Monitoring and analysis framework to inform the environmental assessment of water management options for Kangaroo Island

DEW Technical note 2018/52

Government of South Australia
Department for Environment and Water

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Summary

The Kangaroo Island Natural Resources Management Board (the 'board') along with Natural Resources Kangaroo Island (NR KI) have made a commitment to ensure that the water resources of the island are used sustainably and equitably for the benefit of the Kangaroo Island community, economy and environment. Together with other policies for the management of water resources on the island, the current method for limiting surface water take on Kangaroo Island is a by setting a maximum development threshold of 25% of total surface water yield (referred to as the '25% rule'). This general rule was designed as a "rule of thumb" in absence of having any data to underpin decision-making and is designed to ensure that a portion of the water resource is available to downstream users (including aquatic flora and fauna). However, this method does not take into consideration the specific environmental water requirements of different water dependent ecosystems on Kangaroo Island and therefore, may still result in the gradual decline in condition of water dependent ecosystems.

It has been identified through the regional NRM Plan that the condition of water dependent ecosystems on the island is a priority for the board. In order to achieve this, there needs to be an understanding of how current and future development impacts he condition of water dependent ecosystems on Kangaroo Island. Conceptually, there is a an understanding that the development of water resources will have a detrimental impact on water dependent ecosystems. Quantifying this impact on Kangaroo Island will provide the board with greater certainty when making decisions about water resource development on the island.

The environmental assessment of water management options for Kangaroo Island project will seek to develop this understanding through a process of data collection, hydro-ecological modelling and improved conceptual understanding of the interaction between water resource development and the water dependent ecosystems of the island. This improved understanding will then be used to provide guidance over future water management options through a risk assessment process.

The purpose of this document is to describe the framework that will be used to achieve the goals of the environmental assessment of water management options for Kangaroo Island project. It:

- identifies a monitoring program based on indicators selected to align with the Kangaroo Island NRM Plan objectives and targets
- identifies methods to collect data to be used for the assessment and data storage procedures
- discusses a series of options for the risk assessment process
- discusses a series of options for the risk assessment process.

1 Introduction

1.1 Background

The Kangaroo Island Natural Resources Management Board ('the board') is legislatively responsible under the *Natural Resources Management Act 2004* for developing and enforcing regulations to manage activities that affect surface water or groundwater resources. These regulations are set out in the Board's regional Natural Resources Management (NRM) Plan.

The 2017 NRM Plan for Kangaroo Island identifies several key objectives relating to water management and the health of water dependent ecosystems on the island. Improved water resource management will help the board achieve the following strategic objectives from the 2017 NRM Plan:

Strategic objective 2.8 Aquatic biodiversity on KI is described and understood, suitably protected and species loss is minimised while the evolutionary character of KI's aquatic ecosystems is maintained.

Strategic objective 2.9 Water take limits are used to balance environmental, social and economic needs

Strategic objective 2.10 Water quality in priority catchments and wetlands is improved, while riparian habitat condition is maintained or improved

Strategic objective 2.11 Watercourse connectivity is maximised and refugia are identified and protected

Strategic objective 2.12 Water management is effective, efficient and sensitive to landholder needs, recognising the economic and social benefits of water resources.

The current Kangaroo Island NRM Plan limits the take of water from catchments based on the '25% Rule', which suggests that 25% of mean annual catchment yield (runoff) can be taken and subsequently used to derive socio-economic benefits (e.g. stock use, irrigation, commercial forestry).

The '25% Rule' does not necessarily reflect an ecologically sustainable water take limit; rather it sets out to protect the equitability/reliability of supply for other users in the catchment. The limitation of this rule was identified by a Commonwealth Scientific and Industrial Research Organisation (CSIRO) review of the current methods used for managing water on Kangaroo Island, which concluded that the current provisions may not be adequate for maintaining the health of water dependent ecosystems (Aryal, 2010). The CSIRO report recommended that the board progress to more ecologically considered methods for calculating water take limits in the region.

The board subsequently initiated a project derive ecologically sustainable water take limits for the surface water resources of Kangaroo Island. The purpose of this document is to describe the framework that will be used to characterise the risk to water dependent ecosystems on Kangaroo Island due to the development of the water resources of the island. This will include identifying ecological objectives and ecological performance measures, description of a monitoring program to collect on ground data to inform the assessment and options for the risk assessment process.

Inherent in this process is the assumption that the development of water resources on Kangaroo Island has had a detrimental impact on the water dependent ecosystems of the island. This assumption is based on an extensive evidence base from both South Australia, as well as internationally. In general terms, the development of water resources for consumptive use results in less water available for the environment. This results in reduced flow volumes, reductions in the time the waterway is flowing, and changes in water quality. Using the framework presented here, evidence will be collected that will quantify the impact of water resource development on water dependent ecosystems of Kangaroo Island, this information can then be used as the foundation to develop more sustainable water use limits that seek to achieve the NRM plan strategic objectives listed above.

1.2 Project outcomes and links to Kangaroo Island's NRM Plan

This project will seek to provide the board with knowledge to support the development of improved water policies for the region. The specific objectives of the project are to:

- Design and implement a scientifically robust data gathering program that can inform future ecologically sustainable water resource management on Kangaroo Island (refer Figure 1).
- Analyse the ecological data available to determine the level of risk to water dependent ecosystems based on different water resource management policy scenarios.

The achievement of these objectives will allow NR KI to deliver the following outcomes:

- NR KI are able to develop policies and make decisions about water resource development within a more scientifically robust and defensible framework.
- NR KI able to assess environmental risks due to different water management options.
- Increased transparency and community understanding of the trade-offs between environmental, social and economic factors when defining water take limits.

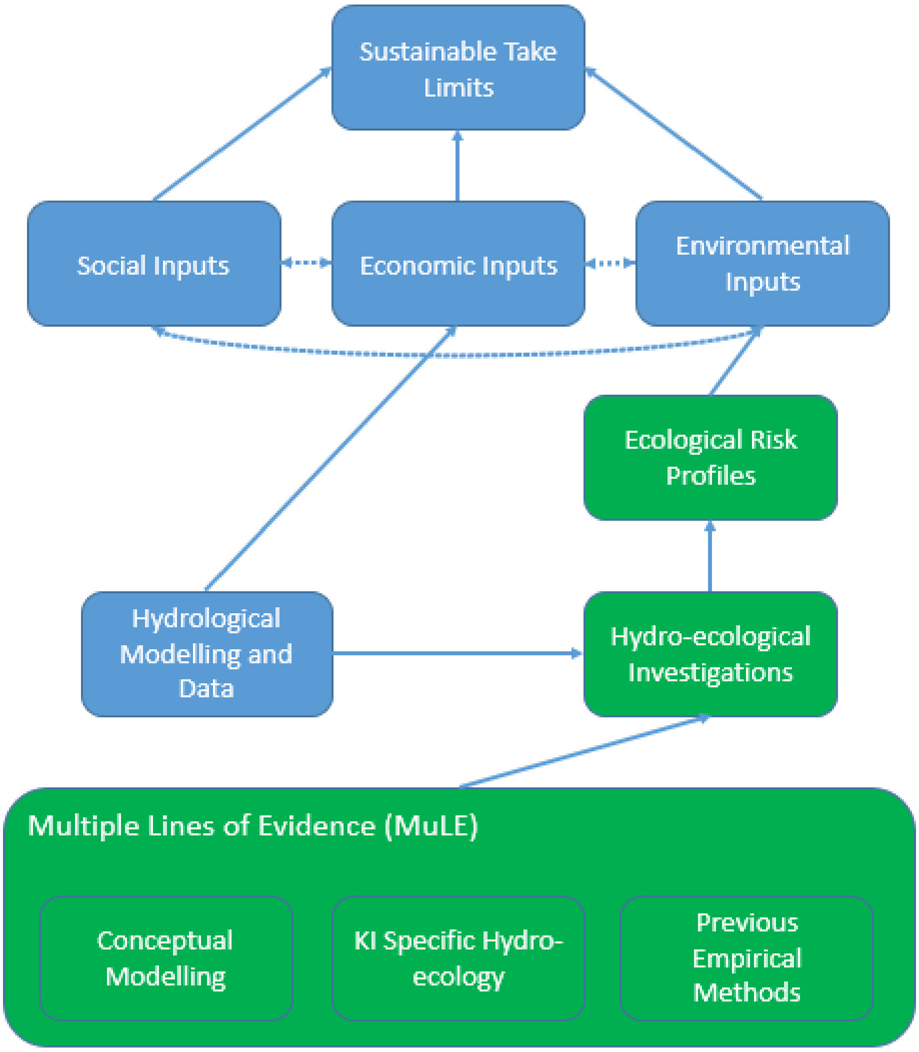

Figure 1: Conceptual diagram of the components of this project (in green), illustrating how project outputs will lead to the development of sustainable take limits.

1.3 Project context

The impacts from water resource development vary across the range of water dependent ecosystems (Acreman & Dunbar, 2004). Factors such as the clearance of land (Richardson et al., 2007), installation of weirs and dams capturing flow (Alcorn, 2008; Alcorn, Savadamathu, Cetin, & Shrestha, 2013; Jones-Gill & Savadamathu, 2014; Poff, Olden, Merritt, & Pepin, 2007; Teoh, 2006), changes to water quality (Buck, Niyogi, & Townsend, 2004; Quinn, Cooper, Davies-Colley, Rutherford, & Williamson, 1997; Sheldon & Fellows, 2010) and increased volume and speed of runoff due to lack of vegetation (cf. Poff et al. 2007) have a direct impact on the flow regime[1] of the rivers, and therefore, the condition of WDEs (Lake & Bond, 2007). There are also effects not directly related to flow regime

[1] Flow regime is the term used to describe the overall collection of timing, frequency and duration of flow events in a river system. This is a key concept in the management of rivers and streams as this is what the local ecosystem has evolved to. Changes to the timing, frequency and duration of flow events will mean that the established biota are no longer suited to the area and may become locally extinct.

(e.g. channel incision: Quinn et al. 1997), the combined effects of these changes has led to the overall degradation of the condition of water dependent ecosystems across temporary rivers (Allan, 2004).

In order to understand the effects of altered water management practices on Kangaroo Island, the data gathering program developed, and the subsequent analysis, will focus on the rivers and streams of the island. Rivers and streams are considered to be the most directly impacted by changes to water management practices (Lanard et al. 2010). While it is acknowledged that there are impact to other water dependent ecosystems, the focus on rivers and streams will allow for a more focused investigation. It is envisaged that the results of this work could conceptually inform further work on other water dependent ecosystems in the future.

This project will use historic information (e.g. Middle River environmental water requirements work (unpublished) and the 'Rivers of Life Project' (Nilsen, 2006) and concurrently collected information from other projects (e.g. Catchment to Coast Project) as far as possible. Additional monitoring undertaken through this project will supplement this information with new data collected to fill specific gaps in knowledge.

