Aquatic ecosystem condition reports

2019 panel assessment of creeks and drains from the South East NRM region

Issued May 2020

EPA 1126/20: This information sheet describes the outcome of the panel assessment of creeks and drains from the South East Natural Resources Management (NRM) region, which was sampled in spring 2019.

Introduction

The Environment Protection Authority (EPA) coordinates a monitoring, evaluation and reporting (MER) program on the aquatic ecosystem condition of South Australian creeks and rivers. This MER program is designed to meet several objectives:

- Providing a statewide monitoring framework for creeks and rivers that revolves through the NRM regions with sufficient frequency to allow for state of the environment reporting purposes.
- Describing aquatic ecosystem condition for broad general public understanding.
- Identifying the key pressures and management responses to those pressures.
- Providing a useful reporting format that can support environmental decision making within government, community and industry.

This information sheet provides a summary of the scientific work used in assessing monitoring data from creeks and rivers. Aquatic ecosystem science is not always rigid and precise; it is often open to different interpretations in several respects. Therefore, the EPA has decided that the best way to assess the condition of streams is through an expert panel deliberation that uses a consistent descriptive modelling approach. The panel members comprised an environmental consultant and two biologists from the EPA (the authors of this assessment). All have at least 20 years' experience in monitoring and assessing a range of streams across South Australia.

The panel members were:

- Peter Goonan, EPA
- Tracy Corbin, EPA
- Chris Madden, Freshwater Macroinvertebrates

This information sheet is a technical document that contains relatively sophisticated concepts and content. It summarises the scientific assessment of data collected from creeks and drains throughout the South East during spring 2019.

Site selection and sampling design

A total of 21 sites were sampled in the region from 13-18 November 2019. Sites were largely selected from a list of previously sampled (fixed) sites throughout the region to ensure that the spatial extent of the stream network (comprising mostly drains and a small number of creeks) that could be accessed by roads was sampled. Two new sites were included to extend the knowledge of permanent, groundwater fed pools on Mosquito Creek (Schulzs and Wombeena) where the South East NRM has been regularly monitoring. An additional new site was also included on the Mount Burr-Heath Drain because the Glenelg Nature Trust has been carrying out a rehabilitation program in recent years and were interested in a current assessment of the condition of the drain.

Note that when the South East was last visited in 2014, sampling was carried out in autumn and spring to account for periods when surface inland waters were expected to be both water stressed (autumn) and saturated with water (spring). However since 2018, all assessments have only used data collected from spring because most of the pattern in the data has been evident from sampling during the wetter period.

Fixed sites versus random site selection

It is important to note that selecting fixed sites provides targeted information about the sampled sites and a broad indication of the general condition of waters in a catchment or region. The lack of randomly selected sites limits the ability for this sort of study design to provide a statistically valid assessment of all waters in a region with some measure of known error (Stevens and Olsen 2004).

The EPA has developed a database covering all stream reaches found in South Australia that can be used to identify randomly selected sites (Catchment Simulations Solution 2011), which would allow the findings to be statistically scaled up to report on the number or proportion of stream reaches in different condition classes or subject to a water quality or habitat disturbance. If this type of information is required in the future then sites can be selected using this approach, modified to account for the artificial drain network that cuts across natural catchments in the South East, but as part of negotiations with partner organisations (eg Department for Water, South East NRM, Glenelg Nature Trust), the fixed and selected site sampling approach was endorsed and used in sampling creeks and drains from the region in 2019.

Sampling strategy

Each site comprised a 100-m section of watercourse which was selected to represent the typical physical conditions present in the creek or drain to be assessed. Site coordinates were taken from near the middle of each site using a Garmin GPS.

Aquatic macroinvertebrates (invertebrates visible to the naked eye) were sampled using a 250-µm meshed triangular dip-net to sample non-flowing edge and fast-flowing riffle habitats, whenever they extended over at least 10 m within the site to be sampled. The majority of South Australian streams have non-flowing edge or pool habitats present but some of the wetter catchments also maintain sufficient riffle habitat to enable an additional sample to be taken of the organisms that inhabit flowing waters. In cases where the available habitat does not meet the 10-m distance threshold, no formal sample is taken but notes are recorded of the animals seen in the field with the naked eye from whatever habitat is present when sampling a site.

A rapid field processing method was used to identify collected macroinvertebrates, which ensures that the results are capable of being reported soon after the completion of each sampling campaign. Each habitat sample was placed in a white tray and specimens were sorted and identified for at least 30 minutes, and an estimate of the total abundance of each taxon was made on the field sheet at the conclusion of processing. If a new taxon was recorded within the last 5-minute period, then an additional 5 minutes was added to the sorting period until no new species were detected. Representative specimens of each taxon were preserved in a labelled container for each sampled habitat and all identifications were later verified using microscopes in the laboratory after the completion of field sampling.

The data for each sampled habitat was entered separately onto an Excel spreadsheet, which includes a possible 817 macroinvertebrate taxa listed on the current inland waters database for South Australia. Consequently, well-watered sites had data available from both edge and riffle habitats, whereas the drier sites lacked flowing water and comprised edge data taken from non-flowing, connected channel or isolated pool habitats.

