Marne Saunders PWRA ecological condition assessment 2024

Department for Environment and Water

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Foreword

The Department for Environment and Water (DEW) is responsible for the management of the State's natural resources, ranging from policy leadership to on-ground delivery in consultation with government, industry and communities.

High-quality science and effective monitoring provides the foundation for the successful management of our environment and natural resources. This is achieved through undertaking appropriate research, investigations, assessments, monitoring and evaluation.

DEW's strong partnerships with educational and research institutions, industries, government agencies, Landscape Boards and the community ensures that there is continual capacity building across the sector, and that the best skills and expertise are used to inform decision making.

Ben Bruce
CHIEF EXECUTIVE
DEPARTMENT FOR ENVIRONMENT AND WATER

Acknowledgements

The Department for Environment and Water (DEW) acknowledges the First Nations people as the First Peoples and Nations of the lands and waters we live and work upon and we pay our respects to their Elders past, present and emerging. We acknowledge and respect the deep spiritual connection and the relationship that Aboriginal and Torres Strait Islander people have to Country. The work documented in this report was undertaken on the traditional lands of the Peramangk and Ngarrindjeri Nations. DEW acknowledges the care for country that these Nations provide and have provided since time immemorial.

DEW thanks the various groups and bodies that have collected the data that underpins this assessment. In particular the Environmental Protection Authority of South Australia, Nature Glenelg Trust, Australian Water Quality Centre, Freshwater Macroinvertebrates and the Bioblitz Program for the Marne Saunders.

DEW thanks the Murraylands and Riverlands Landscape Board for the opportunity to undertake the work and providing the funding for the work.

Contents

1 Background and Context

Under the *Landscapes South Australia Act 2019* (the Act), a water allocation plan (WAP) must include an assessment of the capacity of the water resource to meet environmental objectives [s. 53(1)(b)(i)]; a statement of the environmental outcomes expected to be delivered on account of the provision of environmental water under the plan [s. 53(1)(b)(iii)]; and must set out principles associated with the determination of water access entitlements and for the taking and use of water so that an equitable balance is achieve between environmental, social and economic needs for the water [s. 53(1)(d)(i)]. The Act also requires a WAP to be reviewed on a comprehensive basis at least once every 10 years (54, 1) that provides an assessment of whether the WAP remains appropriate or requires amendment (54, 2b) among other requirements.

The WAP for the Marne Saunders Prescribe Water Resource Area (PWRA) was first adopted in 2010 and has been amended twice (2018 and 2019). In 2023, a comprehensive investigation into community sentiment and concerns relating to water management in the Marne Saunders PWRA was undertaken by the Board (Murraylands and Riverlands Landscape Board, 2023). This investigation highlighted these community concerns relating to water management and, in response, the Board have opted to undertake a review of the WAP to identify what is working well in the current plan and areas that could be improved to address community concerns.

In preparation for the review, the Board requested the Department for Environment and Water (DEW) Water Science to undertake an assessment of the current condition of the aquatic ecosystems to provide context and background information for stakeholders that relates to the review of the environmental principles of the WAP.

The purpose of this report was to summarise the trend and status/condition of the fish and macroinvertebrate communities of the two PWRAs. The results from this assessment are accompanied by an assessment of a series of key ecologically relevant flow metrics recorded at locations across the PWRA. This report is not intended as a full evaluation of the environmental outcomes outlined in the current WAPs; however, the information presented here will form part of the evidence base for an evaluation of the environmental outcomes of the WAPs in combination with the modelling work currently underway as part of the hydro-ecological modelling investigations for the Marne Saunders PWRA.

This assessment focused on three areas: flow; macroinvertebrates; and fish. The assessment of the key ecologically relevant flow metrics was undertaken to provide context to the ecological assessments. All the assessments were undertaken on monitoring data collected across the region. Macroinvertebrate community trend and condition was assessed as macroinvertebrate community condition is considered to be one of the best overall indicators of aquatic ecosystem condition (Chessman, 2003; Smith et al., 1999).. An assessment of the trend and condition of the fish community was undertaken as the fish community condition is considered to be a high priority for many stakeholder groups and provides a good indication of overall ecosystem health (Gannon et al., 2021).

While this report is not considered to be an evaluation of the full suite of ecological objectives and targets from the Marne Saunders WAP, reference will be made to summarised ecological objectives. There are a total of 53 environmental objectives listed in Table 4 of the WAP many of which are the same objective for different reaches. By grouping these objectives together it is possible to simplify the objectives into summarised objectives for the purposes of this report (Table 1). Where relevant, these are discussed.

Table 1: High level summary of objectives from the Marne Saunders WAP.

Focus area	Objective
Water quality	Restore or rehabilitate water quality delivered to the reach downstream.
Geomorphology	Maintain or rehabilitate channel shape and structure.
Flow	Provide suitable flow and habitat conditions.
Fish	Maintain or restore a self-sustaining population of Obscure Galaxias.
	Maintain or restore a self-sustaining population of River Blackfish.
	Maintain diversity, demographics and composition of fish community.
	Maintain a self-sustaining population of Carp Gudgeon.
Macroinvertebrates	Maintain macroinvertebrate community at reference condition in refuge area.
	Restore macroinvertebrate community to droughted areas.
Plants	Maintain a high diversity aquatic plan community.
	Restore riparian plant community.
	Rehabilitate riparian Redgum community.

2 Methods

2.1 Flow assessment

The Board and DEW invest in continuous flow monitoring across the Marne Saunders PWRA with six flow monitoring stations currently operating that have suitable data record to be used as part of this assessment. Stations were identified as being suitable if they had 10 or more years of suitable flow data and flow data up to, or beyond, 2022. The longest running site is the Marne Gorge monitoring station that has data from 1973 to present while other sites have only been operating for less than 10 years.

Flow data from monitoring stations were downloaded from the Aquarius database accessed via the Water Data portal. Data from the gauges were downloaded as average flow rate per day in megalitres per day (ML/day). Along with the flow data, quality codes were also downloaded to ensure that interpolated data or data considered potentially compromised were not included in the assessment.

Flow data were grouped into flow years (December to November) to ensure that flow seasons assessed were not split over different years.

Flow data were screened to ensure the flow data were of suitable quality (quality codes greater than 1, i.e., only measured data used) and there was no more than 5% missing data in any given flow year. If any given flow year had more than 5% missing flow data, the year was dropped from the assessment. This is to ensure that missing data are not interpreted as no flow.

The environmental water requirements (EWR) for the Marne Saunders WAP were characterised using a series of flow metrics that related to different aspects of the flow regime. These EWR metrics were the further developed for the Mount Lofty Ranges WAPs. However, recently, the methods associated with calculating and assessing these metrics has been shown to suffer high levels of internal correlation and; therefore, have been superseded by a simpler series of metrics that cover the same information in an easier to interpret framework that are not internally correlated (see Green and Savadamuthu, In Review - 2023; Maxwell et al., 2015b). For the purpose of this assessment, the newer generation of EWR metrics are used here as these, or a slight variant of these, will most likely be used in any future amendment of the Marne Saunders WAP.

Flow data were processed using the R language and environment, operated in R Studio (R Studio version 1.2.5042, running R version 4.0.0 R Core Team, 2013). The metrics used to assess the flow regime are described in Table 2.

Table 2: Key ecologically relevant flow metrics for seasonal rivers including units and calculation process. Adapted from Green and Savadamuthu (in review 2023).

Flow metric	Unit	Definition	Ecological relevance
Intermittency	Number of days	Days of flow defined as days of recorded flow for gauged sites (See Green and Savadamuthu, In Review - 2023).	• Considered the master variable for intermittent rivers (Datry et al., 2014). • Longer cease to flow periods leads to deteriorating water quality in refuge habitat (Chapin et al., 2014; Schmarr et al., 2014). • Length of flow period dictates habitat availability and expected lifecycle completion (Bonada et al., 2007).
Low flow season flow days	Number of days	Days of flow over the low flow season (Dec – April inclusive) above the low flow season flow threshold (See Green and Savadamuthu, In Review – 2023).	• Flushing of permanent pools. • Maintenance of habitat. (Vander Vorste et al., 2020) • Watering of in channel riparian vegetation over low flow season (Nicol, 2013). • Opportunities for dispersal (Baumgartner et al., 2014).
Break of season	Number of days	Number of days past 1 April the cumulative flow reaches a flow threshold transitioning from low to higher flow (See Green and Savadamuthu, In Review - 2023).	• Cues for migration and breeding (Lucas and Baras, 2008; Mackay, 1992; Pires et al., 2014). • Increased stress on refuge habitats (Vander Vorste et al., 2020). • Likelihood of lifecycle completion (Mackay, 1992).
Spring flows	ML/day/KM^2	Average runoff from August to November (inclusive).	• Promotes resilience leading into the low flow/cease to flow period (eWater, 2022).

			• Promotes fish recruitment success (Green et al., 2014). • Migration of obligate aquatic fauna (Lucas and Baras, 2008). • Discourages exotic fish species (Seebacher and Kazerouni-Ghanizadeh, 2021).
Median flows	Number of days	Days above the median (50th percentile exceedance) of non-zero daily flows.	• Promotes large-scale fish migration (Lucas and Baras, 2008). • Discourages exotic fish species (Moore et al., 2008). • Expand riffle habitat for macroinvertebrate species (Bonada et al., 2007). • Inundate vegetation on benches and lower banks (Maxwell et al., 2015c). • Control terrestrial vegetation in channel (Maxwell et al., 2015c).
High flows	Number of days	Days above the 20th percentile exceedance value of non-zero daily flows.	• Inundate vegetation higher on banks (Maxwell et al., 2015c). • Habitat maintenance including silt removal and algae scouring (Fuller et al., 2010; Loire et al., 2019). • Entrain organic material from banks (Caraco and Cole, 2004). • Plant propagule transport (Stromberg et al., 2007) • Management of reed beds (Stromberg et al., 2007).

Each of these metrics provides an annual value providing a measure of each individual year relative to all years in the record for each site. This is used to characterise the most recent year's status based on the thresholds in Table 3.

Table 3: Status assessment thresholds used for the assessment of the flow regime. Adapted from the Water Resource Assessment framework used by DEW.

Status assessment	Percentile range
Highest on record	100th
Very much above average	90th to 99th
Above average	70th to 89th
Average	30th to 69th
Below average	10th to 29th
Very much below average	2nd to 9th
Lowest on record	1st

Trend assessment

Trend assessment was undertaken on the flow metrics listed in table 2 for the flow data gathered for each of the flow monitoring stations in the Marne Saunders PWRA. Trend assessment was undertaken using R Studio (version 1.2.5042, running R version 4.0.0 R Core Team, 2013) using Bayesian Generalized Linear Mixed Models (using the stan-glmer function in the rstanarm package, Stan Development Team, 2016). The number of days each of the metrics were met per flow year was modelled for each site. Each run of the model produced an estimate of slope. Estimates of slope from the 5000 model iterations were used to characterise the likelihood of trends within the data in line with the Intergovernmental Panel on Climate Change likelihood categories (based on Mastrandrea et al., 2010, Table 4).

Table 4: Trend assessment classes based on the percentage of positive/negative slopes returned from the Bayesian modelling approach.

% positive slope results	% negative slope results	Trend assessment
99-100	0-1	Virtually certain increase
95-99	5-1	Extremely likely increase
90-95	10-5	Very likely increase
66-90	10-33	Likely increase
33-66	33-66	About as likely as not
10-33	66-90	Likely decrease
10-5	90-95	Very likely decrease
5-1	95-99	Extremely likely decrease
0-1	99-100	Virtually certain decrease

2.2 Macroinvertebrate assessment

The assessment of macroinvertebrate community condition was undertaken using a newly developed contemporary macroinvertebrate condition model (CMCM) for the region (DEW, in prep.). The model uses a biological condition gradient method to assign condition based on a series of community attributes based on the original biological condition gradient model framework from Davies and Jackson (2006). The CMCM model provides an overall community score ranging from 1 (very poor) through to 6 (excellent).

Data for assessment were sourced from the BioBlitz program operated by DEW and Murraylands and Riverlands Landscape Board. Data for each site were pooled per year rather than keeping habitat and season separate. This provides annual picture of condition across the whole of the site.

Additional data was sourced from the Environmental Protection Authority's Aquatic Ecosystem Reporting (AECRs) program (EPA 2023). These data are presented without modification using the EPA's AECRs condition rating system. Additional information on the AECRs program and the individual site assessments can be found here. The EPA data were also used to inform on the expected community for the CMCM assessment as per DEW (in prep.).

Trend assessment

Trend data were assessed using the same analysis model described in the flow trend assessment section. Sites that had been visited across five or more years were assessed for trend. Sites with fewer visits were not considered suitable for trend assessment due to natural variability within the macroinvertebrate community being dominate of trends through time. Trend assessment was undertaken for each site individually; however, the data were not considered suitable for undertaking any regional assessments. Trends were classified as per Table 4.

Condition assessment

The condition assessment was undertaken by assessing the most recent year of data available for each site, limited to 2021 - 2023. Data before this were not considered recent enough to be informative of the current condition.

2.3 Fish assessment

Fish data were sourced from the Board (formerly NRM Board) funded programs across the Marne Saunders PWRA. Fish community condition information and recruitment information for the EMLR and Marne Saunders was sourced directly from Nature Glenelg Trust. All fish data used in this report are either currently available or will be available via the biological database of South Australia (DEW, 2024) (available here). All condition scores are calculated based on this raw data, though condition assessments are not captured in the biological database; hence, being sourced direct from samplers.

