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Darling Baaka River Health Project 2023 to 2025

Chapter 7 Hydrological stress

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.

This resource may contain images or names of deceased persons in photographs or historical content.

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

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Environment and Heritage
Department of Climate Change,
Energy, the Environment and Water
Locked Bag 5022, Parramatta NSW 2124
Phone: +61 2 9995 5000 (switchboard)
Phone: 1300 361 967 (Environment and Heritage enquiries)
TTY users: phone 133 677, then ask for 1300 361 967
Speak and listen users: phone 1300 555 727, then ask for 1300 361 967
Email info@environment.nsw.gov.au
Website www.environment.nsw.gov.au

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7.1 What is hydrological stress?

Hydrological stress is a measure of the degree of alteration to natural river flows (DPE 2023a). It is a way to assess the pressure placed on water resources due to human influences such as river regulation, water extraction, and installation of dams and weirs. Hydrological stress occurs when the natural volume and/or seasonality of water is disrupted, often due to the demands on water resources for agriculture and other industrial activities, or due to dams and weirs.

In natural conditions, all rivers have a distinct hydrological signature shaped by the complex interactions of climate, geology and geomorphology (McManamay et al. 2022). The hydrological signature is particularly influenced by the spatial and temporal distribution of rainfall. The large dryland rivers of the Murray–Darling Basin, including the Darling Baaka River, are known as ‘allogenic’ rivers. In these river systems, the vast majority of runoff is generated in relatively wetter headwater catchments and flows downstream across broad semi-arid floodplains (McMahon 1979). The river systems are typically characterised by downstream declining discharge as water is lost to evaporation, transpiration and shallow groundwater. Australian dryland rivers are also characterised by significant interannual flow variability, with prolonged low flows during drought periods punctuated by extremely large flood events (McMahon 1979; McMahon et al. 1987, 2007; Grootemaat 2008). This variability is largely a function of regional climate driven by global-scale phenomena such as the El Niño Southern Oscillation, the Indian Ocean Dipole and the Southern Annular Mode (Grootemaat 2008).

The Darling Baaka River experiences significant modification of natural flow regimes, causing considerable hydrological stress (Figure 1). These modifications are fundamentally related to river regulation and water extraction for primary production, and the large network of weirs, bridges, culverts and roads which alter flow paths and influence flood behaviour.

7.2 Why use hydrological stress in river health assessments?

Hydrological stress is a measure of the pressure exerted on the river's flow regime and the degree of alteration to natural flow (DPE 2023a). Managing hydrological stress is crucial for maintaining a healthy and sustainable river system, as flow impacts not only water quality and biota, but also the river shape (geomorphology), connectivity with groundwater, riparian vegetation and water quality. Therefore, in any assessment of river health, hydrological stress needs to be understood and evaluated.

River regulation is one of the most significant factors causing declines in river condition across Australia (Kingsford 2000; Boulton and Brock 1999; Arthington and Pusey 2003). The health of the Darling Baaka River has long been impacted by river regulation, particularly on its tributaries. The upper reaches of the river system contain headwater dams in many major tributaries and numerous weirs interrupting natural flow regimes (Figure 1). Water resource development in the northern Murray–Darling Basin has reduced the frequency and magnitude of small freshes (pulses of increased flows that remain within the channel banks) in the lower Darling Baaka and has increased the duration of cease-to-flow periods (Sheldon 2017; Mallen-Cooper and Zampatti 2018).

The conceptual diagrams in Figure 1 and Figure 2 show the ecological impacts likely to happen in low-flow and zero-flow conditions (DPE 2023a). Figure 1 illustrates hydrologic stress in low-flow conditions, where good condition (left) leads to an increased wetted area, reduced water temperature and higher dissolved oxygen levels. Conversely, in the poor condition (right), water extraction in low-flow conditions leads to reduced wetted area, increased water temperature, and lower dissolved oxygen levels. Figure 2 presents hydrologic stress in no-flow conditions. The no-flow conditions have increased pool volumes and depth, higher wetted areas and expanded pool refugia. The water extraction in no-flow conditions results in reduced pool volumes and depth, a decrease in wetted areas, and the loss of pool refugia, which in turn increases external predation.

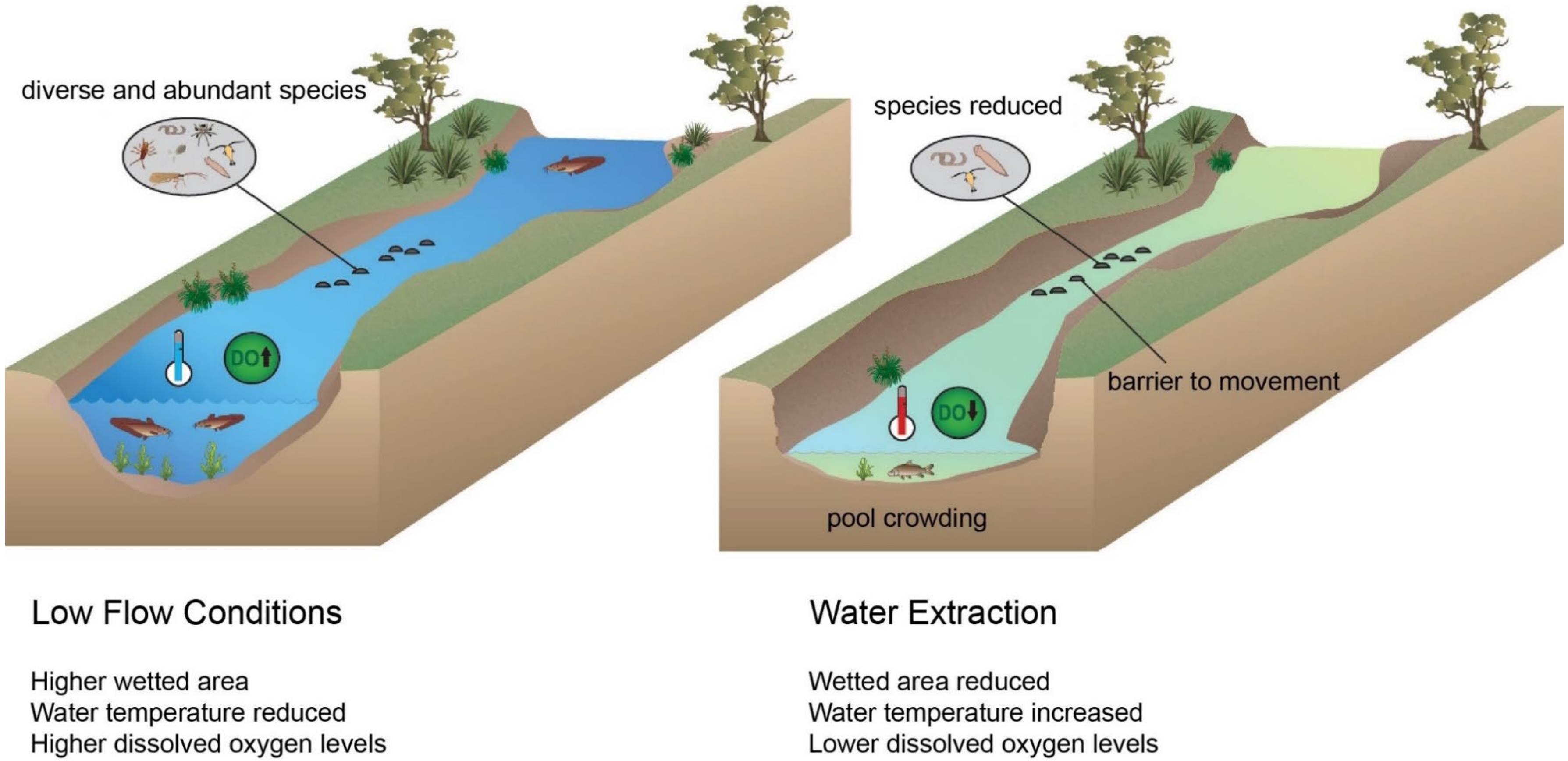

Figure 1 Hydrologic stress in low-flow conditions and water extraction in low-flow conditions (based on DPE 2023a)

