Monitoring Program for the Broken River

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A MDFRC Consultancy report for Goulburn-Broken Catchment Management Authority

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The Murray-Darling Freshwater Research Centre

Development of a Monitoring Program for the Broken River

A report prepared for Goulburn-Broken Catchment Management Authority by the Murray-Darling Freshwater Research Centre.

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Acronyms and Abbreviations used in this report

ARI	Arthur Rylah Institute for Environmental Research
BMP	Best Management Practice
CMA	Catchment Management Authority
CLM	Crown Land Management
CRP	Current Recommended Practice
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
DPI	Department of Primary Industries
DSE	Department of Sustainability
EC	Electrical Conductivity
EPA	Environment Protection Authority
FRP	Filterable Reactive Phosphorus
GB CMA	Goulburn Broken Catchment Management Authority
ISC	Index of Stream Condition
MDBC	Murray-Darling Basin Commission
MDFRC	Murray Darling Freshwater Research Centre
ML	Mega litre (1,000,000 litres)
MSOMP	Major Storages Operational Monitoring Program
MU	Management Unit
NH_4	Ammonia
NOx	Oxidised Nitrogen
NRMMC	Natural Resource Management Ministerial Commission.
RHA	Rapid Habitat Assessment
RRHS	Regional River Health Strategy
RTA	Riparian Trend Assessment
SRA	Sustainable Rivers Audit
TKN	Total Kjeldahl Nitrogen
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
VCMC	Victorian Catchment Management Council
VQA	Vegetation Quality Assessment
VWQMN	Victorian Water Quality Monitoring Network
VWRDW	Victorian Water Resources Data Warehouse
WES	Water ECOscience

Executive Summary

The Broken River is a mid-slope tributary of the Goulburn River which rises in the highlands near Tolmie and flows in a westerly direction joining the Goulburn River at Shepparton. The river experiences variable flows with the period between July and September accounting for over half of the annual flow while historically the river experienced both floods and prolonged periods of low flow. The reservoirs on the river provide water for stock, domestic and irrigation supplies

The objective of the Goulburn Broken Catchment Management Authority (GB CMA) is to protect and improve the ecological health of the catchments land and water resources while maintaining it's commitment to the sustainability of the region and its community. In developing the Regional River Health Strategy, the GB CMA identified river health and waterway management to be its highest priority natural resource management issue within the catchment.

The Broken River was identified as a high priority waterway due to its high value assets of environmental significance, including its populations of Murray cod, Silver and Macquarie perch, and its association with wetlands of national significance. Key actions in the Strategy for the Broken River include:

- enhance flow regimes;
- improve passage for native fish species;
- improve water quality;
- enhance in-stream diversity; and
- protect riparian and floodplain zones

The purpose of this report is to recommend an appropriate monitoring program to assess the impacts of the management initiatives that the GB CMA implements on the Broken River. A variety of characteristics have been identified as potential threats to high value assets on the Broken River. These include: (i) Barriers to fish migration; (ii) Stock Access; (iii) Water Quality ; (iv) Introduced Fauna and Flora ; (v) Bed Instability, Channel Modification, Loss of in-stream habitat; (vi) Flow deviation; and (vii) Degraded Riparian Vegetation.

The following suite of indicators is recommended to be monitored to provide information on the success of the management actions implemented. (i) Fish migration; (ii) Fish community assemblages; (iii) Water quality – including nutrients and temperature; (iv) Flow Deviation; and (v) Index of Stream Condition (ISC).

More specifically, the Goulburn Broken Regional River Health Strategy (GB CMA 2005) identified desired outcomes from the implementation of their management initiatives, which formed Resource Condition Targets. This monitoring program provides recommendations for monitoring the success of the management initiatives in reaching these Resource Condition Targets. Many of the Resource Condition Targets listed are a change in environmental condition; however there are several Resource Condition Targets that need to be defined that are reliant on either risk assessments, reviews or infrastructure works to be undertaken.

The recommendations in this monitoring program are made considering the two types

of monitoring which apply to each resource condition target. These are:

1. monitoring using environmental indicators to detect a change in environmental condition; and
2. compliance monitoring which assess if management initiatives have been implemented.

A summary of the recommendations made for monitoring using both methods are as follows:

1. Measure EC, turbidity, pH, DO, TSS samples as part of assessment of current condition.
2. A site immediately above Lake Nillahcootie added to the sites currently being monitored for water quality and nutrients.
3. Nutrients to be monitored for TP.
4. Flow or gauge heights measured to calculate loads.
5. Temperature loggers should be deployed upstream, within and at three sites below Lake Nillahcootie.
6. The gauge downstream of Bridge Creek is upgraded to measure the suite of parameters currently monitored by the other gauges.
7. The ISC monitoring is continued.
8. Conduct Riparian Trend Assessment in between the ISC Streamside Zone Sub-index monitoring surveys as an interim indicator of change in Riparian Vegetation.
9. The ISC monitoring is continued.
10. Continue monitoring of Casey's weir fishway.
11. Install fishway at Gowangardie weir (compliance monitoring)
12. Investigate the installation of a fish way at Lake Nillahcootie (compliance monitoring)
13. Sampling for fish abundance, and richness is recommenced in M2.
14. Sampling for fish to be continued in M1 and L5.
15. Sites for fish monitoring be established in M1 above Lake Benalla.
16. Continue with existing monitoring program for Macroinvertebrates.

An overall monitoring framework for each management unit including site and parameter selection, frequency of sampling and justification have been outlined in the following tables which is designed to assist the GB CMA in the implementation of the monitoring program.

Site and Parameter selection for Management Unit L5 (Reaches 1 and 2)

The lower Broken River (Reaches 1 & 2) extends from the Broken Rivers confluence with the Goulburn River to downstream of Casey's Weir. There are two ISC reaches in this Management Unit, and five sites have been recommended for monitoring (Table 1, Figure 3). Taking into consideration the impoundment on this section of the River two sites are located between the Broken Rivers confluence with the Goulburn River and Gowangardie Weir. Two sites are located between Gowangardie Weir and Casey's Weir, and one site is located at the Gowangardie Weir Head Gauge.

Table 1. Overall Monitoring Framework for Mgt. Unit L5

Site	Justification of Site Selection.	Parameter	Justification of parameter	Sampling Frequency	Justification of Frequency (power analysis)
Keats Road	Site situated between Broken River's confluence with the Goulburn River and Gowangardie Weir and has extensive background data.	Fish Community Assemblages	Directly addresses RCT. See Table 7	Initial sampling should be seasonal, scaled back to twice per year between 1st November and 30th April	See section 3.13
Cosgroves Road	Site situated between Broken River's confluence with the Goulburn River and Gowangardie Weir and has extensive background data.	Fish Community Assemblages	Directly addresses RCT. See Table 7	Initial sampling should be seasonal, scaled back to twice per year between 1st November and 30th April	See section 3.13
Gowangardie Weir	As determined by RCT	Water Quality	Directly addresses RCT. See Table 7	TBD (See Table 10)	TBD (See Table 10)
	As determined by RCT	Total Phosphorus (TP)	Directly addresses RCT of reduction in Phosphorus exports at gauge 404224.	Fortnightly; Measure more frequently during an event such as a flood or prolonged periods of low flow.	See section 3.9

Site	Justification of Site Selection.	Parameter	Justification of parameter	Sampling Frequency	Justification of Frequency (power analysis)
	Consistent with sampling other parameters at this site.	Hydrology (Flow)	Must measure flow addition to TP to calculate loads.	Simultaneous with TP samples	See section 3.9.
	As determined by RCT	Fish Migration	Directly addresses RCT. See Table 10.	As determined by ARI	As determined by ARI
Gowangardie Weir Up Stream	Site situated between Gowangardie and Casey's weir and has extensive background data.	Fish Community Assemblages	Directly addresses RCT. See Table 7.	Initial sampling should be seasonal, scaled back to twice per year between 1st November and 30th April	See section 3.13
Quinn Road	Site situated between Gowangardie and Casey's weir and has extensive background data.	Fish Community Assemblages	Directly addresses RCT. See Table 7.	Initial sampling should be seasonal, scaled back to twice per year between 1st November and 30th April	See section 3.13
ISC Reach 1	As determined by RCT	ISC Physical Form Sub-index	Directly addresses RCT. See Table 7	Every 5 Years	As determined by ISC
		ISC Streamside Zone Sub-index	Directly addresses RCT. See Table 7	Every 5 Years	As determined by ISC
		Riparian Trend Assessment	Initial performance indicator for Riparian Vegetation in between ISC surveys.	Every 2 years in between ISC	Provides short term monitoring (<5 yrs)
ISC Reach 2	As determined by RCT	ISC Physical Form Sub-index	Directly addresses RCT. See Table 7	Every 5 Years	As determined by ISC
		ISC Streamside Zone Sub-index	Directly addresses RCT. See Table 7	Every 5 Years	As determined by ISC
		Riparian Trend Assessment	Initial performance indicator for Riparian Vegetation in between ISC surveys.	Every 2 years in between ISC	Provides short term monitoring (<5 yrs)

Site and Parameter selection for Management Unit M1 (Reaches 3 and 4)

The mid Broken River (Reaches 3 & 4) extends from downstream of Casey's Weir to the downstream wall of Lake Nillahcootie and has two ISC reaches. Based on Resource Condition Targets for this Management Unit, also taking into consideration the impoundments on this section of the River, six sites have been recommended for monitoring (Table 2, Figure 3). One site is located at Casey's Weir Head Gauge; two sites are located between Casey's Weir and Lake Benalla and three sites are located between Lake Benalla and Lake Nillahcootie.

Table 2. Overall Monitoring Framework for Mgt. Unit M1

Site	Justification of Site Selection	Parameter	Justification of Parameter	Sampling Frequency	Justification of Frequency (power analysis)
Goorambat (Casey's weir head gauge)	As determined by RCT.	Water Quality.	Directly addresses RCT. See Table 8.	TBD (See Table 10).	TBD (See Table 10).
	As determined by RCT.	Total Phosphorus.	Directly addresses RCT of reduction in Phosphorus exports at gauge 404216.	Fortnightly; Measure more frequently during an event such as a flood or prolonged periods of low flow.	See section 3.9.
	Consistent with sampling other parameters at this site.	Hydrology.	Must measure flow addition to TP to calculate loads.	Simultaneous with TP sampling.	See section 3.9.
	As determined by RCT	Fish Migration.	Directly addresses RCT. See Table 8.	As determined by ARI.	As determined by ARI.
Casey's Weir Upstream	Site situated between Casey's Weir and Lake Benalla and has extensive background data.	Fish Community Assemblages.	Directly addresses RCT. See Table 8.	Initial sampling should be seasonal, scaled back to twice per year between 1st November and 30th April.	See section 3.13.