The project will be broken into stages (Figure 2). The first stage will involve developing the structure of the project and planning how, when and where activities should be undertaken. This stage will also develop, in collaboration with NR KI and the board, ecological targets to be used to identify the indicators for monitoring and for the risk assessment process. The second stage will be the implementation of the process through the collection of data across the island. The final stage of this project will be hydro-ecological modelling and the development of risk profiles for the rivers of Kangaroo Island. This is a process that has been used for water resource planning for other regions in South Australia (e.g. Barossa Prescribed Water Resources Area, see Green et al. 2014). These risk profiles will define the level of risk to ecological targets and objectives associated with different water resource management policies that may be implemented as part of the NRM Plan for Kangaroo Island.

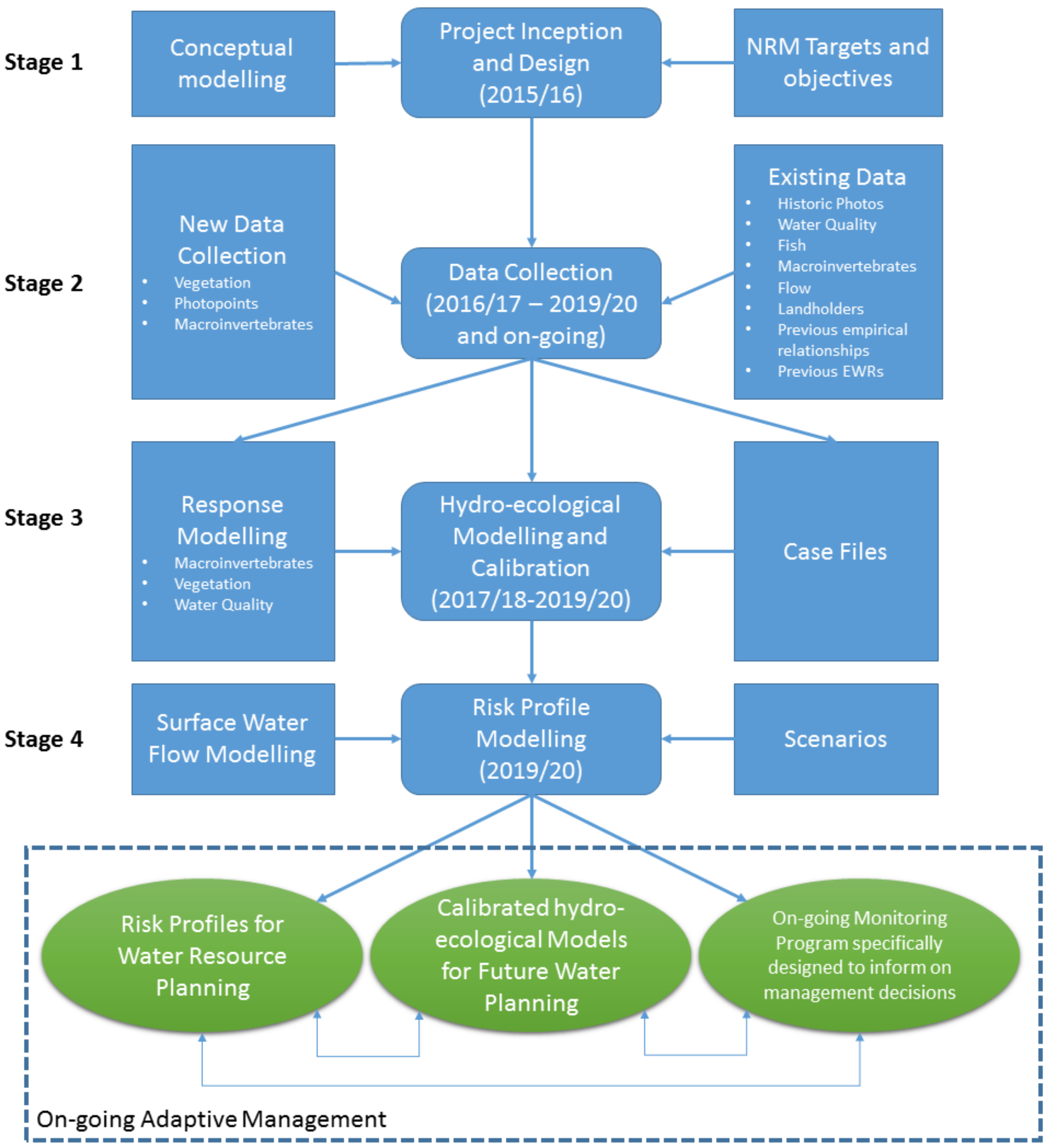

Figure 2: Project phases showing the inputs and timing for each step and the final outputs of the project

2 Program logic

Program logic is a method used to link project objectives and outcomes through an easy to interpret diagram. Presented below is a program logic diagram and the associated key assumptions for the ecological outcomes for water dependent ecosystems identified in the Kangaroo Island regional NRM Plans (past and present). The objectives and outcomes described in the program logic will be identified and discussed in Sections 3 and 4

The program logic presented in Figure 3 explains how the ecological performance measures, developed from the conceptual model of system function, are logically connected to the achievement of the ecological objectives identified in the NRM Plans. The logic is based on two types of foundational NRM activities, (1) rules or conditions imposed on new water-affecting activity developments and (2) watercourse restoration activities undertaken on a voluntary basis.

In summary, the program logic links the two key foundational activities available for water resource management on Kangaroo Island, being the NRM Plan and voluntary actions of landholders. The key outcome of water resource management on the island is the establishment and protection of a flow regime that provides the needs of water dependent ecosystems. If outside influences are controlled or minimal then the provision of an appropriate flow regime should lead to the achievement of the intermediate term outcomes (the overall maintenance of current conditions). Coupled with any possible improvements stemming from voluntary actions by landholders to improve riparian conditions (improvement in current conditions) this should lead to the achievement of the long-term outcomes which are the objectives of the NRM Plan.

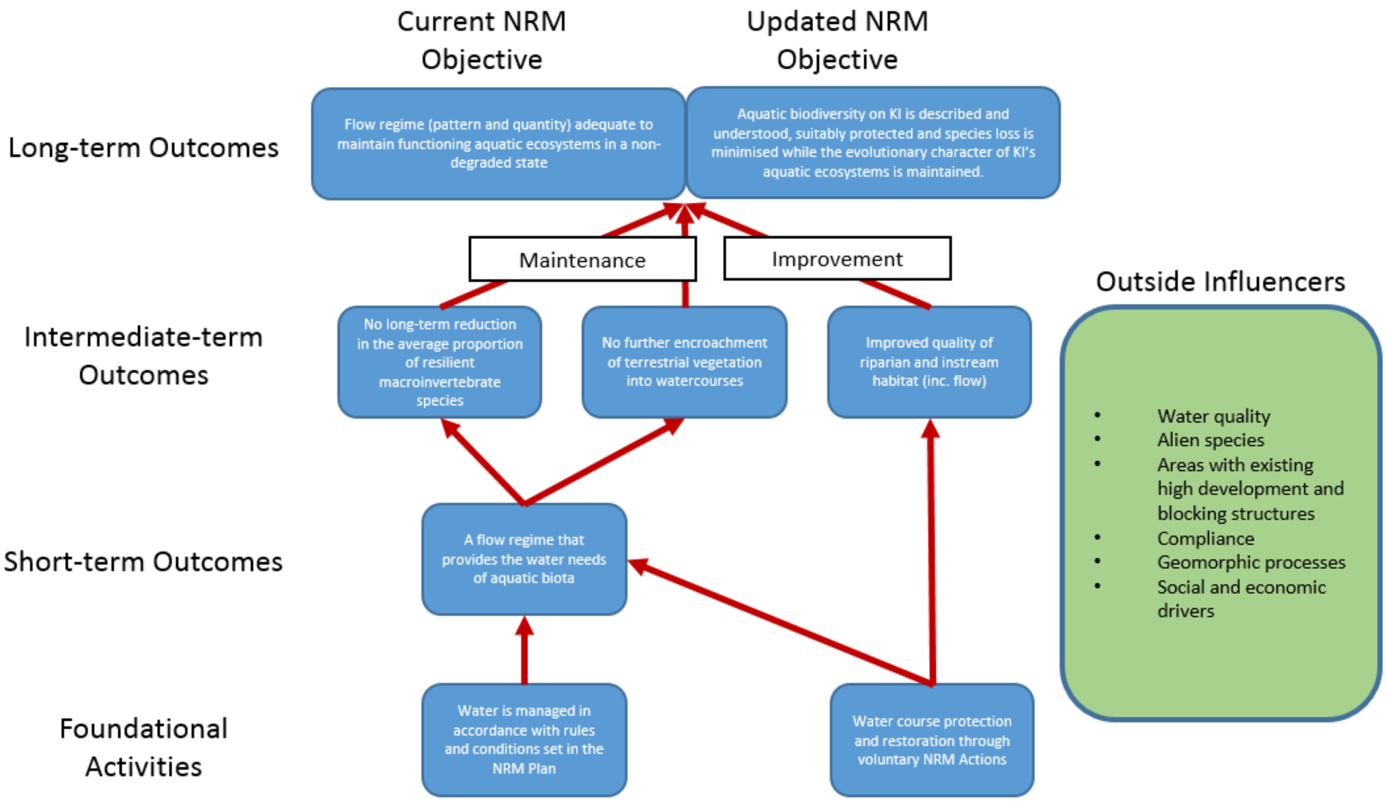

Figure 3: Program logic detailing the logic behind the achievement of the ecological objectives identified in Section 3 and the achievement

3 Indicator selection

Indicators need to be linked to the ecological performance measures, and will have a large influence on many aspects of the monitoring program design, including sampling and analysis methods.

Three factors guide the selection of indicators:

1. Strategic objectives set in the Kangaroo Island NRM Plan
2. Conceptual model
3. Management and ecological criteria.

3.1 Conceptual modeling

To establish what should be monitored, it is important to conceptually understand how different components of an ecosystem interact and how a change in one component may affect others. This theoretical understanding of a system, illustrated through a conceptual model, provides one means to identify suitable indicators for monitoring the health or condition of the system (in this case, a water-dependent ecosystem). The conceptual model also provides the theoretical links between the chosen indicators and the causal factors or driving forces (drivers) of change in the system.

The box and line conceptual model approach schematically connects drivers with responders (components in boxes) using arrows to represent system processes. A change in the state of a driver will affect a responder via the process identified by the arrow. This approach can be used to present a, simplified description of a complicated system. It is important to note that the strengths of the interactions between drivers and responders are not uniform, i.e. not all arrows are equally thick; some represent stronger linkages between components than others. Processes that link the drivers and responders are identified in Appendix 1. It is important to note that this is a simplified representation of a complex system, and there are local interactions and processes that are not represented by this model. Some of these more detailed interactions will be important when selecting indicators and will be discussed in the text where relevant.

The functioning of temporary rivers, defined as "rivers that periodically cease to flow" (Larned et al. 2010), is conceptually well understood. Models previously developed for other water dependent ecosystems can be easily adapted to the specifics of a particular region. The conceptual model developed for the rivers of Kangaroo Island has been based on several existing models for temporary rivers in South Australia, the most recent and detailed being from the Goyder Water Allocation Planning Project (Maxwell et al. 2015). The model was adapted for use on Kangaroo Island through the addition of several drivers that are considered to be of particular importance to the water dependent ecosystems of Kangaroo Island, particularly the riparian habitat and fish communities.