Left: Hydrologic stress in low-flow conditions leading to higher wetted area, reduced water temperature and higher dissolved oxygen levels. Right: Water extraction in low-flow conditions, leading to reduced wetted area, increased water temperature and lower dissolved oxygen levels

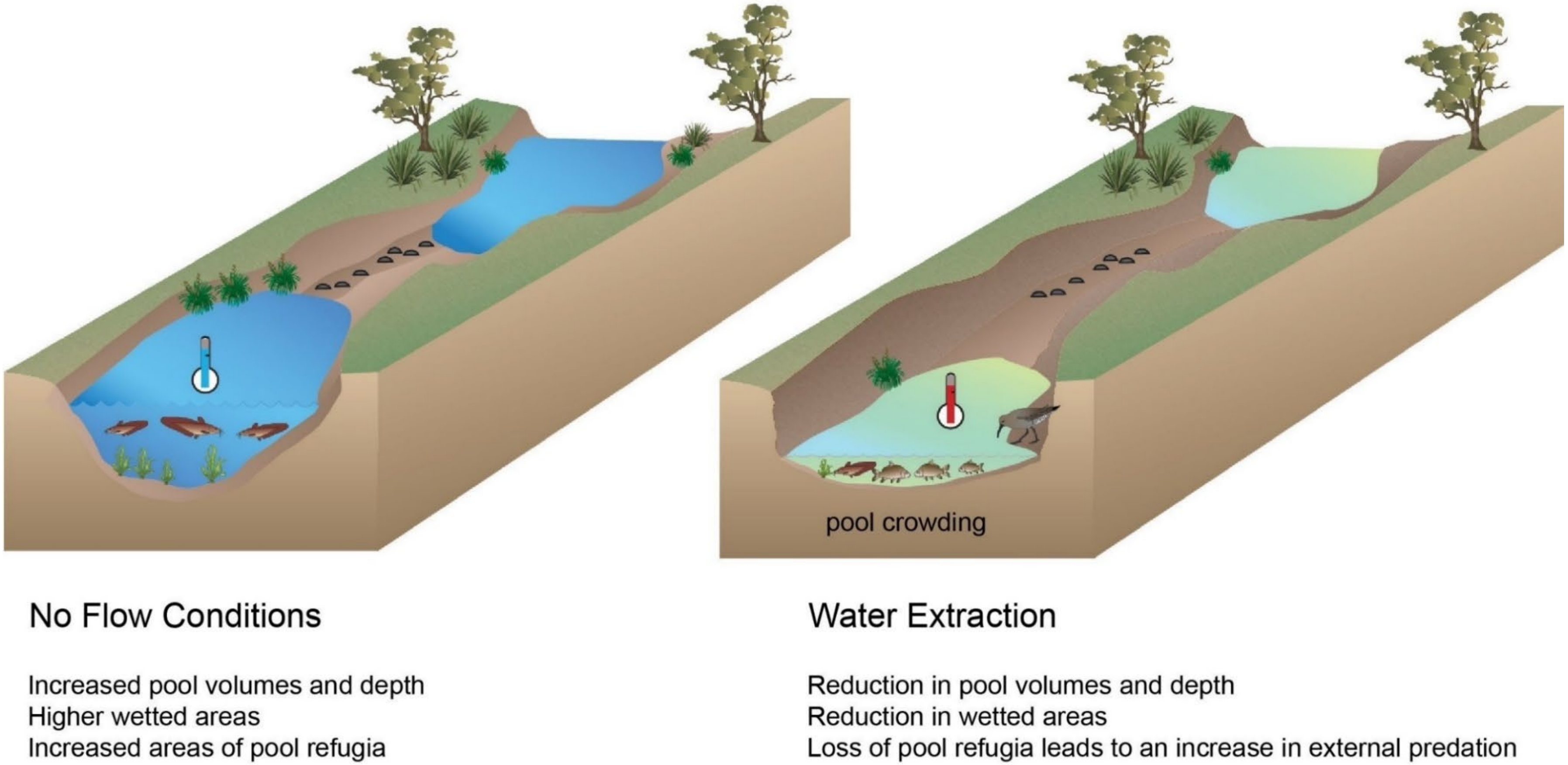

Figure 2 **Hydrologic stress in no-flow conditions and water extraction in no-flow conditions (Source: DPE 2023a)**

Left: Hydrologic stress in no-flow conditions, leading to increased pool volumes and depth, higher wetted areas and increased areas of pool refugia. Right: Water extraction in no-flow conditions, leading to reduced pool volumes and depth, reduction in wetted areas and loss of pool refugia, which in turn leads to an increase in external predation

7.3 Assessing hydrological stress

Hydrological stress can be assessed in various ways. Essentially, all methods evaluate various metrics related to flow and the availability of water within the entire watershed. The Hydrological Stress Index was based on the Key Ecosystem Function Metrics method developed for the Murray–Darling Basin Authority (Alluvium 2010). This method incorporates 17 metrics that assess the degree of disturbance or alteration in flow time-series, comparing pre-development (natural) conditions with current scenarios. This methodology considers the different portions of the hydrograph (that is, the high flows, medium flows, low flows and no flows). For full details methods and analysis of hydrological modelling see the supplementary report by WaterNSW (2025b).

7.3.1 Data used in hydrological modelling

The calculation of the Hydrological Stress Index for the Darling Baaka Project utilised a current operational hydrological model known as the 'Western Weirs Hydrological model' (WaterNSW 2021). This model was used to simulate the pre-development and current state of the river flows, simulating a 119-year period (June 1900 to June 2019), generating daily flow rates in megalitres per day (ML/day). This allowed the assessment of long-term impacts on the river hydrology caused by water resource development and river regulation. The WaterNSW model was improved by incorporating new bathymetric data (NSW ELVIS n.d.), which included 1-m resolution light detection and ranging (LiDAR), and a 5-m resolution digital elevation model from Geoscience Australia (Lawrie et al. 2012). Additionally, a groundwater module was integrated into the model.

The groundwater dataset consisted of 337 sites from WaterNSW (n.d.), which were analysed, filtered and incorporated into the modelling. Additionally, data from field monitoring at 13 bore sites, conducted as part of this project were also used (see Chapter 1). Groundwater time-series data were used to inform the model. The inclusion of the groundwater data into the model allows us to:

- reduce the error in the modelled surface water losses and gains
- predict the low flows in the river more accurately.