Site	Justification of Site Selection	Parameter	Justification of Parameter	Sampling Frequency	Justification of Frequency (power analysis)
Scholes Road	Site situated between Casey's Weir and Lake Benalla and has extensive background data.	Fish Community Assemblages.	Directly addresses RCT. See Table 8.	Initial sampling should be seasonal, scaled back to twice per year between 1st November and 30th April.	See section 3.13.
Yin Barun Road	As determined by RCT.	Temperature.	Directly addresses RCT. See Table 8.	TBD (See Table 10).	TBD (See Table 10).
	Site situated between Lake Benalla and Lake Nillahcootie.	Fish Community Assemblages.	Directly addresses RCT. See Table 8.	Initial sampling should be seasonal, scaled back to twice per year between 1st November and 30th April.	See section 3.13.
Swanpool Road (Moorngag)	As determined by RCT.	Water Quality.	Directly addresses RCT. See Table 8.	TBD (See Table 10).	TBD (See Table 10).
	As determined by RCT.	Total Phosphorus.	Directly addresses RCT of reduction in Phosphorus exports.	Fortnightly; Measure more frequently during an event such as a flood or prolonged periods of low flow.	See section 3.9.
	Consistent with sampling other parameters at this site.	Hydrology.	Must measure flow addition to TP to calculate loads.	Simultaneous with TP sampling.	Must be measured simultaneous to TP sampling.
	Site situated between Lake Benalla and Lake Nillahcootie.	Fish Community Assemblages.	Directly addresses RCT. See Table 8.	Initial sampling should be seasonal, scaled back to twice per year between 1st November and 30th April.	See section 3.13.
	As determined by RCT.	Temperature.	Directly addresses RCT. See Table 8.	TDB (See Table 10). Recommendation is daily logging.	TBD (See Table 10).

Site	Justification of Site Selection	Parameter	Justification of Parameter	Sampling Frequency	Justification of Frequency (power analysis)
Lima South	As determined by RCT.	Temperature.	Directly addresses RCT. See Table 8.	TBD (See Table 10). Recommendation is daily logging.	TBD (See Table 10).
ISC Reach 3	As determined by RCT.	ISC Physical Form Sub-index.	Directly addresses RCT. See Table 8.	Every 5 Years.	As determined by ISC.
		ISC Streamside Zone Sub-index.	Directly addresses RCT. See Table 8.	Every 5 Years.	As determined by ISC.
		Riparian Trend Assessment.	Initial performance indicator for Riparian Vegetation in between ISC surveys.	Every 2 years in between ISC.	Provides short term monitoring (<5 yrs).
ISC Reach 4	As determined by RCT.	ISC Physical Form Sub-index.	Directly addresses RCT. See Table 8.	Every 5 Years.	As determined by ISC.
		ISC Streamside Zone Sub-index.	Directly addresses RCT. See Table 8.	Every 5 Years.	As determined by ISC.
		Riparian Trend Assessment.	Initial performance indicator for Riparian Vegetation in between ISC surveys.	Every 2 years in between ISC.	Provides short term monitoring (<5 yrs).

Site and Parameter selection for Management Unit M2 (Reaches 5 and 6)

The upper Broken River (Reach 5) extends from the downstream wall of Lake Nillahcootie two immediately upstream of the Lake. It has two ISC reaches however only Reach 5 is recognised as a High Priority Reach due to the presence of Murray cod and Macquarie perch. Based on Resource Condition Targets for this Management Unit, three sites have been recommended for monitoring (Table 3, Figure 3). One site is located at Lake Nillahcootie Head Gauge; one site is located directly above the lake, and another site located further upstream near Reach 6. This site has been added to monitor fish community assemblages.

Table 3. Overall Monitoring Framework for Mgt. Unit M2

Site	Justification of Site Selection	Parameter	Justification of Parameter	Sampling Frequency	Justification of Frequency (power analysis)
Lake Nillahcootie Head Gauge	Consistent with sampling water quality at other sites. There is existing baseline water quality data for this site.	Water Quality.	Will contribute to overall water quality assessment.	Fortnightly; Measure more frequently during an event such as a flood or prolonged periods of low flow.	See section 3.9.
	As determined by RCT.	Total Phosphorus.	Directly addresses RCT of reduction in Phosphorus exports.	Fortnightly; Measure more frequently during an event such as a flood or prolonged periods of low flow.	See section 3.9.
	Consistent with sampling other parameters at this site.	Hydrology.	Must measure flow addition to TP to calculate loads.	Simultaneous with TP sampling.	Must be measured simultaneous to TP sampling.
	As determined by RCT.	Fish Migration.	Directly addresses RCT. See Table 9.	TBD (see Table 10).	TBD (see Table 10).
	As determined by RCT.	Temperature.	Directly addresses RCT. See Table 9.	TBD (see Table 10).	TBD (see Table 10).

Site	Justification of Site Selection	Parameter	Justification of Parameter	Sampling Frequency	Justification of Frequency (power analysis)
Lake Nillahcootie Rd @ Barjarg	There is existing data for fish at this site. This site is also within Reach 5 of management unit M2 which is recognised as a High Priority Reach.	Fish Community Assemblages.	Directly addresses RCT. See Table 9.	Initial sampling should be seasonal for the first two years then scaled back to twice per year between 1st November and 30th April.	See section 3.13.
	As determined by RCT.	Temperature.	Directly addresses RCT. See Table 9.	TBD (see Table 10).	TBD (see Table 10).
	As determined by RCT.	Total Phosphorus.	Directly addresses RCT of reduction in Phosphorus exports.	Fortnightly; Measure more frequently during an event such as a flood or prolonged periods of low flow.	See section 3.9.
Old Tolmie Rd at Barwite	This site has been chosen to sample fish as it covers the top of Management Unit M2 and there is limited fish data available for this reach.	Fish Community Assemblages.	Need to obtain baseline condition for Reach 6. Will complete the representation of fish community across the entire Management Unit.	Initial sampling should be seasonal for the first two years then scaled back to twice per year between 1st November and 30th April.	See section 3.13.
ISC Reach 5	As determined by RCT.	ISC Physical Form Sub-index.	Directly addresses RCT. See Table 9.	Every 5 Years.	As determined by ISC.
		ISC Streamside Zone Sub-index.	Directly addresses RCT. See Table 9.	Every 5 Years.	As determined by ISC.
		Riparian Trend Assessment.	Initial performance indicator for Riparian Vegetation in between ISC surveys.	Every 2 years in between ISC.	Provides short term monitoring (<5 yrs).
ISC Reach 6	As determined by RCT.	ISC Physical Form Sub-index.	Directly addresses RCT. See Table 9.	Every 5 Years.	As determined by ISC.
		ISC Streamside Zone Sub-index.	Directly addresses RCT. See Table 9.	Every 5 Years.	As determined by ISC.

Site	Justification of Site Selection	Parameter	Justification of Parameter	Sampling Frequency	Justification of Frequency (power analysis)
		Riparian Trend Assessment.	Initial performance indicator for Riparian Vegetation in between ISC surveys.	Every 2 years in between ISC.	Provides short term monitoring (<5 yrs).

1. Introduction

1.1. Vision

> "*Healthy rivers, streams, wetlands, floodplains and adjacent lands that support a vibrant range and abundance of natural environments, provides water for human use, sustains our native flora and fauna and provides for our social, economic and cultural values"* (GB CMA 2005)

1.2. Goulburn Broken Regional River Health Strategy

In 2004, the Victorian State Government released the White Paper "Our Water, Our Future – Securing Our Water Future Together" in which Catchment Management Authorities were given a greater role in managing the health of Victoria's rivers and streams.

In response to the White Paper the GB CMA developed the Goulburn Broken Regional River Health Strategy. The strategy was developed in accordance with government policies and strategies, and provides a framework for integration of actions, that enable rivers of high quality to be protected and others to be improved in quality for current and future generations.

Specific objectives of the strategy for the Broken River are "*To allocate water resources in a way that balances the needs of the environment with those of water users and to improve the ecological health of the Broken River, and associated wetlands and floodplains*" (GB CMA, 2005).

Key actions in the Strategy for the Broken River include:

- enhance flow regimes;
- improve passage for native fish species;
- improve water quality;
- enhance in-stream diversity; and
- protect riparian and floodplain zones.

1.3. The Broken River Basin

The Broken River Basin covers 770 km^2 or 3.4% of the total area of Victoria. Most of the basin has been cleared for agriculture, comprised mainly of grazing in the south and mixed cereal and livestock farming in the central region. A large part of the northern section is within the Murray Valley irrigation district which supports horticultural, dairy and livestock production. The catchment experiences hot dry summers and cool wet conditions from winter through spring with most of the rainfall occurring in this period. In the south of the catchment there is generally higher average rainfall and lower temperatures (GB CMA, 2005). The Broken River is a mid-slope tributary of the Goulburn River with a mean annual discharge of 325,000 ML (Williams, 2005). The river rises in the highlands near Tolmie and flows in a westerly direction joining the Goulburn River at Shepparton. Flows are variable between seasons and years with the period between July and September accounting for over half of the annual flow, and historically the River experiencing both floods

and prolonged periods of low flow with a minimum of 5,000 ML in the drought year (1943), to more than 1,000,000 ML in the flood years of 1917 and 1956 (GB CMA, 2005).

Two major storages have been constructed on the Broken River. Lake Nillahcootie located 35km upstream of Benalla was built in 1967, and has a storage capacity of 40,000 ML. Lake Mokoan, built in 1971, is an off-river reservoir with a capacity of 365,000 ML which can supplement flows in the lower Broken River. Lake Mokoan is expected to be decommissioned in December 2008 as part of the Victorian Government's Our Water Our Future action plan. The decommissioning of Lake Mokoan is expected to increase winter median and reduce summer median flows in the lower half of the river.

These impoundments are the primary regulating bodies in the Broken River catchment with flows released during summer and autumn, providing a reliable water supply for stock, domestic and irrigation supplies (Williams, 2005). Casey's and Gowangardie Weirs are two smaller impoundments on the Broken River, both located between Benalla and Shepparton. Water is diverted from Casey's Weir into the Broken Creek system, and is also the site where water is released from Lake Mokoan for supplementary flows to the lower Broken River. Further downstream towards Shepparton is Gowangardie Weir, where the water-level is elevated to improve diversion efficiency for adjoining water diverters.

In the GB CMA Regional River Health Strategy (2005), the Broken River has been identified as a high priority reach for the reason that it contains multiple high value assets of environmental significance. The lower Broken River is recognised as being associated with a nationally significant wetlands (1,268 ha between 8 km NNW of Benalla and Shepparton), and also contains populations of Silver perch and Murray cod which are significant threatened species. The mid and upper Broken River reaches are also considered significant because of their Murray cod and Macquarie perch populations. These high value assets are at risk from multiple threats and the RRHS management actions aim to reduce the threats in order to protect these assets.

1.4. Objectives of this Report

The GB CMA has a responsibility to monitor and evaluate "*comprehensively, efficiently and cost effectively*" the performance of the actions implemented (GB CMA, 2004). The GB CMA has stated in its Monitoring, Evaluation and Reporting Strategy (2004) that it has several objectives in collecting environmental monitoring data. These include:

- to improve understanding and demonstrate the link between cause and effect in a complex integrated system;
- to consolidate baseline monitoring efforts;
- to improve the link between technical experts, community decision makers and investigators;
- to provide direction on how to show assumptions that underpin decisions including the link between outputs and intended (and unintended) outcomes; and

- to provide direction on how to show progress via monitoring, evaluation and reporting against identified outcomes and milestones.

The GB CMA has allocated funding to a monitoring program in order to assess the effectiveness of the actions and targets set by the Regional River Health Strategy. The monitoring program will occur in three phases:

1. A review of historic monitoring.
2. Design of an appropriate monitoring program (Appendix A).
3. Implementation of the proposed monitoring program.