Condition Assessment

The Nature Glenelg Trust condition model is based around recruitment (0+ years) and survival (2+ years) numbers as well as overall community diversity (Gannon et al., 2021). The assessments undertaken at each site are specific to the site based on previously caught species, i.e., the assessment for each site is bespoke. The fish condition score is assessed out of nine with scores three or less being classed as poor, four to six being classed as fair and seven or greater being classed as good.

Trend assessment

Trend data were assessed using the same analysis model for the flow and macroinvertebrate metrics. The condition scores were used at sites with four or more visits. However, as with the other trend assessments, there was no attempt to characterise a regional trend. Similarly, trend was also assessed for the number of Obscure Galaxias recruits recorded at each site as a compliment to the risk assessment undertaken in the condition section.

3 Results

3.1 Flow assessment

A total of six flow monitoring stations were identified for assessment across the Marne Saunders PWRA. These locations are mostly within the Marne catchment with only two locations found in the Saunders Catchment (Table 5). The duration of flow record for each of the sites is also shown in Figure 1.

Table 5: Flow monitoring locations used for the flow regime assessment for the Marne Saunders PWRA condition assessment.

Site	Location	Easting	Northing
A4260605	Marne River at Marne Gorge	337994	6161660
A4261007	Marne River upstream Redbanks Road Ford Crossing	344830	6162245
A4261011	Marne River upstream Black Hill Springs	359745	6158773
A4261014	North Rhyne River near Kappalunta	332812	6165408
A4261030	Marne River 1km downstream Jutland Road Crossing	1381180	1697735
A4261174	Saunders Creek in Saunders Gorge	1385090	1689014

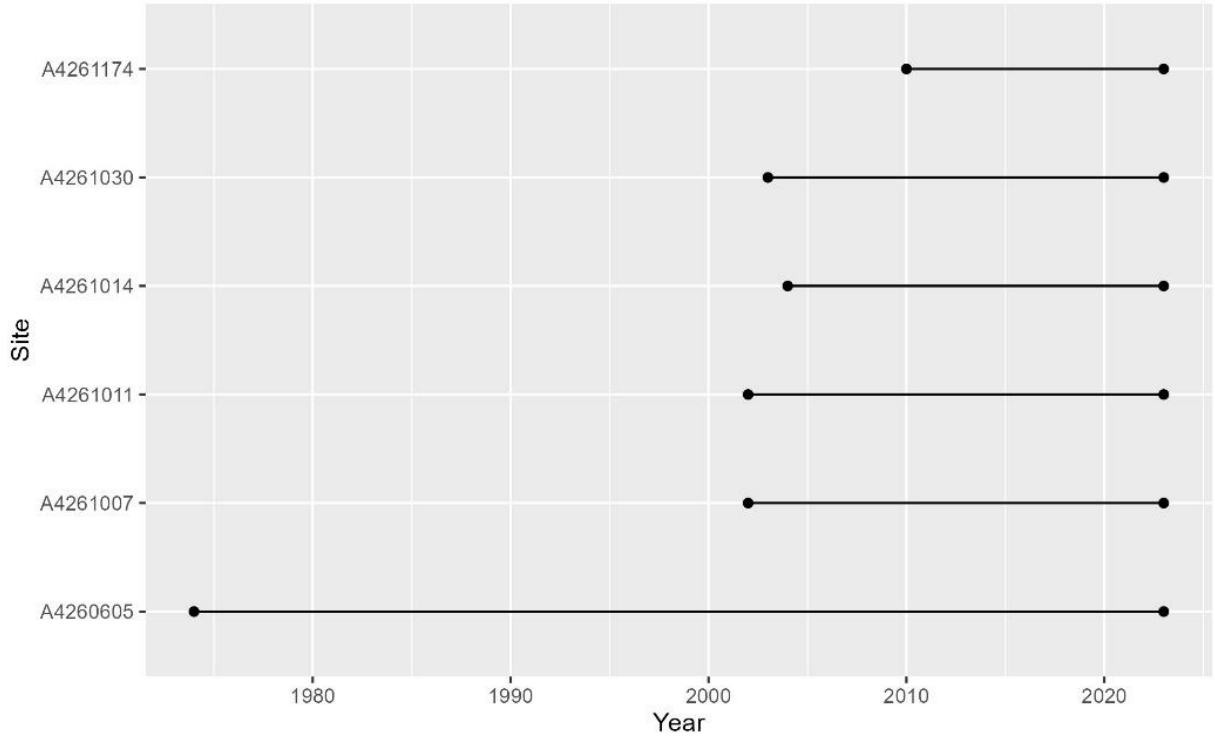


Figure 1: Flow record duration for the flow monitoring sites of the Marne Saunders PWRA used for all assessments in this report.

The majority of flow monitoring stations started monitoring in the early 2000s with the exception of A4260605 (Marne River at Marne Gorge) which started monitoring in the early 1970 and A4261147 (Saunders Creek in

Gorge) which started monitoring in 2010. The time period of available data is important as most sites started monitoring during the Millennium Drought. This will affect the interpretation of flow trend and status as general understanding is that conditions should have recovered since the drought leading to better status ratings and improving trend being the default assumption.

Flow data for the A4260605 (Marne River at Marne Gorge) are a composite dataset made from the combination of two co-located gauges. The original gauge (A4260529 – Marne River upstream of Cambrai) ceased in 2006 while the new gauge (A4260605) started records in 2001. Both were operated concurrently in order to establish a link between the datasets such that they could be merged into a single dataset.

Status

Across all stations and metrics assessed, most sites reported a status of average, with all nearly site/metric combinations being between 10th and 90th percentiles. The only instance of any values outside the 10th to 90th percentile was seen in the break of season assessment with flow metrics at three stations being classed as very much above average, i.e., flows started very late in 2023 (Figure 2). The individual site assessment plots are provided in appendix 1. A point to note for these assessments, in general, is that increasing numbers represent conceptually increasing condition for aquatic ecosystems (i.e., flow conditions are getting better for aquatic ecosystems) with the exception of the break of season metric. Increasing values for the break of season metric represent delay to the onset of flow, conceptually leading to harsher conditions for aquatic flora and fauna (i.e., flow conditions are getting worse for aquatic ecosystems).

The status results for the 2023 flow year are shown in Table 6 along with the 2023 value and the three-year moving average value to 2023.

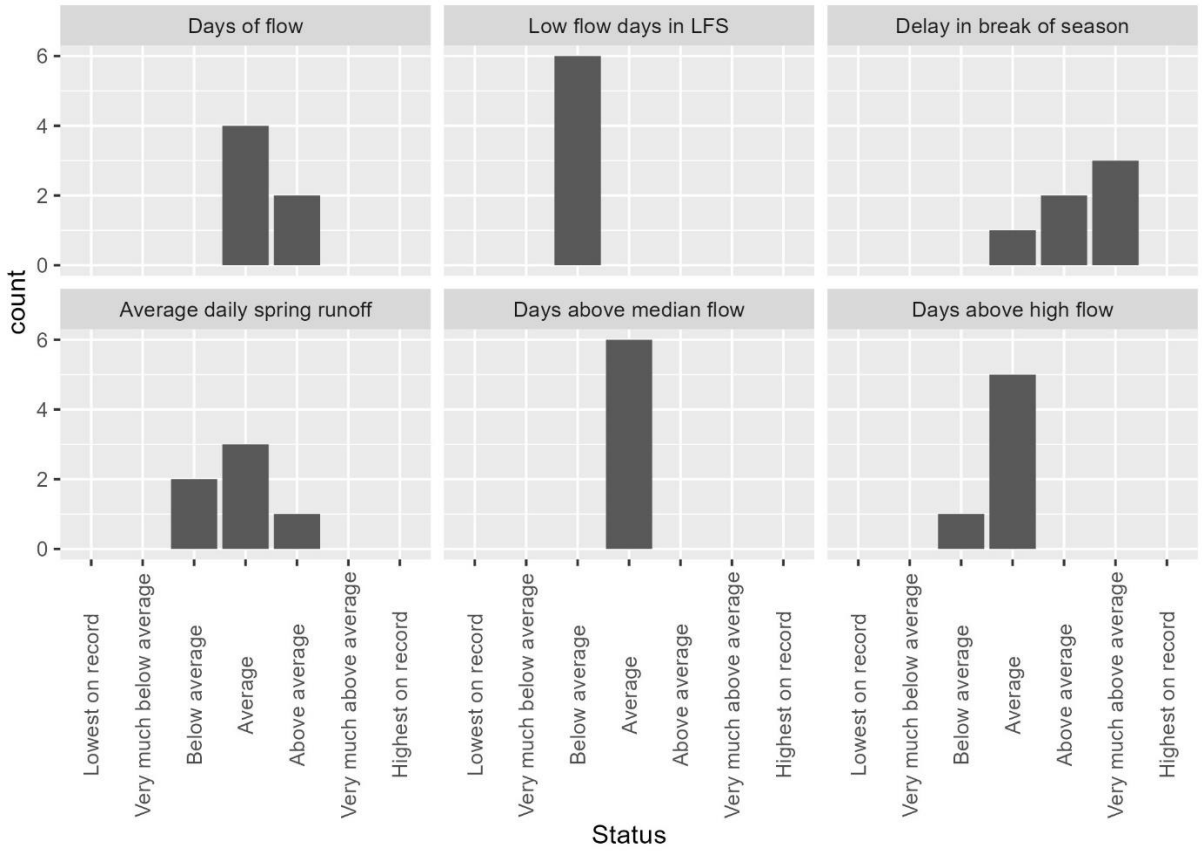


Figure 2: Histograms of the status ratings across all of the sites assessed across the Marne Saunders PWRA for 2023 relating to the average from all complete flow years for the assessed station.

Table 6: Status assessment for the six flow monitoring gauges operating across the Marne Saunders PWRA for 2023 including their 2023 value and the three-year moving mean. Status relates to the relative value of the 2023 value against the average value for the site across all years (see figure 1).

Site	Flow days			Low flow days			Break of season		
	2023 value	3 year moving average	Status	2023 value	3 year moving average	Status	2023 value	3 year moving average	Status
A4260605	221	213.7	Above average	54	18.0	Below average	214	121.7	Average
A4261007	1	18.7	Average	0	0.0	Below average	214	214.0	Very much above average
A4261011	0	3.3	Average	0	0.0	Below average	214	214.0	Above average
A4261014	4	33.3	Average	1	0.3	Below average	214	162.7	Very much above average
A4261030	123	117.3	Above average	28	9.3	Below average	100	124.0	Above average
A4261174	24	52.7	Average	4	1.3	Below average	214	187.7	Very much above average

	Spring flow			Days above median flow			Days above high flow		
	2023 value	3 year moving average	Status	2023 value	3 year moving average	Status	2023 value	3 year moving average	Status
A4260605	0.363	17.8	Below average	44	106.7	Average	2	36.0	Average
A4261007	0.000	25.2	Above average	0	12.0	Average	0	4.7	Average
A4261011	0.000	2.0	Average	0	2.0	Average	0	1.0	Average
A4261014	0.000	14.7	Average	0	14.7	Average	0	7.7	Below average
A4261030	0.717	44.8	Average	19	49.3	Average	2	29.0	Average
A4261174	0.011	1.5	Below average	5	35.0	Average	0	15.7	Average

The status assessment suggests that 2023 was generally an average year across the whole of the Marne Saunders PWRA. No site was considered to be totally above or below average across all metrics; however, it is worthy to note that all sites were below average for the low flow season flow days. It is also worthy to note the break of season results suggesting that, despite the average flow year, flows are still not starting as early as they used to (e.g. prior to the Millenium Drought).

It is also worth noting that the time period that this assessment covers is biased for some of the flow gauges due to the start date of collection occurring during the drought. The only flow monitoring station that has a record

predating the start of the drought, A4260605 – Marne River at Marne Gorge, shows a significant long-term decline in multiple metrics (see site results in Appendix 1).

For context, total river flow was also assessed for each of the six stations. While total flow is not considered overly ecologically relevant in terms of having a set ecological function, it is worthwhile to assess the trend in total flows to provide context to the total water available for all users including the environment. The reduction in total flow observed across all of the flow monitoring gauges will be linked to the change in the flow regime, especially in areas downstream of dam development (Figure 3). Less total flow volume has a two-part impact on the flow regime downstream of dams. Firstly, the dams will capture a greater portion of the total flows meaning less water for downstream users including the environment and secondly, less flow is correlated with increased water demand for irrigation so dams will generally be emptier, requiring more volume to fill and spill.