In addition to the groundwater time-series, hydraulic conductivity data from a recent study by Geoscience Australia (2025) were incorporated into the model. These hydraulic conductivity data were found to be similar to the average hydraulic conductivity determined by a separate study by the Southern Cross University (Damien Maher, pers. comm., 2024). The hydraulic conductivity was obtained from Geoscience Australia (Lawrie et al. 2012).

Due to the differences in methodologies and models used to calculate the hydrological stress index, comparing the results for the 2023 River Condition Index (RCI) (DPE 2023a) and 2025 Darling Baaka RCI is not a true indication of hydrological changes over time. Despite the differences between the application of the RCI framework, it is important to understand the differences between the 2023 RCI and the 2025 Darling Baaka RCI presented in this report (see Chapter 9).

7.4 Methods used for the Hydrological Stress Index

7.4.1 Flow metrics for the Hydrological Stress Index

The flow metrics used for the Hydrological Stress Index are common hydrological assessments used to derive an understanding of riverine systems. These metrics are summarised in Table 1. The flow metrics were evaluated across 6 critical flow ranges:

- zero flows (river drying events)
- low flows (small volumes)
- freshes (temporary in-bank flow increases)
- 3 high-flow ranges:
  - 2 near bank-full flows
  - one just overbank flow.

For the first 3 flow types (zero, low and freshes), multiple individual metrics were used:

- 6 metrics for zero flows
- 2 metrics for low flows
- 6 metrics for freshes.

These 17 metrics were used to evaluate the flow ranges. For detailed information, refer to Alluvium (2010). Only two of these metrics were used to create the 2023 Hydrological Stress Index in each subcatchment (DPE 2023a). In contrast, our analysis uses all 17 metrics, in a simplified way, to produce the Hydrological Stress Index as suggested by the 2023 River Condition Index (RCI) report (DPE 2023a).

Two modelling scenarios were computed for the region. The first modelling scenario describes the 'pre-development' or natural state of the system before the flow restrictions, extractions and developments were made. The second modelling scenario describes the 'current' or altered state of the system, that is, with the weirs, dams and water release and extraction. The percentage deviation (between the current flow and pre-development scenarios) for each of the 17 metrics is calculated. The average of these 17 percentage deviations for each location is the locational hydrological stress score. These locational stress scores are then used to derive the subcatchment hydrological stress scores. These scores are then standardised for inclusion in the calculation of the overall River Condition Index (described in section 7.4.5).

Table 1 **Summary of the 17 flow metrics used to determine the Hydrological Stress Index, based on Alluvium (2010)**

Season/flow component	Metric	Compliance assessment
Low-flow season		
Baseflow, where baseflow is a flow equivalent to the 80th percentile exceedance probability based on non-zero flows for season of interest	1. Flow rate (ML/day)	% deviation in flow rate = (natural flow rate for 80th percentile flow − current flow rate for 80th percentile flow) × 100/natural flow rate for 80th percentile flow
Cease-to-flow	2. No. of years with at least one cease-to-flow spell (no.)	% deviation in years = (natural no. of years − current no. of years) × 100/(natural no. of years)
	3. Average number of cease-to-flow spells per year (no.)	% deviation in average number of cease-to-flow spells per year = (natural no. per year − current no. per year) × 100/natural no. per year
	4. Average duration of cease-to-flow spells (no. of days)	% deviation in the duration of cease-to-flow spells = (natural no. of days − current no. of days) × 100/natural no. of days
Fresh, where a fresh is a flow that exceeds 20th percentile exceedance probability based on non-zero flows for season of interest (ML/day)	5. No. of years with at least one fresh (no.)	% deviation in years = (natural no. of years − current no. of years) × 100/natural no. of years
	6. Average number freshes per season (no.)	% deviation in average number of freshes per year = (natural no. per year − current no. per year) × 100/natural no. per year
	7. Average duration of freshes (no. of days)	% deviation in the duration of freshes = (natural no. of days − current no. of days) × 100/natural no. of days

Season/flow component	Metric	Compliance assessment
High-flow season		
Baseflow, where baseflow is a flow equivalent to the 80th percentile exceedance probability based on non-zero flows for season of interest	8. Flow rate (ML/day)	% deviation in flow rate = (natural flow rate for 80th percentile flow − current flow rate for 80th percentile flow) × 100/natural flow rate for 80th percentile flow
Cease-to-flow	9. No. of years with at least one cease-to-flow spell (no.)	% deviation in years = (natural no. of years − current no. of years) × 100/natural no. of years
	10. Average number of cease-to-flow spells per year (no.)	% deviation in average number of cease-to-flow spells per year = (natural no. per year − current no. per year) × 100/natural no. per year
	11. Average duration of cease-to-flow spells (no. of days)	% deviation in the duration of cease-to-flow spells = (natural no. of days − current no. of days) × 100/natural no. of days)
Fresh, where a fresh is a flow that exceeds 20th percentile exceedance probability based on non-zero flows for season of interest (ML/day)	12. No. of years with at least one fresh (no.)	% deviation in years = (natural no. of years − current no. of years) × 100/natural no. of years
	13. Average number freshes per season (no.)	% deviation in average number of freshes per year = (natural no. per year − current no. per year) × 100/natural no. per year
	14. Average duration of freshes (no. of days)	% deviation in the duration of freshes = (natural no. of days − current no. of days) × 100/natural no. of days)

Season/flow component	Metric	Compliance assessment
Any season		
Bank-full	15. The 1.5-year annual recurrent interval (ARI) flow rate (based on a partial series analysis) (ML/day)	% deviation in flow rate = (natural flow rate for 1.5-year ARI − current flow rate for 1.5-year ARI) × 100/natural flow rate for 1.5-year ARI
Overbank	16. The 2.5-year ARI (based on partial series analysis) (ML/day)	% deviation in flow rate = (natural flow rate for 2.5-year ARI) − (current flow rate for 2.5-year ARI) × 100/(natural flow rate for 2.5-year ARI)
	17. The 5-year ARI (based on partial series analysis) (ML/day)	% deviation in flow rate = (natural flow rate for 5-year ARI − current flow rate for 5-year ARI) × 100/natural flow rate for 5-year ARI

7.4.2 The hydrological model

The model used simulated a 119-year period (1900 to 2019), generating daily flow rate outputs in megalitres per day (ML/day). The model provided flow time-series for 82 locations (Figure 3) distributed in the 28 subcatchments considered in this study. The 82 locations represent where the time-series data were extracted from the model to calculate the Hydrological Stress Index.

The existing numerical model incorporated the operational rules (that is, water extractor and release based on the hydrologic conditions and water needs) from the regulated portion of the river system. As part of this project, the WaterNSW model was improved using the latest LiDAR-derived bathymetric data, and implementation of the groundwater module into the model.

To incorporate groundwater flows, which interact with surface waters, a simple built-in module in the SOURCE modelling package was used. This used the groundwater height time-series, the river water level height time-series, and the catchment hydraulic conductivity to estimate the groundwater fluxes. The groundwater time-series data collected from dataloggers deployed in this study were used to inform the model. The hydraulic conductivity data were adopted from earlier studies (Lawrie et al. 2012).

