good geomorphic condition was the Cawndilla subcatchment (1477), at the northern most point of the Great Darling Anabranch (Table 6).

The Cawndilla subcatchment was assessed as having a high proportion of river length in poor geomorphic condition (Table 6). This is related to river regulation associated with the Menindee Lakes Storage Scheme and the construction of artificial channels and embankments to manage to the flow of water. In this region, the outlet channels from Lake Cawndilla have been artificially straightened and/or deepened and are typically in poor geomorphic condition. These modified channels, designed to maximise efficiency of water delivery, are geomorphologically homogenous, significantly reduce the connectivity between channel and floodplain, and are generally associated with elevated rates of erosion and sediment transport.

The most significant degradation of geomorphic condition was recorded in the Lake Wetherell subcatchment (1483) (Table 6; Figure 5). In this subcatchment Main Weir and its associated embankments impound the lower Darling Baaka River, resulting in semi-permanent inundation of the floodplain in the downstream section of Lake Wetherell. Geomorphic processes are highly altered under such conditions with very low potential for geomorphic recovery. Further upstream, the backwater effects associated with Lake Wetherell extend well into the Wilcannia Downstream subcatchment (3249). In these reaches, the channel is over-widened with evidence of eroded notches and undercutting

of the riverbanks. This is likely associated with persistent, stable water levels causing erosion of within-channel benches and reducing cross-sectional variability and geomorphic diversity (Lauchlan Arrowsmith et al. 2022).

Table 6 Proportion of river length in each of the geomorphic condition categories

Subcatchment name	Subcatchment number	Total river length (km)	Geomorphic condition		
			% good	% moderate	% poor
Darling Baaka River subcatchments					
Lower Paroo	3411	91.93	0.77	99.23	0.00
Lake Woytchugga	3254	21.15	0.00	100.00	0.00
Wilcannia Downstream	3249	364.59	15.90	72.90	11.19
Lake Wetherell	1483	99.77	0.23	63.57	36.20
Downstream Weir 32	1518	14.17	4.26	95.74	0.00
Lower Yampoola Creek	1515	64.92	1.11	98.89	0.00
Cuthero Creek	1514	44.83	14.83	85.17	0.00
Upstream Pooncarie	1484	154.47	14.94	85.06	0.00
Downstream Pooncarie	1475	133.02	9.18	90.82	0.00
Palinyewah	1504	79.07	3.07	96.93	0.00
Lower Darling	1512	60.75	0.89	96.78	2.33
Murray–Darling Confluence	1507	26.05	23.98	76.02	0.00
Great Darling Anabranh subcatchments					
Cawndilla	1477	129.66	46.82	21.41	31.77
Lower Redbank Creek	1476	54.28	90.74	9.26	0.00
Anabranh North Lakes	1474	112.37	100.00	0.00	0.00
Coonalhugga Creek	1481	68.12	99.62	0.38	0.00
Popio	1522	33.52	100.00	0.00	0.00
Anabranh Offtake	1516	23.92	100.00	0.00	0.00
Anabranh North	1473	63.21	100.00	0.00	0.00
Lake Milkengay	1495	16.93	97.30	2.70	0.00
Warrawenia Lake	1467	91.92	93.48	6.52	0.00

Subcatchment name	Subcatchment number	Total river length (km)	Geomorphic condition		
			% good	% moderate	% poor
Lower Anabranh	1521	151.51	99.43	0.57	0.00
Talyawalka Creek subcatchments					
Upper Talyawalka Creek	3251	253.70	100.00	0.00	0.00
Middle Talyawalka Creek	3248	214.61	99.08	0.13	0.79
Lower 3 Mile Creek	1531	14.61	37.47	62.53	0.00
Lower Talyawalka Creek	1530	22.07	72.19	27.81	0.00
Yampoola Creek	1480	67.88	97.59	2.41	0.00
Charlie Stones Creek	1482	21.47	100.00	0.00	0.00