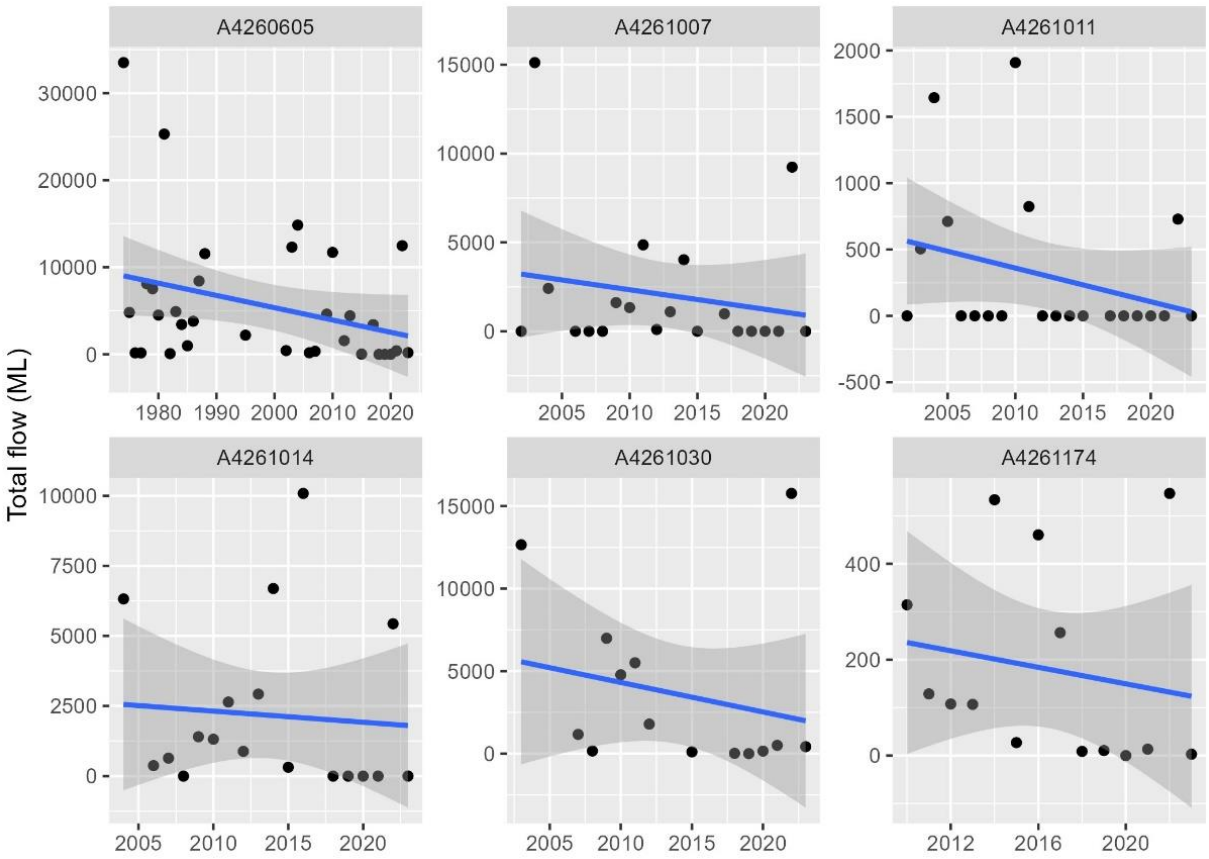


Figure 3: Total annual flow for the flow monitoring gauges across the Marne Saunders PWRA for each year with 95% or greater data availability. The blue line represents a general linear regression and the grey shaded portion represents the general error of the mean.

Flow Trend

At the PWRA scale the trend results across all metrics showed a strong decreasing trend with the exception of the break of season metric which showed an increasing trend (Table 7). This was supported by the trend assessment for total flow which also showed a decreasing trend for the PWRA (Table 7). This is despite the higher flow year in 2022 and the generally average results for the status assessment for 2023.

Table 7: Flow metric trend results for the Marne Saunders PWRA based on the flow data for the six flow monitoring stations used across all complete years of flow data (see figure 1). Trend results are based on Bayesian linear modelling (5000 model runs).

Metric	Mean slope	Proportion of negative slopes	Credible interval (5th and 95th percentile)	Trend
Flow days	-0.0326	0.994375	-0.0552 to -0.0109	Virtually certain decrease.
Low Flow season Flow Days	-0.0795	1	-0.1113 to -0.05	Virtually certain decrease.
Break of season	0.00888	0.120125	-0.0036 to 0.0212	Likely increase.
Spring flow	-0.7582	0.99925	-1.1084 to -0.3951	Virtually certain decrease.
Days above median flow	-0.0266	0.971125	-0.0499 to -0.0039	Extremely likely decrease.
Days above high flow	-0.03238	0.9795	-0.0597 to -0.0062	Extremely likely decrease.
Total Flow	-148.586	0.999875	-211.5227 to -83.133	Virtually certain decrease.

The assessment of trend for each of the individual sites and metrics is shown in Table 8. The increasing trend shown in the break of season results represent an increasing time to the break of season and is generally considered to be a negative outcome. Consistent with the overall trends, the relatively consistent outcome is a decreasing trend. For a full description of the trend results for each of the metrics at each site, see Appendix 2.

Table 8: Trend results for each of the individual flow monitoring gauges for the individual metrics assessed.

Site	Flow days	Low Flow season Flow Days	Break of Season	Spring flow	Days above median flow	Days above high flow	Total Flow
A4260605	Decreasing	Decreasing	Stable	Decreasing	Decreasing	Decreasing	Decreasing
A4261007	Decreasing	Decreasing	Increasing	Decreasing	Decreasing	Decreasing	Decreasing
A4261011	Decreasing	Stable	Stable	Decreasing	Decreasing	Decreasing	Decreasing
A4261014	Decreasing	Decreasing	Increasing	Stable	Decreasing	Decreasing	Stable
A4261030	Decreasing	Stable	Increasing	Decreasing	Decreasing	Decreasing	Decreasing
A4261174	Decreasing	Decreasing	Increasing	Stable	Decreasing	Decreasing	Decreasing

3.2 Macroinvertebrate assessment

The BioBlitz program for the Marne and Saunders has been operating since 2017 and to the end of 2023 has visited a total of 11 sites across the PWRA. There has been a total of 53 samples collected since 2017.

The most commonly collected taxa was a non-biting midge (*Chironomus* sp.) found at 46 out of the 53 sites sampled. This was followed by small diving beetles (*Necterosoma sp*.) found at 41 of the 53 sites sampled and backswimmers (*Anisops* sp,) found at 39 of the 53 sites. In total, there were 126 different taxa identified from the sampling to date across the Marne Saunders.

The most diverse site in the record was Upper Saunders Creek (USC-002) with a total of 41 taxa recorded, followed by Gratz Town Bridge (NRH-010), Springton Creek with 36 taxa recorded and Vigars Road (MAR-280) with 33 species recorded. All of these results were from 2023. The site with the highest average taxa recorded is Vigars Road (MAR-280) averaging 23 taxa per sampling trip between 2017 and 2023. The site with the lowest average taxa recorded was Myrtle Grove (USC-001) with an average of 9 taxa recorded between 2017 and 2023.

In general, the communities present suggest that the area generally has short flowing windows and higher salinity levels. These conditions favour more tolerant species with the ability to disperse between pools such as diving beetles. Other common species found are tolerant of higher salinity levels reflective of the longer times between flow events and the degraded conditions experienced over those prolonged dry periods. The lack of many flow-sensitive species or large numbers of obligate aquatic species suggests that longer flowing windows are not common and that permanent water may become inhospitable for many obligate aquatic species.

Notable taxa found include several rare and moderately sensitive mites (Hydrodromidae sp. and Limnesiidae sp.), sensitive midge (*Dixella* sp.), several caddisflies (*Hellyethira simplex*, Hydroptilidae sp., *Triplectides australis*) and a mayfly (*Tasmanocoenis tillyardi*).

Condition assessment

The majority of the sites were assessed as being in poor condition for 2023 with three of the 11 sites being classed as fair (Table 9, Figure 4). The site with the best condition score was Vigars Road (MAR-280) which had a score of 3.0 while the site classed as being the worst condition was Myrtle Grove (USC-001) with a score of 1.78. These low condition scores are somewhat expected despite the average flow conditions as the Marne Saunders is still recovering from the dry period from 2017-2020 and subsequent below average years. There is no established condition target for the Marne Saunders PWRA for macroinvertebrates, so an assessment of target achievement is not possible for condition.

Table 9: Macroinvertebrate community condition scores and ratings derived using the CMCM on the 2023 data for the Marne Saunders. The condition score is out of a possible six.

Site	Site ID	Condition score	Condition rating
Cranford Road	MAR-270	1.91	Poor
Vigars Road	MAR-280	3	Fair
Lartunga	MAR-300	2.16	Poor
Netherford	MAR-310	2.33	Poor
Jutland Water Reserve	MAR-315	2.63	Fair
North Rhyne	NRH-003	2.13	Poor
Graetz Town Bridge	NRH-010	2.37	Poor
Myrtle Grove	USC-001	1.78	Poor
Upper Saunders Creek	USC-002	2.03	Poor
Springton Creek	MRS-040	2.61	Fair
One Tree Hill Creek, near Springton	OTH-001	1.85	Poor

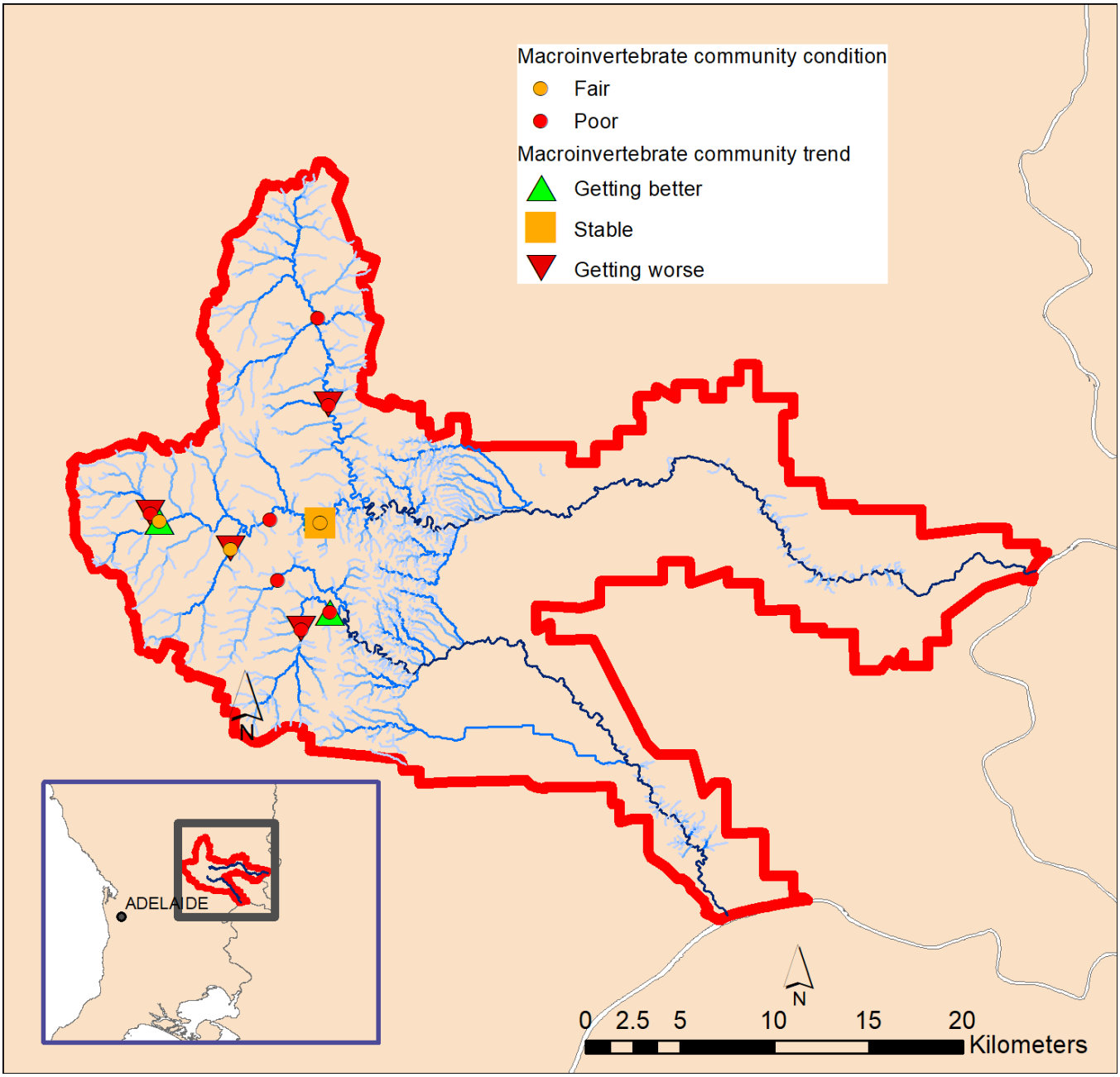


Figure 4: Macroinvertebrate trend and condition assessment results based of the CMCM process across the Marne Saunders PWRA.

Trend assessment

Of the 11 sites assessed as part of the Bioblitz program in the Marne Saunders PWRA, seven had sufficient visits to allow for a trend assessment to be undertaken. All of these sites had data ranging from 2017 to 2023 meaning a consistent range to compare trends across the region. The nature of the data collection across the region does not allow for a regional assessment of trend, rather the regional assessment is a qualitative assessment based on the individual site results. The trend assessment showed that four sites were likely decreasing, one site was stable and two sites were classed as likely increasing (Table 10).

Table 10: Trend assessment for the macroinvertebrate community condition for the Marne Saunders PWRA based on a Bayesian linear model run for 5000 iterations.