The flow rate at Wilcannia (the model's upstream boundary) is derived from a combination of observed flow rates and indirectly from the stage-discharge curve. Therefore, the upstream boundary inflows implicitly contain the operational rules for the regions upstream of Wilcannia. Table 2 presents a summary of the characteristics of the model for the Darling Baaka River.

Table 2 Characteristics of the 2025 Hydrological Stress Index for the Darling Baaka River

Indicator component	2025 index
Number of time-series locations	82
Operational rules	Yes
Catchments used	28
Bathymetric survey	Yes
Groundwater modelling	Yes
Groundwater monitoring	13
Geomorphic data included in the groundwater model	Yes
Number of flow metrics considered	17

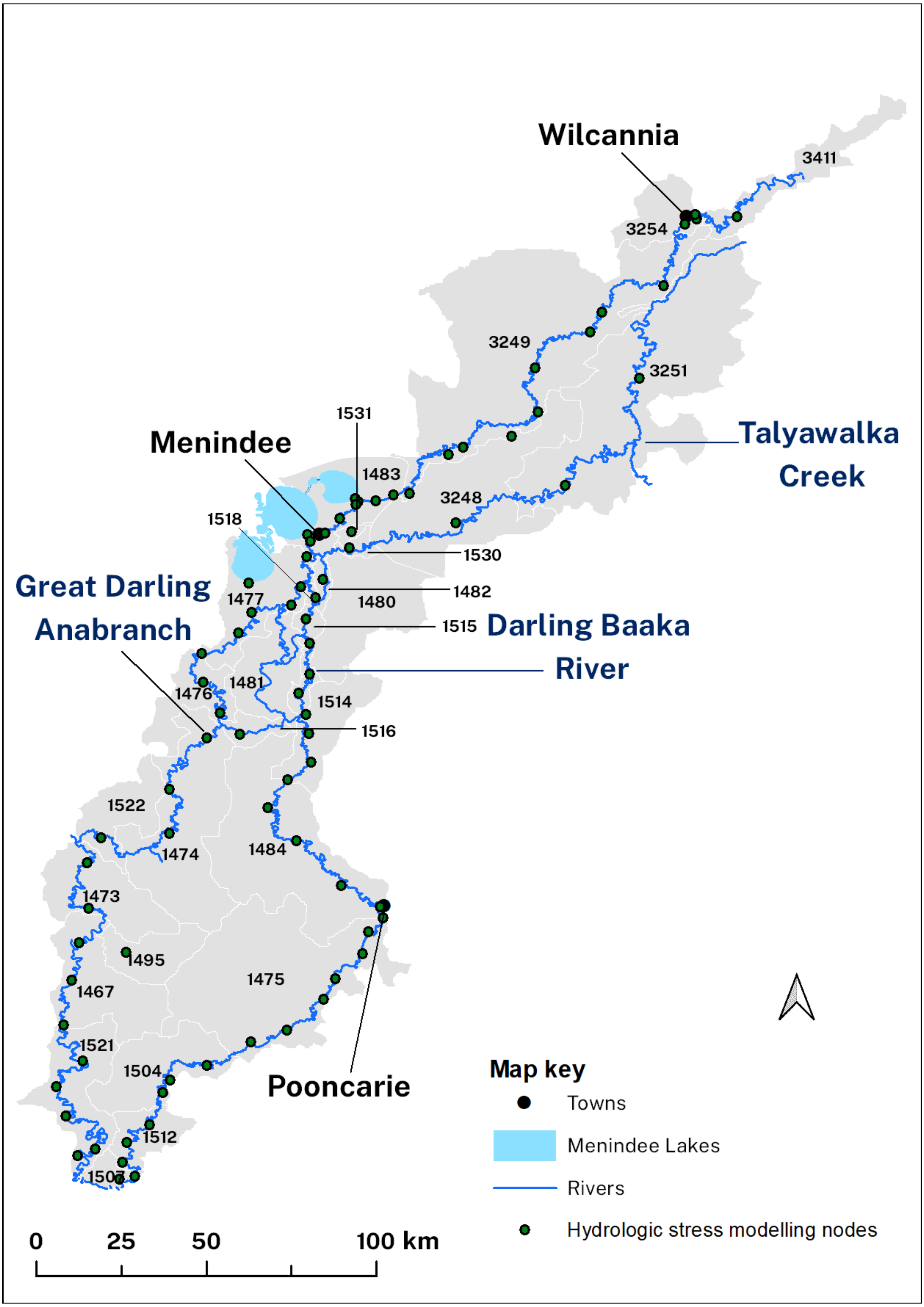

Figure 3 The 82 locations for the model time-series on the lower Darling Baaka River and Great Darling Anabranch. Numbers refer to subcatchments (see Table 3)

7.4.3 Classification of hydrological stress

The Hydrological Stress Index was calculated using the output of numerical simulations of water flow across the pre-selected locations (Figure 3).

The percentage of deviation from the pre-development scenario to the current condition scenario was computed for all 17 metrics for each of the 82 locations. Only the magnitude of percentage deviation was considered, and not the polarity of the deviation (that is, negative percentage deviations were converted to positive magnitudes). At each of the 82 locations, the average deviation of the 17 metrics was determined. This is the 'locational hydrological stress score'. Multiple locations, each with stress grades calculated, were present within most subcatchments (Table 3) thus the overall hydrological stress score for each subcatchment was determined as an average of all hydrological stress grades within the subcatchment.

This 'subcatchment hydrological stress score' was used to determine the hydrological stress grade using Table 4.The grade limits are determined such that only minimal deviations are rated as very good (<5%). This is within the volume bias error of the modelling output. The grade limit for good is limited at <20%, moderate is limited at <40%, poor is limited at <70% and very poor at >70%. Percentage deviations greater than 20% (over a long-term simulation) are generally considered a significant impact on the flow regime.

Table 3 Number of locations where modelled flows are extracted for each catchment

Subcatchment name	Subcatchment number	No. of locations
Darling Baaka River subcatchments		
Lower Paroo	3411	1
Lake Woytchugga	3254	3
Wilcannia Downstream	3249	8
Lake Wetherell	1483	9
Downstream Weir 32	1518	1
Lower Yampoola Creek	1515	5
Cuthero Creek	1514	3
Upstream Pooncarie	1484	4
Downstream Pooncarie	1475	7
Palinyewah	1504	3
Lower Darling	1512	4
Murray–Darling Confluence	1507	1

Subcatchment name	Subcatchment number	No. of locations
Great Darling Anabranch subcatchments		
Cawndilla	1477	6
Lower Redbank Creek	1476	3
Anabranch North Lakes	1474	3
Coonalhugga Creek	1481	0
Popio	1522	1
Anabranch Offtake	1516	1
Anabranch North	1473	2
Lake Milkengay	1495	1
Warrawenia Lake	1467	3
Lower Anabranch	1521	6
Talyawalka Creek subcatchments		
Upper Talyawalka Creek	3251	2
Middle Talyawalka Creek	3248	2
Lower 3 Mile Creek	1531	1
Lower Talyawalka Creek	1530	1
Yampoola Creek	1480	0
Charlie Stones Creek	1482	1