The conceptual model presented in Figure 4 illustrates the theoretical understanding of temporary rivers of Kangaroo Island. There are three overarching drivers that are ultimately responsible for the condition of water dependent ecosystems on Kangaroo Island; 'land use', 'topography and soil type' and 'climate'. The primary driver of change that will be analysed in this project will be changes in land use, specifically, how changing land use drives the capture, storage and use of water. Changes in water resource development will be the primary driver of contemporary changes to the condition of water dependent ecosystems on Kangaroo Island. While changes in topography and soil type are considerations on a long time scale, changes in these, with the exception of erosion, are longer term, natural processes that are not considered as part of this project. Changes in climate are also considered to be long term processes and while important to consider in NRM planning, are not considered in this project.

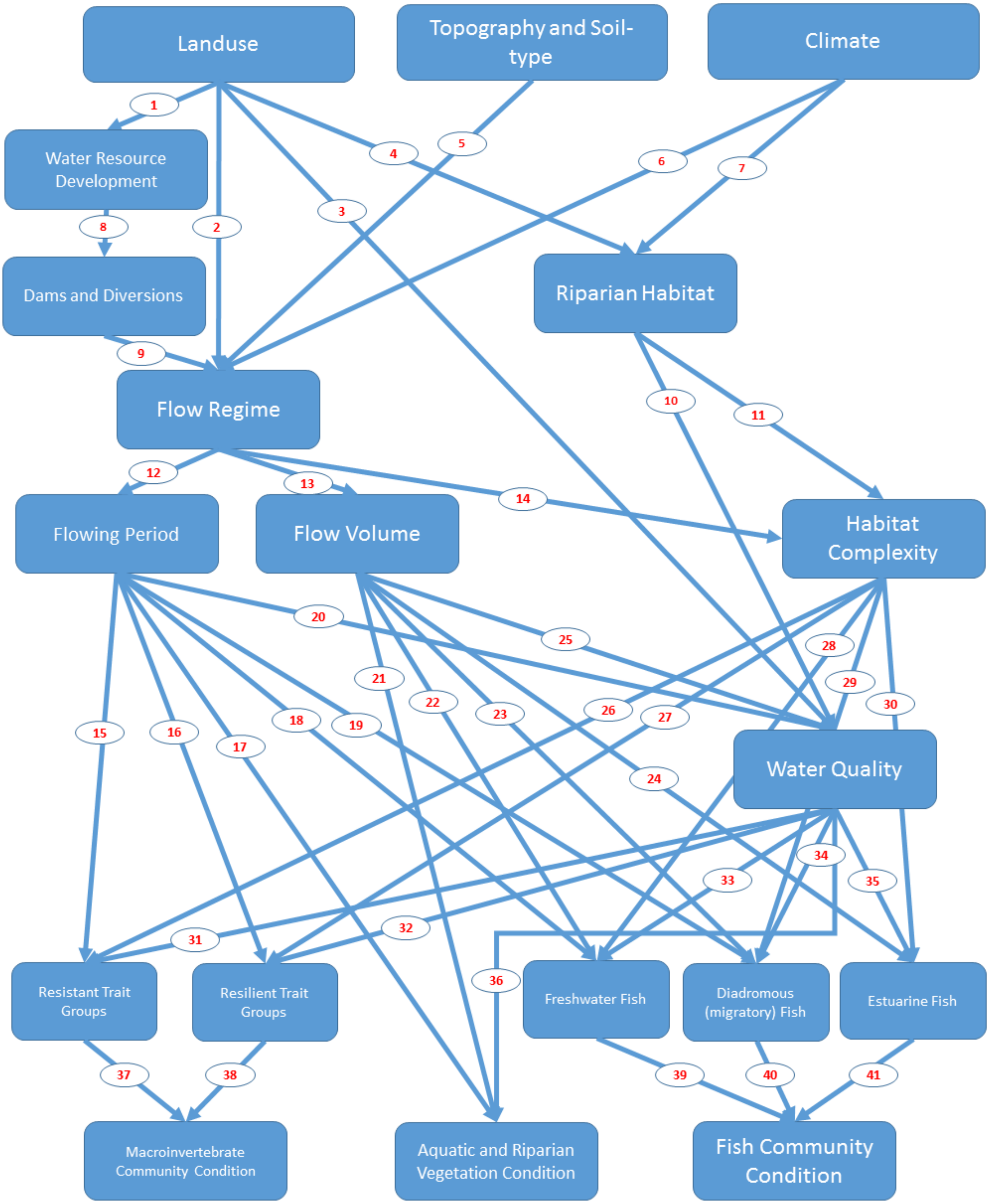

Figure 4: Conceptual model of the water dependent ecosystems of Kangaroo Island illustrating the key drivers and responders. The arrows linking components in boxes represent processes (refer Appendix 1).

3.2 Guiding indicator principles

The objectives identified in the Kangaroo Island NRM Plan 2017-2027 (Section 1.2) are high level objectives that cover the knowledge, condition and protection of water dependent ecosystems. However, they do not suggest any key indicators that could be used for assessment.

There are commonly accepted criteria that indicators should meet. A good indicator should:

- Reflect important ecological values and associated threats
- Provide outputs that are easy to interpret
- Respond predictably to change
- Relate to appropriate scales of time and space
- Be cost effective to measure
- Relate to management levers
- Be scientifically defensible.

Appendix 2 provides an evaluation matrix used for a range of potential indicators in terms of the key criteria and considerations for indicator selection.

3.3 Chosen indicators

The selection of indicators is based on the application of the criteria described above as well as their ability to be translated into suitable performance measures. The indicators chosen are discussed below.

3.3.1 Macroinvertebrates

The use of different aspects of the macroinvertebrate community as indicators of the health of water dependent ecosystems is well established (Chessman, 2003; Dewson, James, & Death, 2007; EPA, 2014; Menezes, Baird, & Soares, 2010; Miller, Budy, & Schmidt, 2010). Macroinvertebrates are useful as indicators of condition for several reasons, including the diversity of the macroinvertebrate community with multiple species that respond to different pressures (Chessman, 2003; Menezes et al., 2010), their documented response to changes in flow regime (Datry et al., 2014; Maxwell, Green, & Peeters, in prep.) and changes in water quality (Chessman, 2003). Current information shows that there are several species of taxa that are known to be sensitive to reductions in flow present on the island – "A number of rare and sensitive macroinvertebrates were found on the island in 2013, including several mites (*Oxus, Australiobates* and *Coaustraliobates*), a stonefly (*Riekoperla naso*), and most of the above-listed mayflies, stoneflies, caddisflies and blackflies that are typically found in or associated with flowing streams" (EPA, 2014). They are also relatively cheap to monitor using the EPA sampling technique.

The standard EPA sampling technique has been used across South Australia since 2008 and provides an effective and efficient method to sample and identify macroinvertebrates. While the method identifies all of the macroinvertebrates present in the sample, the ones of interest are the **resilient** taxa, i.e. those species that are not able to survive in a degraded environment and persist by retreating to refuge habitats until conditions improve. The recent Goyder Research Institute Water Allocation Project (GWAP Project, Maxwell, et al., 2015.) identified macroinvertebrates life histories, tolerances and responses to changes in abiotic conditions and catalogued these into a trait database. One of the key traits identified was either resilient or resistant, with those classed as resilient species being those that are sensitive to changes in the flow regime. The specific indicators that will be used will be the proportion of resilient macroinvertebrate taxa.

3.3.2 Aquatic vegetation

Aquatic vegetation, defined as vegetation that is dependent on water logging/inundation occurring within the channel, is important for the rivers of Kangaroo Island for several reasons. It provides habitat and shelter for aquatic fauna, and provides stability for river banks and channels, minimizing erosion and other negative geomorphic processes and functions, as a link to the terrestrial environment.

The distribution of aquatic vegetation is a function of current and historical flow regimes. Due to the reductions in both the frequency and duration of inundation, the aquatic vegetation is at risk of being replaced by terrestrial vegetation. This represents a major shift in the aquatic vegetation community and provides a highly visual and quantitative representation of change in water dependent ecosystem condition. Monitoring of riparian vegetation is relatively resource efficient, with many methods available to quantify changes in cover. In addition, hydro-ecological relationships have been developed for over 40 species of aquatic vegetation in South Australia that could be applied to the Kangaroo Island data (Maxwell, et al., 2015.).

3.3.3 Supporting information

In order to more completely understand the responses observed in the indicators, there are several sources of supporting information that will be collected. While this information will not be used as an indicator, the information will be important in the understanding of the system and likely important in the modelling process. The data that will be collected will include aspects of the stream geomorphology, flow regime and other biotic groups (discussed in Section 4).

In addition to the collection of the data from the field, there is significant benefit to be gained from having a surface water model developed. The modelling of surface water flow allows for the pairing of more sites with flow data to provide more complete datasets for the hydro-ecological modelling. Further to this, it allows for the modification of the underpinning management options. The changes in the flow regime can then be linked through the hydro-ecological models to assess the effects of different management options.

As part of the project, it was recommended that the board invest in the development of a surface water model for the Cygnet River Catchment. The Cygnet was chosen as it is the largest river catchment on the island and it covered several different terrain types, current demand levels and landuse types. This recommendation was enacted by the board for the 2017/18 year and the model for the Cygnet River Catchment will be developed and calibrated to provide additional information to the hydro-ecological modelling process to be undertaken in 2019/20.

3.4 Ecological perfomance measures

Based on the objectives and outcomes identified in Section 2, and the selection of indicators identified in Section 3.3, two specific ecological performance measures have been identified for the chosen indicators and the objectives of the Kangaroo Island NRM Plan. These performance measures represent quantifiable ecological outcomes that can be measured through a monitoring program and that can provide direct links to the achievement of objectives and outcomes. The performance measures that have been identified are:

1. No long-term reduction in the average proportion of resilient macroinvertebrate species as a proportion of the whole macroinvertebrate community present
2. No further encroachment of terrestrial vegetation into watercourses.

4 Sampling and analysis methods

4.1 Site selection and setup

The modelling process requires having complete (or as near as possible) data files for each site that can be used to train the models[2]. Once the models are trained, they can be applied to other sites across the island which may or may not have previous data. The primary focus of the sampling will be in developing complete datasets covering all variables of interest while future monitoring can continue to provide data that will partially satisfy the variables of interest. Based on the conceptual model, the data of interest and their data sources are described in Table 1.

Table 1: Data of interest for the assessment of the environmental impact of water resource development on Kangaroo Island.

Data	Data Source
Landuse	GIS landuse layers
Topography and soils	GIS soil layers and digital elevation models
Climate	Remote sensing
Water resource development level	Existing water policy information and spatial information
Dams, diversions and forestry	GIS layers
Flow regime (including flowing period and flow volumes)	Flow gauges, flow modelling, salinity monitoring
Physical cross-sections of the sampling sites	Need to be collected at sites using surveying techniques
Riparian habitat	Rivers of life project GIS data
Habitat complexity	Assessed on site and through photos
Water quality	Historic records, on site collection, continuous loggers
Macroinvertebrates	Data from previous surveys, collected on site
Aquatic vegetation	Data collected on sites
Fish community	Historic data and concurrent projects

Using these data requirements it is possible to prioritise the sites that will be used for the monitoring program to ensure that the data collection is maximised for the life of the project. For each of the 33 sites initial sites identified (Figure 5), a prioritisation was undertaken to establish which sites were the highest priority for sampling. This was based on which sites had the most data available that could not be gathered via a site visit (e.g. flow records). The site information that was used for the prioritisation process is presented in Appendix 3. The final prioritised list of sites in presented in Appendix 4.