The first phase in this process was undertaken by Williams et al. (2005) where a report "A Review of Historic Monitoring (river health and water quality) within the Broken River System" was prepared for the GB CMA. The findings of this report suggest that while many agencies and organisations have undertaken monitoring on the Broken River over a long period of time, there is great variation in the data sets in terms of spatial and temporal distribution, continuity, quality assurance and duration of data collection (Williams et al. 2005). Although the GB CMA shares some of the objectives of each monitoring agency, not all of the data is applicable to the GB CMA's monitoring objectives.

This report represents the second phase in this process, which is to develop a monitoring program for the Broken River which will evaluate and assess the management actions, resource condition targets and vision of the Regional River Health Strategy within an Adaptive Management framework.

The applicability of the existing data to GB CMA's monitoring objectives, as outlined in Williams et al. (2005) has been determined in relation to the Resource Condition Targets and recommendations on appropriate monitoring have been made.

The Broken Catchment is divided into eight management units (Figure 1), of which this monitoring program is specific to management units L5, M1 and M2 which encompasses the entire length of the Broken River. However, the monitoring program does not include any of the Broken River tributaries.

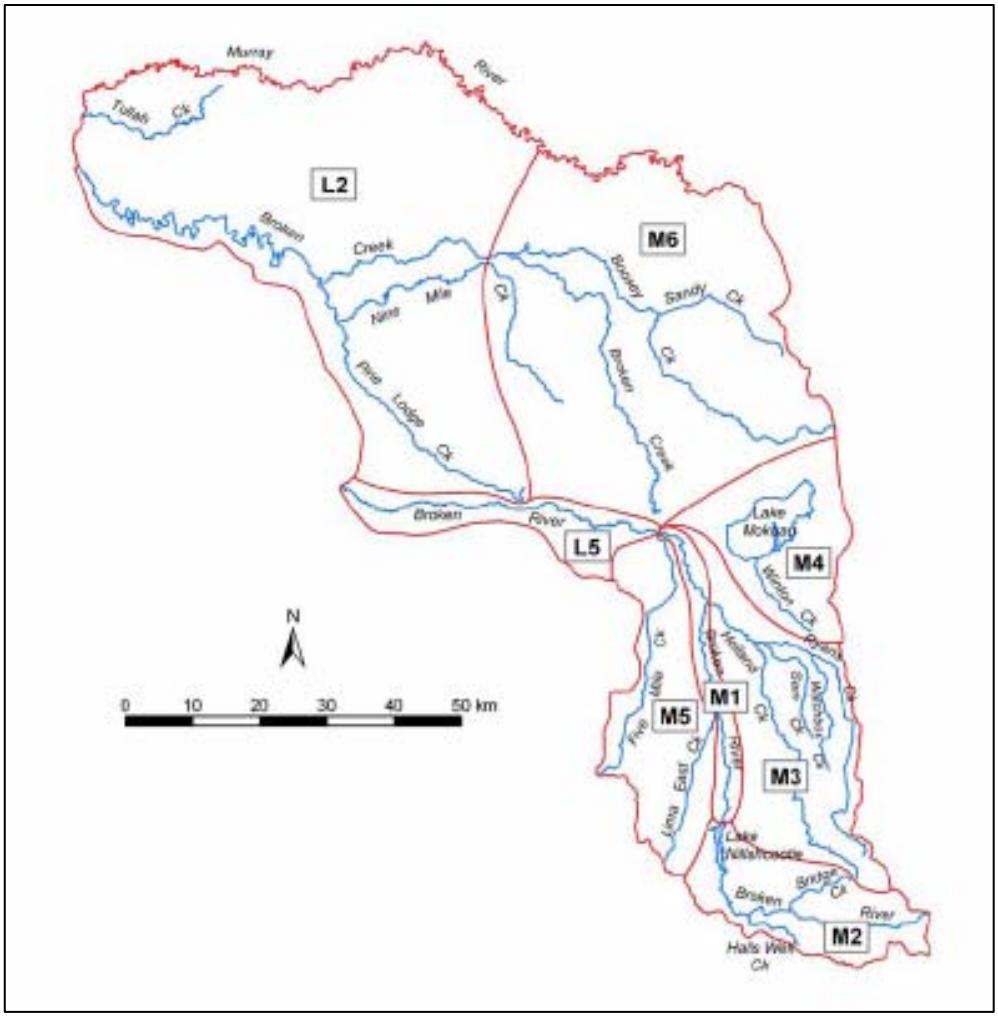

Figure 1. Map of the Broken Basin showing Management Units *(GB CMA, 2005).*

2. Resource Condition Targets and Environmental Indicators

In an effort to protect and enhance the ecological health of high priority reaches within the Catchment, the Goulburn Broken Regional River Health Strategy (GB CMA 2005) identified a number of threats to high value assets in each reach. Management Action Targets and Resource Condition Targets were identified as desired outcomes from the implementation of their management initiatives. This monitoring program provides recommendations for monitoring the success of the management initiatives in reaching these targets.

Outlined below are the valuable assets identified as being at a high risk from threats and the conservation status of each asset (Table 4). More detail on the conservation status of each asset may be found at:
http://www.environment.gov.au/biodiversity/threatened/index.html

Table 4 Valuable Assets at risk

Management Unit	Reach	Assets at Risk	Conservation Status
L5 – lower Broken River	Reaches 1 & 2 – from the Broken Rivers confluence with the Goulburn River to downstream of Casey's Weir.	Murray cod	Vulnerable
		Silver perch	Vulnerable
		Associations with Wetlands of National Significance*	N/A
M1 – mid Broken River	Reaches 3 & 4 – from downstream of Casey's Weir to the downstream wall of Lake Nillahcootie.	Murray cod	Vulnerable
		Macquarie perch	Endangered
M2 – upper Broken River	Reach 5 – immediately upstream of Lake Nillahcootie – recognised as a High Priority Reach.	Murray cod	Vulnerable
		Macquarie perch	Endangered

* Monitoring of the condition of Wetlands of National Significance is covered in the Wetlands Strategy (GB CMA, 2005).

The Natural Resource Management Ministerial Council (NRMMC) has established the National Natural Resource Management Monitoring and Evaluation Framework to assess progress towards improved natural resource condition. The objective of the NRMMC is: "*to promote the conservation and sustainable use of Australia's natural resources*" (NRMMC 2002). Indicators are used to assess change in resource condition and the performance of management actions implemented. The National Natural Resource Management Monitoring and Evaluation Framework have set the following "SMART" criteria for potential indicators to be monitored and assessed

against.

Characteristics of indicators:

- simple (easily interpreted);
- measurable (statistically verifiable, reproducible and show trends);
- accessible (regularly monitored, cost effective and consistent);
- relevant (directly address the objectives of the Natural Resource Management Ministerial Council); and
- timely (provide early warning of potential problems).

Standard indicators under the National Natural Resource Management Monitoring and Evaluation Framework (NRMMC 2002) relevant to the Goulburn Broken RRHS are listed in Table 5.

The recommended indicators for this monitoring program have been assessed against "SMART" criteria in Table 6. The Resource Condition Targets identified from the Goulburn Broken RRHS (GB CMA 2005) for Management Units L5, M1 and M2 are listed in Tables 7, 8 and 9 respectively, with key response indicators recommended for each target.

These key response indicators provide a guide to what should be monitored, and the most suitable methods are suggested in section 3.

Table 5. List of standard indicators for Resource Condition Targets relevant to the Broken River (NRMMC 2002)

Target	Indicator Heading	Recommended indicators
Inland Aquatic Ecosystems Integrity	River condition	For regionally significant reach based issues that is the subject of targets in regional plans. The indicators are: • Benthic macroinvertebrate community assemblages • Fish community assemblages • Benthic diatom community assemblages • Riparian vegetation community assemblages • Riverine physical structure and in-stream habitat • Water quality • Hydrology • If all or most of these indicators are measured, it may be possible to use monitoring data to develop an index of river condition
	Wetland ecosystem extent and distribution	• Extent of regionally significant wetlands
	Wetland ecosystem condition	• Condition of regionally significant wetlands
Nutrients in Aquatic Environments	Nitrogen in aquatic environments	• Total Nitrogen + flow leaving sub-catchment or whole catchment
	Phosphorus in aquatic environments	• Total phosphorus + flow leaving sub-catchment or whole catchment
Turbidity/suspended particulate matter in aquatic environments	Turbidity/suspended solids	• Turbidity OR • Total Suspended Solids (TSS) + flow
Significant native species and ecological communities	Selected significant native species and ecological communities extent and conservation status	• For significant species that are the subject of targets in regional plans: • Range area and location of each species: area • Area, location and condition of key habitat of each species • Relative abundance of each species • For significant ecological communities that are the subject of targets in regional plans • Extent of each ecological community: estimated area (in hectares) • Condition of each ecological community
Ecologically significant invasive species	Selected ecologically significant invasive vegetation species extent and impact	• The areal extent and density of weeds under selected regulatory controls that are being addressed by regional bodies or community projects

Table 6. Recommended indicators assessed against "SMART" criteria

Indicator	**Method**	**Simple** (Easily interpreted and monitored)	**Measurable** (Statistically verifiable, reproducible and show trends)	**Accessible** (Regularly monitored, cost effective and consistent)	**Relevant** (Directly address the objectives of the NRMMC)	**Timely** (Provide early warning of potential problems)
Water Quality (Turbidity, Dissolved Oxygen and Conductivity)	Multimeter: measured in-situ	Easy to accurately measure in-situ and easy to interpret data.	Quantitative; provided QA/QC protocols are followed, results should be reproducible. Frequent sampling will ensure that change or trends are detected.	Low cost once equipment has been purchased.	Directly addresses objectives of improving water quality.	If regularly monitored, can provide timely warning of potential problems.
Total Phosphorus	Collected water sample, laboratory analysis.	Easy to accurately measure, results easily interpreted provided QA/QC protocols are followed.	Quantitative; provided QA/QC protocols are followed, results should be reproducible. Frequent sampling will ensure that change or trends are detected.	Not labour intensive so can be monitored frequently. The cost of analyses varies between laboratories.	Directly addresses objectives of reduction in Phosphorus levels within the catchment.	If regularly monitored, can provide timely warning of potential problems.
Temperature	Temperature loggers	Easy to accurately measure, results easily interpreted.	Quantitative; provided QA/QC protocols are followed, results should be reproducible. Frequent sampling will ensure that change or trends are detected.	Temperature loggers are relatively inexpensive and are able to be deployed for extended periods in the field and log data at predetermined intervals.	Directly addresses objectives in measuring impacts of impoundments on temperature.	If regularly monitored, can provide timely warning of potential problems.
Hydrology (flow)	Gauging stations	Easy to interpret and monitored regularly by gauges.	Quantitative; gauging stations accurately record daily flow and will show trends.	Low cost as gauging stations already in place. Regularly monitored.	Directly addresses objectives in monitoring for improved flow regimes.	Provides early warning of potential problems as gauges calculate average daily flow.