A total of 101 observations were also recorded of the vegetation within the channel, on the riparian edge, and from the surrounding terrestrial buffer zone to provide an additional biotic data layer to contribute to the assessment of stream condition. This enables dry sites that lack aquatic macroinvertebrates to be given an interim condition assessment based on the vegetation present at the site.

An additional 156 measurements and observations were also taken at each site comprising data about water quality, flow rate, sediment composition, habitat extent and adjacent land use which was intended to characterise the main stressors likely to affect each sampled site. Field water quality was recorded using a calibrated YSI multimeter and included measurements of the electrical conductivity (surrogate for salinity), dissolved oxygen content, pH and temperature.

A water sample was also taken at each site by compositing several 1-L samples taken from different depths and parts of the site into a clean bucket. A 1-L amber plastic bottle and two 125-mL PET bottles were filled with water from the well mixed bucket and stored in the dark on ice for later laboratory analysis by the NATA (National Association of Testing Authority) accredited Australian Water Quality Centre. The amber plastic bottle was collected for chlorophyll *a* and *b* analyses. One of the small PET bottles was collected unfiltered for total nitrogen and phosphorus analyses. The other PET bottle was filled with about 100 mL of water that had been filtered through 0.45-µm filter discs for the determination of dissolved nitrogen concentration (part of the total nitrogen analysis). All analyses were carried out using standard methods.

This sampling strategy enabled all data collected in the field and processed by the laboratory to be finalised within two months, and the results were fully analysed, assessed and reported within 3-4 months after collection.

The assessment

Members of the expert panel individually rated each site using a descriptive model for interpreting change in aquatic ecosystems in relation to increasing levels of disturbance (Davies and Jackson 2006). The assumption in this assessment is that biological (ecological) condition deteriorates as the degree of human disturbance in the catchment increases, and conversely the best condition occurs where there is little to no human disturbance of the environment (

Figure 1).

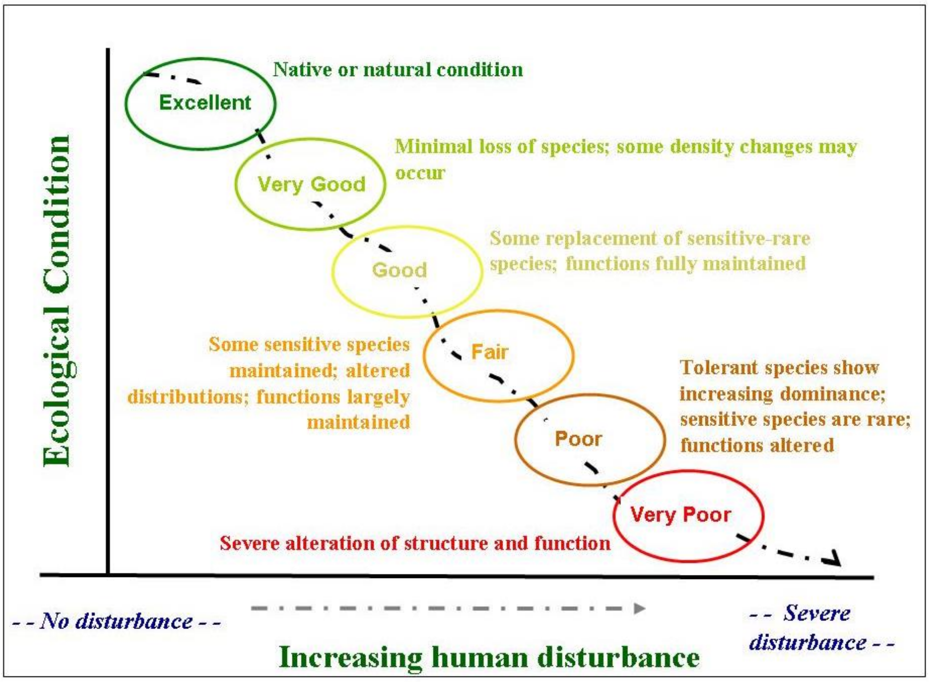

Figure 1 Human disturbance gradient showing the six different ecological condition grades or ratings ranging from Excellent (best) to Very Poor (worst) with a brief definition of each condition

The process used to grade or rate sites involved the following steps. Firstly, a conceptual model describing the biological and environmental responses to a general disturbance gradient was developed, reviewed and updated by the panel (Table 2). Secondly, species lists were compiled which described the expected biotic assemblage for up to six potential condition ratings, based on the data that was collected in 2019 (Table 3). Thirdly, each site was given an 'observed' condition rating based on the macroinvertebrate communities, vegetation assemblages, water chemistry and sediment features that were recorded during the spring sampling period. Lastly, the individual ratings derived by the panel members were combined to produce an overall, or final, rating for each site (Table 4).

The final reported ratings were derived by determining the mode (ie the most common rating from the panel ratings for each site). In the interests of being transparent about the final ratings derived using this process, all results have been included in Table 3 to show where the panel agreed or showed some difference of opinion in terms of rating individual sites.

The ratings in the model range from Excellent to Very Poor. However given the extent of drainage and land-use modifications in the South East that include extensive vegetation clearance, cropping, grazing by stock and feral animals, and the presence of introduced aquatic species, the panel considered that examples of Excellent and Very Good watercourses probably no longer occurs in the region and was not evident from the sites sampled in 2019.