[2] Training the models is the term used to describe the process of developing models based on real data. The process involves developing a model based on the best conceptual understanding and then testing it against real-world data. After every test, the models are recalibrated, or trained, to ensure that they are as accurate as possible.

Part of the annual implementation plan will be to review the sites that have been put forward, review any new possible sites that have been identified in the previous year and redo the prioritisation to ensure that the optimal sites are being monitored.

All sampling sites will be established in a similar manner as far as permitted by the topography and geomorphology at each site. The stylized site configuration is shown in Figure 6. Each of the sites will comprise approximately 100 m of watercourse containing at least one pool and one riffle[3]. At each site, three transects across the watercourse (plus one metre each side) will be surveyed in order to develop theoretical rating curves[4]. These transects will be through the deep of the pool, the cease to flow point[5] of the pool and one through the riffle section. These transects will also be the focus of the vegetation sampling.

Some of the sites have flow/water level logging equipment and do not need any additional hydrological monitoring equipment. Other sites will require the installation of a gauge board, a permanent depth measurement tool used to measure the water level during a site visit. This gauge board will be the focus of the site photopoint which will be established as a photographic record of site conditions. Macroinvertebrate sampling will occur along the 100 m site with the sample collected from the variety of microhabitats present in each of the pool and riffle environments.

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[3] Pool and Riffle are habitat types associated with small, temporary rivers. Pools represent habitats where there is no visible flow in the water. Riffles represent habitat the surface of flowing water is broken by the streambed.

[4] Rating curves are a mathematical relationship that links the flow rate of a river and the height of the water. They are also called stage-discharge relationships.

[5] The cease to flow point is the downstream point on the edge of the pool where the pool is considered full and the water begins to flow downstream.

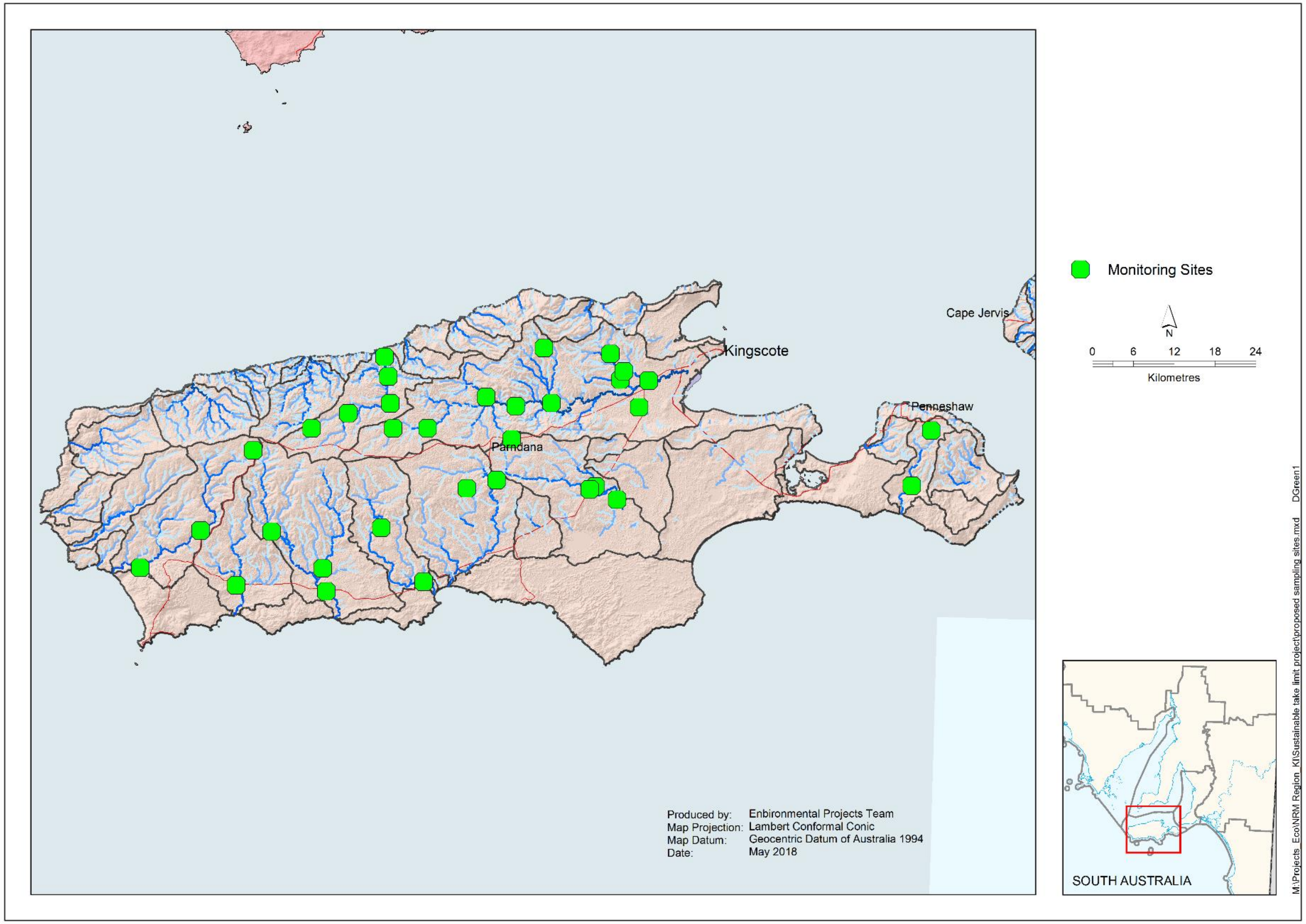

Figure 5: Proposed sampling sites that shall be the focus of the monitoring program on the island. Note: additional sites may be included through the course of the project

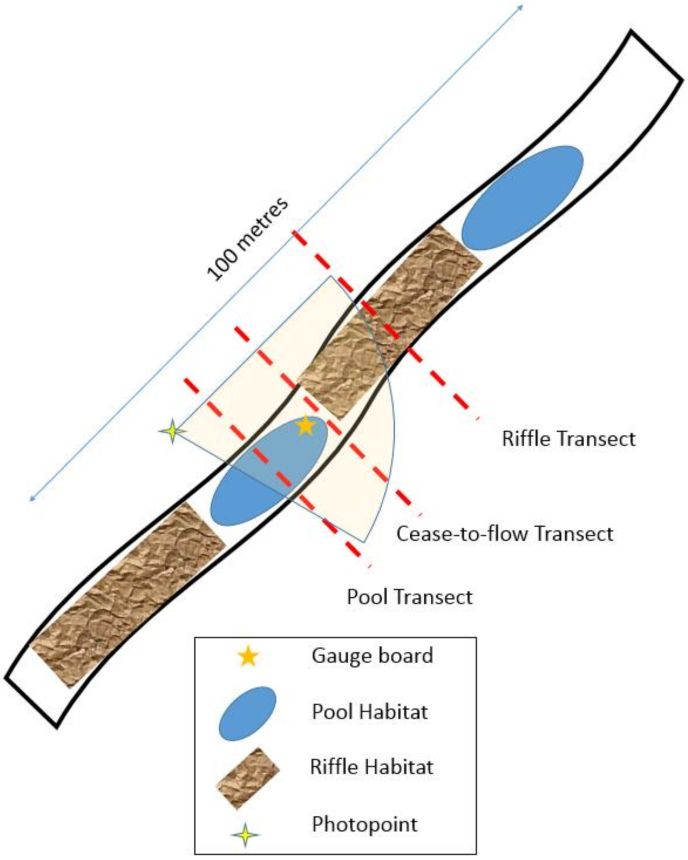

Figure 6: Stylised site configuration showing the general position of the different sampling methods

4.2 Sampling methods

4.2.1 Base data: physical conditions and flow

Cross-sectional survey

Cross-sections of the water course will be surveyed at three points for each site, the deep of the pool, the cease to flow point of the pool and across the riffle section. These cross-sections will start from one metre past the top of the left bank and will finish one metre past the top of the right bank. The cross-sections will be measured using a total station, or similar equipment, to ensure the accuracy of the data. Measurements will be taken at least every 50 cm across the transect, but may be closer to capture changes in bank shape (as close as 1 cm intervals).

Surveying the geomorphology of the watercourse is important for developing a relationship between flow characteristics/regime at a site and vegetation inundation history. Additionally, the relationship between stage height (water level) and flow rate is important for determining various aspects of macroinvertebrate and fish ecology, including habitat availability and dispersal ability.

Three cross-sections will be undertaken at each vegetation transect, one at the controlling section of a pool, one through the pool and one through the riffle habitat.

Flow measurements

A flow measuring device (gauge board) will be installed at each site that does not have any flow or water level monitoring equipment. The water level can be read off the board at any given time, ideally every few weeks. This will provide a record of the water level through time. Using the rating curve, it is possible to estimate flow through the site based on the height of the water. This flow information can be compared to flow data from other sites to produce a time series of flow information.

4.2.2 Macroinvertebrate sampling

The macroinvertebrate data that will be collected will be a presence/absence matrix of species for each habitat at the sampling sites. This data can then be used to investigate the proportions of different traits[6] present (see Maxwell et al. in prep) as well as general community metrics such as species richness, trait richness and EPT Taxa[7].

The South Australian Environment Protection Agency (EPA) has, since 2008, implemented consistent methods for collecting macroinvertebrate data across the State based on the AusRivAS method (EPA, 2014). The method, has been used for several sampling events on Kangaroo Island, while the data analysis method used by the EPA is primarily used to determine water quality, the sampling method provides a taxonomic list that can be interrogated and interpreted in multiple ways.

The EPA method involves sampling pool and riffle habitats (where present) with a 250 micron triangular dip net and identifying macroinvertebrate taxa in the field. Representatives of each taxa sampled are collected for later verification under a microscope. The pool sample is a combined sample from all of the microhabitats present in the pools at the site, up to a total of 10 linear metres of sampling. The riffle sample uses a kick-sweep method wherein the net is placed downstream of the area being sampled in the flowing water while the sampler disturbs the substrate in the riffle with their feet, dislodging any macroinvertebrates present so that they flow into the net. This method is used to cover 10 linear metres of riffle habitat. Sampling takes place twice a year, in autumn and spring. Autumn sampling is carried out shortly after the onset of flow, while spring sampling should occur as annual flows recede, but have not yet ceased. Given the resource limitations of this project, the sampling will only be undertaken in spring, before the rivers cease to flow.