Indicator	**Method**	**Simple** (Easily interpreted and monitored)	**Measurable** (Statistically verifiable, reproducible and show trends)	**Accessible** (Regularly monitored, cost effective and consistent)	**Relevant** (Directly address the objectives of the NRMMC)	**Timely** (Provide early warning of potential problems)
ISC (Streamside Zone and Physical Form Sub-indices)	Rapid Assessment	User friendly; manuals available to provide advice on how ISC results can be interpreted.	Semi-quantitative; based on scientific knowledge and principles. Can detect change at stream reach level.	Monitored every 5 years, cost of labour.	Many of the Resource Condition Targets set in the GB RRHS are changes in ISC scores.	Provides reasonable warning as vegetation change is slow. Needs more regular monitoring of physical form because change can happen quickly.
Riparian Trend Assessment	Rapid Assessment	User friendly, a lot of information available for instruction and interpretation.	Semi-quantitative; based on scientific knowledge and principles, overall able to detect change, long term monitoring will need to be conducted to detect a significant improvement in native vegetation condition.	Regularly monitored (every 2 years), cost of labour.	Addresses objectives.	Provides early warning of potential problems as monitoring is every 2 years.
Fish migration	Fish trap in fishway	Easily monitored, easily interpreted as proportion of natives to exotics.	Quantitative; will show trends.	Easy to regularly monitor, low cost once equipment has been purchased.	Directly addresses objectives of fish migration.	If monitored regularly, can provide early warning of potential problems.
Fish Community Assemblages	Electrofishing and bait traps (SRA protocol)	Easily monitored, easily interpreted.	SRA protocols include quantitative estimates of fish numbers, biomass and community composition. Method is statistically verifiable, reproducible and will detect trends.	Cost is low as only two operators are needed and post-sampling processing is minimal. Can be monitored regularly.	Directly addresses objectives of monitoring high risk assets.	If monitored regularly, can provide early warning of potential problems.

Table 7. Recommended Indicators for Resource Condition Targets for Management Unit L5

Target	Threat	Action	Management Action Target and Resource Condition Target	Indicator heading	Recommended indicators / Parameters
Inland Aquatic Ecosystems Integrity	Barrier to fish migration	• Provide fish passage (Fish Ladder installed) at Gowangardie and Casey's Weir.	• 223km of stream open to fish passage.	River condition	• Fish migration. • Index of Stream Condition (ISC); • Physical Form sub-index.

	Stock Access	• Provide fencing and revegetation incentives.
		• Encourage land managers to adopt CRP for "managing grazing in the riparian zone".
		• Control grazing on public waterfronts.
			• 125km frontage fenced and revegetated.
			• 125km frontage under CRP.
			• 125km frontage controlled.
			• Improve condition of ISC Streamside Zone sub-index by up to 8 points and improve ISC Physical Form sub-index by up to 1 point; over 63km river.
				River condition	• Riparian Trend Assessment.
					• Index of Stream Condition (ISC);
					  • Streamside Zone sub-index.
					  • Physical Form sub-index.

	Introduced Fauna	• Support actions within the Murray-Darling Basin Native Fish Management Strategy - management of alien fish species focusing on reducing the impacts of introduced fish on native species, rather than complete eradication.	• Control and manage introduced species.	River condition	• Fish community assemblages.
	Bed Instability, Channel Modification, Loss of in-stream habitat	• Monitor assets at risk from threat (Assets are Murray cod populations).	• Monitoring program implemented • No decline in condition of assets.	River condition	• Fish community assemblages. • Index of Stream Condition (ISC); • Physical Form sub-index (Riverine physical structure and in-stream habitat). • Hydrology.

Target	Threat	Action	Management Action Target and Resource Condition Target	Indicator heading	Recommended indicators / Parameters
	Flow deviation	• Develop a flow rehabilitation plan (Broken River).	• Flow plan to be developed - establish environmental water reserve and improve flow regimes.	River condition	• Compliance. • Hydrology.
Ecologically significant invasive species	Introduced flora	• Monitor assets at risk from threat (Assets are Murray cod populations and wetland conditions).	• Monitoring program implemented. • No decline in condition of assets.	Selected ecologically significant invasive vegetation species extent and impact	• Fish community assemblages. • Riparian Trend Assessment. • Index of Stream Condition (ISC); • Streamside Zone sub-index.

Turbidity/suspended particulate matter in aquatic environments	Water Quality (Turbidity, EC and DO)	• Conduct Ecological Risk Assessment for DO and Turbidity, using *Guidelines for Environmental Management Risk-based Assessment of Ecosystem Protection* to determine further work.	• Ecological Risk Assessment.	Turbidity/suspended solids	• Compliance.
					• Water quality;
					  • Turbidity (or TSS).
					  • DO and EC.

Nutrients in Aquatic Environments	Water Quality (Nutrients)	• Provide fencing and revegetation incentives. • Minimise nutrient run off into irrigation drains by implementation of on-farm BMP by irrigators as outlined in the irrigation Drainage Program of the Water Quality Strategy. • Remove Phosphorus from irrigation drains through water reuse, sediment removal and nutrient stripping. • Implement BMP for urban drainage as outlined in the Urban Stormwater Management Program of the Water Quality Strategy.	• 125km frontage fenced. • Reduction in phosphorus exports of 312.5kg/year at gauge 404224 (Gowangardie). • Programs implemented as determined; Contribute to reduction in phosphorus exports of 84.5 tonnes per year from the Shepparton Irrigation District. • Programs implemented as determined; Contribute to reduction in phosphorus exports of 2.85 tonnes per year from the Shepparton Irrigation District.	Phosphorus in aquatic environments	• Total phosphorus + flow leaving sub-catchment or whole catchment.

Table 8. Recommended Indicators for Resource Condition Targets for Management Unit M1

Target	Threat	Actions	Management Action Target and Resource Condition Target	Indicator heading	Recommended indicators
Inland Aquatic Ecosystems Integrity	Barrier to fish migration	• Provide fish passage (Fish Ladder installed) at Gowangardie and Casey's weirs.	• 2 fishways installed. • 55km of stream open to fish passage.	River condition	• Fish movement through fishways. • Index of Stream Condition (ISC); • Physical Form sub-index.

	Stock Access	• Provide fencing and revegetation incentives (CMA).
		• Encourage land managers to adopt CRP for "Managing grazing in the riparian zone" (DSE, CMA).
		• Control grazing on public waterfronts (DSE (CLM)).
			• 110km frontage fenced and revegetated.
			• 110km frontage under CRP.
			• 110km frontage controlled.
			• Improve condition of ISC Streamside Zone sub-index by up to 8 points and improve ISC Physical Form sub-index by up to 1 point; over 22.5km of river.
				River condition	• Riparian Trend Assessment.
					• Index of Stream Condition (ISC);
					  • Streamside Zone sub-index.
					  • Physical Form sub-index.

	Water Quality (Temperature)	• Assess impact of Lake Nillahcootie on downstream temperature regimes. If significant, assess potential for modification of release water temperature in conjunction with modifications to the weir wall outlined in the white paper.	• Review conducted; Resource Condition Target determined by review.	River condition	• Compliance. • Temperature. • Hydrology.
	Channel Modification	• Assess causes of channel modification (de-snagging or alignment) and prepare appropriate management actions.	• Review conducted; Resource Condition Target determined by review.	River condition	• Compliance. • Fish community assemblages. • Index of Stream Condition (ISC); • Physical Form sub-index (Riverine physical structure and in-stream habitat). • Hydrology.
	Flow deviation	• Develop a flow rehabilitation plan (Broken River).	• Flow plan to be developed - establish environmental water	River condition	• Compliance. • Hydrology.

Target	Threat	Actions	Management Action Target and Resource Condition Target	Indicator heading	Recommended indicators
			reserve and improve flow regimes.		
	Degraded Riparian Vegetation	• Monitor assets at risk from threat (Assets are Murray cod populations and Macquarie perch populations).	• Monitoring program implemented. • No decline in condition of assets.	River condition	• Fish community assemblages.

Turbidity/suspended particulate matter in aquatic environments	Water Quality (Turbidity, EC and DO)	• Conduct an Ecological Risk Assessment in Management unit M1 for turbidity, using Guidelines for Environmental Management Risk-based Assessment of Ecosystem Protection to determine further work required.	• Ecological Risk Assessment resource condition targets determined by review.	Turbidity/suspended solids	• Compliance.
					• Water quality;
					  • Turbidity. OR
					  • Total Suspended Solids (TSS) + flow.
					  • DO and EC.

Nutrients in Aquatic Environments	Water Quality (Nutrients)	• Provide fencing and revegetation incentives.	• 110km frontage fenced and revegetated. • Reduction in phosphorus exports of 312.5kg/year at Gauge 404216 (Broken River @ Goorambat – Casey's Weir Head gauge).	Phosphorus in aquatic environments	• Water quality • Total phosphorus + flow leaving sub-catchment or whole catchment
Ecologically significant invasive species	Introduced flora	• Monitor assets at risk from threat (Assets are Murray cod populations and Macquarie perch populations).	• Monitoring program implemented. • No decline in condition of assets.	Selected ecologically significant invasive vegetation species extent and impact	• Fish community assemblages. • Riparian Trend Assessment. • Index of Stream Condition (ISC); • Streamside Zone sub-index.

Table 9. Recommended Indicators for Resource Condition Targets for Management Unit M2

Target	Threat	Actions	Management Action Target and Resource Condition Target	Indicator heading	Recommended indicators

Inland Aquatic Ecosystems Integrity	Stock Access	• Provide fencing and revegetation incentives (CMA).
		• Encourage land managers to adopt CRP for "Managing grazing in the riparian zone" (DSE, CMA).
		• Control grazing on public waterfronts (DSE, (CLM)).
			• 15km frontage fenced and revegetated.
			• 15km frontage under CRP.
			• 15km frontage controlled.
			• Improve condition of ISC Streamside Zone sub-index by up to 8 points and improve ISC Physical Form sub-index by up to 1 point; over 3.7km of river.
				River condition	• Riparian Trend Assessment.
					• Index of Stream Condition (ISC);
					  • Streamside Zone sub-index.
					  • Physical Form sub-index.

	Barrier to Fish Migration	• Explore opportunities to provide fish passage at Lake Nillahcootie in conjunction with modifications to the weir wall outlined in the White Paper.	• Investigation conducted; Resource Condition Target determined by review.	River condition	• Compliance.
	Channel Modification	• Assess causes of channel modification (de-snagging or alignment) and prepare appropriate management actions.	• Review conducted; Resource Condition Target determined by review.	River condition	• Compliance. • Index of Stream Condition (ISC); • Physical Form sub-index (Riverine physical structure and in-stream habitat). • Hydrology.
	Loss of in-stream habitat	• Monitor assets at risk from threat – Murray cod and Macquarie perch populations.	• Monitoring program implemented; no decline in condition of assets.	River condition	• Compliance. • Fish community assemblages. • Index of Stream Condition (ISC); • Physical Form sub-index (Riverine physical structure and in-stream habitat). • Hydrology.

Target	Threat	Actions	Management Action Target and Resource Condition Target	Indicator heading	Recommended indicators
Ecologically significant invasive species	Introduced flora	• Control exotic vegetation on streams and revegetate with native species.	• 7.5km of stream subject to riparian weed control (heavy infestation). • ISC Streamside Zone sub-index improved by up to 7 points over 3.7km of river.	Selected ecologically significant invasive vegetation species extent and impact	• Riparian Trend Assessment. • Index of Stream Condition (ISC); • Streamside Zone sub-index.