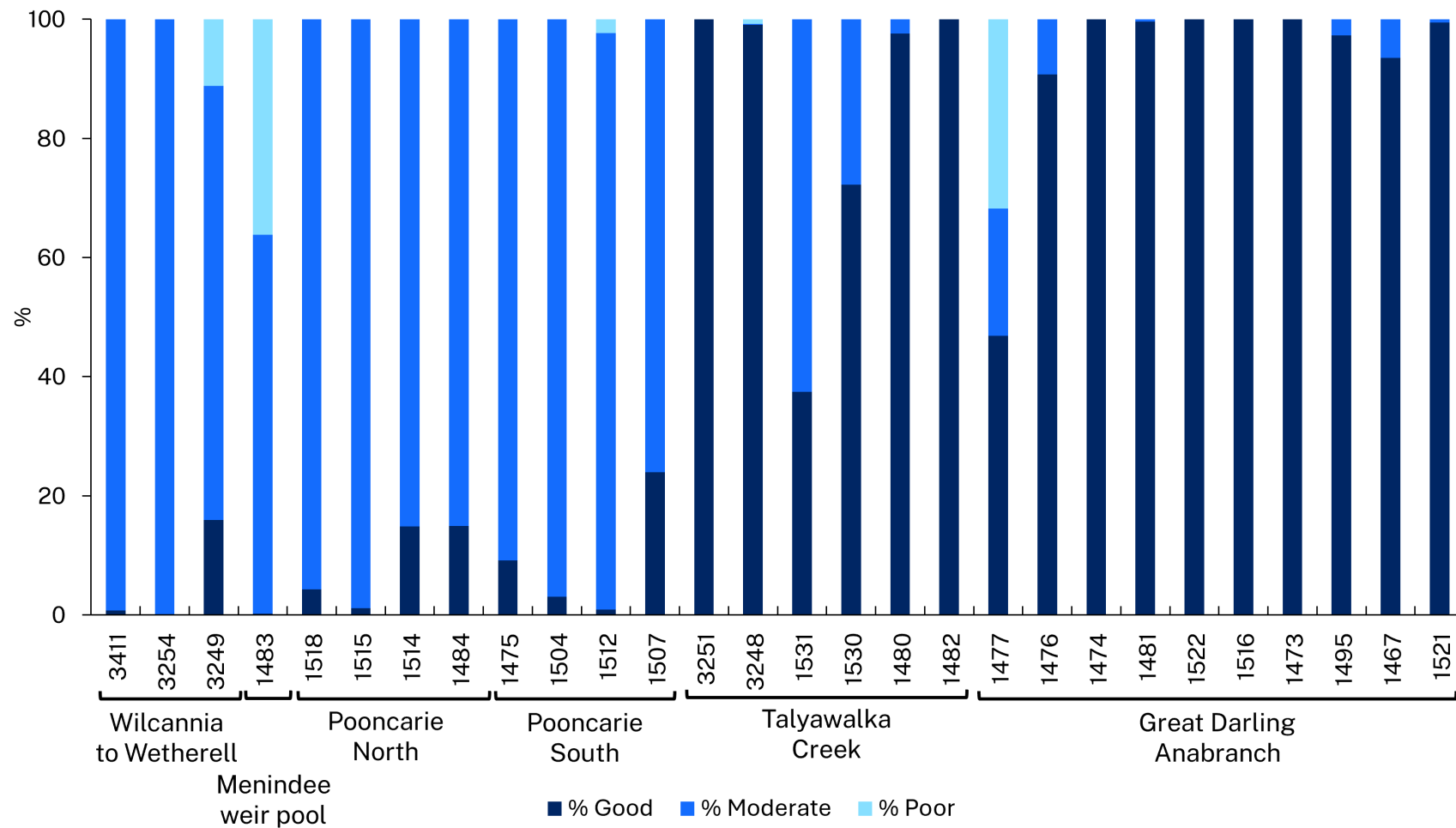


Figure 5 Proportional river lengths in each of the geomorphic condition indicator grades

Recovery potential indicator

Generally, the major anabranches in the study area are considered mostly intact in terms of their recovery potential, indicating good geomorphic condition (Table 1). Thus, these subcatchments contained the highest proportion of intact reaches (Table 7) and have been assessed as not requiring recovery either because the reach has not been recently disturbed or has fully recovered from past disturbances.