More details on EPA sampling methods can be found here:

http://www.epa.sa.gov.au/environmental_info/water_quality/aquatic_ecosystem_monitoring_evaluation_and_reporting

4.2.3 Vegetation sampling

Surveys to record vegetation species diversity and distribution within and around sites will be conducted using a belt transect[8]. Belt transects will be undertaken along the three surveyed cross-sections at each site. The sampling design will be modified from the Goyder water allocation plan (GWAP) project (Maxwell et al. in prep -a).

The presence of species will be recorded in 1 x 1 m quadrats along the surveyed transects. While there are many species that are likely to be found using this process, it may be possible to limit the species that are required to be identified based on previous work. Appendix 5 has a list of plant species that were investigated, and had response models developed, as part of the GWAP project.

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[6] Traits are the biological features of the macroinvertebrates that identify them in different groups (i.e. predators/filter feeders/algae eaters etc.). The idea behind traits is to simplify the data into a series of groups that represent the whole community.

[7] EPT Taxa are macroinvertebrates from the three families Ephemeroptera (Mayflies), Plecoptera (Stoneflies) and Trichoptera (Caddisflies). These three family groups are well studied for their response to changing conditions. It is well accepted that their diversity and abundance reduces under degrading conditions.

[8] Belt Transects are a vegetation survey technique that surveys a specific width of vegetation along a transect line as opposed to the more common point-intercept method. The advantages of this method are the increased likelihood of recording small, rare species which may be missed using an intercept transect.

Given the slow turn-over in plant communities, vegetation sampling will be undertaken on a rolling cycle allowing at least two years between sampling events at a given site to allow for any changes in community to manifest. Sampling will be conducted in spring (coinciding with the macroinvertebrate sampling), to maximize the number of annual species of plants that are detected.

4.2.4 Water quality

Water quality data is currently collected across the island as part of multiple projects and community programs. Based on feedback from the EPA, the usefulness of this data is considered to be limited to salinity data. The use of other parameters measured by point samplers are too unreliable for use in this project.

Given the amount of current investment into the collection of water quality data across the island, specific monitoring is not considered necessary. However, based on the amount of effort required to collect a point sample using a composite probe, it is considered logical to collect data from each site when visited. This will provide paired salinity/flow records that will be helpful in establishing relationships between flow and water quality.

Currently, NR KI are undertaking a program to collate all of the previously collected water quality data on the island into a database. While not part of this project, the database will provide information that will be useful for this project.

4.2.5 Data collection summary

The key points identified above have been summarised into Table 2.

Table 2: Summary of the data to be collected as part of the monitoring program

Indicator	Key data collected	Collection method	Sampling schedule	Notes
Macroinvertebrate community composition	Presence/absence macroinvertebrate data	Standard EPA method	Minimum once a year in spring, with Autumn sampling if resourcing permits	In kind support from the EPA will assist with the data collection
Presence of specific macroinvertebrate species (yet to be determined)	Presence of specific species (yet to be determined)	Rapid assessment method	As required, up to weekly for brief periods of time to detect key changes due to changes in flow	This method is still being developed as part of several projects. Current timelines will allow for application of this protocol in the later years of the project if desired
Riparian vegetation	Presence/absence vegetation data	Belt transect	Can be undertaken any time of year, likely to be undertaken in conjunction with physical surveys and macroinvertebrate surveys	Additional sites may be added into this method to extend the dataset if resourcing permits
Geomorphology	Detailed representation of the vertical change in height across the channel	Cross-sectional surveys	Once at site establishment	These sites will permanently marked for repeat use through the project and beyond
Physical habitat	Water level	Observation. Possibly flow gauging if resources allow	Every time site is visited. Flow gauging opportunistically	Maximizing data collected using this method will result in greater accuracy in the Source Surface Water model as well as allow the extrapolation of flow records to new sites.

4.3 Data management

Data management is a vital consideration in any successful monitoring program. Data generated by the project will be managed according to DEW Managing Environmental Knowledge protocols to ensure they will be secure and accessible in the future. A large volume of data and metadata will be generated through this monitoring program that needs to be sorted and accounted for. Table 3 identified the different data that is going to be produced, where it will be stored in the short term (life of the project) and where it will be stored in the long term post analysis (post project).

Table 3: Data type, format and storage information for thee data that will be generated as part of this project.

Data source	Data type	Information contained	Data format	Short-term storage	Long-term storage
Macroinvertebrate	Table	Species lists, point sample water quality	Excel spreadsheets	Project iShare site	BDBSA*
Vegetation	Table	Species presence/ absence	Excel spreadsheets	Project iShare site	BDBSA
Water height	Table	Water depth and estimated flow	Excel spreadsheet	Project iShare site	Hydstra virtual sites
Cross-sections	Table	Physical cross-section heights	Excel spreadsheets	Hydstra virtual sites	Hydstra virtual sites
Hydro-ecological Models	Model	Relationships between flow and biological responses	Unknown	Unknown	SMK Model Warehouse***
GIS layers	Spatial	Spatial data for the project including site locations and details, locations of points of interest and collated layers for use in modelling.	GIS layer files	Spatial geo-databases on DEW Network drives	Spatial geo-database on Network Drives EGIS SDE

* There is currently a process investigating how the macroinvertebrate data collected across the state can be stored more effectively in BDBSA.
** As part of the proposed monitoring of the Low Flows program in the Mt Lofty Ranges there is a task to develop a storage system for photopoint data, including photos. If this task is completed by the end of this project the feasibility of storing data in this system will be investigated.
***Currently under development

4.4 Analytical methods

The degree of sophistication of data analysis and modelling methods will depend on available project resources. The goal of the analyses are to develop hydro-ecological relationships that can be used to assess the effects of various water resource management regimes on the island, and based on these relationships, assess the level of risk to WDEs. There are several methods that can be used to develop the hydro-ecological relationships. These include:

1) Conceptual modelling:
   - A method that uses conceptual links between process (drivers), and things that respond to these processes (responders), to look at how changes in an interconnected network of drivers and responders. This is a simple method that requires little empirical evidence, however, it is not overly rigorous.
2) Using expert elicitation:
   - This method involves asking experts in their respective fields how they believe drivers will affect responders based on their expert opinion and experience. This can provide more rigor to a conceptual modelling process, however, is still based on opinion.

3) Developing specific relationships for representative taxa:

   - Using simple empirical modelling processes it is possible to develop relationships for specific drivers and responders. Simple methods such as linear modelling and Gaussian response functions can produce simple linear models which are easy to interpret and use for predictions.

4) Multivariate analysis of multiple ecologically relevant hydrological metrics:

   - Ecologically relevant hydrological metrics are derived from environmental water requirements that have been identified for difference species or groups of species. Using multi-variate analysis it is possible to look at changes across all of these metrics and simplify them down to a single number that represents let level of deviation from a predetermined optimal situation. This allows for a simple comparison of scenarios to establish a comparative assessment of risk.

5) Generalised linear:

   - This is a more complex empirical modelling method that is able to look at how a responder behaves in response to several different drivers. This allows for the incorporation of multiple factors into the model, which reduces the number of models needed. However, it is a more complex method and requires multiple repeated measures for each driver and responder.

Once the hydro-ecological relationships have been developed, a framework will need to be developed to assess how all of the different models interact. In previous investigations, this framework has been a simple matrix that used the worst case out of all of the models developed and based the risk assessment on this (Barossa PWRA Assessment, Green et al. 2014). Other frameworks have identified the most important, or rigorous response models available, and used these for the risk assessment (Mount Lofty Ranges Assessments, VanLaarhoven & van der Wielen 2009).

For this project, it is suggested that a Bayesian Belief Network (BBN) would provide the optimal process for linking the different response functions into a single assessment. Bayesian Belief Networks are a modelling process that uses probabilities to link drivers and responders. Because of the use of probabilities, it is possible for the BBN to use different types of response models. Empirical response models can be incorporated with high certainty, while conceptual links or expert opinion response models can be incorporated with lower levels of certainty. The pictorial representation of a BBN looks similar to a conceptual model (such as the one presented in Sect. 3.1) where each of the boxes can be in different levels or 'states'. Inputs (or 'parent nodes') are the top nodes that allow for the inputting of information into the models. Responders (or 'child nodes') have their 'state' dictated based on the states of their parent nodes and how the 'states' of the parent nodes interact based on the response model used to link them together. This process allows for all of the available information to be put into a single BBN and provide a single output which can be used as the basis for the risk assessment.

BBNs are a powerful modelling process that allows for the input of multiple lines of evidence within a single model. In the context of this project, this means that the modelling process can take into account not only the monitoring data that is collected as part of the project, but the additional data and knowledge that exists on and off the island. There have been several projects on the island that have focused on WDEs and attempted to develop relationships between flow and ecology that could be used to further inform this project. For example, projects such as Rivers of Life (Nilsen, 2006) and the Middle River EWR Project (unpublished report) collected large volumes of data specifically for use in understanding how changes in flow regimes alter the WDEs of KI.

The other key advantage of a BBN is that it is a 'learning' method. Unlike other methods that use a combination of qualitative and quantitative data, a BBN is able to take known examples of the system and 'learn' how to best set itself up to provide the most accurate outcome, based on the information available.

5 Development of risk profiles

The second key outcome of this project is to determine the level of risk to the achievement (risk assessment) of the ecological performance measures identified in Section 3.4. These performance measures are linked to the achievement of the outcomes identified in the Kangaroo Island NRM Plan (identified in Section 1.2).

In order to determine the level of risk to the water dependent ecosystems, there are several pieces of information that are needed. Those are:

1. Predications of how the environment will respond to changes in water resource management
2. Response models that predict how the performance measures will response to changes in the environment
3. Thresholds of acceptable change for those performance measures.

This process has been undertaken across several water resource areas in South Australia in the last decade, with a gradual evolution of methods, with an associated increase in the use empirical data and reduction in the reliance on expert opinion. The process used for Kangaroo Island will build on these previous risk assessments, most recently undertaken for the Barossa Prescribed Water Resources Area (Green et al. 2014). Unlike previous risk assessments, the risk assessment for Kangaroo Island will primarily revolve around new development as the NRM Plan has limited scope to modify existing developments on the island.

The predictions for how the environment will change due to changes in water resource management will be developed through two sources. The sampling sites have been selected to ensure that there is a range of development levels upstream of the sampling location as well as a range of development types (e.g. small dams, large dams and forestry). This range of development levels will provide insights into the effect of increased water use. The second source will be surface water modelling, planned to be undertaken for the Cygnet River Catchment. Using the surface water model it will be possible to model different water resource management scenarios and interrogate the resulting predicted flow patterns.

The response models that will be used are discussed in Section 4. The application of these models for the risk assessment process will be undertaken at the subcatchment scale and will utilize all of the information that is available for that area. For each subcatchment, different scenarios will be run that will reflect different management options, and the associated changes in the environment, providing a prediction of the ecological performance measures.

The final step is the assessment of the predicted ecological performance measure against a desired state. The performance measures seek to prevent further degradation of water dependent ecosystems (meaning that the desired state is the current state or better). The final output of the response models will be a probability distribution of likely outcomes[9]. This will provide the likelihood that there will a degradation in condition. The higher the likelihood of a degradation, the higher the level of risk.