	Degraded Riparian Vegetation	• Control exotic vegetation, and provide fencing and revegetation incentives.	• 15km frontage fenced and revegetated, 7.5km of stream subject to riparian weed control. Improve condition of ISC Streamside Zone index by up to 8 points and improve ISC Physical Form sub-index by up to 1 point; over 3.7km river.	Selected ecologically significant invasive vegetation species extent and impact	• Riparian Trend Assessment
					• Index of Stream Condition (ISC)
					  • Streamside Zone sub-index
					  • Physical Form sub-index

Nutrients in Aquatic Environments	Water Quality (Nutrients)	• Provide fencing and revegetation incentives.	• 15km frontage fenced and revegetated. • Reduction in phosphorus exports of 30kg/year.	Phosphorus in aquatic environments	• Water quality. • Total phosphorus + flow leaving sub-catchment or whole catchment.

2.1. Initial Performance Indicators

There are no initial performance indicators for Fish, Water Quality or Hydrology as these parameters are monitored frequently and potential trends potentially discernable. The Riparian Trend Assessment (RTA) can be used as an interim indicator for Riparian Vegetation change as the RTA can be conducted in between ISC surveys. The ISC is done every five years and this time frame may make it difficult to assess progress towards Resource Condition Targets.

3. Recommendations for monitoring program

3.1 Adaptive Management Framework

Adaptive Management is "a systematic process for continually improving management policies and practices by learning from the outcomes of operational programs" (Bennett and Lawrence 2002). It is seen as a useful way in helping decision makers make informed management decisions and changes within a short time frame without having to wait while further data are collected given the long timeframes for environmental responses. Monitoring and evaluation is a vital component within the Adaptive Management framework whereby further management actions are based on the outcomes derived (Bennett and Lawrence 2002).

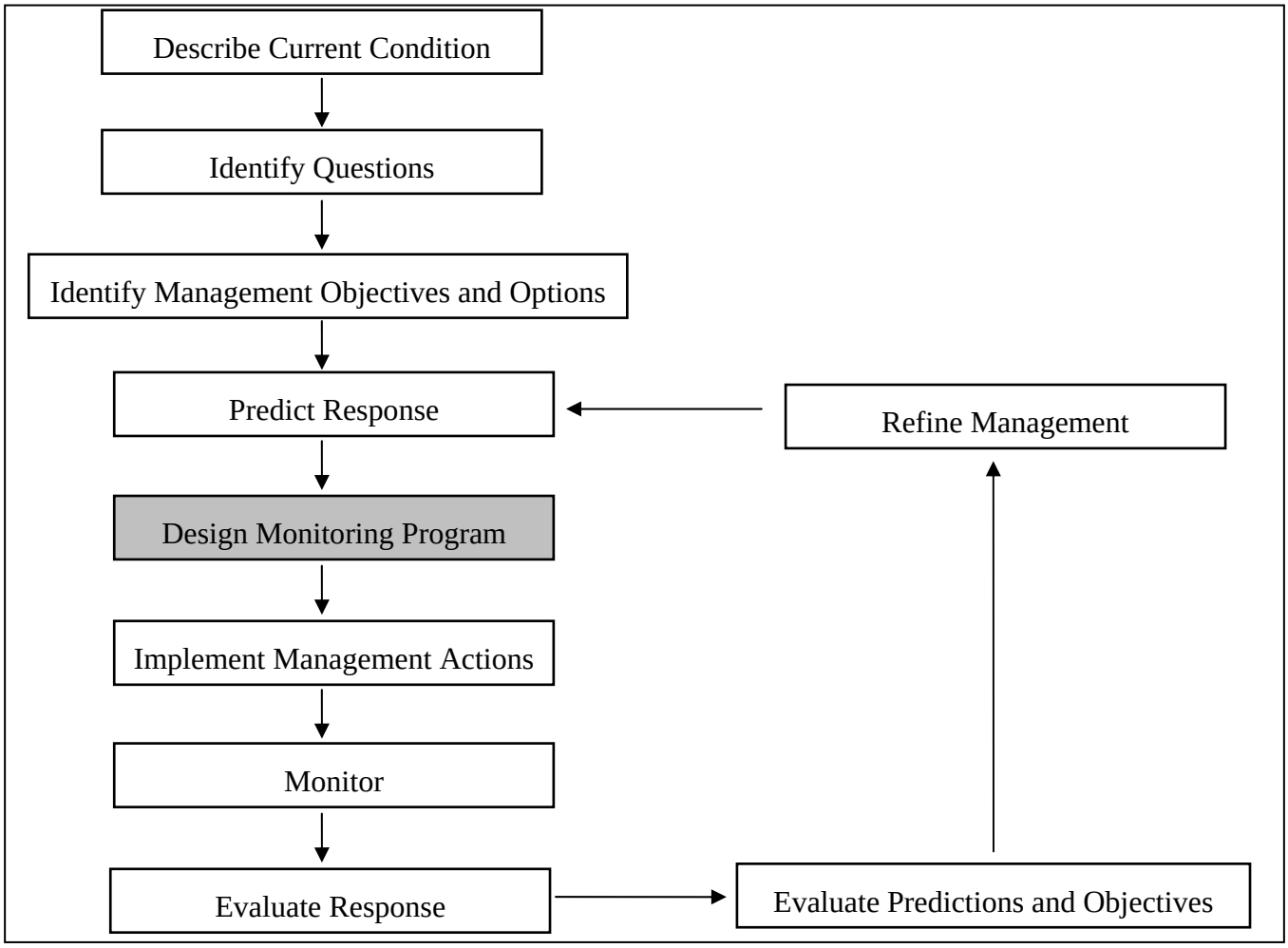

Figure 2. The Adaptive Management framework (modified from Tucker 2003)

The design of this monitoring program focuses on the RRHS aim to protect identified valuable assets in High Priority reaches. A 'BACI' (Before – After – Control – Impact) approach may not be applicable as there are no reaches which can be identified as a "Control". That is, there are no High

Priority waterways with the same assets that are not to be the subject of management (GB CMA 2004). Therefore, this monitoring program will focus on the completion of works program to reduce threats, the actual reduction in threat levels, and the maintenance (improvement) in high value assets in High Priority Waterways (GB CMA 2004). Baseline data is essential in this monitoring program for the impact of management practices to be assessed.

This document is the 'Design Monitoring Program' phase within the Adaptive Management Framework where the monitoring program is designed to reflect management objectives. The results derived from monitoring the recommended indicators will allow Managers to evaluate the effects of their management actions against their predicted responses. It is then the responsibility of the managers to refine the management actions to better achieve their objectives. However, each indicator has different response times and needs to be evaluated independently at different times. This is addressed in section 3.6 Temporal and Spatial Scale.

3.2 Conceptual Models

To successfully implement a monitoring program in an adaptive management framework, the program is based on a conceptual model of how the system works. A representation (written or figurative) of the model should be included in the documentation associated with the monitoring program. A conceptual model of how the system works not only helps identify ecosystem elements with predictable responses, but also identifies changes that may be detrimental — and will, therefore, also require monitoring. Conceptual models of the Broken River have been developed by Williams *et al*. 2005.

3.3 Compliance Monitoring

Management Actions and associated Resource Condition Targets were outlined in the Regional River Health Strategy (GB CMA, 2005) and are to be implemented over the next 10 years (2005 – 2015). Currently there are a number of Management Actions yet to be completed (Table 10). Many of the Resource Condition Targets listed in the Regional River health Strategy (GB CMA, 2005) are a change in environmental condition; however there are several Resource Condition Targets that need to be defined which are reliant on either risk assessments, reviews or infrastructure works to be undertaken. Therefore monitoring of these targets can only be compliance monitoring of the Management Actions, awaiting the outcome of defined Resource Condition Targets.

Table 10. Resource condition target yet to be achieved due to incomplete management actions

Management Unit	Threat	Action	Management Action Target	Resource Condition Target
L5	Barrier to fish migration	Provide and monitor fish passage at Gowangardie and Casey's weirs	Two fishways installed	223km of stream open to fish passage
L5	Flow Deviation	Develop a Flow Rehabilitation Plan (Broken River)	Flow plan developed (establish environmental water reserve & improve flow regime)	As determined by flow plan
L5	Water Quality (turbidity, DO)	Conduct an Ecological Risk Assessment in Management Unit L5 for turbidity and DO, using *Guidelines for Environmental Management Risk-based Assessment of Ecosystem Protection* to determine further work required.	Ecological Risk Assessment conducted	As determined by Risk Assessment
M1	Flow deviation	Develop a Flow Rehabilitation Plan (Broken River)	Flow Plan developed	As determined by Flow Plan
M1	Barrier to fish migration	Provide fish passage at Gowangardie and Casey's weirs	Two fishways installed	55km of stream open to fish passage
M1	Water Quality trend (turbidity, DO, EC)	Conduct an Ecological Risk Assessment in Management Unit M1 for turbidity, using *Guidelines for Environmental Management Risk-based Assessment of Ecosystem Protection* to determine further work required.	Ecological Risk Assessment conducted	As determined by Risk Assessment
M1	Temperature	Assess impact of Lake Nillahcootie on downstream temperature regimes. If significant, assess potential for modification of release water temperature in conjunction with modifications to the weir wall outlined in the White Paper.	Review conducted	As determined by Review
M1	Channel modification	Assess causes of channel modification (de-snagging or alignment) and prepare appropriate management actions.	Review conducted	As determined by Review
M2	Barrier to fish migration	Explore opportunities to provide fish passage at Lake Nillahcootie in conjunction with modifications to the weir wall outlined in the White Paper.	Investigation conducted	As determined by investigation.
M2	Channel Modification	Assess causes of channel modification (de-snagging or alignment) and prepare appropriate management actions .	Review conducted	As determined by Review

3.4 Management objectives and questions

Monitoring is a process that provides information for management purposes (Finlayson and Mitchell 1999) and must be able to measure changes in reference to a set of objectives (Baldwin *et al*. 2004).

Management objectives are developed from clearly defined questions or issues (Downes *et al*. 2002). An example of such as question would be: "*How will environmental flows affect native fish breeding in the Broken River over the next 20 years?*" The question can then be fed into the conceptual model, from which responses can be predicted and objectives derived. For example, in relation to the above question, an objective of re-introducing wood back into the river channel might be "*To improve native fish breeding in the Broken River 20 years*." The question or objective can also be reframed in the form of a hypothesis: "*The re-introduction of large wood into the Broken River will improve native fish breeding*." It is important that these objectives are clear, concise and specifically detail what is to be achieved (ANZECC and ARMCC 2000).

3.5 QA/QC

Quality Assurance and Quality Control are important components in monitoring programs, and essential for ensuring the quality of collection, storage and processing of samples. It is recommended that a Quality Assurance plan be established before the implementation of the monitoring program. Guidelines for appropriate QA/QC for each methodology can be found in Baldwin *et al*. 2004. If water quality monitoring continues using the Victorian Water Quality Monitoring Network then sampling protocols will need to conform to VWQMN Manual of Procedures (1999) and the Audit protocol for the Victorian Water Quality Monitoring Network (EPA, 1999).