In 2018 the panel members were also provided with an estimate of the expected condition of the sampled stream reaches using a newly developed machine learning approach called boosted regression trees (Edith *et al* 2008, Waite and Van Metre 2017) as part of the assessment process. The expected ratings (called Tier 1 assessments) were generated by identifying the most significant map-based variables (eg land use, climate, soils) that correlated with previous condition assessment ratings, and using the predictor variables to estimate the condition of unsampled reaches[1]. This approach was not included for the 2019 panel because the artificial drain network in the South East cuts across and connects different upstream catchments and will require modification if it is to be applied in this region. Consequently, the final results included a simpler estimate of the likely condition of sampled sites in 2019 based the land-use relative risk paper by Bryce *et al* (1999); this was applied on the same or similar sites sampled from the region in 2014, so those 'expected' condition results have also been included in Table 3.

Results and discussion

Table 1 provides a summary of the overall condition rating for each site sampled in 2019. No sites were in Excellent, Very Good or Very Poor conditions, three sites (14%) were given a Good rating and the remaining 18 sites (86%) were given either a Fair or Poor rating due to their generally degraded condition.

Table 1 Summary of condition ratings for South East NRM sites sampled in 2019

Condition rating	South East # sites (%)
Excellent	0
Very Good	0
Good	3 (14%)
Fair	9 (43%)
Poor	9 (43%)
Very Poor	0
TOTAL	**21**

1 https://www.epa.sa.gov.au/files/14069_inland_waters_methods.pdf

Sites assigned to the Good rating included Deep Creek, Eight Mile Creek and Piccaninnie Ponds Outlet Creek from the Lower South East. These sites were characterised by flowing, freshwater draining small agricultural catchments, with narrow riparian zones that included a range of aquatic plants, and each waterway provided habitat for several rare, sensitive and flow-dependent species of macroinvertebrates among aquatic communities that also included many generalist and tolerant species as well. Each site showed evidence of moderate to gross nutrient enrichment but none were overwhelmed by the effects that excessive growths of algae or plants can cause (eg low oxygen levels, sediments dominated by detritus).

The Fair sites included Bray Drain, Drain M (dry), Stony Creek, Drain at Bevilaqua Ford, Narrow Neck Drain, Picks Swamp Outlet Drain, Mt Burr‑Heath Drain, and two sites from Mosquito Creek (Schulz and Wombeena). These sites showed evidence of significant nutrient enrichment and some were affected by moderate salinity (electrical conductivity >1,000 µS/cm). All were characterised by degraded riparian zones. Aquatic communities were dominated by generalist and tolerant macroinvertebrate species but also included at least a few rare or sensitive species.

The Poor streams included the Blackford Drain, Reedy Creek–Mt Hope Drain, Drain 44, Naracoorte Creek, Tatiara Creek, Drain L, Jerusalem Creek, Henry Creek and Hitchcox Main Drain. These sites showed evidence of significant nutrient enrichment and a few were salinised (eg Blackford Drain and Henry Creek). They also had limited native vegetation remaining in their upstream segments and catchments, introduced grasses and weeds dominated their riparian zones, and they only provided habitat for a sparse community of pollution tolerant macroinvertebrates.

Variability in panel member ratings

The results in Table 3 show that the expert panel members assigned the same condition rating to 13 of the 21 sites sampled (62%), varied by one rating at 7 sites (33%) but at one site (5%) were more variable and differed by two ratings from each other. Consequently, there was considerable consistency for rating the condition of sites using this approach, which indicates that the conceptual model provided a good representation of the range of watercourses that occurred in the region in 2019.

It is important to note that it would be unrealistic to expect to obtain complete agreement in rating sites using an expert panel approach, or indeed any other means of integrating and reporting on measures of stream condition (eg classifying sites using indices or models based on the reference-based concept, gradient analysis, comparisons against guidelines) due to the problems associated with separating groups along what is actually a continuum of possible groups, using environmental data that is typically inherently highly variable.

The site where the panel had the greatest difficulty agreeing on a rating was unprecedented because the field team sampled a couple of days after a mixture of insecticides and fungicides was sprayed adjacent to Reedy Creek‑Mt Hope Drain, which resulted in some of the pesticides drifting into the drain and causing the death of numerous macroinvertebrates in the drain. While the drain supported a wide range of living species and individuals, it also included a large number of recently dead yabbies, snails, beetles, waterbugs, damselflies and terrestrial spiders which were collected or observed from the shallow margins of the drain and on the bank. Consequently, panel members either considered that the site was adversely affected by a toxicant due to pesticide exposure and rated the site very poorly, or considered that even though the site showed evidence of a chemical drift event it still supported a diverse community of aquatic species in good numbers and rated the site as either fair or poor. When reviewed by the panel it was clear that different sections of the conceptual model could support either viewpoint. Interestingly, if the data was assessed using non-parametric analyses then it is likely that different results could be generated for this site depending on whether the dead taxa were included or not.