The reaches between Menindee and Wentworth have been identified as high recovery potential reaches, meaning that disturbances to geomorphic condition have occurred, but these areas have high potential to improve quickly. This region has a substantially lower frequency of alluvial gullies than upstream reaches and the relatively well-established riparian vegetation buffers indicate a high recovery potential (Table 7; Figure 6).

The lower Darling Baaka River reaches with moderate recovery potential tend to occur between Wilcannia and Lake Wetherell. This indicates that upon removal of pressures, the geomorphic condition may improve at a slow to moderate rate. This is related to the elevated number and size of alluvial gullies, indicating a persistent geomorphic threat that may hinder geomorphic recovery. An exception is the Palinyewah subcatchment (1504) where cropping activities and associated earthworks extend to the riverbank, reducing the extent of riparian vegetation and impinging on potential lateral adjustment of the channel.

The reaches with the lowest recovery potential occur in the Lake Wetherell (1483), Cawndilla (1477) and Wilcannia Downstream (3249) subcatchments. Again, this is related to anthropogenic impacts associated with river regulation. The interruption to fundamental geomorphic processes caused by semi-permanent inundation behind weirs and embankments means that any geomorphic recovery is unlikely to occur over management timeframes.

Table 7 Proportion of river length in each subcatchment for the recovery potential categories

Subcatchment number	Total river length (km)	Recovery potential			
		% Intact	% high recovery potential	% moderate recovery potential	% low recovery potential
Darling Baaka River subcatchments					
3411	91.93	0.77	0.00	99.23	0.00
3254	21.15	0.00	27.70	72.30	0.00
3249	364.59	15.90	0.15	56.44	27.50
1483	99.77	0.23	17.00	36.29	46.48
1518	14.17	4.26	95.74	0.00	0.00
1515	64.92	1.11	98.89	0.00	0.00

Subcatchment number	Total river length (km)	Recovery potential			
		% Intact	% high recovery potential	% moderate recovery potential	% low recovery potential
1514	44.83	14.83	85.17	0.00	0.00
1484	154.47	14.94	85.06	0.00	0.00
1475	133.02	9.18	67.55	23.28	0.00
1504	79.07	3.07	77.99	18.94	0.00
1512	60.75	0.89	55.81	36.64	6.66
1507	26.05	23.98	25.83	47.89	2.31
Great Darling Anabranch subcatchments					
1477	129.66	46.82	18.75	2.66	31.77
1476	54.28	90.74	9.26	0.00	0.00
1474	112.37	100.00	0.00	0.00	0.00
1481	68.12	99.62	0.38	0.00	0.00
1522	33.52	100.00	0.00	0.00	0.00
1516	23.92	100.00	0.00	0.00	0.00
1473	63.21	100.00	0.00	0.00	0.00
1495	16.93	97.30	0.00	2.70	0.00
1467	91.92	93.48	0.00	6.52	0.00
1521	151.51	99.43	0.00	0.57	0.00
Talyawalka Creek subcatchments					
3251	253.70	100.00	0.00	0.00	0.00
3248	214.61	99.08	0.00	0.13	0.79
1531	14.61	37.47	62.53	0.00	0.00
1530	22.07	72.19	27.81	0.00	0.00
1480	67.88	97.59	2.41	0.00	0.00
1482	21.47	100.00	0.00	0.00	0.00