3.6 Temporal and Spatial Scale

The Goulburn Broken Regional River Health Strategy has set objectives within a 10 year time frame (2005 – 2015). Many changes in resource condition occur slowly over time such as vegetation condition; however others such as changes in water quality can occur rapidly, therefore there needs to be a framework in place which will encompass all timeframes. As part of the Adaptive Management Framework, each recommended indicator has been assessed as to how often the results should be evaluated by managers against the objectives and predictions made in the RRHS. The evaluate response times and factors such as time of year, site selection, frequency of sampling and sample replication have been addressed in Tables 11, 12, 13 and 15.

3.7 Statistical methods

It is beyond the scope of this report to include a detailed discussion on the statistical methods that could be potentially used in the design and interpretation of the monitoring. It is strongly recommended that professional statistical knowledge is sort prior to the implementation of the monitoring program. Recommendations are made for the frequency and intensity of sampling for the recommended parameters.

3.8 Water Quality

The key response indicators identified several water quality parameters that should be monitored: electrical conductivity (surrogate for salinity), turbidity, dissolved organic carbon (DOC), dissolved oxygen (DO), pH and Chlorophyll a. It is important that flow data is recorded (or available) when

water quality parameters are sampled to enable loads to be calculated. Water quality will impact directly on other parameters recommended for monitoring.

The EPA monitor physical and chemical water quality, measuring DO, pH, temperature and EC in the field and nutrient concentrations (TN TP) and turbidity in the laboratory. Water ECOscience has good data sets at 4 sites on the Broken River. At Casey's Weir Head Gauge, Moorngag, and Broken River at Gowangardie a range of VWQMN "core parameters" have been measured including:

- Electrical Conductivity (EC) (µS/cm)
- Colour (filt.)
- Chlorophyll-*a*
- Discharge
- Dissolved Organic Carbon (DOC)
- Dissolved Oxygen
- Oxidised Nitrogen (NOx) (mg/L N)
- pH
- Phaeophytin
- Filterable Reactive Phosphorus (FRP) (mg/L P)
- Suspended solids
- Temperature
- Total Kjeldahl Nitrogen (TKN) (mg/L N)
- TP

In addition a range of metals have been measured by Water ECOscience; however gauge height, turbidity, alkalinity, hardness, TDS and TOC, plus major ion concentrations have not been included in the monitoring at these sites. Lake Nillahcootie Head Gauge has been monitored for most "core parameters" excluding gauge heights and turbidity.

3.9 Nutrients

There is a lack of adequate monitoring of nutrient levels across all three Management Units. WES has four sites across Management Units L5, M1 and M2 where several VWQMN "core parameters" are measured including Total Kjeldahl Nitrogen (TKN) and Oxidised Nitrogen (NOx). TKN is the measurement of organic nitrogen plus ammonia. More appropriate measures to address GB CMA's targets are TN, nitrate and nitrite (NOx) and ammonia (NH_4) as separate measurements. FRP and TP measurements are most useful to the GB CMA's monitoring objectives as most resource condition targets set in the RRHS are a reduction in phosphorus loads.

It is important to note that a weir or reservoir can have many affects on the continuum of a river. As water current speed slows above the dam wall, suspended sediment from upstream often containing heavy metals and nutrients, will settle out which can lead to an accumulation of these contaminants within the reservoir (Baldwin and Bowen, 2005).

When interpreting data from samples taken directly below an impoundment, it is important to take into consideration the possibility of pulses in nutrient levels attributed to nutrient cycling within the reservoir. If water in a dam or weir becomes thermally stratified (i.e. no mixing of bottom and surface waters), the cooler water at the bottom (hypolimnion) can become depleted in oxygen (anoxic). Periods of anoxia play an important role in the biogeochemical cycling of nutrients, and some metals, and lead directly to the build up of dissolved phosphorus, ammonia, sulphide, iron and manganese in the hypolimnion. If stratification breaks down, the nutrient rich bottom water can mix with the surface waters, which is often observed as algal blooms. If the reservoir is shallow,

turnover events would occur more frequently than in deeper reservoirs. This means that there is a possibility that pulses of nutrients from the sediments to surface water could occur more frequently (Baldwin and Bowen, 2005).

Sampling considerations:

- The frequency of sampling is an important factor in calculating loads of nutrients, where a sampling program of low frequency may not be able to detect a change in loads.
- Previous studies suggest that fortnightly sampling over a number of years is the most cost effective strategy to estimate loads of nutrients in rivers (Robertson and Richards, 2000), with more frequent sampling during a flow event such as a flood or a prolonged period of low flow.

3.10 Thermal Pollution

A review of the impacts of thermal pollution below Lake Nillahcootie is yet to be undertaken. Monitoring of cold water releases from Lake Nillahcootie has been conducted as part of the Major Storages Operational Monitoring Program (MSOMP) from November 2002 through to August 2004.

3.11 Hydrology and Flow deviation

Hydrology is fundamental to the Broken River and should be measured regularly and accurately. Thiess Environmental Services measure flow using calculated values at four sites along the Broken River. These sites are listed in Table 8.

3.12 Index of Stream Condition (ISC)

ISC is a tool used to assess the health and establish a benchmark of the condition of Rivers and Streams and can be used to assess the long-term effectiveness of management actions. ISC (1999) was assessed for the entire length of the Broken River. The river was divided into 6 reaches and given an overall score of environmental condition for each one. The ISC is made up of 5 sub-indices. Two of these are the Physical form sub-index and Streamside Zone sub index both of which measure different aspects of habitat. ISC scores for the Broken River are stored in the Victorian Water Resource Data Warehouse (http://www.vicwaterdata.net/). These indicators are recommended as tools for monitoring the Broken River as many of the Resource Condition Targets set are an improvement in ISC scores.

3.13 Fish

Fish can be useful tools for assessing aquatic environments. They cover a broad trophic range and can occur across wide spatial scales. The taxonomy of most groups of fish is well established and, in comparison to some biotic groups, they are relatively inexpensive to sample (Harris 1995). The inclusion of fish in monitoring programs may also have benefits with community acceptance of and participation in the wider program. Fish communities in the Broken River have been sampled previously, so a body of information regarding current condition exists.

There is adequate baseline data for fish abundance and fish weights and lengths across Management Units M1, M2 and L5 (Williams et al, 2005). These consisted of a large number of sites; more than 20 sites in L5; between 10 and 60 sites in M1 and six sites in M2. However, sampling by DSE, DPI and ARI ceased prior to 2002 (Williams et al. 2005).

Sampling considerations:

- Seasonal sampling of fish will give an indication of changes in communities and species over time and will give an indication of which period is best to sample to maximise numbers caught.
- Power analysis of fish abundance numbers recorded from the Broken River restoration project have indicated that a minimum of 40 electrofishing runs (each run consisting of 8 shots of 150 second duration) are needed to detect a 10 percent change in fish abundance at any given site.

3.14 Macroinvertebrates

There has been increasing interest in monitoring macroinvertebrates in aquatic environments, particularly in rivers, which has resulted in the development of rapid bioassessment techniques (e.g. National River Health Program – Davies 1994). There are many advantages in using invertebrates to assess the health of rivers, they are common, widely distributed, comprise an important component of food webs and are known to respond to changes in the environment (Batzer et al, 2001; US EPA 2002a). As such they are good indicators of river health/water quality. Although these are not recommended for assessing against resource condition targets, they are used to assess long term changes. The EPA has conducted monitoring throughout all three Management Units, using Rapid assessment Methodology for a period of 10 years.

Sampling considerations:

- Sampling for macroinvertebrates should be undertaken during the summer months to maximise the number of taxa and abundance of taxa collected

4. Monitoring Framework for the Broken River

An overall monitoring framework for each management unit including site and parameter selection, frequency and justification has been set out in Tables 11, 12 and 13. The methodologies for the indicators / parameters listed in section 2 have been set out in Table 15 along with the recommendations for monitoring.

5. Data Analysis, Interpretation and Reporting

5.1. Data Analysis

In all likelihood the different components of the monitoring programs will be undertaken by different organisations, and the statistical analysis, rigour and power to detect change for each component will differ. Each organisation involved in the monitoring program should seek professional statistical advice be sort prior to the comment of the monitoring program.

5.2. Interpretation

A scientific reference committee should be established. Members of this committee should encompass a range of expertise capable of interpreting the results and advising on modifications to the monitoring programs.

5.3. Reporting

Reporting should be annually and submitted to the reference committee prior to its annual meeting.

6. Overall Site and Parameter selection for Management Unit L5 (Reaches 1 and 2)

The lower Broken River (Reaches 1 & 2) extends from the Broken Rivers confluence with the Goulburn River to downstream of Casey's Weir. There are two ISC reaches in this Management Unit, and five sites have been recommended for monitoring (Table 11, Figure 3). Taking into consideration the impoundment on this section of the River two sites are located between the Broken Rivers confluence with the Goulburn River and Gowangardie Weir. Two sites are located between Gowangardie Weir and Casey's Weir, and one site is located at the Gowangardie Weir Head Gauge.

Table 11. Overall Monitoring Framework for Mgt. Unit L5

Site	Justification of Site Selection.	Parameter	Justification of parameter	Sampling Frequency	Justification of Frequency (power analysis)
Keats Road	Site situated between Broken River's confluence with the Goulburn River and Gowangardie Weir and has extensive background data.	Fish Community Assemblages	Directly addresses RCT. See Table 7	Initial sampling should be seasonal, scaled back to twice per year between 1st November and 30th April	See section 3.13
Cosgroves Road	Site situated between Broken River's confluence with the Goulburn River and Gowangardie Weir and has extensive background data.	Fish Community Assemblages	Directly addresses RCT. See Table 7	Initial sampling should be seasonal, scaled back to twice per year between 1st November and 30th April	See section 3.13
Gowangardie Weir	As determined by RCT	Water Quality	Directly addresses RCT. See Table 7	TBD (See Table 10)	TBD (See Table 10)
	As determined by RCT	Total Phosphorus (TP)	Directly addresses RCT of reduction in Phosphorus exports at gauge 404224.	Fortnightly; Measure more frequently during an event such as a flood or prolonged periods of low flow.	See section 3.9
	Consistent with sampling other parameters at this site.	Hydrology (Flow)	Must measure flow addition to TP to calculate loads.	Simultaneous with TP samples	See section 3.9.
	As determined by RCT	Fish Migration	Directly addresses RCT. See Table 10.	As determined by ARI	As determined by ARI

Site	Justification of Site Selection.	Parameter	Justification of parameter	Sampling Frequency	Justification of Frequency (power analysis)
Gowangardie Weir Up Stream	Site situated between Gowangardie and Casey's weir and has extensive background data.	Fish Community Assemblages	Directly addresses RCT. See Table 7.	Initial sampling should be seasonal, scaled back to twice per year between 1st November and 30th April	See section 3.13
Quinn Road	Site situated between Gowangardie and Casey's weir and has extensive background data.	Fish Community Assemblages	Directly addresses RCT. See Table 7.	Initial sampling should be seasonal, scaled back to twice per year between 1st November and 30th April	See section 3.13
ISC Reach 1	As determined by RCT	ISC Physical Form Sub-index	Directly addresses RCT. See Table 7	Every 5 Years	As determined by ISC
		ISC Streamside Zone Sub-index	Directly addresses RCT. See Table 7	Every 5 Years	As determined by ISC
		Riparian Trend Assessment	Initial performance indicator for Riparian Vegetation in between ISC surveys.	Every 2 years in between ISC	Provides short term monitoring (<5 yrs)
ISC Reach 2	As determined by RCT	ISC Physical Form Sub-index	Directly addresses RCT. See Table 7	Every 5 Years	As determined by ISC
		ISC Streamside Zone Sub-index	Directly addresses RCT. See Table 7	Every 5 Years	As determined by ISC
		Riparian Trend Assessment	Initial performance indicator for Riparian Vegetation in between ISC surveys.	Every 2 years in between ISC	Provides short term monitoring (<5 yrs)

7. Overall Site and Parameter selection for Management Unit M1 (Reaches 3 and 4)

The mid Broken River (Reaches 3 & 4) extends from downstream of Casey's Weir to the downstream wall of Lake Nillahcootie and has two ISC reaches. Based on Resource Condition Targets for this Management Unit, also taking into consideration the impoundments on this section of the River, six sites have been recommended for monitoring (Table 12, Figure 3). One site is located at Casey's Weir Head Gauge; two sites are located between Casey's Weir and Lake Benalla and three sites are located between Lake Benalla and Lake Nillahcootie.