Recent research by Siddeque *et al* (2020) also points to the more subtle sublethal effects (eg reduced survival, growth and mating rates) that can occur in aquatic species exposed to low but frequent pulses of pesticides in agricultural catchments, which can degrade ecosystem function (eg suppress populations of selected functional feeding groups that are sensitive to chemical pollution). Future assessments will need to consider how the conceptual models and monitoring program can be modified to account for both direct chemical drift incidents and the more subtle population changes associated with low doses of agricultural chemicals entering different waters of the state.

Comparison of Tier 1 expected and observed condition from 2019 results

Seven sites were assigned the same condition rating and the other 14 sites only varied by one condition rating, which indicates that landscape features seen from maps provides a good indication of the biological condition of drains and creeks in the South East.

Water chemistry of South Australian streams

Table 5 provides a statistical summary of the major chemistry and algal biomass (estimated using chlorophyll measurements) parameters taken at each site in spring. The median values indicate that most watercourses were fresh (salinity ca 416 mg/L based on multiplying electrical conductivity x 0.6 to convert between units), alkaline (pH 8), well oxygenated (8.8 mg/L), and had low chlorophyll concentrations (4.3 ug/L), moderate phosphorus concentrations (0.04 mg/L) but were enriched with high nitrogen concentrations (1.6 mg/L).

The South East lacks any watercourse that has not been modified by drainage works or land-use change post European settlement to be able to use as a reference site which is representative of the 'undisturbed natural or near natural' condition for the region. For comparable regions that lack suitable reference sites, the US EPA (2000) recommended using the 25th percentile of all data to provide an indication of the tipping points where waters are likely to be at increased risk of being degraded by excessive nutrients. Using this approach for the data collected in spring 2019, the nutrient thresholds for the South East were as follows:

Total nitrogen (TN) – 1.2 mg/L

Total phosphorus (TP) – 0.02 mg/L

This TN concentration is higher than most ecological and management values cited in the literature but the TP concentration is comparable to that given in Chambers *et al* (2012), Smucker *et al* (2013) and the trigger value proposed for the protection of sensitive mayflies and stoneflies in South Australian waters (Corbin and Goonan 2010).

Complementary analyses of attached diatoms from sites sampled in the South East during a limited campaign carried out in autumn and spring 2014 indicated that significant species change occurred around a TP concentration of 0.05 mg/L (Tibby *et a*l 2015). A more extensive diatom dataset comprising sites sampled in 2014–16 from the South East, Mount Lofty Ranges and Eyre Peninsular regions showed that a distinct loss of diatom species occurred at a TP concentration of 0.029 mg/L using threshold indicator taxa analysis (TITAN); the 95th percentile of species change point of 0.031 ug/L supported the significance of this threshold for diatoms in the southern part of South Australia (Tibby *et al* 2019). TP was highly correlated with TN but only relationships between diatoms and TP concentrations were assessed because partial canonical correspondence analysis showed that TP explained a higher amount of the variance in the diatom species dataset.

A comparative study analysing macroinvertebrate data from two large South Australian catchments and diatom data from South Australian streams using TITAN and gradient forest models identified both similar and different water quality thresholds for different indicators (Sultana *et al* 2020). TITAN identified significant change points at an electrical conductivity (EC) of 407 µS/cm, TP 0.02 mg/L and TN 0.28 mg/L using macroinvertebrate data from the Torrens and Onkaparinga Rivers in the Mount Lofty Ranges. A higher conductivity of 1,004 µS/cm was identified using the statewide diatom dataset but diatoms responded to the same low TP value of 0.02 mg/L. Gradient forest analyses showed comparable water quality thresholds using the macroinvertebrate data but higher thresholds were identified using the diatom data (eg EC 1,004 µS/cm and TP 0.25 mg/L).

More recent analyses of an extensive macroinvertebrate datasets from South Australia and each separate natural resource management region dating back to 1994 has identified significant change points associated with nutrients in the South East are evident at a TN of 2.25 mg/L and TP of 0.017 mg/L (EPA, unpublished data). These thresholds suggest that species tolerant of high nitrogen concentrations occur in the region but that a TP concentration of 0.02 mg/L represents the tipping point where sensitive aquatic species are lost and more tolerant species become dominant in South East drains and creeks.

Conceptual model issues

A central assumption of the conceptual model is that the high nutrient concentrations recorded from many South Australian watercourses originates from human activities in each catchment, rather than from a natural source (NLWRA 2001). This is consistent with the general poor nutrient status of ancient Australian soils and the need for native plants to conserve and recycle nutrients, rather than allow the regular export of nitrogen and phosphorus from the land into streams, where the nutrients may eventually be deposited many kilometres away further downstream. Consequently, it was assumed that historical and present stock and feral animal grazing land uses and cropping activities since European settlement have contributed towards the nutrient enrichment of many watercourses in each region in modern times. This may be evident through measuring higher than expected concentrations of nutrients in water samples (eg TN >2.25 mg/L or TP > 0.02 mg/L as described earlier) and/or noting signs of enrichment due to the presence of large growths of phytoplankton, filamentous algae or aquatic plants.

Under such conditions, a generalist assemblage of aquatic macroinvertebrates typically dominates because they are capable of exploiting the high plant productivity and tolerating occasional poor water quality events that often occur in such streams. In contrast, few if any, of the regionally rare, sensitive and/or habitat specialists would be expected to occur in such waters, and never in large numbers. These types of enrichment responses were subsequently incorporated into the conceptual models to represent the biological and chemical patterns that have been described in the scientific literature for well over 100 years.