Site	Site ID	Proportion of negative slopes	Mean slope	Credible interval (5th and 95th percentiles)	Trend	Start year	End year
Cranford Road	MAR-270	0.886	-0.115	-0.277 to 0.051	Likely decrease	2017	2023
Vigars Road	MAR-280	0.177	0.081	-0.077 to 0.238	Likely increase	2017	2023
Netherford	MAR-310	0.888	-0.125	-0.306 to 0.058	Likely decrease	2017	2023
Jutland Water Reserve	MAR-315	0.459	0.007	-0.127 to 0.142	Stable	2017	2023
Springton Creek	MRS-040	0.734	-0.065	-0.257 to 0.129	Likely decrease	2017	2023
Myrtle Grove	USC-001	0.912	-0.030	-0.067 to 0.008	Very likely decrease	2017	2023
Upper Saunders Creek	USC-002	0.217	0.078	-0.098 to 0.257	Likely increase	2017	2023

With the exception of Myrtle Grove, all of the trend results are not considered to be overly strong. This can be seen in the plots of the condition scores through time (Figure 5). While the simple linear regression shows positive or negative slope, the standard errors (represented by the grey shaded section) span both positive and negative slope possibilities. This is driven by the variability in results over the last six years.

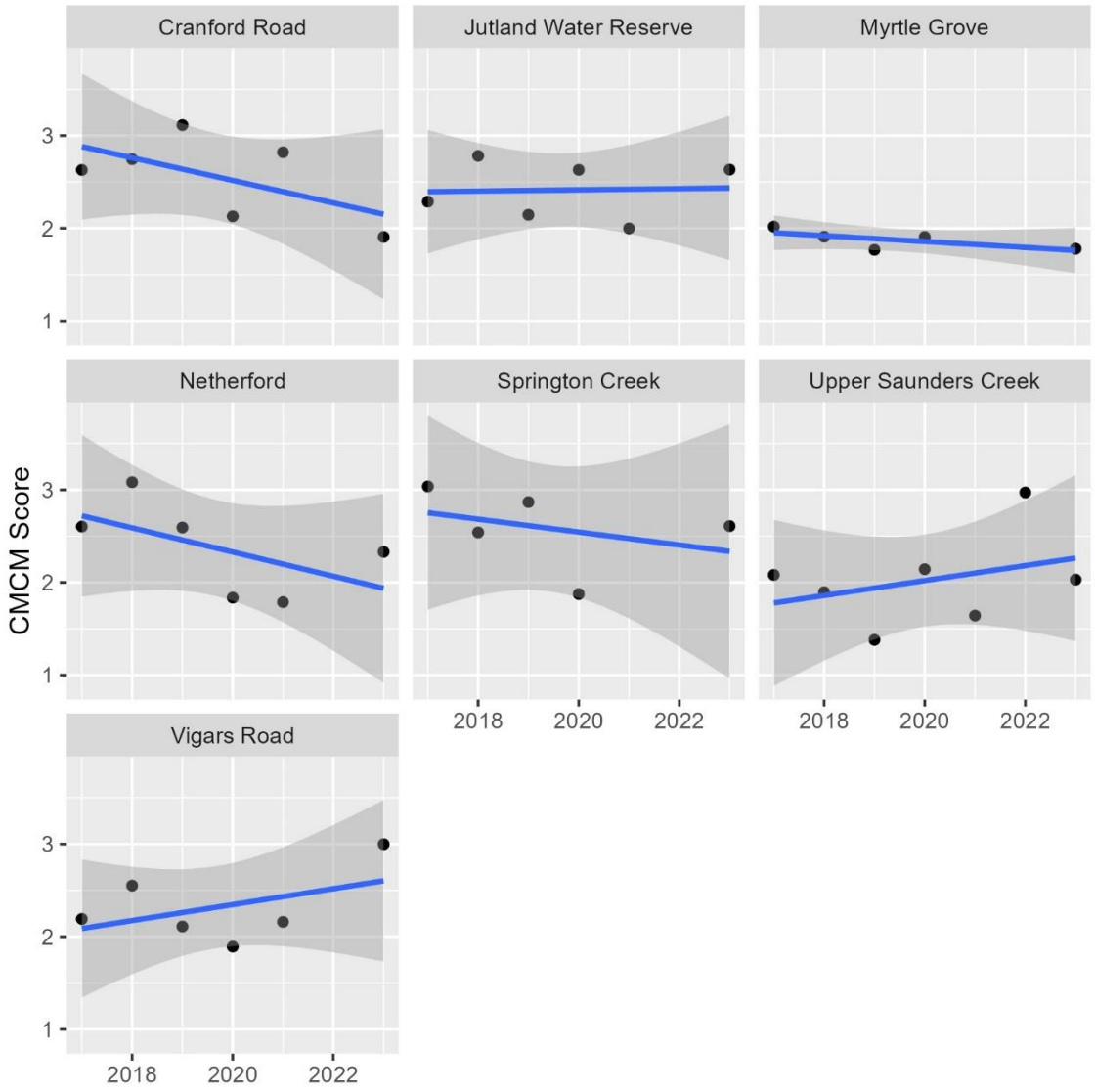


Figure 5: Contemporary macroinvertebrate condition model scores for the sites in the Marne Saunders PWRA that were assessed for trend. The blue line represents a simple linear regression and the grey shaded portion represents the standard error of the regression.

The data collection is concurrent with the start of a significant dry period in the PWRA that ran from the end of 2017 through to 2020. This period represented some of the driest conditions experienced in the PWRA in the last 100 years. Therefore, it is expected that the macroinvertebrate community condition score would be lower at the start of the period. The return to average conditions over 2021 to 2023 was anticipated to result in some recovery in condition; however, lag effects from the dry period, both in regard to catchment rewetting and ecological lags, may take several years to overcome.

The two sites that show an increasing trend (Vigars Rd – MAR-280 and Upper Saunders Creek – USC-002) are likely responding in different ways to the improved flow conditions. Upper Saunders Creek has had a low diversity of species over the majority of the sampling; therefore, the better flow conditions in 2023 and the resulting influx of any flow or sensitive species will result in a large increase in condition. Vigars Rd is one of the key refuge habitats in the Marne Saunders. It was the only site to maintain flow sensitive species over all sampling events. Therefore, it was expected to be the first to show improvement given its higher base condition.

The WAP for the Marne Saunders has an objective relating to the maintenance of macroinvertebrate populations at key refuges. Given the results in Table 10, it could be argued that this objective has been achieved at three of the seven sites since the start of monitoring in 2017. However, it would be a significant assumption to say that this represents achievement of the objective as the objective relates to the communities present at the time of the adoption of the WAP in 2010.

3.3 Fish results

There are nine sites regularly monitored annually for fish community across the Marne Saunders PWRA, two in the Saunders Catchment and seven in the Marne Catchment. All but one of these sites ware sampled in 2023 (Saunders Creek Gorge was last sampled in 2020). There are some additional sites sampled across the Marne Saunders PWRA; however, these sites are not part of the condition monitoring program and; therefore, do not get condition scores described. They have been excluded from this assessment.

There was a total of 4585 fish caught in the 2023 sampling from 11 different species, two of which were alien species - Common Carp (*Cyprinus carpio*) and Eastern Gambusia (*Gambusia holbrooki*). The most common fish sampled in 2023 was the Carp Gudgeon (*Hypseleotris* sp.) with a total of 2681 fish caught from five sites, all in the lower reaches. This was followed by the alien Eastern Gambusia with a total of 1269 fish caught across four sites also all in the lower reaches. The third most common fish was the Obscure Galaxias with a total of 359 fish caught across four sites mostly from the mid and upper reaches of the Marne River. Only a single site (Pine Hutt Rd) had no fish present and was dry at the time of sampling. The most diverse site was the Marne Mouth with eight species recorded (including the two alien species) due to its connection with the River Murray.

Condition assessment

Across the eight sites assessed in 2023, the mean condition score was 3.4 with the minimum being zero (Legner Reserve and Pine Hut Rd) and the maximum being nine (Vigars Rd) (Table 11, Figure 6). Both Vigars Rd and Jutland Rd which were scored as good due to the good population numbers and demographics of Obscure Galaxias (*Galaxias oliros*) at the sites. This reflects a significant turnaround as the Obscure Galaxias population was nearly lost from the Marne Catchment during the 2018-2020 extreme dry period.

Table 11: Condition score and ratings of the long-term fish monitoring sites in the Marne Saunders PWRA using the Aquasave condition scoring.

River	Site name	Site ID	Year	Condition score	Condition rating
Marne River	Black Hill Springs	MR_R8_S3	2023	2.5	Poor
Marne River	Jultand Road	MR_R2_S2	2023	7	Good
Saunders Creek	Lenger Reserve	SA_R5_S2	2023	0	Poor
Marne River	Marne Gorge	MR_R5_S1	2023	4	Moderate
Marne River	Marne Mouth	MR_R9_S1	2023	2	Poor
Marne River	Pine Hut Road	MR_R4_S1	2023	0	Poor
Marne River	Three sisters pool	MR_UNK_2	2023	2.5	Poor
Marne River	Vigars Rd	MR_R2_S1	2023	9	Good
Saunders Creek	Saunders Creek Gorge	SA_R3_S1	2020	0	Poor

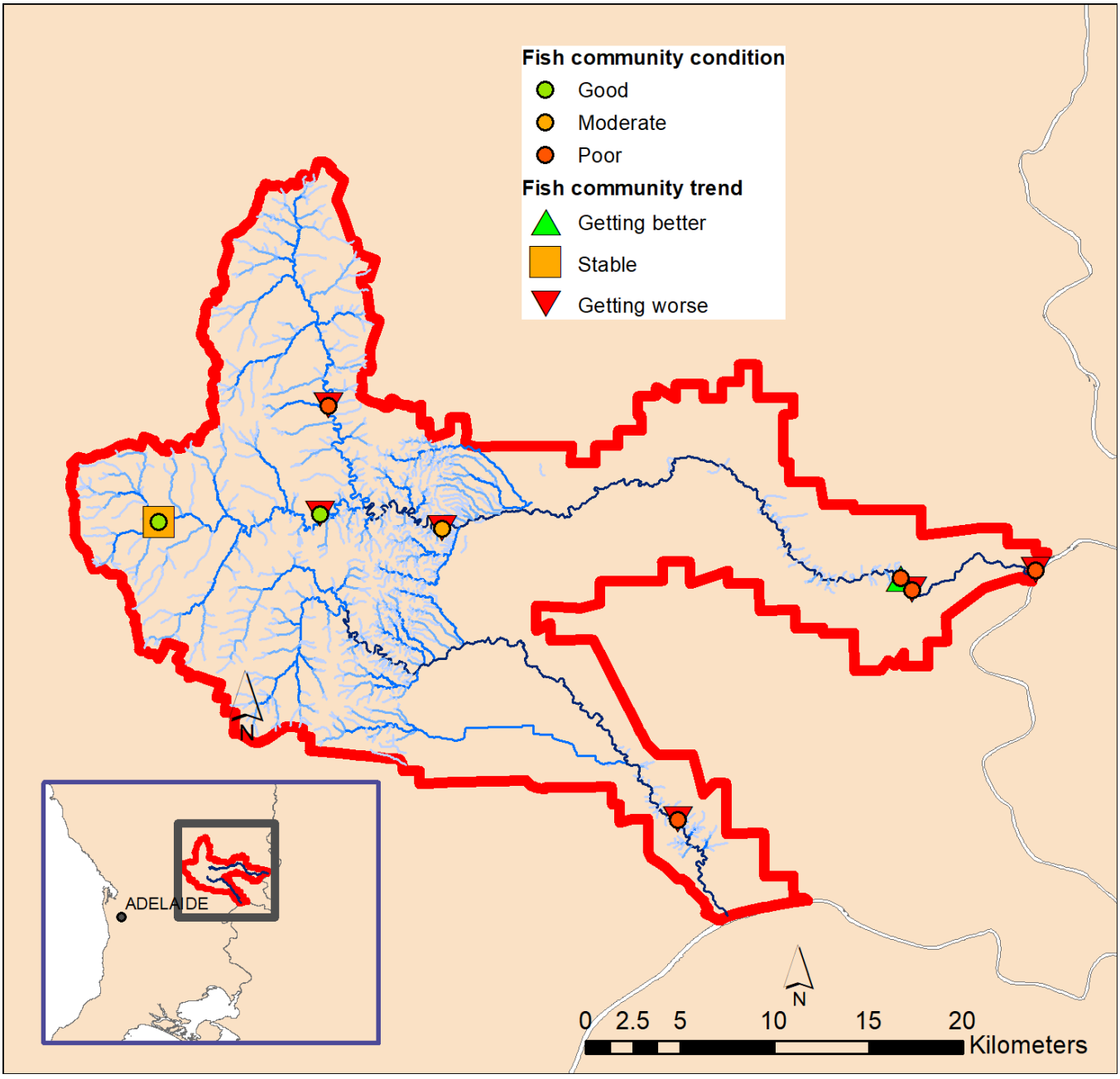


Figure 6: Fish community trend and condition assessment results using the Aquasave Fish Condition Model across the Marne Saunders PWRA.

Trend assessment

Of the nine long term fish monitoring sites assessed, eight were assessed for trends while one was classed as stable with a constant score of zero (Saunders Gorge). Most of the sites have data from 2002 while Legner Reserve started monitoring in 2011, the Marne Mouth started monitoring in 2012 and Three Sisters Pool started monitoring in 2014.

A single site showed a likely increase in condition (Three Sisters Pool), one site was considered stable (Vigars Rd) and six were considered to be decreasing in condition (Table 12). The time series plots show that the increase in condition at the three Sisters Pool is driven mostly from the initial visit score of 0 in 2014 and a longer time series may show that this site is stable (Figure 5). It should be noted that while this site is classed as improving, the iconic species (River Blackfish - *Gadopsis marmoratus*) was not recorded at this site in 2023. This species was represented

by a single individual captured at a site not assessed as part of the long-term monitoring program at the Old Ruins in the lowland reach of the Marne River.