Table 4 **Hydrological Stress Index (HSI) scores and grades based on percentage change between pre-development and current flow conditions**

Index score	HSI grade
metric > 0.70	Very poor
0.40 < metric < 0.70	Poor
0.20 < metric < 0.40	Moderate
0.05 < metric < 0.20	Good
0.00 < metric < 0.05	Very good

7.4.4 Interpretation of the Hydrological Stress Index score

In order to understand the driving metrics for the grades, the 17 metrics for all locations for each index grade were analysed. For example, all locations graded poor had their respective 17 metrics collated and tallied to identify which metrics were driving the percentage change in the index score. Figure 4 shows an example of the percentage deviations of the 17 metrics extracted for a location upstream of Lake Wetherell. In this example, the metrics related to zero-flow events during both the low-flow and high-flow seasons were significantly larger (average of ~120%) than the rest of the metrics (average of ~35%). The higher contribution of the zero-flow event metrics increases the site average deviation and scores this site as poor (and very close to exceeding the very poor limit). This comparison was performed at the subcatchment level and allowed integration into the metrices driving scores and Hydrological Stress Index grades.

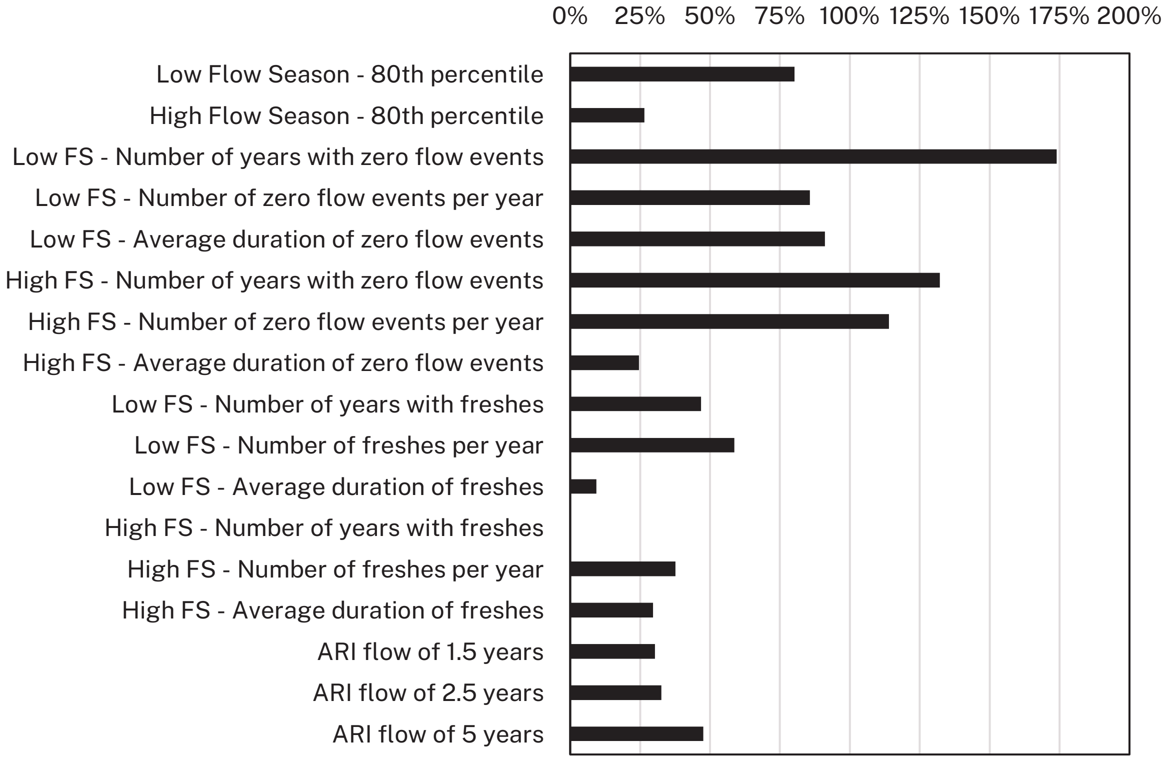

Figure 4 **Example of the percentage deviation of the 17 flow metrics, relative to pre-development flows, at one of the 82 modelled locations (this location is just upstream of the Lake Wetherell)**

7.4.5 Normalisation of the Hydrological Stress Index score

The Hydrological Stress Index score was calculated based on the category bins listed in Table 4. This was then standardised to fit into the River Condition Index (RCI) boundaries. A polynomial fit, correlating the centre bins of the data presented in Table 5 to the centre of the RCI bins yielded Equation 1 below. The R^2 of this fit was 0.9942 and there were no shifts to adjacent categories due to this normalisation process.

Equation 1: $\boldsymbol{Hydrological\ Stress\ Index_{norm} = 0.6812HSI^2 - 1.5173HSI + 0.9092}$

Table 5 The relationship between the Hydrological Stress Index (HSI) score and the normalised River Condition Index (RCI) score

HSI score	RCI normalised score	RCI condition grade
0.7 < 1	<0.2	Very poor
0.4 < 0.7	0.2 < 0.4	Poor
0.2 < 0.4	0.4 < 0.6	Moderate
0.05 < 0.2	0.6 < 0.8	Good
<0.05	0.8 ≤ 1	Very good

7.5 Results and discussion

7.5.1 Groundwater module

The inclusion of the calibrated groundwater module in the hydrological model resulted in significant improvement in modelling low-flow periods. Prior to groundwater being incorporated, the hydrological model underestimated low flows (that is, flows <100 ML/day), indicating that surface water losses to groundwater aquifers were not properly represented. Implementing modelling with the groundwater module indicated the overestimation of losses was reduced, leading to a more accurate representation of low-flow conditions (Figure 5).

Groundwater and surface water are interlinked, thus extraction in one area may impact water availability in the other. By including groundwater into the hydrological model, water managers can better predict the outcomes of extraction on river flows. It is also possible to use these models to further our understanding of the contribution of groundwater to river flow and potentially river health.

Interactions between surface and groundwater have been investigated throughout the study area. Figure 6 demonstrates the locations where the river loses water to the groundwater system ('loss') or gains water from the groundwater system ('gain'). This has been based on average flows for the water flow scenarios tested in the model (over 119 years). The modelling results of the upstream regions of the lower Darling Baaka River, from Wilcannia to Lake Wetherell, indicate that the river is losing water to groundwater storages in these reaches. The model indicates that this dynamic changes below Weir 32 and the river may shift from losing water to gaining water. More investigations into the interactions between surface water and groundwater are needed, in particular with respect to the impact of groundwater on river water quality and biological health. Groundwater health has been assessed as part of this study, and is reported in a supplementary report (Hose et al., 2025).