Similarly, another assumption of the model is that the high salinity of some watercourses has been caused, or at least exacerbated, by the extent of native vegetation clearance and replacement by cropping and grazing practices in some catchments in the past, which has often created conditions that has promoted the secondary salinisation of waters due to inflow of saline groundwater. High salinity has been recognised as a major factor for the loss of salt-sensitive species and creation of conditions that favour only the more salt-tolerant species to be able to colonise and subsequently complete their life cycles. Recent research indicates that most freshwater species are generally replaced by salt-tolerant species when salinities exceed about 5,000–10,000 mg/L, and that different threshold effects are evident with different taxonomic groups at often lower concentrations (eg Nielsen *et al* 2008, Kefford *et al* 2011). While it is possible that some waters from the drier parts of the South East (eg Blackford Drain and parts of Henry Creek) may have approached or exceeded this salinity range prior to European settlement, it was assumed as part of this assessment that the extensive land-use changes brought about by farming has mobilised more salt into each affected watercourse than would have occurred if the landscape had remained unchanged, and that waters with a salinity at or above 5,000 mg/L represent a highly disturbed state in the conceptual model for the region.

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Further information

Legislation

Online legislation is freely available. Copies of legislation are available for purchase from:

Service SA Government Legislation Outlet
Adelaide Service SA Centre
108 North Terrace
Adelaide SA 5000

Telephone: 13 23 24
Facsimile: (08) 8204 1909

Website: https://service.sa.gov.au/12-legislation
Email: ServiceSAcustomerservice@sa.gov.au

General information

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Website: https://www.epa.sa.gov.au
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Table 2 Conceptual model of ecological responses to a disturbance gradient in the South East NRM region

Rating	Excellent	Very Good	Good	Fair	Poor	Very Poor
Stressor description	As naturally occurs; probably no longer present in the South East due to the extent of wetland drainage and associated construction of earthen drains, as well as the degree of vegetation clearance and modification from widespread agricultural land use.	Least impacted; also probably no longer present in the South East due to the extent of wetland drainage and associated construction of earthen drains, as well as the degree of vegetation clearance and modification from widespread agricultural land use. However, small coastal creeks and drains in Lower South East with extensive catchments of native vegetation may demonstrate this condition on some occasions.	Best condition sites showing initial signs of enrichment; not common in the South East where constructed drains and only a few natural streams are located in an agricultural landscape. Most likely to occur in small coastal creeks and drains in Lower South East.	Moderate nutrient enrichment; commonly occurring in the South East where many drains and agricultural creeks show enrichment effects.	Gross nutrient enrichment; commonly occurring in the South East where many drains and agricultural creeks show high levels of enrichment effects.	Severely altered; downstream from industrial discharges, recently constructed drains and urban drains which provide limited habitat and poor water quality for ecosystem values to be supported or to have established.
Biological assemblages	Native assemblages of plants and animals; usually with many rare or sensitive species present; typically high *Ephemeroptera, Plecoptera* and *Trichoptera* (EPT) richness; no symptoms of stress or introduced	Best of 'what is left, least disturbed' assemblages; high richness; intolerants and specialist taxa dominate abundances; may include some introduced species present in low abundances.	Typical assemblages for least impacted streams; good richness; generalist assemblage that includes at least some rare and sensitive species; emerging symptoms of stress in relation to nutrients and fine sediments; at least	Impaired assemblages; generalists and tolerant taxa dominate numbers which usually includes some very abundant taxa; sensitive and rare taxa, if present, present in very low numbers; usual absence of some taxa expected for the	Degraded assemblages; tolerant and generalist species dominate but numbers usually reduced, although 1–2 generalist taxa may be present in high abundances; only 1–2 rare or sensitive species present in low	Severely degraded assemblages with few taxa and generally low abundances; may have large numbers of 1 tolerant taxon such as worms, mosquito larvae, amphipods (*Austrochiltonia*) or midges (eg