Table 12: Trend assessment for the fish community condition for the Marne Saunders PWRA based on a Bayesian linear model run for 5000 iterations.

Site	Site ID	Proportion of negative slopes	Mean slope	Credible interval (5th and 95th percentiles)	Trend	Start year	End year
Vigars Rd	MR_R2_S1	0.387	0.036	-0.164 to 0.241	Stable.	2002	2023
Jultand Road	MR_R2_S2	0.974	-0.209	-0.384 to -0.033	Extremely likely decrease.	2002	2023
Pine Hut Road	MR_R4_S1	0.996	-0.160	-0.248 to -0.072	Virtually certain decrease.	2002	2023
Marne Gorge	MR_R5_S1	0.958	-0.168	-0.329 to -0.008	Extremely likely decrease.	2002	2023
Black Hill Springs	MR_R8_S3	1.000	-0.143	-0.202 to -0.084	Virtually certain decrease.	2002	2023
Marne Mouth	MR_R9_S1	0.953	-0.067	-0.129 to -0.002	Extremely likely decrease.	2012	2023
Three sisters pool	MR_UNK_2	0.035	0.279	0.035 to 0.518	Extremely likely **increase.**	2014	2023
Lenger Reserve	SA_R5_S2	0.875	-0.173	-0.427 to 0.087	Likely decrease.	2011	2023

The assessment shows that the trend results are conclusive for most sites with the proportion of negative slopes being high (0.875 or higher) for sites classed as decreasing condition or low (0.035) for the single site classed as getting better. The results for Vigars Rd are well within the bounds for a stable trend result and an assessment of the conditions scores through time (Figure 7) support this. The decreasing trend at Pine Hutt Rd appears to be linked to the expatriation of fish from this site since 2006.

The WAP for the Marne Saunders PWRA has several objectives that relate to the fish community (Table 1). Two of these objectives refer to maintaining and restoring self-sustaining populations of Obscure Galaxias and River Blackfish. It is clear from the assessment provided here that the population of River Blackfish has not been maintained and is now considered functionally extinct from the Marne River. The population of Obscure Galaxias is still present but is still considered to be at high risk of loss having been lost from several sites. While the Obscure Galaxias is a species that experiences a boom-bust lifecycle, the number and quality of refuge habitats across the upper Marne Catchment has declined leaving the species vulnerable during times of bust.

The objective relating to the Carp Gudgeon (a specific objective for Legner Reserve in the lower Saunders Catchment) has generally been met with the population of the species persisting at Lenger Reserve, although increasing salinity and increasing numbers of Gambusia do pose a risk. Salinity at Lenger Reserve was 12,134 uS/cm in 2022 and 13,103 uS/cm in 2023 and has steadily increased over time (Gannon et al. 2021). Only 29 Carp Gudgeon were sampled in 2023 and they were undetected in 2022.

The objective relating to the maintenance of the diversity, demographics and composition of the fish community is difficult to assess as there are multiple components to a single objective; however, the general decline in condition observed across the majority of sites it considered evidence that this objective is generally not being met across the PWRA.

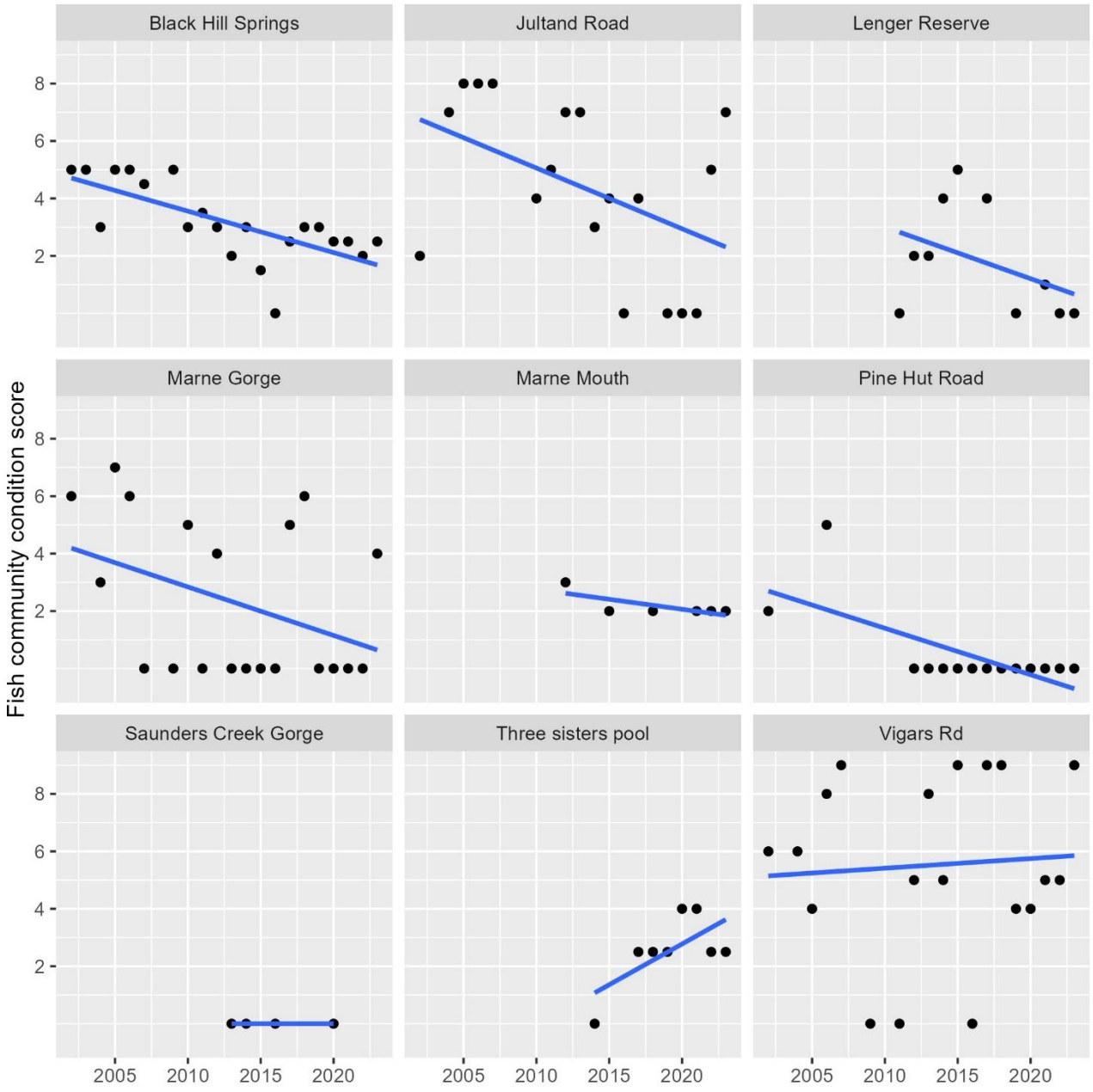


Figure 7: Time series plots of the fish condition scores for the nine long term monitoring locations across the Marne Saunders PWRA assessed using the Aquasave fish community condition model.

4 Discussion

4.1 Flow trend and status assessment

The general results from the flow regime assessment showed that while 2023 was an average year for most of the flow metrics, the long-term trend is declining across the vast majority of trends assessed. The total flow volumes for 2023 were low which suggests that the average results for 2023 are linked to the higher flow year in 2022.

The two consistent results from the flow status assessment were the below average number of low flow season flow days and the delayed break of season. All six sites assessed show that the number of low-flow season flow days were below average. This suggests that there was limited summer storm activity, and any rainfall events were insufficient to generate meaningful flow in the lower parts of the catchment, or all flows were captured by headwater dams before they could be recorded at the gauges.

The delay in the break of season being above average across five of the six sites assessed could be ascribed to several, inter-related drivers. Low rainfall over the summer months results in increased irrigation demand resulting in lower dam water levels at the end of the irrigation season. This then requires additional flows to fill and spill the dams delaying the onset of flow downstream. Combined with any delay in the onset of rainfall over the autumn months, the net effect is a delay in the onset of flows. The overall reductions in total flow observed support the lower water levels in dams.

Changes in the seasonality of rainfall have been observed in neighbouring catchments over the last 20 years (Savadamuthu et al., 2023) and it is considered likely that similar changes have occurred in the Marne Saunders PWRA. Further investigations into rainfall patterns are suggested as part of future investigations to assess and quantify any changes in rainfall seasonality.

The trend results across all of the individual metrics reflects the overarching decreasing trend. The lack of any metrics showing any positive trends suggests that the catchment is experiencing long-term drying. This is against a background of significant variability, common in seasonal rivers in Mediterranean climates. When the three-year moving average is considered, the general trend across all sites and metrics is less clear with the muting effect of the three-year average showing in some cases that over the last 15-20 years there has been no clear trend. Many of the metrics show a depressed start, followed by improvements through the early 2010s, followed by decrease corresponding with the 2018-2020 dry period.

Considering the timeline of the data from the gauges and the corresponding relatively extreme events associated with the period from the early 2000s to present, it is difficult to draw any clear conclusions about the flow regime as a whole. The Marne Gorge gauge data (A4260605) provides a longer-term picture with some clear take away messages relating to the reduction in flowing period, low flow season flowing days and spring flows. It is considered likely that this similar pattern would have been observed across all gauges if there was sufficient flow record. This is based on the similar patterns observed in the neighbouring Barossa Catchment where two flow gauges have long term records back to or beyond 1980 (Green and Savadamuthu, In Review - 2023).

The long-term changes in flow patterns are considered to be compounded effects of long-term changes in rainfall patterns and water resource development. As the total rainfall decreases across the PWRA, the relative impact of the farm dam development and water extraction increases due to farm dams capturing a greater proportion of the runoff. This effect is felt to a proportionally greater degree the further downstream water users are which produces an imbalance in the security of supply for users including the environment (which are generally downstream of water resource development).

The ecological implications of this change in the flow regime of the rivers of the PWRA are significant. It is well established that the degree of intermittency of a seasonal river is the master variable in driving ecological condition and community structure (Datry et al., 2014). Further, it is documented that changes in flow regimes can negatively impact of the fish community of the PWRA (Whiterod et al., 2017).

The spread of flow monitoring information across the Marne and Saunders is relatively good compared to the other regions around South Australia. The shortcoming of the data; however, is the general lack of data before the start of the Millennium Drought meaning understanding of general patterns before the region started to experience extreme events is limited. Despite this, the window of the data does provide a relatively clear picture of the upper and lower limits that could be expected across the region which allows managers to consider the impacts of these events into the future.

4.2 Macroinvertebrate community trend and condition

The condition assessment of the macroinvertebrate community across the PWRA showed a generally degraded community with a mix of trend results. The general community structure of the macroinvertebrate communities is reflective of degraded systems with high salinity levels and low levels of flow. To some extent this is reflective of the conceptual understanding of the PWRA as it is at the northern extent of the Mount Lofty Ranges in a low rainfall area. However, the poor condition results show that the current condition is low relative to the expected condition in the area. Historic sampling of macroinvertebrates has shown greater diversity and a higher presence of flow sensitive or salinity sensitive species (EPA, 2024) which the CMCM model uses to establish current condition.

The lack of any sites rated as excellent in the CMCM scores is a reflection of the modified nature of the system and it should be noted that, in the CMCM, a score of excellent is generally considered not to be possible. The lack of sites in good or very good condition is considered to be an accurate reflection of the macroinvertebrate community condition. Previous assessments have clearly identified that lack of a suitable flow regime for the macroinvertebrate communities of the Mount Lofty Ranges (VanLaarhoven 2010, VanLaarhoven 2012) and this is expected to be consistent with the Marne Saunders PWRA, being at the drier end of the Mount Lofty Ranges. The flow regime is identified at the master variable in driving macroinvertebrate community condition (Datry et al. 2014). This is not to suggest that other drivers are not important, and (in some localised instances) more significant drivers may be present; however, at the regional scale, improvements to the flow regime will lead to improvements in virtually all other drivers of macroinvertebrate community condition.

The lack of clear targets and objectives in the WAP for the Marne Saunders for macroinvertebrates means that an evaluation of the effectiveness of the WAP in managing the risks to macroinvertebrates is not currently possible. The objective relating to the maintenance of current condition is not possible to assess as there is little knowledge of the baseline condition. The CMCM modelling process does provide some insight into potential condition as the score incorporates an assessment of previously collected taxa; however, to refer to this as a baseline is erroneous. Given the likely updates to the WAPs, including targets and objectives, the validation against the existing EWRs and Environmental Water Provisions (EWP)s is of limited value with a suggestion to focus rather on aligning CMCM scores to future targets and objectives. This should be coupled with more flow specific targets and objectives that relate more specifically to the WAP process.

The mixed trend results are mostly related to the short-term window of the assessment as well as the variable nature of the climatic conditions since 2017. The window since 2017 has seen some very wet years as well as two of the driest years on record. The two extreme dry years would have caused species to retreat to refuge locations, significantly limiting their distribution across the landscape. The wet years, especially 2021 and 2022, would have seen range expansion from those refuge habitats but perhaps may have been limited give the low starting conditions. The two sites that show an increase in condition are suggested to show increases for two different reasons, both related to the increase in flowing days over 2022 and 2023. Vigars Rd (MAR-280) is generally the most diverse site in the PWRA with the highest frequency and diversity of flow sensitive taxa. This places it in a better position to respond to improved flow conditions, i.e., starting from a better baseline. Upper Saunders Creek (USC-002) is at the other end of the diversity spectrum and was very depauperate over the early stages of the 2017-2023 window, meaning that any increase in the diversity of taxa would represent a proportionally significant increase leading to an improved condition.