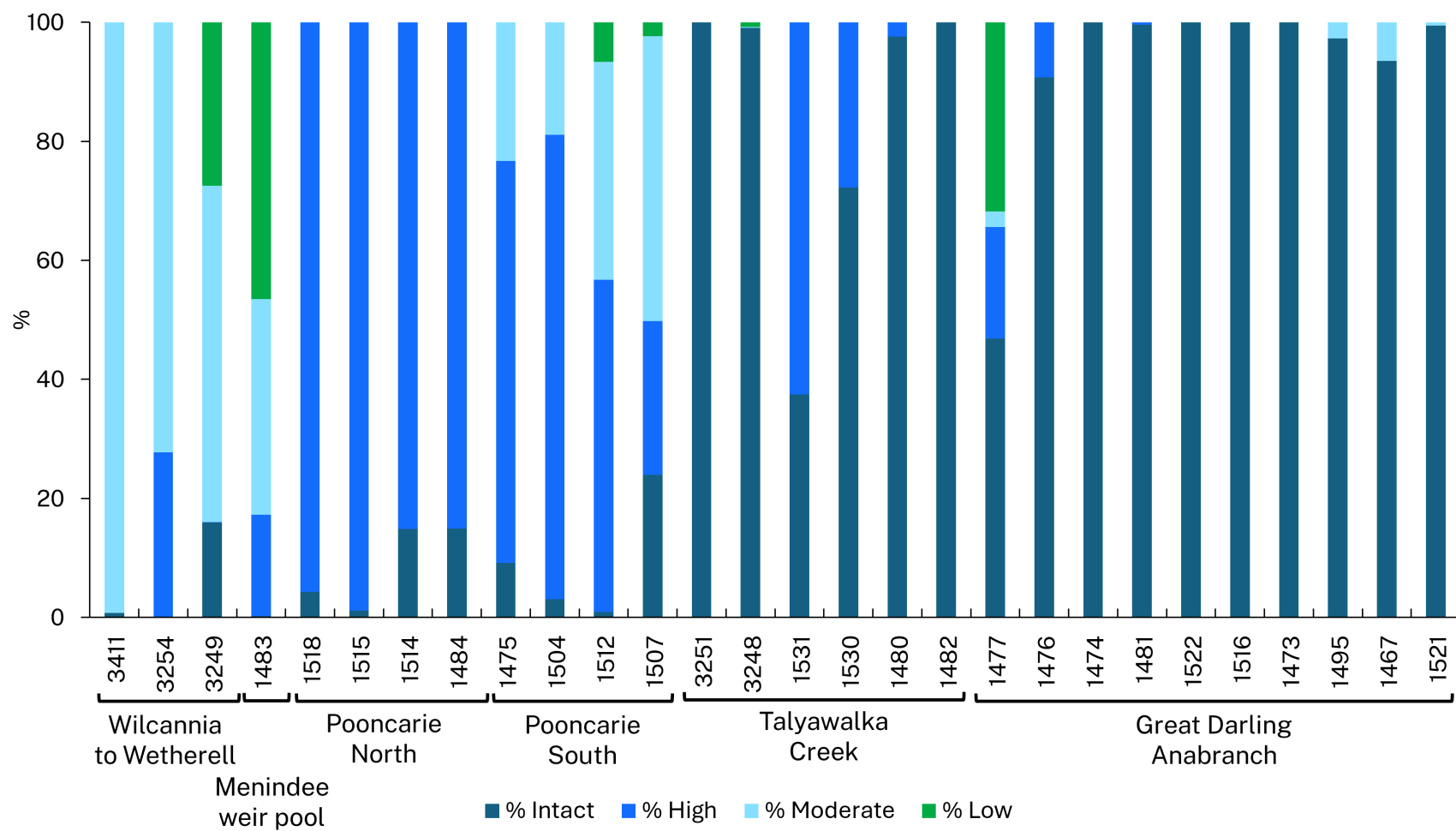


Figure 6 Proportion of river lengths in each of the recovery potential categories

3.6 Geomorphic Condition Index

The River Styles Geomorphic Condition Index used for the RCI combines the geomorphic condition and recovery potential indicators (refer to matrix in Table 3) to produce a reach length-weighted average geomorphic condition score. Field verification of 21 sites (Table 2) along the lower Darling Baaka, the Great Darling Anabranch, and other anabranches (such as Talyawalka Creek, Yampoola Creek, Charlie Stones Creek and 3 Mile Creek) informed the geomorphic condition and recovery potential assessments for the lower Darling Baaka River.

Table 8 includes the proportion of river lengths in each Geomorphic Condition Index category in each subcatchment, and Table 9 and Figure 7 show the final overall geomorphic condition grade for each subcatchment.