Table 12. Overall Monitoring Framework for Mgt. Unit M1

Site	Justification of Site Selection	Parameter	Justification of Parameter	Sampling Frequency	Justification of Frequency (power analysis)
Goorambat (Casey's weir head gauge)	As determined by RCT.	Water Quality.	Directly addresses RCT. See Table 8.	TBD (See Table 10).	TBD (See Table 10).
	As determined by RCT.	Total Phosphorus.	Directly addresses RCT of reduction in Phosphorus exports at gauge 404216.	Fortnightly; Measure more frequently during an event such as a flood or prolonged periods of low flow.	See section 3.9.
	Consistent with sampling other parameters at this site.	Hydrology.	Must measure flow addition to TP to calculate loads.	Simultaneous with TP sampling.	See section 3.9.
	As determined by RCT	Fish Migration.	Directly addresses RCT. See Table 8.	As determined by ARI.	As determined by ARI.
Casey's Weir Upstream	Site situated between Casey's Weir and Lake Benalla and has extensive background data.	Fish Community Assemblages.	Directly addresses RCT. See Table 8.	Initial sampling should be seasonal, scaled back to twice per year between 1st November and 30th April.	See section 3.13.
Scholes Road	Site situated between Casey's Weir and Lake Benalla and has extensive background data.	Fish Community Assemblages.	Directly addresses RCT. See Table 8.	Initial sampling should be seasonal, scaled back to twice per year between 1st November and 30th April.	See section 3.13.
Yin Barun Road	As determined by RCT.	Temperature.	Directly addresses RCT. See Table 8.	TBD (See Table 10).	TBD (See Table 10).

Site	Justification of Site Selection	Parameter	Justification of Parameter	Sampling Frequency	Justification of Frequency (power analysis)
	Site situated between Lake Benalla and Lake Nillahcootie.	Fish Community Assemblages.	Directly addresses RCT. See Table 8.	Initial sampling should be seasonal, scaled back to twice per year between 1st November and 30th April.	See section 3.13.
Swanpool Road (Moorngag)	As determined by RCT.	Water Quality.	Directly addresses RCT. See Table 8.	TBD (See Table 10).	TBD (See Table 10).
	As determined by RCT.	Total Phosphorus.	Directly addresses RCT of reduction in Phosphorus exports.	Fortnightly; Measure more frequently during an event such as a flood or prolonged periods of low flow.	See section 3.9.
	Consistent with sampling other parameters at this site.	Hydrology.	Must measure flow addition to TP to calculate loads.	Simultaneous with TP sampling.	Must be measured simultaneous to TP sampling.
	Site situated between Lake Benalla and Lake Nillahcootie.	Fish Community Assemblages.	Directly addresses RCT. See Table 8.	Initial sampling should be seasonal, scaled back to twice per year between 1st November and 30th April.	See section 3.13.
	As determined by RCT.	Temperature.	Directly addresses RCT. See Table 8.	TDB (See Table 10). Recommendation is daily logging.	TBD (See Table 10).
Lima South	As determined by RCT.	Temperature.	Directly addresses RCT. See Table 8.	TBD (See Table 10). Recommendation is daily logging.	TBD (See Table 10).
ISC Reach 3	As determined by RCT.	ISC Physical Form Sub-index.	Directly addresses RCT. See Table 8.	Every 5 Years.	As determined by ISC.
		ISC Streamside Zone Sub-index.	Directly addresses RCT. See Table 8.	Every 5 Years.	As determined by ISC.
		Riparian Trend Assessment.	Initial performance indicator for Riparian Vegetation in between ISC surveys.	Every 2 years in between ISC.	Provides short term monitoring (<5 yrs).
ISC Reach 4	As determined by RCT.	ISC Physical Form Sub-index.	Directly addresses RCT. See Table 8.	Every 5 Years.	As determined by ISC.
		ISC Streamside Zone Sub-index.	Directly addresses RCT. See Table 8.	Every 5 Years.	As determined by ISC.

Site	Justification of Site Selection	Parameter	Justification of Parameter	Sampling Frequency	Justification of Frequency (power analysis)
		Riparian Trend Assessment.	Initial performance indicator for Riparian Vegetation in between ISC surveys.	Every 2 years in between ISC.	Provides short term monitoring (<5 yrs).

8. Overall Site and Parameter selection for Management Unit M2 (Reaches 5 and 6)

The upper Broken River (Reach 5) extends from the downstream wall of Lake Nillahcootie two immediately upstream of the Lake. It has two ISC reaches however only Reach 5 is recognised as a High Priority Reach due to the presence of Murray cod and Macquarie perch. Based on Resource Condition Targets for this Management Unit, three sites have been recommended for monitoring (Table 13, Figure 3). One site is located at Lake Nillahcootie Head Gauge; one site is located directly above the lake, and another site located further upstream near Reach 6. This site has been added to monitor fish community assemblages.

Table 13. Overall Monitoring Framework for Mgt. Unit M2

Site	Justification of Site Selection	Parameter	Justification of Parameter	Sampling Frequency	Justification of Frequency (power analysis)
Lake Nillahcootie Head Gauge	Consistent with sampling water quality at other sites. There is existing baseline water quality data for this site.	Water Quality.	Will contribute to overall water quality assessment.	Fortnightly; Measure more frequently during an event such as a flood or prolonged periods of low flow.	See section 3.9.
	As determined by RCT.	Total Phosphorus.	Directly addresses RCT of reduction in Phosphorus exports.	Fortnightly; Measure more frequently during an event such as a flood or prolonged periods of low flow.	See section 3.9.
	Consistent with sampling other parameters at this site.	Hydrology.	Must measure flow addition to TP to calculate loads.	Simultaneous with TP sampling.	Must be measured simultaneous to TP sampling.
	As determined by RCT.	Fish Migration.	Directly addresses RCT. See Table 9.	TBD (see Table 10).	TBD (see Table 10).
	As determined by RCT.	Temperature.	Directly addresses RCT. See Table 9.	TBD (see Table 10).	TBD (see Table 10).
Lake Nillahcootie Rd @ Barjarg	There is existing data for fish at this site. This site is also within Reach 5 of management unit M2 which is recognised as a High Priority Reach.	Fish Community Assemblages.	Directly addresses RCT. See Table 9.	Initial sampling should be seasonal for the first two years then scaled back to twice per year between 1st November and 30th April.	See section 3.13.
	As determined by RCT.	Temperature.	Directly addresses RCT. See Table 9.	TBD (see Table 10).	TBD (see Table 10).

Site	Justification of Site Selection	Parameter	Justification of Parameter	Sampling Frequency	Justification of Frequency (power analysis)
	As determined by RCT.	Total Phosphorus.	Directly addresses RCT of reduction in Phosphorus exports.	Fortnightly; Measure more frequently during an event such as a flood or prolonged periods of low flow.	See section 3.9.
Old Tolmie Rd at Barwite	This site has been chosen to sample fish as it covers the top of Management Unit M2 and there is limited fish data available for this reach.	Fish Community Assemblages.	Need to obtain baseline condition for Reach 6. Will complete the representation of fish community across the entire Management Unit.	Initial sampling should be seasonal for the first two years then scaled back to twice per year between 1st November and 30th April.	See section 3.13.
ISC Reach 5	As determined by RCT.	ISC Physical Form Sub-index.	Directly addresses RCT. See Table 9.	Every 5 Years.	As determined by ISC.
		ISC Streamside Zone Sub-index.	Directly addresses RCT. See Table 9.	Every 5 Years.	As determined by ISC.
		Riparian Trend Assessment.	Initial performance indicator for Riparian Vegetation in between ISC surveys.	Every 2 years in between ISC.	Provides short term monitoring (<5 yrs).
ISC Reach 6	As determined by RCT.	ISC Physical Form Sub-index.	Directly addresses RCT. See Table 9.	Every 5 Years.	As determined by ISC.
		ISC Streamside Zone Sub-index.	Directly addresses RCT. See Table 9.	Every 5 Years.	As determined by ISC.
		Riparian Trend Assessment.	Initial performance indicator for Riparian Vegetation in between ISC surveys.	Every 2 years in between ISC.	Provides short term monitoring (<5 yrs).