The assessment of current condition suggests that the environmental water requirements are not being met which does appear to be counter to the average rating applied to the current flow conditions. The simple explanation for this is the ecology has not had sufficient time of average or better flow conditions to recover, i.e., despite the better flow conditions observed since 2022, the macroinvertebrate community is still not receiving the flow conditions it requires to recover condition. It is likely that should the current average flow conditions continue, the macroinvertebrate community condition will continue to improve; however, it may take several years of average or better flow conditions to see the return of some of the more flow sensitive species or salinity sensitive species.

4.3 Fish

The general assessment of the fish community of the Marne Saunders shows a highly variable community with an associated highly variable condition through time. This is considered to be typical of seasonal rivers that are verging on ephemeral and of the communities of fish present. The most recent review of the fish communities was undertaken in 2021 and showed that the fish communities were generally in poor condition (Gannon et al., 2021). The assessment presented in this report shows that there has been some recovery in the fish communities across the PWRA but declines in condition are still evident. This recovery is evident at Jutland Rd, Marne Gorge and Vigars Rd, all sites that have demonstrated an increase in the Obscure Galaxias populations.

Vigars Rd represents an interesting study as it shows a site that is capable of going from a condition score of zero to a condition score of 9 in a single year, and vice versa (e.g., 2015 – 9, 2016 – 0, 2017 - 9). This is suggested to be due to how the model assesses condition with significant focus placed on the lower end of the condition spectrum. It is well established that the NGT fish condition model is designed to detect changes in poor condition sites and to establish improvements at such sites. As a result, it quickly loses sensitivity for sites that are in good condition. This is most evident in sites that only have Obscure Galaxias present as this species is opportunistic and capable of responding quickly to positive changes in the flow regime. This is not considered to present an issue for the assessment presented here, as no site is reported as being at a condition of 9 consistently, meaning the condition model still retains sensitivity for all sites. This is not to say that improvements to the model could not be made and should be investigated.

The general improvement in the condition scores seen in the upper catchment in 2023 is reflective of the recovery of the Obscure Galaxias population. Over the 2018-2020 dry period, the population of these fish was reduced to a single site (Vigars Rd) and the population was considered at extreme risk of localised extinction. The wet year of 2021 is considered to be the difference between losing the population and the conditions overserved in 2023. It is important to note that where there were events that reduced the population to a handful of individuals (in this case less than 10 fish), there is an ongoing risk to the population in the form of a genetic bottleneck, whereby population genetics are significantly shifted and genetic diversity is significantly reduced due to the loss of the majority of the population. The level of risk here is not possible to quantify without dedicated analysis but it should be noted that repeated genetic bottlenecks will reduce genetic diversity placing the population at high risk of being lost independent of flow conditions.

The upper catchment of the Saunders is generally considered to not support fish populations. The only records of fish in the upper Saunders Catchment is the alien Gambusia from 2004 and 2007 (Sourced from BDBSA, DEW, 2024). Whether this has always been the case is unclear. It is highly likely that during periods of higher rainfall, galaxias species (most likely Obscure Galaxias) would have made their way into the headwaters of the Saunders Catchment but would have been naturally displaced as conditions returned to average or dry conditions.

The population of River Blackfish in the lower Marne River is considered to be functionally extinct with no recruitment detected since 2002 and the number of mature fish constantly declining. No River Blackfish were detected in 2022 and a single individual was detected in 2023 at one of the lowland sites despite three lowland sites being sampled in 2023. The three lowland sites sampled in 2023 showed salinity values ranging from 6090 uS/cm to 7588 uS/cm whereas the salinity threshold for River Blackfish recruitment is considered to be around 4000 uS/cm (Whiterod and Hammer, 2014).

Based on the results of this assessment and the failure of majority of the fish objectives in the WAP, it is considered that the general environmental water requirements for the fish populations of the PWRA are not being met. The declining trends observed across most sites show that conditions across the PWRA are not sufficient to maintain the populations at historic levels. While there are a multitude of drivers of condition of fish communities, it is considered that the key reason for this decline is the changes in flow regime that have been effected over the last few decades by the development of water resources and the general drying of the climate, noting that these two effects are interactive and compounding. The lack of flows is also driving an increase in salinity across the

permanent pools of the region as there is insufficient flushing flows to move the salinity downstream and out of the catchment.

4.4 Considerations for next steps

This assessment of trend and condition of ecological indicators was designed to provide an insight into the current ecological health of the aquatic ecosystems of the PWRA. The assessment used the data available and existing methods to assess condition. Currently, the Marne Saunders WAP is due for review and the information presented in this report will play a significant role in assessing the effectiveness of the WAP in meeting stated environmental outcomes. Through the completion of the work, several considerations have been identified that warrant explicit identification for the upcoming review and potential amendment of the Marne Saunders WAP.

Some of the issues that could be considered during the review and possible amendment of the WAPs include the following.

1) **Updates to WAP ecological condition targets and objectives**
   The ecological condition targets and objectives identified in the WAP are lacking the detail that allows for their assessment to be undertaken in an effective and transparent manner. While the ecological objectives for the WAP are detailed spatially, the level of detail in what is required to meet these objectives in not explicit as there are no underlying targets. The development of a sound program logic for the targets, objectives and outcomes should be considered along with clearly identified methods for their assessment.

2) **Updates to the flow metrics used for the EWR and EWP description.**
   The flow metrics that underpin the EWRs and EWPs have been identified as difficult to use and interpret as well as showing high levels of internal correlation. This report makes no attempt to use the existing suite of EWR metrics for the Marne Saunders PWRA, opting for a simplified set developed for the neighbouring Barossa Valley PWRA. These metrics still cover the same breadth of the flow regime but use fewer metrics and avoid any of the issues relating to correlation seen with the larger suites of metrics (Green and Savadamuthu, In Review - 2023; Maxwell et al., 2015a). The metrics used in this assessment also allow for an annual assessment of status providing a simple mechanism for adaptive management processes or trigger assessment.

3) **Consideration of the impacts of a changing climate.**
   The impacts of a changing climate are becoming evident in other areas of South Australia. Flow regimes are changing, generally resulting in less flowing days and overall reduced flow volumes (Savadamuthu et al., 2023). This suggests that, irrespective of the impacts of water resources development, the water-dependent ecosystems of the Marne Saunders PWRA are likely to continue to change as the rainfall patterns shift. The identified environmental assets now and into the future will be key for the development of EWRs and EWPs.

5 Relating results to the current WAP

The intent behind this work is to provide stakeholders with a background understanding of the current condition of the aquatic environment in the Marne Saunders PWRA as input to the review of the WAP. As such, some general notes comparing the results back to the objectives of the WAP are presented for each of the assessments undertaken.

Across all indicators, it is apparent that there is variability due to the climatic conditions experienced as well as a general degraded condition relative to the objectives identified in the WAP. Note that the fish and flow assessment cover periods that start during or just after the Millennium Drought and; therefore, some of the worst conditions for aquatic ecosystems experienced in the state. In this sense, anything other than an improving trend

is cause for concern as this reflects a lack of recovery since the drought. It is acknowledged that there will always be a lag period between improved physical conditions and improved ecological conditions; however, 10 years is considered to be sufficient for this process. The extreme dry years of 2018 and 2019 could play a role in the lack of defined increasing trends across the region. The process of considering how these sorts of extreme events are considered in WAP target assessment is not covered in this report.

The Marne Saunders WAP has provisions for the passing of low flows from all licensed dams. This principle is designed to restore the low flow component of the flow regime downstream of dams to provide better flow conditions for aquatic ecosystems. The Flows for the Future Program has been implementing low flow devices in the Marne Saunders since 2017 and has successfully implemented 70 devices out of the 113 dams identified as needing a low flow device (~62% implementation). The ongoing implementation of low flow devices, in combination with new methods for providing environmental flows currently being investigated, should see an improvement in the flow conditions across the PWRA. However, the nature of the program and of the dam development in the PWRA means that tangible success of the overarching program will only be realised once implementation is complete or near complete. Unfortunately, the nature of dam development and the low flows program is that one large blocking dam can undo the effort in bypassing upstream dams, i.e., a downstream dam not participating in the F4F program can block the majority of released flows from upstream, resulting in little benefit to the ecosystems downstream. Currently, participation in the program is voluntary, representing a significant risk to the success of the low flows principles in the WAP.

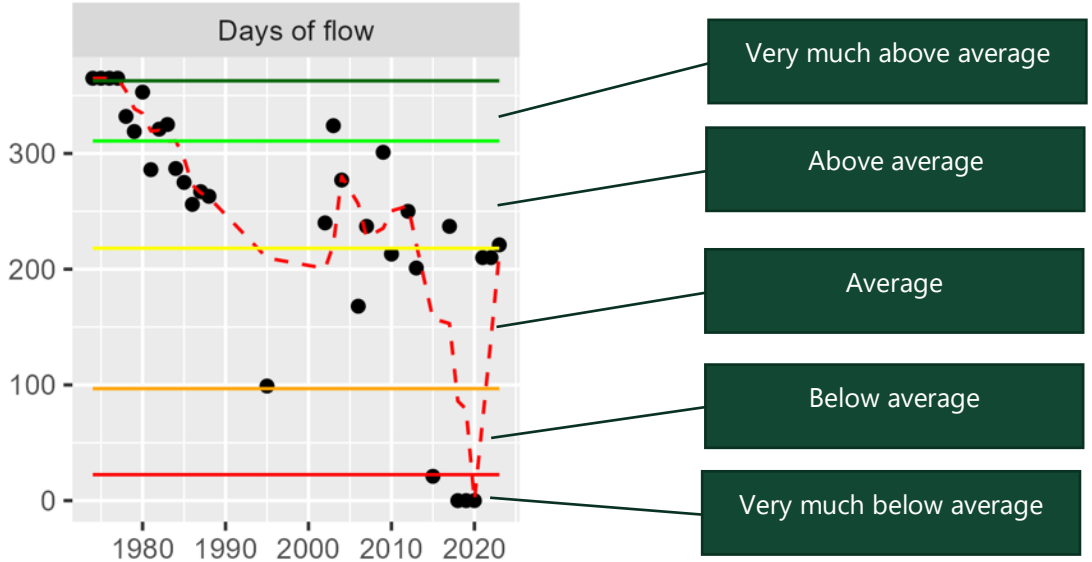
Based on the assessments presented in this report it is not possible to distinguish between failure to meet environmental objectives due to the lack of implementation of WAP principles or due to the recent climatic conditions. It is likely that, even with full implementation of the WAP principles, the 2018-2020 dry period would have resulted in reductions in environmental condition. Without dedicated modelling and associated assumptions, it is not possible to unpick these two interactive effects and the purpose of this report was to report data collected across the PWRA without modelled inputs. It is considered highly desirable to undertake modelling to unpick the impacts of climate driven changes, the impacts of water resource development and their compound effects, both in the recent past (WAP review) and into the future (potential WAP amendment). As part of the WAP review process, the Board have engaged DEW Water Science to undertake this modelling work. The results from that modelling work will need to be used alongside the results from this assessment to inform the achievement of and reasoning behind the achievement, or lack thereof, of the ecological objectives of the WAP.

6 Appendices

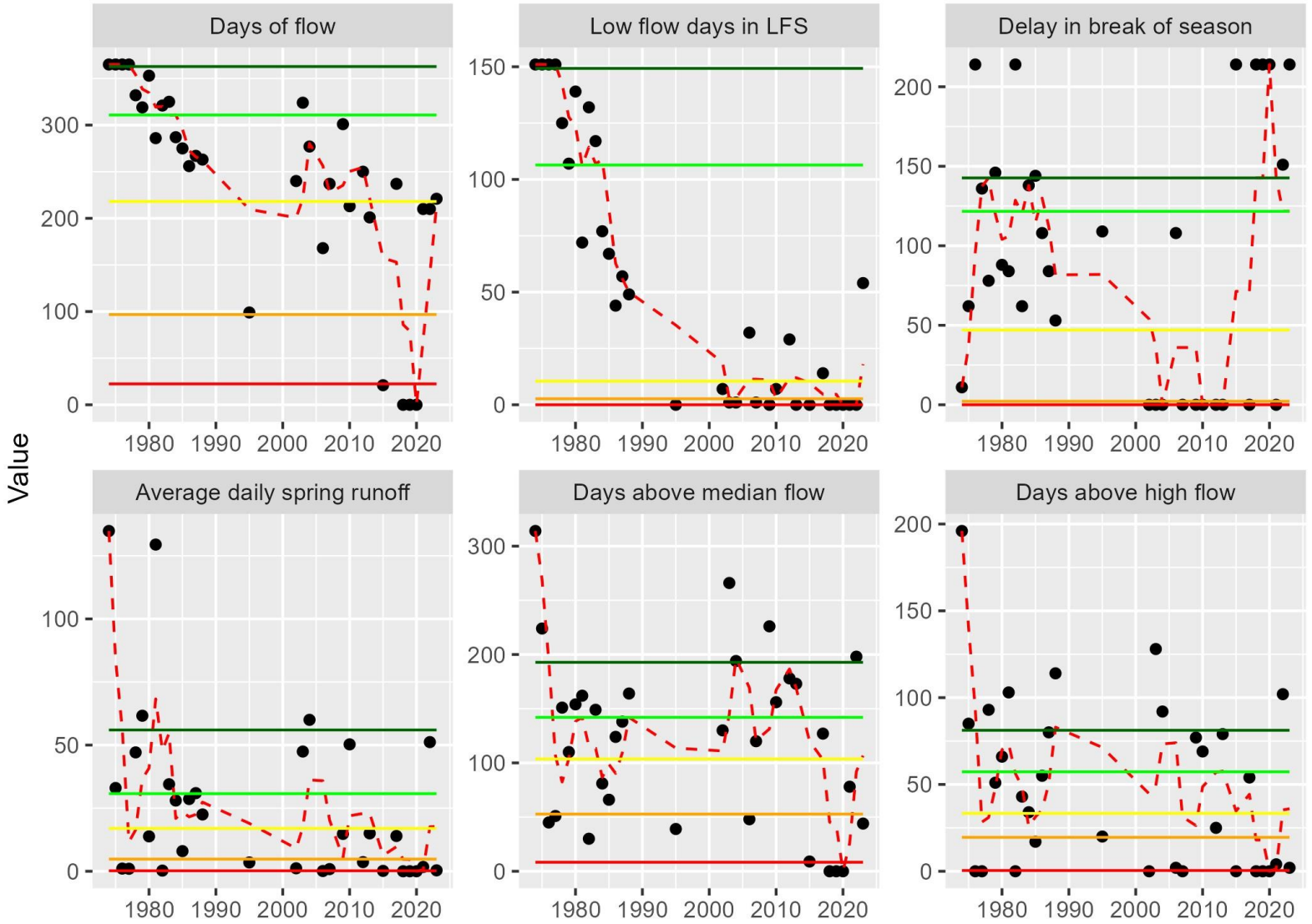
6.1 Appendix 1 – Individual site flow status assessment plots

Assessment of the six flow metrics across the six flow monitoring stations of the Marne Saunders PWRA. The assessment is based on the three-year moving average of the annual score for each of the metrics. For each plot there are several pieces of information displayed.