Rating	Excellent	Very Good	Good	Fair	Poor	Very Poor
	aquatic species present. Note that temporary and ephemeral habitats may have a low EPT assemblage but provide habitat for a rich group of colonising insects (eg beetles, waterbugs and dipterans), with abundances of all species generally low.		some remnant native vegetation present in the catchment and near the watercourse.	available habitats present; at least some trees present in the local catchment and on the banks.	abundances or absent; often only few or 1–2 scattered trees in the catchment and on the banks.	*Chironomus, Procladius* or *Tanytarsus)*; can include organic feeders from highly polluted waters such as rat-tailed larvae; vegetation often entirely comprised introduced species with little to no remnant native vegetation.
Water chemistry conditions	As naturally occurs; no human sources of contaminants present and pest species not impacting on water quality (eg nutrient enrichment, deposits of waste with high levels of hormones).	Best condition sites with associated water quality; high proportion natural features means waters are well oxygenated and low in nutrients and turbidity.	Largely unremarkable water quality with at least some nutrients present at higher than expected concentrations, coupled with at least 1 plant indicator showing emerging signs of enrichment effects (eg chlorophyll *a* >10 ug/L, filamentous algae >10% cover and/or macrophytes >35% cover) but site not overwhelmed.	Fair water quality with generally saturated dissolved oxygen (when sampled during the day), at least 1 nutrient present at high concentrations and high algal and higher plant growths (eg chlorophyll *a* >10 ug/L, filamentous algae >10% cover and/or macrophytes >35% cover) evident throughout the site.	Poor water quality with generally saturated dissolved oxygen (when sampled during the day), nutrients present at high concentrations and high plant productivity evident at the site (eg usually chlorophyll *a* >10 ug/L, filamentous algae >10% cover and macrophytes >35% cover) dominating the site and local reach.	Very poor water quality with at least 1 parameter at a toxicant concentration that is likely to limit the aquatic diversity of a stream; often very low dissolved oxygen and may be saline and enriched in nutrients but algal and plant growth limited.
Physical habitat and flow patterns	Natural habitat and flow patterns; no extractions into farm dams or other	Near natural habitat and flow regimes; well vegetated catchments	Good habitat structure and flow patterns that may include	Fair habitat structure and flow patterns that may include artificial	Poor habitat structure and flow patterns that may include artificial	Severe modifications to physical habitat and flow patterns; unnatural

Rating	Excellent	Very Good	Good	Fair	Poor	Very Poor
	uses; range of sediment types present and not always anaerobic.	with few dams present; range of sediment types present and not always anaerobic.	channelised drains and/or coastal streams; human activities have not caused an obvious loss of riffle (flowing) habitats; range of sediment types present and not always anaerobic.	drains and modified channels of some coastal creeks; catchment development and land uses likely to affect flow patterns; anaerobic fine sediments usually present, except when large algal growths occur and oxygenate the sediments.	drains and temporary streams; catchment modifications likely to affect flow patterns; anaerobic fine sediments usually present, except when large algal growths occur and oxygenate the sediments.	flow patterns due to abstraction or discharges; little to no remnant native vegetation remaining; cleared agricultural or urban sites; anaerobic fine sediments, rip-rap or alien sediments often dominate on the margins of these drains or channelised streams.
Human activities and sources in the catchment	No obvious human disturbances but may include roads and sparse rural housing; no point sources and diffuse pollution not obvious or detectable, largely due to the extent of vegetation surrounding each site.	No significant human disturbances but may include some rural housing and roads; no point source discharges and diffuse pollution not obviously affecting the aquatic ecosystem due to the extent of native vegetation surrounding each site.	Effects of human disturbance becoming obvious; point sources may be present but do not dominate flows; good buffer zones and/or riparian vegetation present that help to mitigate diffuse pollution effects from surrounding land uses.	Point and diffuse source enrichment effects evident; riparian zone not effective at mitigating nutrients and fine sediment typically entering these sites.	Obvious point and/or diffuse source enrichment effects present; unbuffered channel with ineffective or no riparian vegetation remaining other than introduced grasses; major changes to catchment land use with little remnant vegetation remaining and agriculture and/or urban uses dominate.	Severe point and/or diffuse source effects that may include toxicant responses; effects dominate water quality and biological response with little signs of the original waterway evident; unbuffered channel that has undergone extreme modifications in an agricultural or urban setting.

Table 3 List of biota expected to occur for each rating in the South East NRM region

Note: Excellent and Very Good grades are not expected to occur given the extent of drainage and land-use modification in the region; any Very Good site would be expected to have most of the species found from Good sites but also include a wide range of mayflies, caddisflies and support a few stoneflies as well. Attributes listed follow those described in Davies & Jackson (2006).

Attribute	Good	Fair	Poor	Very Poor
1 – Rare and/or regionally endemic	Amphipoda Paracalliopidae; Ephemeroptera *Thraulophlebia nousia*; Trichoptera *Atriplectides dubius*	Amphipoda Paracalliopidae	None present	None present
2 – Sensitive, rare or vulnerable specialist taxa with narrow environmental requirements	Ephemeroptera *Offadens confluens*, *Atalophlebia australasica* and *A. australis*; Trichoptera *Lingora;* Diptera *Austrosimulium*; Fish Southern Pygmy Perch	Ephemeroptera *Offadens confluens*, *Atalophlebia australis*; Trichoptera *Lingora;* Fish Southern Pygmy Perch	Ephemeroptera *Atalophlebia australis;* Fish Southern Pygmy Perch	None present
3 – Sensitive, ubiquitous taxa	Mollusca *Austropyrgus* (formerly *Angrobia*)*;* Coleoptera *Aulonogyrus*	Mollusca *Austropyrgus*; Coleoptera *Aulonogyrus*	None present	None present
4 – Opportunistic or generalist taxa	Mollusca *Glyptophysa*; Acarina *Arrenurus, Piona, Eylais,* Oribatida*;* Decapoda *Amarinus, Paratya, Austrogammarus;* Ephemeroptera *Cloeon*, *Tasmanocoenis*; Trichoptera *Notalina*, *Oecetis, Triplectides, Hellyethira;* Odonata	Acarina *Arrenurus, Piona, Eylais,* Oribatida; Mollusca *Glyptophysa;* Decapoda *Amarinus, Paratya, Austrogammarus;* Ephemeroptera *Cloeon, Tasmanocoenis;* Hemiptera *Diplonychus*; Trichoptera *Notalina*, *Oecetis, Triplectides, Hellyethira,*	Acarina *Arrenurus, Piona, Eylais,* Oribatida; Mollusca *Glyptophysa;* Ephemeroptera *Cloeon*, *Tasmanocoenis*; Hemiptera *Diplonychus;* Trichoptera *Notalina*, *Oecetis, Triplectides, Hellyethira;* Odonata Coenagrionidae	Diptera Chironomidae (*Procladius, Chironomus* (often in large numbers))*;* Coleoptera *Necterosoma*