In general, the major anabranches were in very good overall geomorphic condition, that is, good geomorphic condition and intact recovery potential. This includes all subcatchments along Talyawalka Creek, as well as the Great Darling Anabranch. The exception to this was Cawndilla subcatchment which, due to artificial channels and structures associated with river regulation, received a geomorphic condition value of good, with moderate geomorphic condition and moderate-low recovery potential.

The subcatchments situated on the Darling Baaka River downstream of Lake Wetherell were in good overall geomorphic condition, that is, moderate geomorphic condition and high recovery potential.

The upper reaches of the Darling Baaka River between Wilcannia and Lake Wetherell have been assessed as being in moderate overall geomorphic condition in terms of the RCI. The mainstem of the lower Darling Baaka has a higher level of disturbances to the river's geomorphology than the major anabranches, and most river reaches have a moderate to low potential for recovery. These regions are characterised by features which contribute to the decline of the river's health, such as elevated rates of erosion and associated inputs of sediment by alluvial gullies.

Lake Wetherell (1483) has the lowest overall geomorphic condition grade of poor condition. The Lake Wetherell subcatchment incorporates sections of Lake Wetherell and the Menindee weir pool. This region has experienced significant geomorphic degradation, and many reaches have been classified as having moderate to poor recovery potential. These reaches have a very slow rate of recovery and may not recover without huge financial costs, bank stabilisation and removal of structures such as embankments and weirs. Geomorphic degradation will likely be ongoing in this subcatchment.

Table 8 Proportion of total subcatchment river lengths in each Geomorphic Condition Index condition category

Subcatchment name	Subcatchment number	% river length very good	% river length good	% river length moderate	% river length poor	% river length very poor
Darling Baaka River subcatchments						
Lower Paroo	3411	0.8	0.0	99.2	0.0	0.0
Lake Woytchugga	3254	0.0	27.7	72.3	0.0	0.0
Wilcannia Downstream	3249	15.9	0.2	72.8	1.4	9.8
Lake Wetherell	1483	0.2	14.4	39.3	0.0	30.6
Downstream Weir 32	1518	4.3	95.7	0.0	0.0	0.0
Lower Yampoola Creek	1515	1.1	96.6	0.0	0.0	0.0
Cuthero Creek	1514	14.8	85.2	0.0	0.0	0.0
Upstream Pooncarie	1484	14.9	85.1	0.0	0.0	0.0
Downstream Pooncarie	1475	8.2	60.5	20.9	0.0	0.0
Palinyewah	1504	2.8	70.2	17.1	0.0	0.0
Lower Darling	1512	0.9	55.8	41.0	0.0	2.3
Murray–Darling Confluence	1507	24.0	25.8	50.2	0.0	0.0
Great Darling Anabranh subcatchments						
Cawndilla	1477	45.8	18.4	2.6	0.0	31.1
Lower Redbank Creek	1476	90.7	9.3	0.0	0.0	0.0
Anabranh North Lakes	1474	88.6	0.0	0.0	0.0	0.0
Coonalhugga Creek	1481	80.9	0.3	0.0	0.0	0.0
Popio	1522	100.0	0.0	0.0	0.0	0.0
Anabranh Offtake	1516	100.0	0.0	0.0	0.0	0.0
Anabranh North	1473	100.0	0.0	0.0	0.0	0.0
Lake Milkengay	1495	97.3	0.0	2.7	0.0	0.0
Warrawenia Lake	1467	81.0	0.0	5.6	0.0	0.0
Lower Anabranh	1521	99.4	0.0	0.6	0.0	0.0
Talyawalka Creek subcatchments						
Upper Talyawalka Creek	3251	100.0	0.0	0.0	0.0	0.0
Middle Talyawalka Creek	3248	96.7	0.0	0.1	0.0	0.8
Lower 3 Mile Creek	1531	37.5	62.5	0.0	0.0	0.0

Subcatchment name	Subcatchment number	% river length very good	% river length good	% river length moderate	% river length poor	% river length very poor
Lower Talyawalka Creek	1530	72.2	27.8	0.0	0.0	0.0
Yampoola Creek	1480	71.4	1.8	0.0	0.0	0.0
Charlie Stones Creek	1482	100.0	0.0	0.0	0.0	0.0