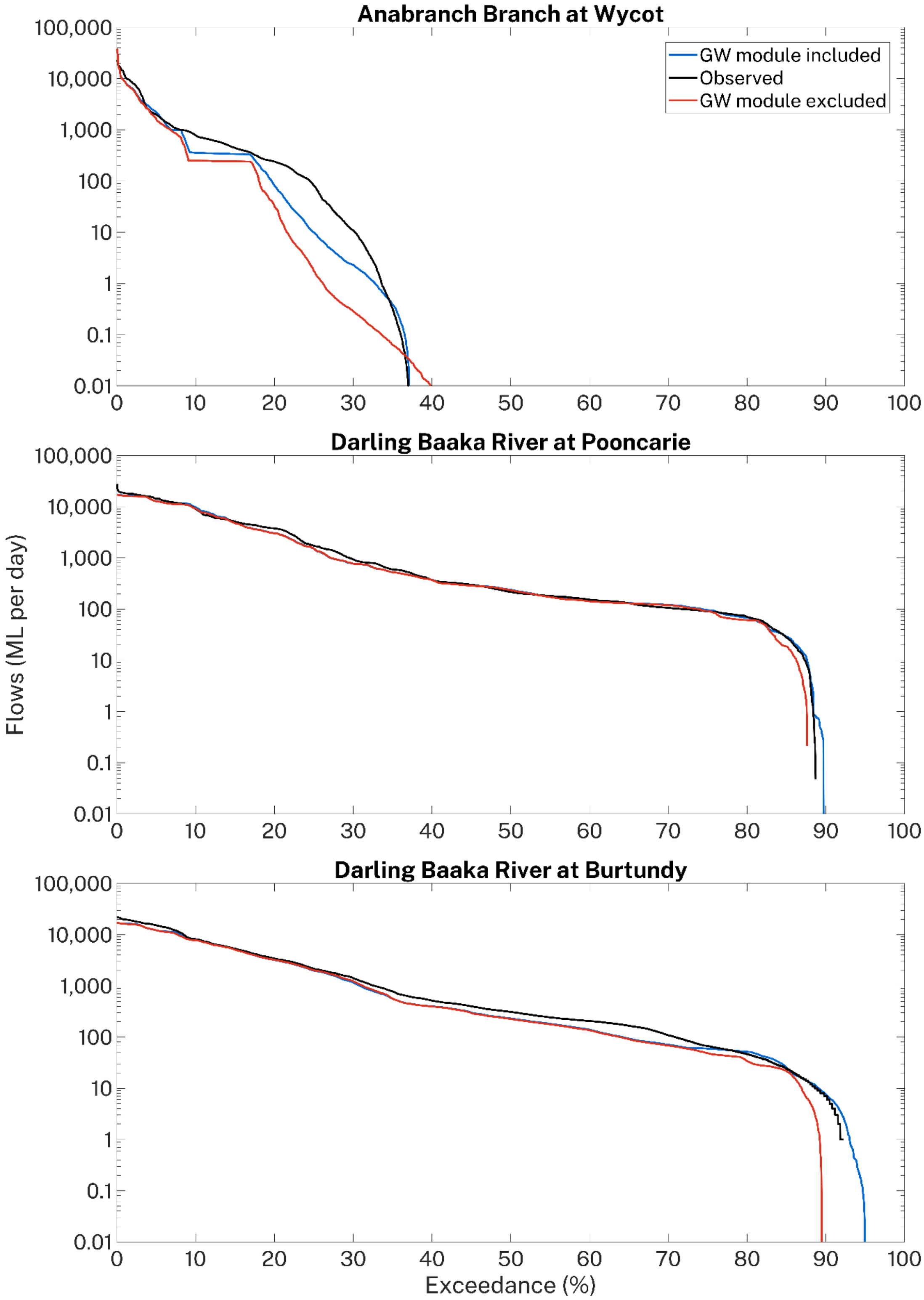

Figure 5 Flow exceedances (%) on the Darling Baaka River at Wycott, Pooncarie and Burtundy comparing observed flows (megalitres per day [ML/day]) with and without the groundwater model included

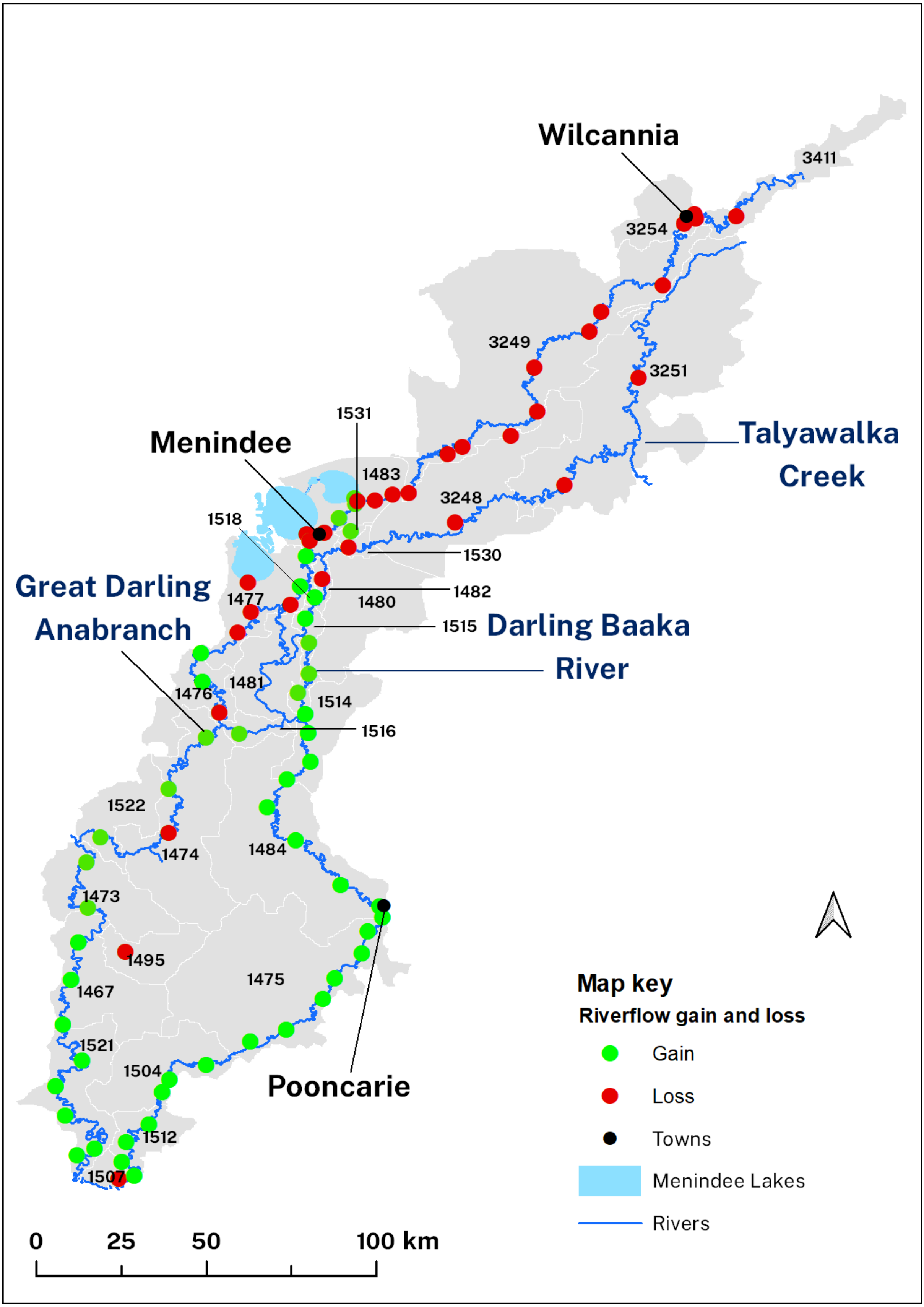

Figure 6 **The impact of groundwater inclusion in the modelling at 82 locations showing where the river loses water to the groundwater system (red dot) or gains water from the groundwater system (green dot)**