Attribute	Good	Fair	Poor	Very Poor
	Coenagrionidae (*Ischnura)*, Lestidae (*Austrolestes*), Libellulidae (*Orthetrum, Diplacodes*), *Hemicordulia;* Diptera *Simulium* and Chironomidae *(Cricotopus, Thienemaniella, Cladotanytarsus, Rheotanytarsus)*	*Ecnomus;* Odonata Coenagrionidae (*Ischnura*), Lestidae (*Austrolestes*), Libellulidae (*Orthetrum, Diplacodes*), *Hemicordulia;* Diptera *Simulium* and Chironomidae *(Cricotopus, Cladotanytarsus, Procladius, Corynoneura, Chironomus, Tanytarsus, Dicrotendipes);* Hemiptera *Naucoris congrex, Paraplea*; Coleoptera Often several taxa that may include *Sternopriscus, Limnoxenus, Onychohydrus*	(*Ischnura*), Lestidae (*Austrolestes*), *Hemicordulia;* Diptera *Simulium* and Chironomidae *(Cricotopus, Procladius, Corynoneura, Chironomus, Tanytarsus, Dicrotendipes, Polypedilum);* Hemiptera *Naucoris congrex, Paraplea*; Coleoptera Often several taxa that may include *Sternopriscus, Necterosoma, Limnoxenus, Onychohydrus*	
5 – Tolerant taxa	Turbellaria; Oligochaeta; Decapoda *Cherax;* Amphipoda *Austrochiltonia* and Corophiidae; Diptera *Anopheles, Culex;* Hemiptera *Microvelia*	Turbellaria; Oligochaeta; Mollusca *Coxiella;* Decapoda *Cherax;* Amphipoda *Austrochiltonia* and Corophiidae; Diptera *Anopheles, Culex;* Hemiptera *Micronecta, Sigara, Anisops, Microvelia*	Turbellaria; Oligochaeta; Mollusca *Coxiella,* Hydrobiidae; Decapoda *Cherax;* Amphipoda *Austrochiltonia* and Corophiidae; Diptera *Anopheles, Culex,* Ceratopogonidae and Ephydridae; Hemiptera *Micronecta, Sigara, Anisops, Enithares, Agraptocorixa, Microvelia*	Oligochaeta (often in large numbers); Amphipoda *Austrochiltonia*; Diptera *Anopheles, Culex;* Ceratopogonidae; Hemiptera *Micronecta, Anisops*
6 – Non-endemic or introduced taxa	Mollusca *Physa, Potamopyrgus* in low numbers	Mollusca *Physa, Potamopyrgus;* Fish Gambusia	Mollusca *Physa, Potamopyrgus;* Fish Gambusia	Mollusca *Physa;* Fish Gambusia (rarely due to poor water quality)

Attribute	Good	Fair	Poor	Very Poor
7 – Ecosystem function	Initial enrichment patterns becoming evident and often extending over much of the watercourse. Usually TKN concentration high and either chlorophyll biomass over 10 ug/L, macrophytes or filamentous algae over 10% cover at the site, but not overwhelmed by nutrient effects yet.	Moderate enrichment patterns becoming evident with high algal and aquatic plant growths extending over much of the watercourse; filamentous algae covers over 35% of the benthos on occasion; sediments usually well aerated except when primary production periodically declines following floods; water column nutrient concentrations usually high.	Gross enrichment patterns becoming evident with very high algal and aquatic plant growth extending widely throughout watercourse; filamentous algae covers much of the benthos on occasion; sediments well aerated when plant growth high but when crashes occur may become sulfidic due to organic breakdown; typically high nutrient concentrations in the water despite high primary productivity.	Algal and aquatic plant growth minimal due to poor water quality and possibly a toxicant effect; low productivity and high decomposition rates evident; typically saline, water highly enriched in nutrients; often ephemeral waters. In exceptional circumstances when concentrated sewage effluent enters waters the phytoplankton biomass may be very high but does not persist in the receiving environment.
Summary of biological patterns evident for rating	Moderate to high taxa richness due to large numbers of tolerant and sensitive taxa, all low to moderate abundances. Vegetation assemblages provide habitat opportunities for many adult insects to utilise.	Moderate to high taxa richness due to large number of generalist taxa and usually includes some rare and sensitive species in low numbers. Scattered trees near water provide some limited habitat for adult insects to utilise.	Moderate to low species richness and usually at least one tolerant taxon present in 100s to 1000s. In-stream vegetation provides major habitat complexity for adult insects to utilise.	Low species richness and usually low abundances, although may get large numbers of 1 pollution tolerant taxa on occasion. Absence of in-stream and riparian vegetation means no significant habitat opportunities for many types of adult insect stages to utilise.