[9] A probability distribution of likely outcomes is the easiest way to interpret the outputs of a BBN. The model output that represents that performance indicator will have a number of possible states (e.g. five levels of terrestrial vegetation encroachment) against which the model will list the likely probability that a given state is the outcome. In the example below it can be seen that the most likely outcome is Moderate (36.7%), with a 31.9% of a low outcome and 24% likelihood of high.

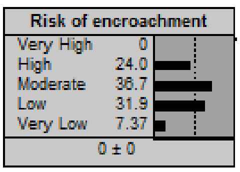

Figure 7 summarizes the modelling and risk assessment process illustrating the process conceptually and shows three possible cases. The first two cases show the difference in risk between two near identical sites but with different levels of current encroachment. The third shows a different spread in the probability distribution.

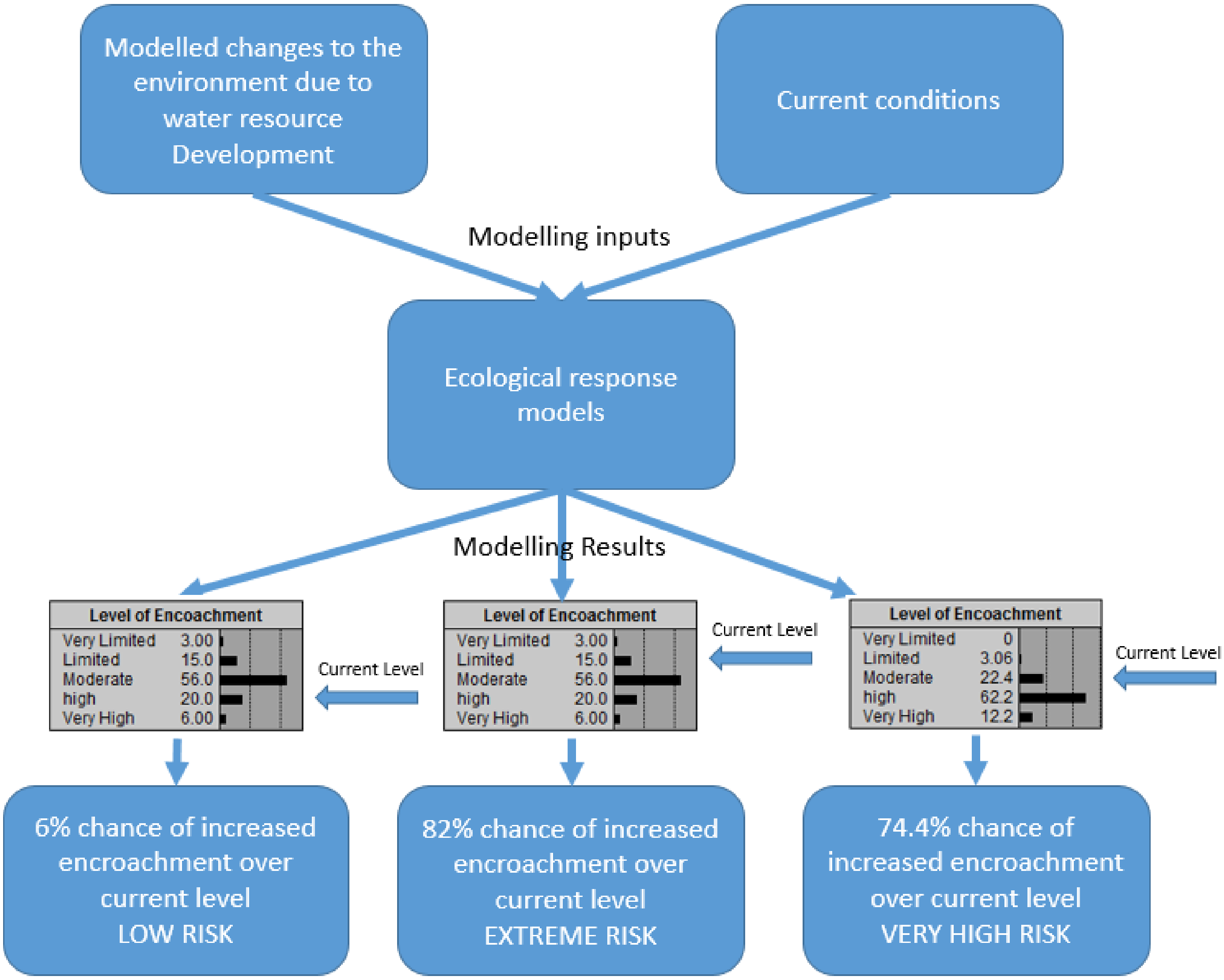

Figure 7: Summarised modelling and risk assessment process showing three examples cases (note: risk levels based on a simple 20% split for risk categories, risk levels used in the final reporting may differ).

The results can be averaged up across at different scales (e.g. catchments, reach types or the whole island) to provide NR KI and the Kangaroo Island NRM Board with an indication about the water resource management that will work best for each scale. Alternatively, the results can be used at an individual subcatchment level to inform management at the subcatchment scale.

6 Ongoing monitoring recommendations

The environmental assessment of water management options for Kangaroo Island project is a five-year project with defined outcomes. The project seeks to increase the understanding of the impacts of water resources development on Kangaroo Island. At the completion of this program, the board will have additional information to better inform the development of water use limits and policies to meet the strategic objectives outlined in the NRM Plan.

This plan describes the monitoring required to achieve the outcomes required for the project, however, it is acknowledged that ongoing monitoring of the water dependent ecosystems of Kangaroo Island may be required to:

1. provide an evaluation of any updated policies
2. continue data collection for future refinement of hydro-ecological evaluation
3. engage the community of Kangaroo Island about water resource management and its impacts on the condition of water dependent ecosystems.

In other regions around South Australia, citizen science approaches to data collection have been implemented to great effect. Specific and relevant examples include the BioBlitz program that has been implemented in the Eastern Mt Lofty Ranges to facilitate data collection on water dependent ecosystems (Miles et al. 2016) and subsequent expansions of this program to the Marne Saunders Prescribed Water Resources Area. These programs have been developed to allow for the collection of high quality, quality checked data as a significantly reduced cost while at the same time increasing community engagement.

In order to support the board with future water resource development investigation as well as maintaining an understanding of the current condition of the water dependent ecosystems of the island, it is recommended that a community monitoring program be developed alongside the monitoring program such that there can be ongoing monitoring of water resources. Following the model already is use across other areas of the state should allow for a smooth transition from the project monitoring process outlined in this document to the community that will allow for the outcomes listed above to be achieved.

7 Appendices

7.1 Appendix 1 – List of the processes referred to in the conceptual model shown in Section 4.1.

Link number	Process or impact	Explanation	Evidence/references
1	Water requirements for agricultural production	Various types of landuse require the active consumption and use of water. In order to provide for these requirements, water resources will be modified and developed.	Impacts of landuse and water resource development of aquatic ecosystems (Lake & Bond, 2007) Links between land use and ET on catchment hydrology (Dunn & Mackay, 1995)
2	Changes to rainfall/runoff relationships	The landuse will affect how water that falls as rainfall onto the land behaves.	KI specific calculations - Whiting and Green (2015)
3	Reduction of water quality	Direct impact on water quality by increasing nutrient inputs (fertilizers, animal waste).	Overview and scale discussion - (Allan, 2004; Buck et al., 2004) Nutrient runoff - (Quinn et al., 1997)
4	Clearing of riparian habitat	The clearance of land for productive use leads to reduction of, or total removal of the vegetation of the riparian corridor.	From (Richardson et al., 2007) Land use immediately adjacent to the river (e.g. cultivation of crops) may increase sediment deposition and eutrophication (Ferrar et al., 1988; Hancock et al., 1996; Kentula, 1997; Patten, 1998). Logging (Hancock et al., 1996; MacNally et al., 2001; Apan et al., 2002; Iwata et al., 2003), grazing and trampling (Mathooko & Kariuki, 2000; Meeson et al., 2002), water extraction

			(Stromberg et al., 1996; Patten, 1998; Meeson et al., 2002; An et al., 2003), and recreation (Washitani, 2001) also affect riparian zones.
5	Differences in slope and runoff characteristics	Differences in slope will causes differences in how runoff is generated. Differences in soil-type will result in different infiltration rates leading to different runoff characteristics	
6	Rainfall	The climate drives the level of rainfall received by a catchment, which will ultimately dictate the level of flow	Extensive literature on links between changing climate and changing rainfall e.g. (Murphy & Timbal, 2008)
7	Vegetation communities adapted to climatic conditions	The vegetation communities of the Riparian corridor will have adapted to the prevailing climate.	Riparian ecosystems changes in response to changes in climate (Capon et al., 2013)
8	Damming and diversion structures holding up water	In order to gain water security, landholders build dams on water courses to capture water for productive use (irrigation, water for stock or domestic use)	Water use calculations for Kangaroo island including estimations of dam development (Whiting & Green, 2015)
9	Capturing water	Blocking structures capture all water passing a given point until the structure is full. This alters the flow regime below the blocking structure until the structure is full.	Impacts on volume of water moving downstream (KI Specific) (Whiting & Green, 2015) Dams impacts on flow regime (Alcorn, 2008, Alcorn et al., 2013, Jones-Gill and Savadamathu, 2014, Poff et al., 2007, Teoh, 2006)
10	Changes in water quality and carbon inputs	As runoff passes through the riparian corridor it is filtered increasing water quality. The vegetation of the riparian corridor also provides carbon inputs to the water course.	Evidence for the use of riparian vegetation buffers (Collins, Doscher, Rennie, & Ross, 2013; Osborne & Kovacic, 1993)
11	Microhabitats	In stream vegetation and woody debris provide additional microhabitats for aquatic fauna.	Connolly et al., 2016, Dobkin et al., 1998, Gregory et al., 1992, Naiman et al., 2008, Opperman and Merenlender, 2004, Pettit et al., 2013
12	Increasing levels of intermittency	The level of intermittency is driven by the low flow component of the flow regime. It is one of the key components of the flow regime	Jones-Gill & Savadamathu, 2014; Teoh, 2006

		for the biota of intermittent rivers.	
13	Reducing flow volume	The volume of flow is one of the key components of the flow regime for the biota of intermittent rivers.	Impacts on volume of water moving downstream (KI Specific) (Whiting & Green, 2015)
14	Fluctuations in water level	Changing flows will lead to the successive inundation and drying of habitats along the river channel leading to the inundation of different microhabitats.	Importance of flow regime (Poff et al., 1997, Poff et al., 2007, Poff and Zimmerman, 2010, Kennard et al., 2010)
15	Maintenance of permanent pools	Resistant macroinvertebrates are able to tolerate harsh conditions for periods of time that vary from taxa to taxa. The longer the cease to flow period, the more likely refuge habitats (permanent pools) will become inhospitable, or completely dry.	Goyder Mt Lofty Ranges Work (Maxwell, Green, & Peeters, in prep.) Intermittency as a master variable (Datry et al., 2014)
16	Maintenance of permanent pools	Resistant macroinvertebrates are able to tolerate harsh conditions for periods of time that vary from taxa to taxa. The longer the cease to flow period, the more likely refuge habitats (permanent pools) will become inhospitable, or completely dry.	Goyder Mt Lofty Ranges Work (Maxwell, Green, & Peeters, in prep.) Intermittency as a master variable (Datry et al., 2014)
17	Flows through Riffles, increased pool depth	Aquatic and riparian vegetation are adapted to different levels of inundation. Changes to the level of intermittency will lead to changes in the duration of inundation, particularly in the riffle sections resulting in changes in the vegetation community, including the invasion of terrestrial plants.	Goyder Mt Lofty Ranges vegetation work (Maxwell, Green, Nicol, et al., in prep.) Reponses to flow overview (Merritt, Scott, Poff, Auble, & Lytle, 2010)
18	Maintenance of permanent pools	The freshwater fish of Kangaroo Island are able to tolerate harsh conditions for periods of time that vary from taxa to taxa. The longer the cease to flow period, the more likely refuge habitats (permanent pools) will become inhospitable, or completely dry.	Goyder Mt Lofty Ranges fish work (Schmarr unpublished) EWRs of KI Fish (McNeil & Fredberg, 2011)
19	Maintenance of permanent pools, flow triggers	Aside from the maintenance of permanent pools, diadromous fish rely on flow triggers for their migration both upstream and downstream.	Goyder Mt Lofty Ranges fish work (Schmarr unpublished) Flow regime triggers example (Jowett, Richardson, & Bonnett, 2005)