7.5.2 Hydrological Stress Index scores

General findings

The Hydrological Stress Index model indicates that the current flows in the river are deviated from pre-development conditions, indicating significant disturbances to hydrological condition (Figure 7;Table 6). Only 2 of the subcatchments have been classified as being in good or very good hydrological condition, with the rest of the subcatchments in moderate or poor condition. Three catchments lacked sufficient data to assess hydrological stress. When the area of the subcatchments was considered, out of the 20,769 km^2 catchment area, 19,813 km^2 (95%) was graded as moderate or poor, and only 956 km^2 (5%) was graded as good or very good (Table 7). This strongly suggests significant flow deviations from the pre-development conditions.

The river flows in the study area are almost entirely driven by the upstream catchment flows, rainfall and water regulation. Hence the hydrological impacts in the most downstream reaches of a catchment are significantly impacted by the upstream land disturbances such as farm dams, weirs and extractions. In this sense, the Hydrological Stress Index is closely related to the Landscape Disturbances Index (Chapter 8), with similar patterns noted. This Hydrological Stress Index only considers the impact of river regulation and extractions within the study area between Wilcannia and Wentworth. So, the hydrological impacts of water extraction upstream of the study area are not explicitly incorporated into this modelling. This means that the scores provided are inherently conservative in terms of the degree of hydrological stress this section of the river experiences.

Upstream of Lake Wetherell, the Hydrological Stress Index grade along the Darling Baaka River is rated moderate to good. These regions are also graded in good condition in the Landscape Disturbance Index, indicating the disturbances on the river health due to land uses are minimal.

There is a clear demarcation point in hydrological stress around the Lake Wetherell region, which was similar to the observations in the Landscape Disturbance Index (Chapter 8). In both the Lake Wetherell and Cawndilla subcatchments, results indicate the disturbances to natural hydrological regime is high (Hydrological Stress Index grade of poor) correlating with the extensive alterations to hydrology caused by the structures, extractions and releases associated with the Menindee Lakes Storage Scheme.

Hydrological stress is experienced immediately downstream of Main Weir and Cawndilla, demonstrating the impacts of water management actions related to the Menindee Lakes Storage Scheme. As both the Darling Baaka River and Great Darling Anabranch flow south, hydrological stress marginally reduces to a moderate condition in the Anabranch North Lakes and upper Pooncarie subcatchments.

Talyawalka Creek is a high-level anabranch diverging from the Darling Baaka River approximately 50 km upstream of Wilcannia. It rejoins the main river just downstream of Weir 32. The creek flows only during floods and there are minimal land disturbances along the creek (Chapter 8). The hydrological stress on Talyawalka Creek is scored as moderate to very poor despite no significant regulation of flows along the creek and limited land disturbances. The factors driving the changes along Talyawalka Creek cannot be clearly pinpointed with the current modelling. The lack of data for Cuthero Creek and Yampoola Creek (Table 6) correspond to catchments with ephemeral rivers, where the available data were insufficient to calculate the hydrological index score.

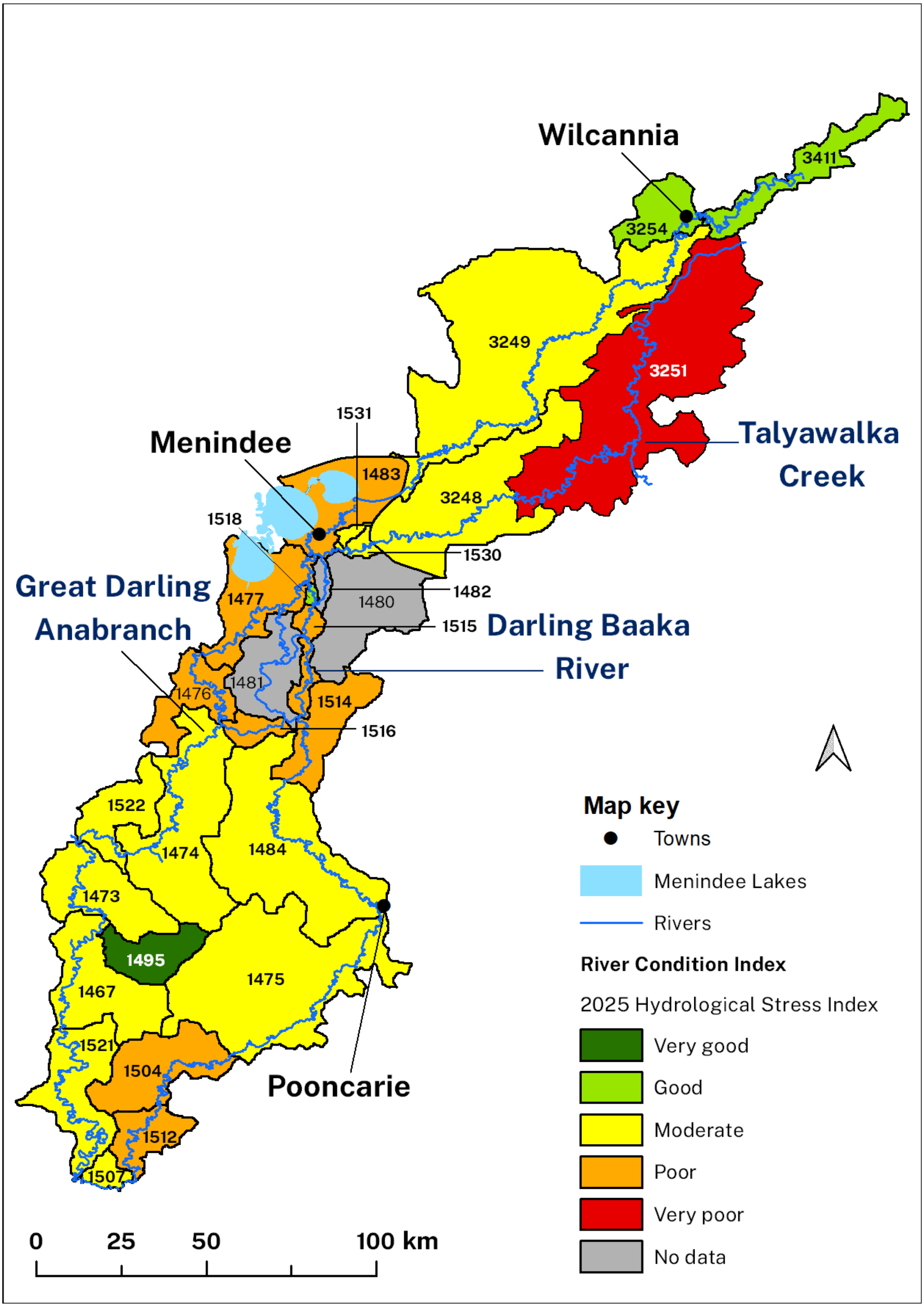

Figure 7 **The 2025 Hydrologic Stress Index grades for the lower Darling Baaka River. Numbers refer to subcatchments (see Table 6)**