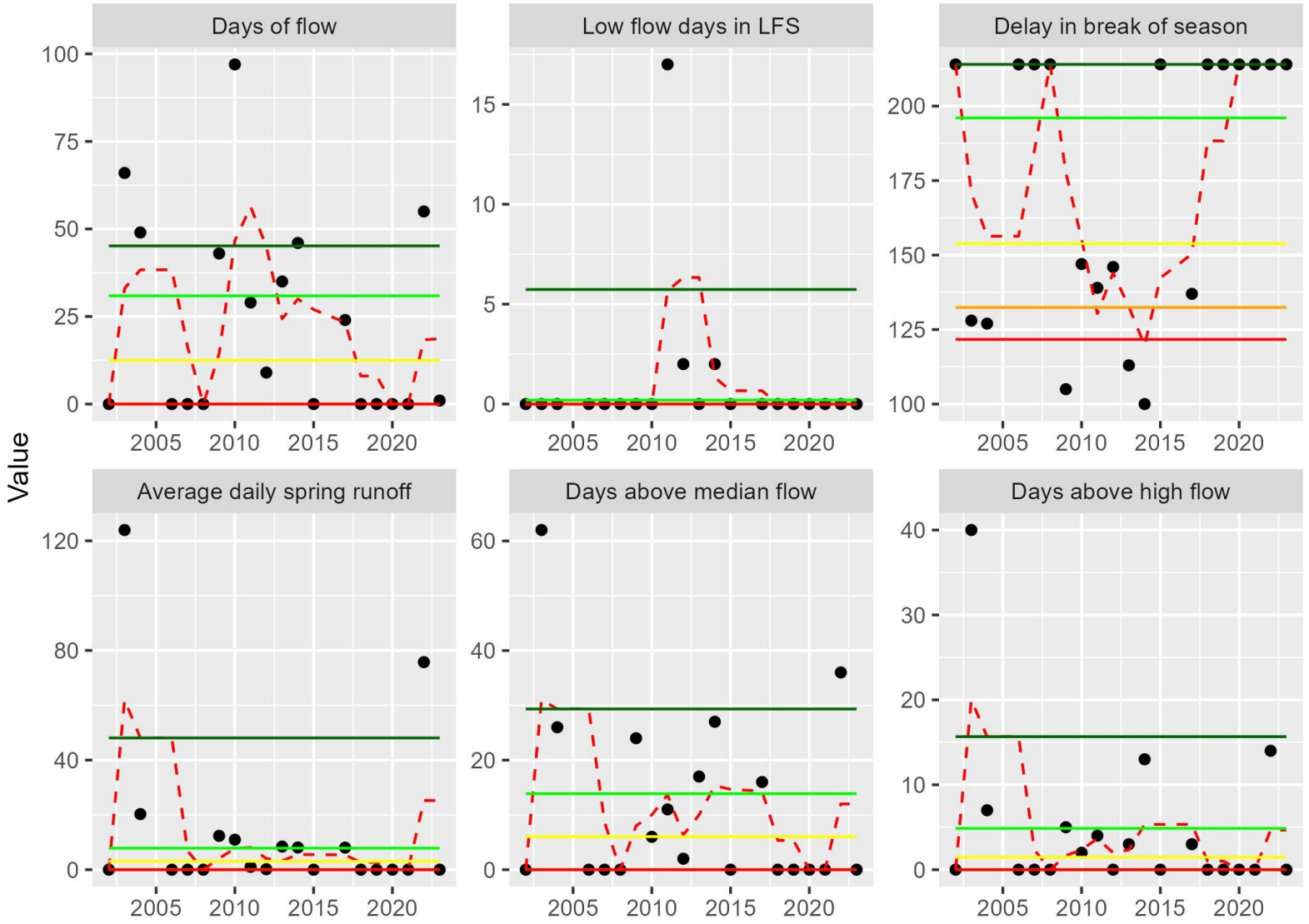
- The black points represent the annual score for the metric for years with available data.
- The red dashed line represents the three-year moving average for the metric (i.e.; the average of the current year and the previous two years).
- The condition ratings are represented by the horizontal coloured lines. These are based on the percentiles presented in Table 2. The bounds for highest on record or lowest on record are not shown.



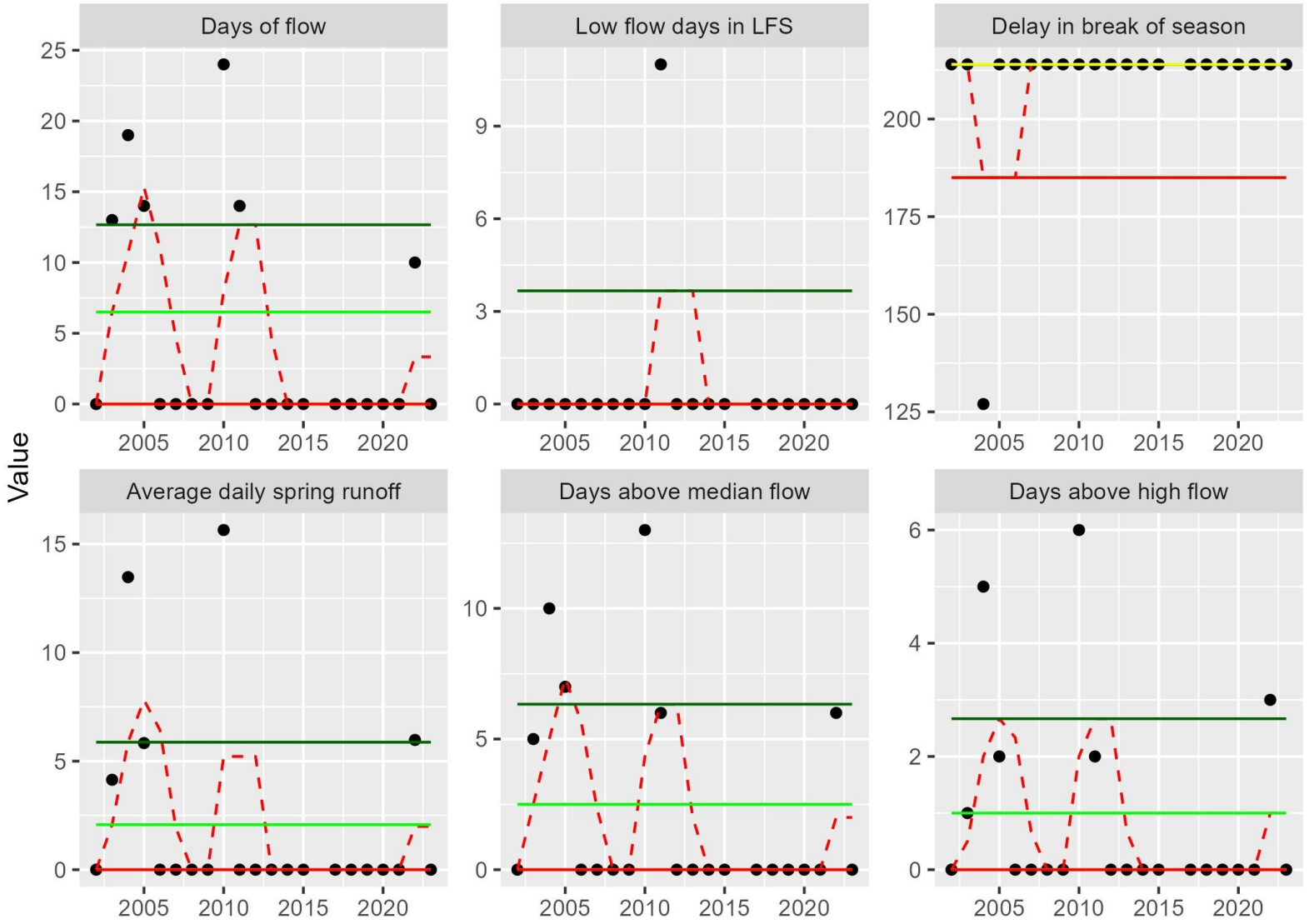
6.1.1 A4260505 – Marne River at Marne Gorge



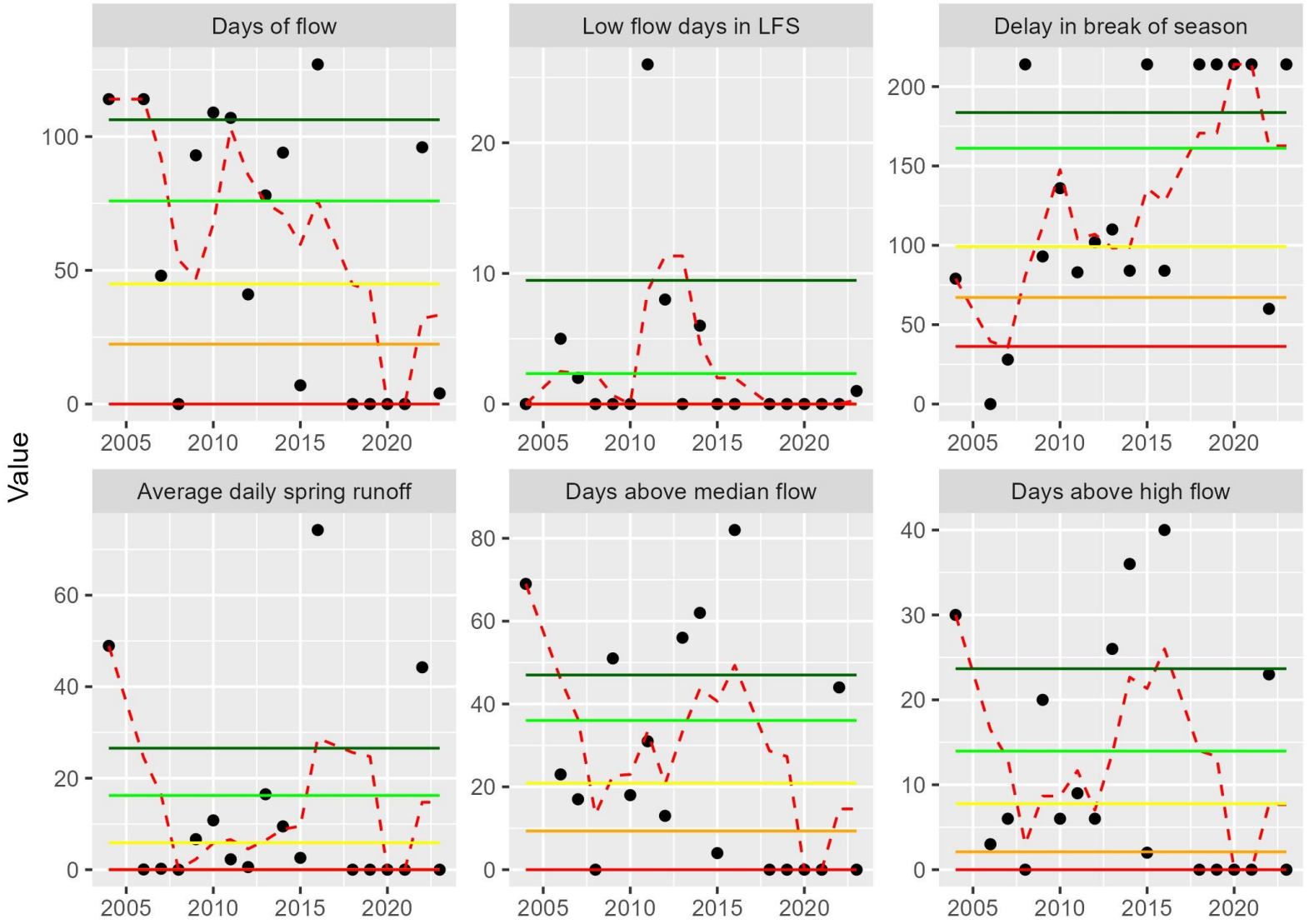
6.1.2 A4261007 - Marne River upstream Redbanks Road Ford Crossing