Table 9 River Styles Geomorphic Condition Index (GCI) scores and grades for subcatchments of the lower Darling Baaka

Subcatchment name	Subcatchment number	GCI score	GCI grade
Darling Baaka River subcatchments			
Lower Paroo	3411	0.50	Moderate
Lake Woytchugga	3254	0.57	Moderate
Wilcannia Downstream	3249	0.53	Moderate
Lake Wetherell	1483	0.36	Poor
Downstream Weir 32	1518	0.76	Good
Lower Yampoola Creek	1515	0.75	Good
Cuthero Creek	1514	0.79	Good
Upstream Pooncarie	1484	0.79	Good
Downstream Pooncarie	1475	0.71	Good
Palinyewah	1504	0.71	Good
Lower Darling	1512	0.63	Good
Murray–Darling Confluence	1507	0.68	Good
Great Darling Anabranh subcatchments			
Cawndilla	1477	0.62	Good
Lower Redbank Creek	1476	0.98	Very good
Anabranh North Lakes	1474	1.00	Very good
Coonalhugga Creek	1481	1.00	Very good
Popio	1522	1.00	Very good
Anabranh Offtake	1516	1.00	Very good
Anabranh North	1473	1.00	Very good
Lake Milkengay	1495	0.99	Very good

Subcatchment name	Subcatchment number	GCI score	GCI grade
Warrawenia Lake	1467	0.97	Very good
Lower Anabranh	1521	1.00	Very good
Talyawalka Creek subcatchments			
Upper Talyawalka Creek	3251	1.00	Very good
Middle Talyawalka Creek	3248	0.99	Very good
Lower 3 Mile Creek	1531	0.84	Very good
Lower Talyawalka Creek	1530	0.93	Very good
Yampoola Creek	1480	0.99	Very good
Charlie Stones Creek	1482	1.00	Very good