*Other taxa previously collected from the region include rare and sensitive specialist species such as:

- Ephemeroptera (mayflies): *Atalophebia aurata* from Bakers Range Drain in 1977; *Ulmerophlebia pipinna* from Cress Creek, Hitchcox Drain, Eight Mile Creek; and *Nousia fuscula* from Eight Mile Ck in 1994–1995 and also recorded from Cress Creek and Deep Creek earlier (Suter 1986).
- Plecoptera (stoneflies): *Dinotoperla brevipennis* from Eight Mile Creek; *Dinotoperla evansi* from a few locations in the region in the 1990s; *Leptoperla primitiva* from Eight Mile Creek; and *Austrocerca tasmanica* from Naracoorte Creek and Mosquito Creek in the 1990s. Note that stoneflies have not been collected from the region in 2009, 2014 or 2019.
- Tricoptera (caddisflies): *Taschorema* complex from Eight Mile Creek and Piccaninnie Creek in autumn 2014; *Triplectides magnus* from Mosquito Creek during 1994–2000; *Triplectides similis* from Naracoorte Creek in 1994; *Triplectides volda* from the region in 2000–2001.
- Diptera (flies): *Apsectrotanypus* sp from Drain M near Beachport in spring 2014.

Table 4 Condition ratings given by each panel member and final overall rating for the 21 sites assessed from the South NRM region during 2019.

Included for comparison are the expected condition ratings for each site based on map-based variables (Tier 1 ratings using 2014 results and extrapolated for Mosquito Creek and Mt Burr−Heath Drain sites).

'Site codes.NRM region': refer to the EPA website for the site map coordinates and the reports.

[1] denotes the habitats at each site, eg edge (E) only or both edge and riffle (ER) aquatic habitats were present.

Site code	Site name	Tier 1 rating	Habitats[1]	Good	Fair	Poor	Very Poor	Final rating
2019.SE01	Bray Drain, near Lake Hawdon South	Poor	E		2	1		**Fair**
2019.SE02	Blackford Drain, near Kingston SE	Poor	E			2	1	**Poor**
2019.SE03	Deep Creek, near Riddock Bay	Fair	E (flowing)	2	1			**Good**
2019.SE04	Eight Mile Creek, Riddock Bay	Fair	E (flowing)	3				**Good**
2019.SE05	Piccaninnie Blue Lake Outlet, Piccaninnie Ponds Conservation Park	Very Good	E	3				**Good**
2019.SE06	Reedy Creek-Mount Hope Drain, Near Hogan's Lane Regulator	Fair	E		1	1	1	**Poor**
2019.SE07	Drain M, near Callendale	Poor	Dry		3			**Fair**
2019.SE8	Stony Creek, near eastern edge of Lake Bonney SE	Poor	E, R		3			**Fair**
2019.SE09	Drain 44, near northern end of Lake Bonney SE	Poor	E, R			3		**Poor**
2019.SE10	Naracoorte Creek, Naracoorte	Very Poor	E			3		**Poor**
2019.SE11	Tatiara Creek, west from Bordertown	Poor	E			3		**Poor**
2019.SE12	Drain L, near Robe	Poor	E, R		1	2		**Poor**
2019.SE13	Jerusalem Creek, east from Port MacDonnell	Fair	E (flowing)		1	2		**Poor**
2019.SE14	Drain at Bevilaqua Ford, south from Rendelsham	Fair	E		3			**Fair**
2019.SE15	Henry Creek, south from the Tilley Swamp Conservation Park	Fair	E		1	2		**Poor**

Site code	Site name	Tier 1 rating	Habitats[1]	Good	Fair	Poor	Very Poor	Final rating
2019.SE16	Hitchcox Main Drain, near Brown Bay	Poor	E (flowing)		1	2		**Poor**
2019.SE17	Narrow Neck Drain, near Rendelsham	Poor	E		3			**Fair**
2019.SE18	Picks Swamp Outlet Drain, west from Piccaninnie Ponds Conservation Park	Fair	E, R		3			**Fair**
2019.SE19	Mosquito Creek, Schulzs Property	Poor	E		3			**Fair**
2019.SE20	Mosquito Creek, Wombeena	Poor	E		3			**Fair**
2019.SE22	Mt Burr–Heath	Poor	E		3			**Fair**

Table 5 Water chemistry and algal summary statistics from sites sampled the South East in spring 2019 (units given are mg/L unless otherwise indicated)

Parameter	South East (n = 20 wet sites)			
	mean	25th percentile	50th percentile	75th percentile
Chlorophyll *a* (ug/L)	11.5	4.3	2.3	16.8
Chlorophyll *b* (ug/L)	1.3	0.2	0.1	1.0
Oxidised N (NOx)	0.86	0.011	0.004	0.977
Total nitrogen	2.0	1.6	1.2	2.3
Total phosphorus	0.1	0.04	0.02	0.12
Water temperature (°C)	16.4	15.8	14.9	17.2
Conductivity (uS/cm)	1,314	693	514	1,218
Dissolved oxygen	8.2	8.8	5.7	9.9
pH (pH units)	8.1	8.0	7.7	8.2