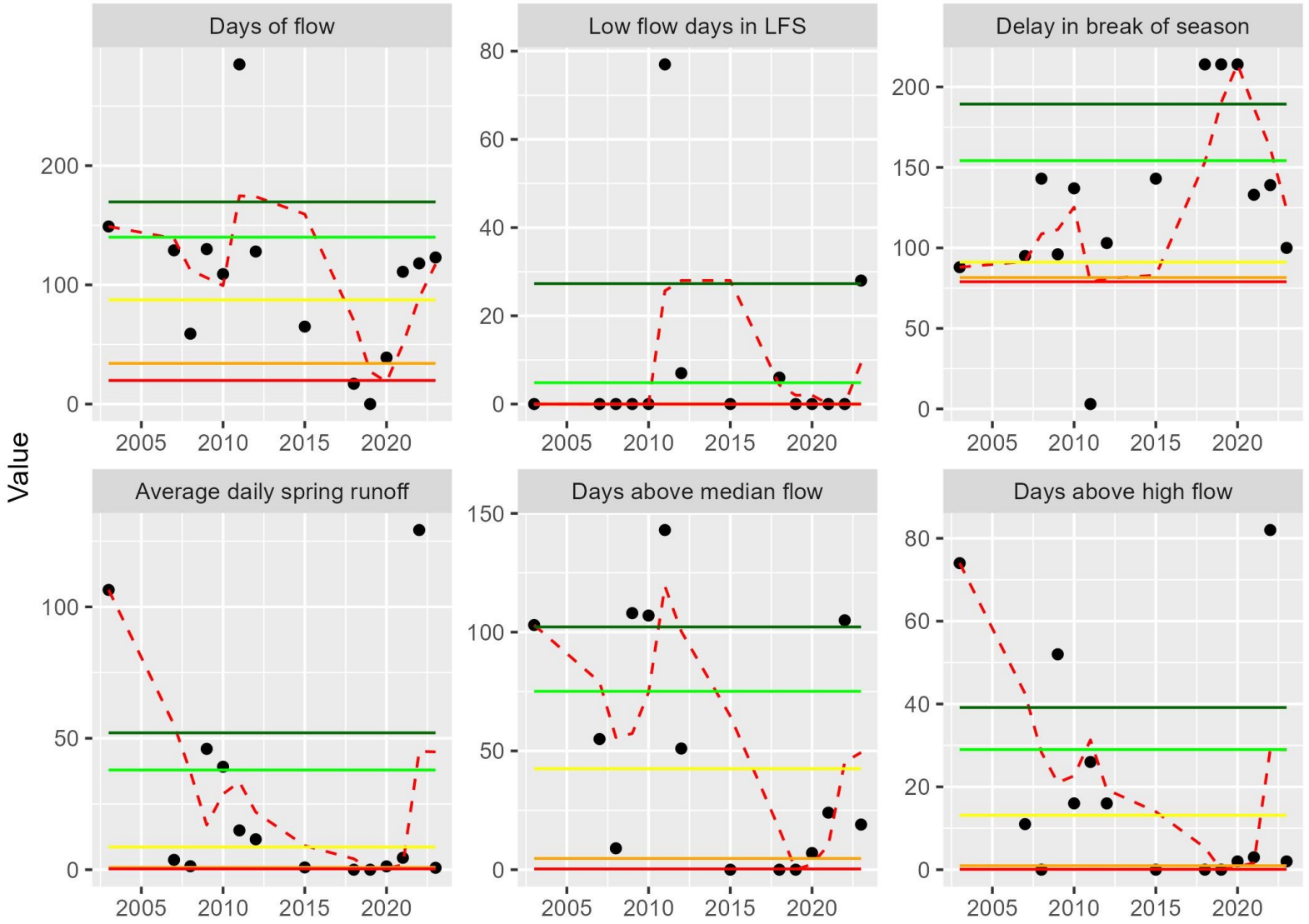
6.1.3 A4261011 - Marne River upstream Black Hill Springs



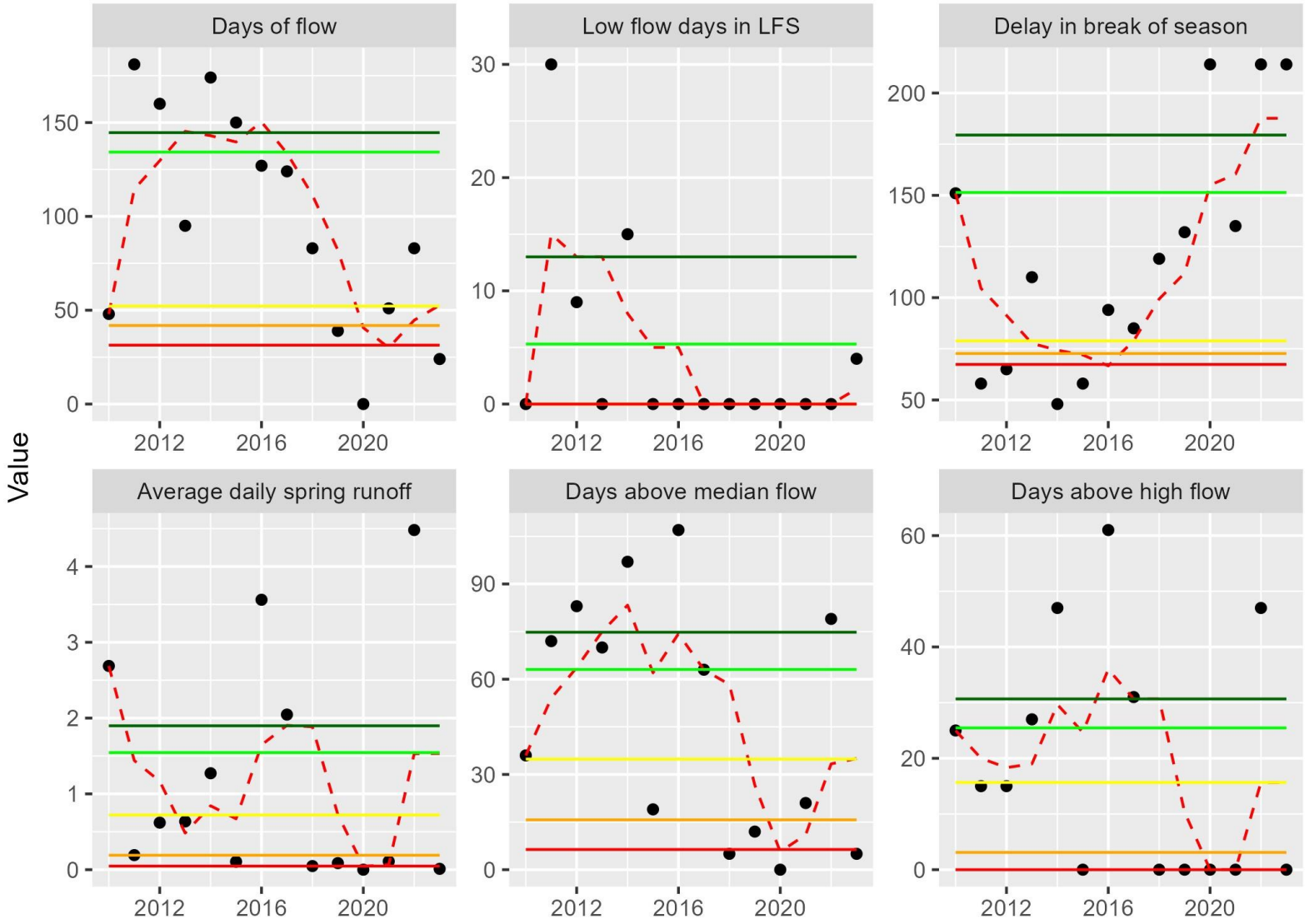
6.1.4 A4261014 - North Rhyne River near Kappalunta



6.1.5 A4261030 - Marne River 1km downstream Jutland Road Crossing



6.1.6 A4261174 - Saunders Creek in Saunders Gorge



6.2 Appendix 2 – individual site/metric trend results

Site	Metric	Mean slope	Proportion of negative slopes	Credible intervals (10th and 90th percentiles)	Trend	Start year	End year	Years in record
A4260605	Flow days.	-0.020	0.98	-0.0367 to -0.0032	Extremely likely decrease.	1974	2023	49
A4260605	Low flow season flow days.	-0.062	1.00	-0.0847 to -0.0398	Virtually certain decrease.	1974	2023	49
A4260605	Break of season.	0.000	0.50	-0.0277 to 0.0291	Stable.	1974	2023	49
A4260605	Spring flow.	-0.790	0.99	-1.366 to -0.2168	Extremely likely decrease.	1974	2023	49
A4260605	Days above median flow.	-0.010	0.83	-0.029 to 0.0081	Likely decrease.	1974	2023	49
A4260605	Days above high flow.	-0.020	0.86	-0.0503 to 0.0109	Likely decrease.	1974	2023	49
A4260605	Total flow.	-140.188	0.96	-265.3351 to -11.1666	Extremely likely decrease.	1974	2023	49
A4261007	Flow days.	-0.046	0.73	-0.1786 to 0.0928	Likely decrease.	2002	2023	21
A4261007	Low flow season flow days.	-0.121	0.67	-0.5723 to 0.3531	Likely decrease.	2002	2023	21
A4261007	Break of season.	0.012	0.20	-0.0118 to 0.0359	Likely increase	2002	2023	21
A4261007	Spring flow.	-0.881	0.78	-2.8401 to 1.0236	Likely decrease.	2002	2023	21
A4261007	Days above median flow.	-0.043	0.73	-0.1678 to 0.0806	Likely decrease.	2002	2023	21
A4261007	Days above high flow.	-0.062	0.82	-0.1795 to 0.0565	Likely decrease.	2002	2023	21
A4261007	Total flow.	-109.109	0.79	-343.7247 to 123.4803	Likely decrease.	2002	2023	21
A4261011	Flow days.	-0.082	0.80	-0.252 to 0.1013	Likely decrease.	2002	2023	21
A4261011	Low flow season flow days.	-0.058	0.57	-0.6107 to 0.4984	Stable.	2002	2023	21
A4261011	Break of season.	0.004	0.36	-0.0152 to 0.0235	Stable.	2002	2023	21
A4261011	Spring flow.	-0.198	0.90	-0.462 to 0.068	Very likely decrease.	2002	2023	21
A4261011	Days above median flow.	-0.072	0.79	-0.2246 to 0.0957	Likely decrease.	2002	2023	21
A4261011	Days above high flow.	-0.066	0.79	-0.2068 to 0.0811	Likely decrease.	2002	2023	21
A4261011	Total Flow.	-25.095	0.91	-56.3696 to 6.5359	Very likely decrease.	2002	2023	21
A4261014	Flow days	-0.085	0.88	-0.2046 to 0.0351	Likely decrease.	2004	2023	19
A4261014	Low flow season flow days.	-0.178	0.88	-0.4271 to 0.0948	Likely decrease.	2004	2023	19
A4261014	Break of season.	0.061	0.05	0.0011 to 0.1213	Extremely likely increase.	2004	2023	19

A4261014	Spring flow.	-0.061	0.52	-1.6717 to 1.5612	Stable.	2004	2023	19
A4261014	Days above median flow.	-0.068	0.82	-0.1994 to 0.0627	Likely decrease.	2004	2023	19
A4261014	Days above high flow.	-0.045	0.73	-0.1711 to 0.0867	Likely decrease.	2004	2023	19
A4261014	Total flow.	-38.796	0.62	-257.617 to 182.5751	Stable.	2004	2023	19
A4261030	Flow days.	-0.035	0.82	-0.1025 to 0.0317	Likely decrease.	2003	2023	20
A4261030	Low flow season flow days.	0.055	0.41	-0.217 to 0.3857	Stable.	2003	2023	20
A4261030	Break of season.	0.034	0.15	-0.0185 to 0.0871	Likely increase.	2003	2023	20
A4261030	Spring flow.	-1.202	0.74	-4.4483 to 2.0829	Likely decrease.	2003	2023	20
A4261030	Days above median flow.	-0.064	0.85	-0.1681 to 0.0412	Likely decrease.	2003	2023	20
A4261030	Days above high flow.	-0.043	0.75	-0.1514 to 0.0609	Likely decrease.	2003	2023	20
A4261030	Total flow.	-172.205	0.77	-560.0575 to 226.0913	Likely decrease.	2003	2023	20
A4261174	Flow days.	-0.111	0.96	-0.213 to -0.0066	Extremely likely decrease.	2010	2023	13
A4261174	Low flow season flow days.	-0.181	0.86	-0.4576 to 0.1303	Likely decrease.	2010	2023	13
A4261174	Break of Season.	0.069	0.03	0.0116 to 0.1237	Extremely likely increase.	2010	2023	13
A4261174	Spring flow.	-0.009	0.54	-0.1825 to 0.1713	Stable.	2010	2023	13
A4261174	Days above median flow.	-0.095	0.90	-0.2153 to 0.028	Very likely decrease.	2010	2023	13
A4261174	Days above high flow.	-0.067	0.70	-0.2968 to 0.1777	Likely decrease.	2010	2023	13
A4261174	Total Flow.	-8.646	0.73	-32.6254 to 15.2425	Likely decrease.	2010	2023	13

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