			EWRs of KI Fish (McNeil & Fredberg, 2011)
20	Dilution of water	The longer the cease to flow the poorer that water quality in permanent pools becomes due to evapo-concentration and nutrient processes. Flows will dilute the water in the pools, increase dissolved oxygen and improve water quality in general.	Role of flow in maintaining water quality (Sheldon & Fellows, 2010)
21	Inundation of vegetation	Aquatic and riparian vegetation are adapted to different levels of inundation. Changes to the level of intermittency will lead to changes in the duration of inundation, particularly in the riffle sections resulting in changes in the vegetation community, including the invasion of terrestrial plants.	Goyder Mt Lofty Ranges vegetation work (Maxwell, Green, Nicol, et al., in prep.) Reponses to flow overview (Merritt et al., 2010) EWRs of KI Fish (McNeil & Fredberg, 2011)
22	Dispersal flows and habitat inundation	Freshwater fish require larger flows to disperse. They also require larger flows to inundate habitat used for spawning or to flush breeding sites of silt and other debris.	EWRs of KI Fish (McNeil & Fredberg, 2011)
23	Dispersal flows and habitat inundation	Diadromous fish require larger flows to trigger dispersal up into the freshwater habitat as well as carry larval fish back downstream. They also require larger flows to inundate habitat used for spawning or to flush breeding sites of silt and other debris.	EWRs of KI Fish (McNeil & Fredberg, 2011)
24	Freshening of estuarine water, triggers for breeding	Estuarine fish live in a habitat that fluctuates between a marine and a freshwater environment. Many of the processes are reliant on the freshwater inputs including breeding triggers and nutrient, sediment and food inputs	EWRs of KI Fish (McNeil & Fredberg, 2011)
25	Dilution and flushing	Larger flow volumes will flush the river system, removing salts, nutrients and sediments, providing fresher water.	Role of flow in maintaining water quality (Sheldon & Fellows, 2010)
26	Provision of microhabitats	The greater the habitat complexity, the more microhabitats there will be for different taxa to colonise, increasing the diversity of resistant taxa.	Review of habitat complexity literature and knowledge gap identification (Kovalenko, Thomaz, & Warfe, 2012)
27	Provision of microhabitats	The greater the habitat complexity, the more microhabitats there will be for different taxa to colonise, increasing the diversity of resilient taxa.	Review of habitat complexity literature and knowledge gap identification (Kovalenko et al., 2012)

28	Provision of microhabitats	The greater the habitat complexity, the greater the opportunities for feeding, breeding and avoiding predation are, leading to healthy populations of freshwater fish	Review of habitat complexity literature and knowledge gap identification (Kovalenko et al., 2012)
29	Provision of microhabitats	The greater the habitat complexity, the greater the opportunities for feeding, breeding and avoiding predation are, leading to healthy populations of diadromous fish	Review of habitat complexity literature and knowledge gap identification (Kovalenko et al., 2012)
30	Provision of microhabitats	The greater the habitat complexity, the greater the opportunities for feeding, breeding and avoiding predation are, leading to healthy populations of estuarine fish	Review of habitat complexity literature and knowledge gap identification (Kovalenko et al., 2012)
31	Taxa tolerances	Resistant macroinvertebrate taxa generally have a high tolerance to degrading water quality, however, as water quality declines there will be reductions in species diversity.	Macroinvertebrate traits (Maxwell, Green, & Peeters, in prep.; Schafer et al., 2011)
32	Taxa tolerances	Resilient macroinvertebrate taxa are generally not as tolerant of degrading water quality as resistant species and will show reductions in species diversity with degrading water quality.	Macroinvertebrate traits (Maxwell, Green, & Peeters, in prep.; Schafer et al., 2011)
33	Taxa tolerances	The freshwater fish that are found on Kangaroo Island are tolerant of low water quality, in particular, salinity. However, degrading water quality will lead to reduced health and recruitment success.	EWRs of KI Fish (McNeil & Fredberg, 2011)
34	Taxa Tolerances	The diadromous fish of Kangaroo Island have variable tolerances to degraded water quality at different points in their lifecycle. In general, degraded water quality will lead to reduced health and recruitment success.	EWRs of KI Fish (McNeil & Fredberg, 2011)
35	Taxa Tolerances	Estuarine fish are, in general, less reliant on water quality from the freshwater system that the freshwater fish. However, the water quality does have an effect on the health of the estuary in general, including vegetation communities and food web production. All of which will impact the health and recruitment of estuarine fish.	EWRs of KI Fish (McNeil & Fredberg, 2011)
36	Nutrient and salinity	Aquatic and riparian vegetation are adapted to different levels of nutrients and salinity. Salinity is likely to be a more significant	Salinity effects on aquatic ecosystems (Hart, Lake, Webb, & Grace, 2003)

	concentrations	driver.	Excess nutrient impacts on aquatic ecosystems (Smith, Tilman, & Nekola, 1999)
37 and 38	Species and functional diversity	Macroinvertebrate community condition is driven by the diversity of functions (traits) and species.	Macroinvertebrate traits (Maxwell, Green, & Peeters, in prep.; Schafer et al., 2011) EPA Condition Assessments (EPA, 2014)
39, 40 and 41	Species and functional diversity	Fish community condition is driven by the diversity of species as well as the relative numbers of those species.	Macroinvertebrate traits (Maxwell, Green, & Peeters, in prep.; Schafer et al., 2011) EPA Condition Assessments (EPA, 2014)

7.2 Appendix 2 – Indicator evaluation for possible indicators for use in the monitoring project for Kangaroo Island

Riparian vegetation condition	Current information	Reflects ecological values	Ease of interpretation	Predictable response	Scale of response	Relative cost	Relation to management levels	Scientifically defensible	Pre-existing knowledge
Biotic									
Macroinvertebrate community condition	Several sites previously surveyed across the island. Established methods	Often used as a surrogate for overall aquatic ecosystem condition. Functional and sensitivities vary greatly across the community allowing for changes to be linked to threatening processes	Simple metrics such as species diversity and trait diversity are commonly used as simple to interpret metrics. More complex interpretation through trait analysis and individual species sensitivities possible through expert investigation	General trends in diversity and for specific trait groups are well understood and demonstrated, however, the community responds to a wide array of drivers and interpreting changes needs to be undertaken with these other drivers in mind.	Site scale	Moderate to high depending on methods	Strong links to changes in flow intermittency and water quality	Commonly used in the scientific literature as an indicator, though specific considerations need to be made to reflect regional characteristics.	State-wide macroinvertebrate monitoring undertaken by the EPA, including Kangaroo Island. Goyder Response models.
Proportion of resistant macroinvertebrate trait groups	Data can be extracted from previous sampling. Traits groups identified	These species are generally considered to be the more tolerant species of macroinvertebrate, capable of surviving, and doing well, in degraded conditions	While easy to interpret, changes are often related to abundance of particular species, requiring additional data to be collected	as for Macroinvertebrate community condition	Site scale	Moderate to high depending on methods (Possible use of Citizen Science)	weak links to changes in flow intermittency and water quality	Resistant macroinvertebrates are rarely used as an indicator of community health as they are considered to be tolerant to changes in conditions and may not reflect changes to other components of the macroinvertebrate community.	State-wide macroinvertebrate monitoring undertaken by the EPA, including Kangaroo Island. Goyder Response models.
Proportion of resilient macroinvertebrate trait groups	Data can be extracted from previous sampling. Traits groups identified	Often referred to as 'sensitive' macroinvertebrate taxa, these species are considered to be the key drivers of macroinvertebrate community value. Generally the first groups to respond the changes in the environment	reduction in resilient taxa easily interpretable and generally well understood	as for Macroinvertebrate community condition	Site scale	Moderate to high depending on methods (Possible use of Citizen Science)	Strong links to changes in flow intermittency and water quality	Commonly used in the scientific literature as an indicator, though specific considerations need to be made to reflect regional characteristics.	State-wide macroinvertebrate monitoring undertaken by the EPA, including Kangaroo Island. Goyder Response models.
Riparian vegetation condition	Limited surveys conducted of taxa, good spatial information of riparian vegetation extent	Riparian and aquatic vegetation are often the most visual representation of the condition of WDEs. The condition and diversity of the vegetation reflects and has influence over many processes in WDEs.	Species diversity easily interpretable. Changes in structure and location relative to the watercourse visually assessable and easy to interpret. Invasion of terrestrial vegetation easily interpretable.	Species diversity and location on the bank are generally predictable in areas where growth is allowed (not grazed). Increasing terrestrial vegetation linked to reduction in flows.	Site scale	Moderate to low	Changes to vegetation occur over longer time periods but occur due to changes to flow regime and water quality.	The use of riparian vegetation as an indicator is becoming increasing common in condition assessments as models of the occurrence become more robust	Goyder Response models. Some existing time series photos from Tom Neilson's project.
Terrestrial vegetation encroachment	Limited surveys conducted of taxa, good spatial information of riparian vegetation extent	The encroachment of terrestrial vegetation represents the loss of ecological diversity and structure	Proportion of terrestrial vegetation in the channel is an easy metric to interpret	Changes in vegetation cover and species distribution generally predictable. Confounding factors need to be considered e.g. Grazing	Site scale	Moderate to low	Changes to vegetation occur over longer time periods but occur due to changes to flow regime and water	The use of riparian vegetation as an indicator is becoming increasing common in condition assessments as models of the occurrence become	Goyder Response models. Some existing time series photos from Tom Neilson's project.