Table 6 The 2025 Hydrologic Score Index (HSI) scores and grades for the lower Darling Baaka and associated River Condition Index (RCI) grade

Subcatchment name	Subcatchment number	Area (km^2)	HSI score	Transformed HSI score*	RCI grade
Darling Baaka River subcatchments					
Lower Paroo	3411	393	0.19	0.64	Good
Lake Woytchugga	3254	279	0.20	0.64	Good
Wilcannia Downstream	3249	2,372	0.33	0.49	Moderate
Lake Wetherell	1483	583	0.53	0.30	Poor
Downstream Weir 32	1518	17	0.52	0.30	Poor
Lower Yampoola Creek	1515	142	0.42	0.39	Poor
Cuthero Creek	1514	767	0.42	0.39	Poor
Upstream Pooncarie	1484	2,617	0.36	0.45	Moderate
Downstream Pooncarie	1475	3,171	0.36	0.45	Moderate
Palinyewah	1504	1,558	0.65	0.21	Poor
Lower Darling	1512	486	0.52	0.31	Poor
Murray–Darling Confluence	1507	82	0.24	0.58	Moderate
Great Darling Anabranch subcatchments					
Cawndilla	1477	548	0.66	0.21	Poor
Lower Redbank Creek	1476	319	0.42	0.39	Poor
Anabranch North Lakes	1474	1,031	0.40	0.41	Moderate
Coonalhugga Creek	1481	398	n.d.	n.d.	n.d.
Popio	1522	352	0.32	0.50	Moderate
Anabranch Offtake	1516	107	0.42	0.39	Poor
Anabranch North	1473	514	0.32	0.49	Moderate
Lake Milkengay	1495	284	0.00	0.91	Very good

Subcatchment name	Subcatchment number	Area (km²)	HSI score	Transformed HSI score*	RCI grade
Warrawenia Lake	1467	614	0.30	0.51	Moderate
Lower Anabranch	1521	547	0.36	0.45	Moderate
Talyawalka Creek subcatchments					
Upper Talyawalka Creek	3251	2,826	0.73	0.17	Very poor
Middle Talyawalka Creek	3248	1,081	0.31	0.50	Moderate
Lower 3 Mile Creek	1531	27	0.26	0.56	Moderate
Lower Talyawalka Creek	1530	50	0.26	0.56	Moderate
Yampoola Creek	1480	639	n.d.	n.d.	n.d.
Charlie Stones Creek	1482	50	n.d.	n.d.	n.d.

Table Notes: * Hydrological Stress Index scores have been transformed by a polynomial transformation to rescale the scores into grade boundaries of 20th percentile increments for incorporation into the final RCI calculation (see Table 5). n.d. = no data.

Table 7 **Area (km²) of each River Condition Index (RCI) grade in the Darling Baaka River**

RCI condition grade	Total area (km²)
Very poor	2,826
Poor	6,540
Moderate	9,742
Good	1,377
Very good	284

Drivers of the Hydrological Stress Index grade

The deviations from pre-development conditions were mostly driven by increases in the frequency and duration of zero-flow events (that is, river drying more frequently and for longer). To a lesser extent, the deviations in the frequency and duration of freshes also contributed to the impacted subcatchments. Finally, the influence of the groundwater as a function of the subcatchments was delineated, showing a loss to groundwater storages in the upstream regions and gains into the river flow downstream of the Main Weir.

In order to understand the driving metrics for the grades, the 17 metrics for all RCI subcatchments for each Hydrological Stress Index grade were analysed. The metrics with higher percentage deviations were identified for each subcatchment (see example in Figure 4), then commonality of these metrics in all subcatchments of the same grade are drawn out and presented here.

The results indicate that poor and very poor Hydrological Stress Index grades were driven by very large percentage deviations (and in fact significant worsening) in more than one of these 6 metrics:

- Low-flow season: number of years with zero-flow events
- Low-flow season: number of zero-flow events per year
- Low-flow season: average duration of zero-flow events
- High-flow season: number of years with zero-flow events
- High-flow season: number of zero-flow events per year
- High-flow season: average duration of zero-flow events.

These results indicate that a significant increase in the frequency and duration of zero-flow events (that is, when the river dries out) is contributing to hydrological stress. The deviations are in the range of 100 to 400% worse than the pre-development conditions.

The moderate Hydrological Stress Index grades tended to be driven by an overall deviation of 40 to 60% in the majority of the 17 metrics. In this respect, the moderate grade score was driven by a lesser increase in frequency and duration of zero-flow events, coupled with a similar change in the frequency and duration of freshes (that is, rain-induced high flows that raise to within the confines of the banks but do not overflow). The good and very good index grades typically had very small percentage deviations in the 17 measured metrics. The very good grades have deviation magnitudes that are considered within the modelling error of the river. For more details on the deviation in each catchment, please refer to Table 7.

Limitations of the methodology

A caveat of the project's methodology is that it considers only percentage deviations from pre-development flows. This means the result is not influenced by (1) the polarity of the change (increase or decrease) and (2) the basal volume flow rate in the metrics. Hence, a worsening of a metric is rated the same as an improvement of the metric, for the same percentage deviation. Further, a large percentage change in small flow values (for example, from 0.001 ML/day to 0.1 ML/day) is recorded as a greater significance than a smaller percentage change in large flow values (for example, from 1,000 ML/day to 950 ML/day), even though the change in the physical volumes is different by several orders of magnitude. This means that deviations in smaller flows appear as more pronounced than those in in larger flows. Further assessment of the grading system should consider a way to address this.

Potential improvements to the Hydrological Stress Index include:

- improving the spatial hydraulic conductivity observations, especially south of Pooncarie

- updating the bathymetric surveys along the Greater Darling Anabranch, especially in the regions that were not LiDAR-surveyed in 2019
- extending the modelling scenario period from 2019 to the latest period, to include the recent devastating flooding events in the region
- including the groundwater extraction pumps along the river length
- using longer term groundwater levels and stream flow levels to develop a more robust correlation
- incorporating assessment of deviations in flows related to extraction and river regulation in the vast catchment area upstream of Wilcannia.

The hydrological datasets developed through the project's long-term model scenarios provide an opportunity to investigate how climate change (such as increase in the zero-flow events) may influence the RCI and the groundwater fluxes.

7.6 Conclusions

The modelling showed that the hydrological condition in the lower Darling Baaka River is characterised by significant hydrological stress presumably due to flow deviations, damming and extraction along the river length. Comparing undisturbed pre-development flow with current conditions, the model showed that nearly 95% of the lower Darling Baaka is in moderate or poor hydrological condition. The poorest hydrological conditions occurred between Lake Wetherell and the Anabranch offtake. The key drivers of these conditions are significant changes to the frequency and duration of zero-flow events. Downstream of the Anabranch offtake, the river flow volumes may potentially be recharged by groundwater input. To our knowledge this is the first modelling study to consider the river flow recovery due to groundwater fluxes for this region, there are several suggestions to improve the model detailed in WaterNSW (2025b).