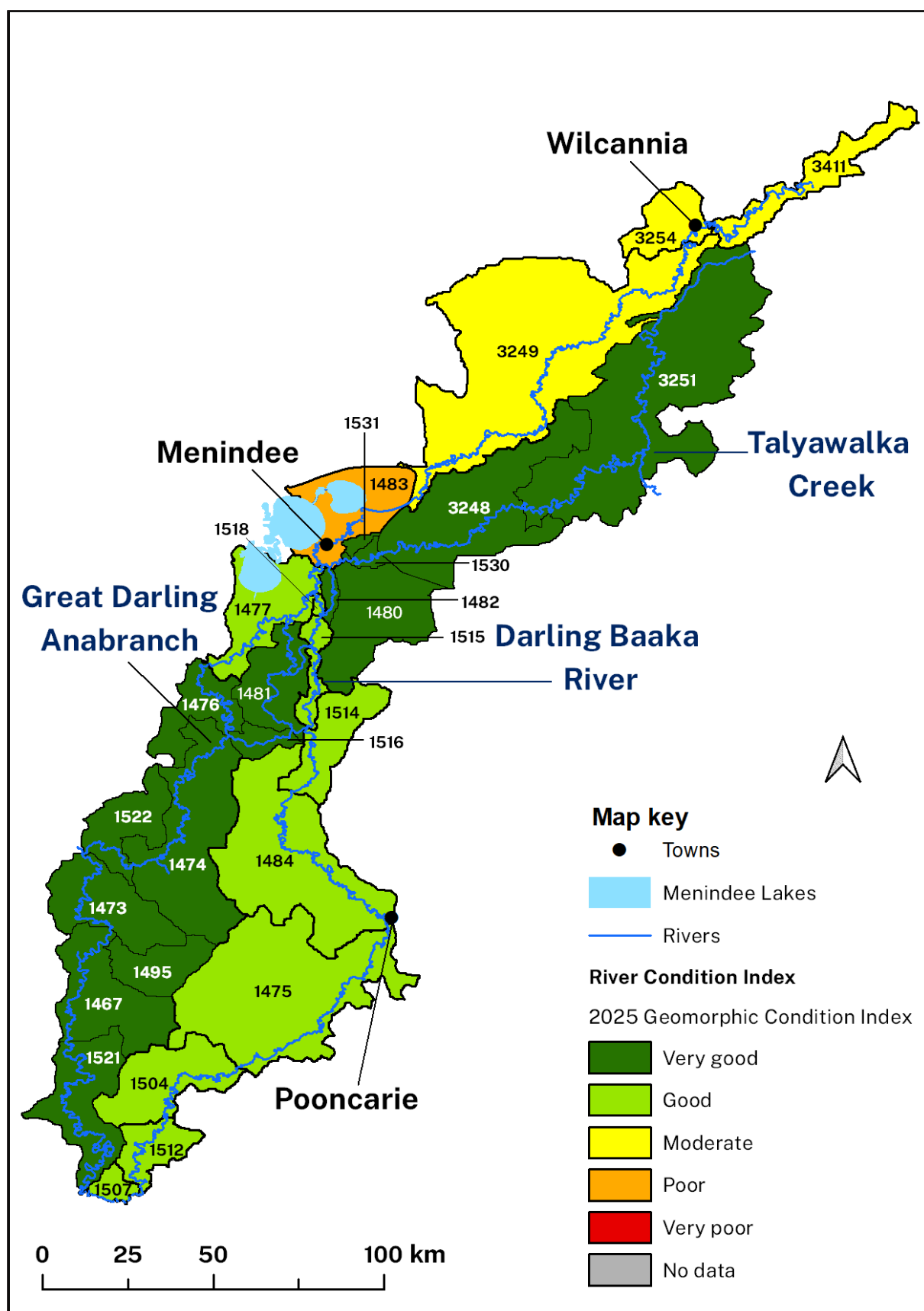


Figure 7 The 2025 Geomorphic Condition Index grades for the lower Darling Baaka. Numbers refer to subcatchments (see Table 9)

3.7 Conclusions

The lower Darling Baaka River is characterised by a complex arrangement of laterally unconfined meandering rivers, shallow floodplain flow paths, waterholes, floodplain wetlands and palaeochannels. Geomorphic condition varies depending on the degree of alteration to geomorphic processes generally associated with structures and river regulation. The poorest geomorphic condition scores occur around Lake Wetherell and Menindee, where weirs, embankments and artificial channels, associated with the Menindee Lakes Storage Scheme, have caused geomorphic degradation and reductions in geomorphic complexity. The key geomorphic threats to the lower Darling Baaka River are the impacts of river regulation and water extraction, alluvial gully formation and expansion, and reduced river red gum recruitment.

Appendix A: Field datasheet

River name:

River Style:

Site name:

Date:

Defining attributes of River Style (sequence from River Styles tree):

Subcatchments in which River Style is observed: (catchment specific)

DETAILS OF ANALYSIS
<i>Map sheet(s) air photographs used:.</i> <i>Analysts:</i> <i>Date:</i>

RIVER CHARACTER		
Valley-setting		
Channel planform • Sinuosity • # of channels • lateral stability		
Bed material texture, bed degradation/aggradation		Bank sample DBD/PSA?
Channel geometry (size and shape)		
Geomorphic units (geometry, sedimentology)	<i>Instream</i>	
	<i>Floodplain</i>	
Vegetation driven features	<i>Instream geomorphic units</i>	
	<i>Floodplain geomorphic units</i>	

RIVER CHARACTER	

RIVER BEHAVIOUR	
<i>Low flow stage</i> <i>Half bank stage</i> <i>Bankfull stage</i> <i>Overbank stage</i>	

CONTROLS	
Upstream catchment area	
Landscape unit and within-catchment position	
Process zone	
Valley Morphology (size and shape)	
Valley slope	
Stream power	

Schematic valley-scale cross-section



River planform diagram (in-bank features, floodplain/terraces, valley margins)



IBRA region/subregion:

Veg community:

Vegetation assembly

Channel cross section showing vegetation presence and type

Vegetation density, spacing and comments

Large wood placement, density, embedding
RRG recruitment?

Other comments (erosion patch