							quality.	more robust	
Fish Community Condition	Previous sampling on island	Fish are likely the apex predator in many of the streams of KI. While the diversity is low, the species present and generally considered to be sensitive and flow responsive. Therefore, they will be responsive to changes flow	Species diversity and population demographics are easy to interpret as changes can be traced back to key drivers	In general the response of the fish species found on KI are understood, however, confounding factors will need to be considered	Reach scale	High	Management to protect permanent pools and flowing habitat are key to maintaining populations	Commonly used in the scientific literature as an indicator, though specific considerations need to be made to reflect regional characteristics.	Goyder response models still under development. Additional fish records from across the state.
Freshwater Fish abundance and demographics	Previous sampling on island	Fish are likely the apex predator in many of the streams of KI. While the diversity is low, the species in this group and generally considered to be sensitive and flow responsive. Therefore, they will be responsive to changes flow	Species diversity and population demographics are easy to interpret as changes can be traced back to key drivers	In general the response of the fish species found on KI are understood, however, confounding factors will need to be considered	Reach scale	Moderate to high depending on methods (Possible use of Citizen Science)	Management to protect permanent pools and flowing habitat are key to maintaining populations	Commonly used in the scientific literature as an indicator, though specific considerations need to be made to reflect regional characteristics.	Goyder response models still under development. Additional fish records from across the state.
Diadromous Fish abundance and demographics	Previous sampling on island	Fish are likely the apex predator in many of the streams of KI. While the diversity is low, the species present and generally considered to be sensitive and flow responsive. Therefore, they will be responsive to changes flow. Diadromous species of fish are also restricted by barriers to fish passage and will provide additional information about barriers across the island.	Species diversity and population demographics are easy to interpret as changes can be traced back to key drivers	In general the response of the fish species found on KI are understood, however, confounding factors will need to be considered	Reach scale	Moderate to high depending on methods (Possible use of Citizen Science)	Management to protect permanent pools and flowing habitat as well as minimise barriers to fish movement are key to maintaining populations	Commonly used in the scientific literature as an indicator, though specific considerations need to be made to reflect regional characteristics.	Goyder response models still under development. Additional fish records from across the state.
Abiotic									
Salinity	Extensive sampling on island, models for Cygnet River	Salinity will drive the distribution of many species on the island, and will restrict the presence of many of the more sensitive species	Increases in salinity are easily related to changes in WDE condition conceptually	Salinity responses are generally considered predictable, however, consideration needs to be given to legacy issues and contemporary drivers	sub-catchment scale (legacy), site/reach (contemporary)	low, once equipment is purchased	Low, major impacts driven by large scale changes in landuse, not as much by water resource management. Very limited opportunities to improve salinity levels	responses to changes in salinity are well documented, the issue is determining what is driving the change in salinity and does a change in development result in a change in salinity levels significant enough to alter the WDE	Links to biotic response currently conceptual or based on other studies

Intermittency (number of cease-to-flow days per year)	Flow gauges located across island	Intermittency is considered to be the 'master variable' in temporary river ecology	changes in intermittency are easy to interpret	Conceptually easy to predict response based on management actions	Reach scale	Low, once sites established	limited links to existing developments, however, new developments under updated WAA policies could have strong links	Commonly used in the scientific literature as an indicator, though specific considerations need to be made to reflect regional characteristics.	Links to biotic response currently conceptual or based on other studies
Flow Volumes	Flow gauges located across island		Changes in flow volumes need to be interpreted relative to averages as seasonal, yearly and longer cycles will be present in the data. Key changes are in relation to long term average changes	Conceptually easy to predict response based on management actions	Reach scale	Low, once sites established	limited links to existing developments, however, new developments under updated WAA policies could have strong links	Commonly used in the scientific literature as an indicator, though specific considerations need to be made to reflect regional characteristics.	Links to biotic response currently conceptual or based on other studies

7.3 Appendix 3 – Site selection prioirtisation criteria used for the selection of sites

Information	Indicator	Priority
Previous sampling	Fish	Low
	Macro	High
	Vegetation	High
	Physical	Very High
	WQ	Moderate
Development level		High
Clearance		High
Upstream land Management	Riparian Vegetation (1 km upstream)	High
	Stock access	High
	Fencing	Moderate
Forestry		Moderate
Flow data		Very High
Bioregion		Low
Landuse		High
Photopoint		Moderate
Permanent pools		High
Access		Very High

7.4 Appendix 4 – Details of the potential long-term monitoring sites

Rank	Site code	Site name	Catchment	Prioritisation score	Reason for selection
1	CYR1401	Huxtable Forest	Cygnet River	32	Site has been used for previous sampling and has current flow gauging providing calibration data for models
2	CYR3901	Koala Lodge	Cygnet River	32	Site has been used for previous sampling and has current flow gauging providing calibration data for models
3	MR0901	Johncock Rd	Middle River	32	Site has been used for previous sampling and has current flow gauging providing calibration data for models
4	MR0101	Upstream Snellings Estuary	Middle River	32	Site is representative of near end of system
5	MR1401	Coopers Rd	Middle River	32	Site is representative of an area within the development with extensive lengths of watercourse with good riparian buffers
6	SBR1201	Stunsail Boom River at South Coast Rd	Stunsail Boom River	29	Site is currently used for flow and water quality monitoring which will allow for the expansion of the modelling process outside of the Cygnet and Middle Rivers using actual data. In addition, it will provide additional calibration points for modelling
7	MR1601	North Coast Rd	Middle River	29	Site is representative of areas high in the catchment with good riparian remnant vegetation
8	RockyRvr01	US of Gorge Falls weir	Rocky River	26	Pristine reference site, South Coast a losing reach, well studied site, flow, macro water quality
9	TC1301	Timber Creek at South Coast Rd	Timber Creek	26	Site is currently used for flow and water quality monitoring which will allow for the expansion of the modelling process outside of the Cygnet and Middle Rivers using actual data. In addition, it will provide additional calibration points

					for modelling
10	MR0701	Downstream Reservoir	Middle River	26	Representative of areas with high levels of surrounding native vegetation
11	TC1201	Timber Crk US Birchmore Rd	Timber Creek	25	Mid catchment site, low demand, Central Plateau
12	SBR1001	North East R. at Gosse Ritchie Rd	North East River	25	High demand area with a mix of forestry and dry prod. Good riparian vegetation
13	CYR5101	Lower Gum Creek	Cygnet River	24	Site is represented of highly cleared catchments, including cleared riparian vegetation
14	HR0501	DS of 2 Wheeler Crk	Harriet River	23	level monitoring, lower reaches of Central Plateau
15	TC0901	Little Timber Crk US Birchmore Rd	Timber Creek	22	Downstream of forestry over subcatchment limit, Central Plateau
16	CYR1301	Pioneer Bend Rd	Cygnet River	22	Site is representative of sites with high forestry development combined with good riparian vegetation
17	CYR3501	Turkey Lane Crossing	Cygnet River	21	Representative of an area over the current development limit
18	CYR4901	Upper Gum Creek	Cygnet River	20	Site is represented of headwater areas in highly cleared catchments, including cleared riparian vegetation
19	CYR0301	Downstream Springs Rd	Cygnet River	20	Site is representative of areas with current low demand and high development potential
20	WR0201	Wilson River at Wilson River Rd	Wilson River	19	Previous macroinvertebrate and on-going water quality monitoring provide data to allow for this site to be used to validate models outside of the Cygnet and Middle Rivers

21	CYR3601	Upstream Ahwans Rd	Cygnet River	18	Representative of sites at or close to the current development limit
22	CYR4601	Brown Creek upstream Duck Lagoon	Cygnet River	17	Site is representative of areas with high dam development, no forestry
23	CYR0501	Bark Hut Road	Cygnet River	16	Site is representative of a mixed use catchment with intensive forestry and differing levels of dam development
24	RockyRvr02	Melrose East	Rocky River	14	Pristine reference site, Central Plateau, losing reach, well studied site, shallow logged piezo, macros
25	SSB0101	North West River at Walsh Track	Stunsail Boom River	14	Previous macroinvertebrate and on-going water quality monitoring provide data to allow for this site to be used to validate models outside of the Cygnet and Middle Rivers
26	HR0801	Harriet River East West Hwy Crossing	Harriet River	13	Previous macroinvertebrate and on-going water quality monitoring provide data to allow for this site to be used to validate models outside of the Cygnet and Middle Rivers
27	SWR1101	South West River West of Kelly Lodge	South West River	13	Previous macroinvertebrate and on-going water quality monitoring provide data to allow for this site to be used to validate models outside of the Cygnet and Middle Rivers
28	RockyRvr03	Headwaters	Rocky River	12	Pristine reference site, Central Plateau, A gaining reach, well studied
29	CYR4001	Chain of Ponds	Cygnet	12	A flood overflow site on the Cygnet
30	ER0601	Eleanor River at Seddon Cons Park	Eleanor River	11	On-going water quality monitoring provide data to allow for this site to be used to validate models outside of the Cygnet and Middle Rivers
31	TC0101	Playford Hwy	Timber Creek	10	Upper catchment, Central Plateau downstream of a large dam
32	ER0501	Narroonda	Eleanor	10	Upper catchment site in a typical headwater site, Central Plateau,

		weir	River		gaining reach, in the lower annual rainfall catchments, a high density of small dams in a well monitored site.
33	WR0101	SE of Penneshaw (Dam 1)	Wilson River	7	Upper catchment on the Eastern Plateau

7.5 Appendix 5 – List of vegetation species that could be targeted as part of the vegetation monitoring program as suggested by Jason Nicol, SARDI Aquatic Sciences (Pers. Comm. 24th May 2016),

Taxa used for GWAP model	**Additional possible taxa**
Arctotheca calendula	Acacia paradoxa
Arundo donax	Alternanthera denticulata
Baumea spp.	Anagallis arvensis
Betula sp. (exotic)	Aster subulatus
Bolboschoenus spp.	Atriplex prostrata
Calystegia sepium	Azolla spp.
Cenchrus clandestinus	Berula erecta
Chara spp.	Carex appressa
Chenopodium album	Carex fascicularis
Cyperus gymnocaulos	Centella asiatica
Distichlis distichophylla	Chenopodium album
Echium plantagineum	Cynodon dactylon
Eucalyptus camaldulensis	Cyperus exaltatus
Exotic Annual Grasses	Cyperus vaginatus
Foeniculum vulgare	Duma florulenta
Fraxinus excelsior (exotic)	Eleocharis acuta
Fumaria bastardii	Eleocharis sphacelata
Gallium murale (exotic)	Ficinia nodosa
Juncus acutus	Hydrocotyle verticillata
Leptospermum sp.	Isolepis spp.
Medicago spp.	Juncus kraussii
Oxalis pes-caprae	Juncus usitatus
Paspalum dilatatum	Lemna sp.
Pennisetum vilosum	Ludwigia peploides
Persicaria lapathifolia	Lycopus australis
Phalaris arundinacea	Marrubium vulgare
Phragmites australis	Mimulus repens
Plantago lanceolata	Paspalum distichum
Ranunculus sp.	Phalaris arundinacea
Rumex bidens	Potamogeton crispus
Sonchus oleraceus	Potamogeton pectinatus
Trifolium spp.	Potamogeton tricarinatus
Typha domingensis	Rubus fruticosus
Vicia sativa	Schoenoplectus pungens
Watsonia meriana	Schoenoplectus validus
	Triglochin procera
	Ulex europaeus
	Villarsia reniformis
	Zantedeschia aethiopica

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