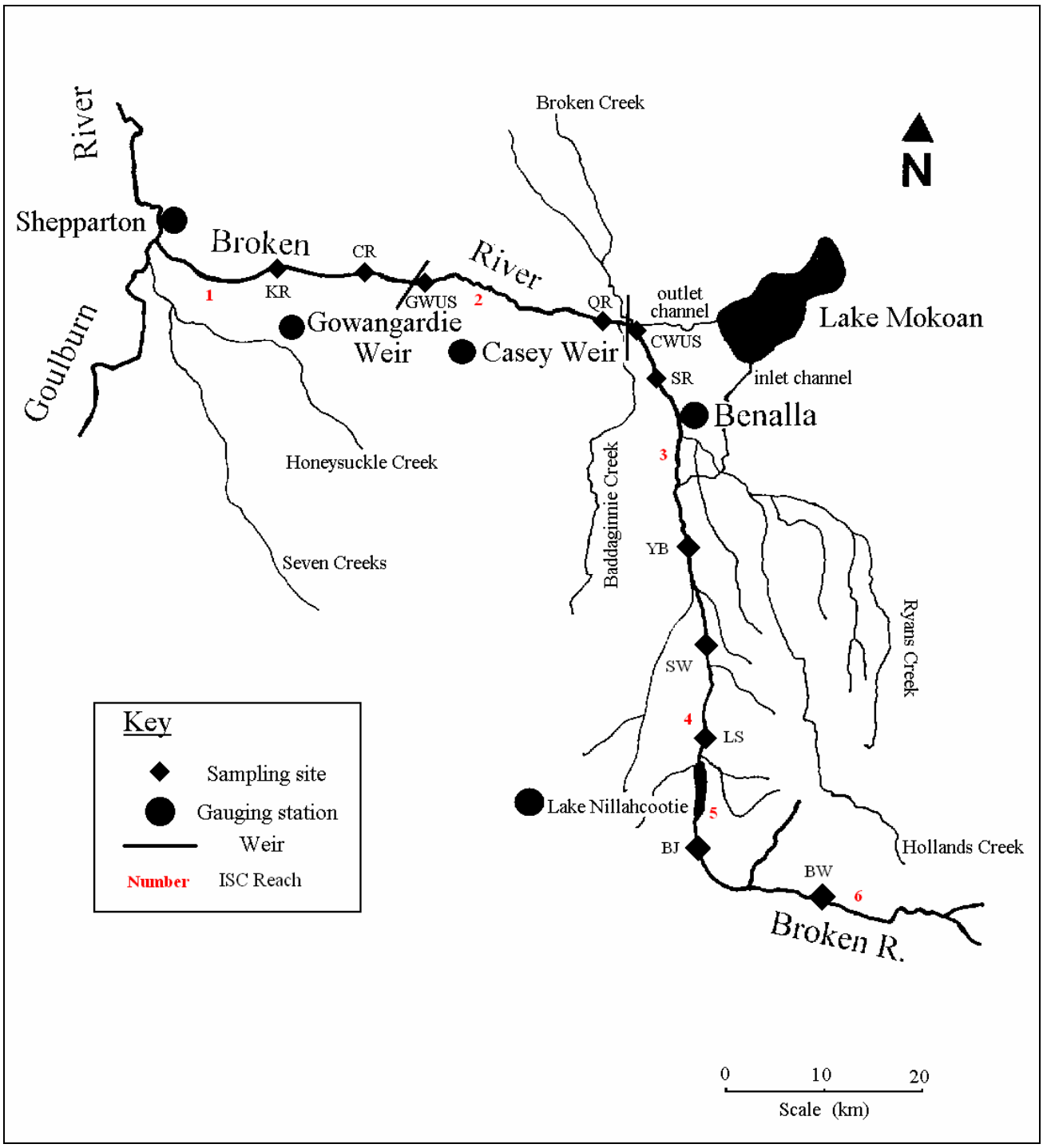

Figure 3. Map of Sampling Sites

Table 14. List of Sampling Sites

Site Code	Site Name	Site Code	Site Name
KR	Keats Road	LS	William Road at Lima South
CR	Cosgroves Road	Lake Nillahcootie	Lake Nillahcootie (Head Gauge)
Gowangardie Weir	Gowangardie Weir (Head Gauge)	BJ	Lake Nillahcootie Road at Barjarg
GWUS	Gowangardie Weir Up Stream	BW	Old Tolmie Road at Barwite
QR	Quinn Road	1	ISC Reach 1
Casey's Weir	Casey's Weir (Head Gauge)	2	ISC Reach 2
CWUS	Casey's weir Up Stream	3	ISC Reach 3
SR	Scholes Road	4	ISC Reach 4
YB	Yin Barun Road	5	ISC Reach 5
SW	Swanpool Road	6	ISC Reach 6

Table 15. Methodologies for recommended indicators / parameters

Recommended Indicator / Parameter	Methodology	Temporal and Spatial Scale	Recommendation	Influencing factors
Water Quality: Turbidity Dissolved Oxygen Electrical Conductivity	Many of the water quality parameters will be, by necessity, measured in situ. These can be conducted adequately in the field using a multimeter (e.g. Horiba U10 Water meter). Parameters that can be monitored by this method are electrical conductivity, turbidity, dissolved oxygen, pH and temperature. The gauging stations used to monitor hydrology are also able to monitor EC. These stations will be valuable for continuous monitoring of salinity levels of inflows and discharge, but they will not provide data on EC in the sections within the creeks. Total suspended solids (TSS) samples can also be collected in the field using a plastic container, and brought back to the laboratory and refrigerated for no longer than 24 hours before being analysed. The methods for monitoring the physical and chemical water quality parameters are set out in the Victorian Water Quality Monitoring Network (VWQMN) Manual of Procedures (1999). Flow must be measure to calculate loads for TSS.	**Spatial: Location of sampling sites** There are currently four sites being monitored by Water ECOscience, • Gowangardie Weir Head Gauge; • Casey's Weir Head Gauge; • Swanpool Road at Moorngag; and • Lake Nillahcootie Head Gauge. It is recommended that these sites continue to be used. **Temporal: Frequency of sampling** Measure fortnightly as part of regular monitoring program. Measure all parameters during an event such as a flood or prolonged periods of low flow. **Replication:** Take at least 3 TSS samples at each site on each sampling occasion.	1. Measure EC, turbidity, pH, DO, TSS at listed sites as part of assessment of current condition.	N/A
Total Phosphorus	The American Public Health Association describes standard techniques for measuring total and soluble phosphorus (APHA 4500- P), total nitrogen (APHA 4500-N), ammonia (APHA 4500NH_3), nitrate (APHA 4500- NO_3-), and nitrite (APHA 4500- NO_2-). However each of those chapters describes a number of different methods (Baldwin *et al* 2005) If filtration in the field is required it is recommended that samples should be filtered though a 0.45µm cellulose acetate filter (AS 5667.1), and a filtering blank included in the QA/QC sampling protocol. Phosphorus and Nitrogen samples should be frozen as means of preservation as it is effective, removes the possibility of contamination from the acid preservative and reduces the occupational health and safety risk	**Spatial: Location of sampling sites** There are currently 4 sites being monitored by Water ECOscience, each with gauging stations present: • Gowangardie Weir Head Gauge; • Casey's Weir Head Gauge; • Swanpool Road at Moorngag; and • Lake Nillahcootie Head Gauge. It is recommended that these sites continue to be used. However, a site above Lake Nillahcootie needs to be included such as Lake Nillahcootie Road at Barjarg. **Temporal: Frequency of sampling**	2. A site immediately above Lake Nillahcootie added to the sites currently being monitored for water quality and nutrients. 3. Nutrients to be monitored for TP. 4. Flow or gauge heights measured to calculate loads.	• If sampling downstream of impoundment then you are probably going to be measuring what's happening in that impoundment (see section 3.9). • Minimum sampling frequency should be fortnightly and is typically

Recommended Indicator / Parameter	Methodology	Temporal and Spatial Scale	Recommendation	Influencing factors
	(Baldwin *et al* 2005). It is important that flow data is recorded when water quality samples are taken so that loads can be calculated.	• Measure Total Phosphorus fortnightly as part of regular monitoring program. • Measure the above during an event such as a flood or a prolonged period of low flow.		restricted to gauging stations. An alternative is to install Stage Height Auto Samplers. Although the initial cost to setup is high, the data obtained is more reliable. They can also be deployed at sites not adjacent to gauging stations.

Temperature	Temperature loggers (e.g. TidbiT Data Loggers) are relatively inexpensive and are able to be deployed for extended periods in the field and log data at predetermined intervals.	**Spatial: Location of sampling sites**
		• Lake Nillahcootie Road at Barjarg;
		• within the lake at Lake Nillahcootie Head Gauge;
		• three sites below Lake Nillahcootie:
		  • William Road at Lima South;
		  • Swanpool Raod at Moorngag;
		  • Yin Barun Road at Yin Barun.
			5. Temperature loggers should be deployed upstream, within and at three sites below the Lake Nillahcootie.	N/A

Hydrology	All gauging stations should be operational and installed with auto-loggers and water level data converted to flow rates via derived rating curves for each station. Flow rate data is usually recorded on a daily basis or more frequently. The network of gauging stations should be sufficient for event monitoring. Data currently collected by Thiess is stored in the Victorian Water Resources Data Warehouse (http://www.vicwaterdata.net/). Parameters monitored include: • Average annual flow; • Average daily flow (computed);	**Spatial: Location of sampling sites** Locations of gauging stations on the Broken River are: In Management Unit L5: • Broken River at Gowangardie Weir Head Gauge; In Management Unit M1: • Broken River at Goorambat (Casey's Weir Head Gauge); • Broken River at Moorngag; In Management Unit M2:	6. The gauge downstream of Bridge Creek is upgraded to measure the suite of parameters currently monitored by the other gauges.	N/A

Recommended Indicator / Parameter	Methodology	Temporal and Spatial Scale	Recommendation	Influencing factors
	• Average daily flow (historic); • Average monthly flow; • Average season flow; • Instantaneous flow; • Rainfall; • Station level; • Temperature; • EC.	• Broken River at Lake Nillahcootie (Head Gauge); • Broken River at d/s Bridge Creek (Station levels only)		
Index of Stream Condition (ISC) Streamside Zone Sub-index	The ISC is made up of five Sub-indices, of which the Streamside Zone Sub-index assesses the quality and quantity of Riparian vegetation. It consists of a list of indicators such as width of streamside zone, longitudinal continuity, structural intactness, cover of exotic vegetation, and regeneration of indigenous woody vegetation. As an ISC assessment has been done on the Broken River in 1999 and 2004, this has provided a benchmark of riparian vegetation condition and monitoring should be assessed against these. For methods see White and Ladson (1999), "An index of stream condition: User's Manual (second edition)" and "An index of stream condition: Reference manual".	**Spatial: Location of sampling sites** There are 6 ISC reaches on the Broken River. The first two reaches are located in Management Unit L5, reach 1 is between Gowangardie Weir and the Broken Rivers confluence with the Goulburn River, reach 2 is located between Gowangardie Weir and Casey's Weir. Reaches 3 and 4 are located in Management Unit M1, reach 3 is between Casey's Weir and Benalla and reach 4 is between Benalla and Lake Nillahcootie. Reaches 5 and 6 are located in Management unit M2, reach 5 is located directly above Lake Nillahcootie and reach 6 is located further up in the catchment near Barwite. For more detail on the sites see the data warehouse website. **Temporal: Frequency of sampling** • Long Term - ISC is designed to be monitored every 5 years; a benchmark of stream condition was set in 1999, and then completed again in 2004.	7. The ISC monitoring is continued.	N/A

Recommended Indicator / Parameter	Methodology	Temporal and Spatial Scale	Recommendation	Influencing factors
Riparian Trend Assessment	The Riparian Trend Assessment is based on two reports submitted to the GB CMA by Earth Tech which assessed current riparian condition of 30 sites in the upper Goulburn catchment, and 33 sites in the lower Broken catchment. Riparian Trend Assessment consists of the following methodologies: • Vegetation Quality Assessment (VQA) This method is a quick assessment of habitat condition in the riparian zone. A final VQA score is based on 7 key attributes, each one given a score out of 5. A final score is obtained between 7 and 35; 7 considered very poor and 35 considered as excellent. The attributes are as follows: o Above bank vegetation width o Soil disturbance o Tree health o Tree regeneration o Weed presence o Species richness o Vegetation structure • Rapid Habitat Assessment (RHA) This method is a modification of the Habitat Hectares approach (Parkes et al, 2003). It provides a measure of quality and quantity of native vegetation and habitat characteristics in relation to native vegetation type. Condition is classified into three categories after a final score has been given; low medium and high. Attributes considered are as follows: o Large trees o Canopy cover o Understorey o Weeds o Recruitment o Organic litter o Logs o Patch size o Neighbourhood o Distance to Core area. • Riparian and Instream Health metrics based on Index of Stream Condition 2004 (2nd edition) This is additional information collected considering different methodologies, including:	**Spatial: Location of sampling sites** Continue assessment at sites in the lower part of the Broken catchment (L5 and lower part of M1) and adding sites in the mid and upper catchment to obtain benchmark information. **Temporal: Frequency of sampling** Measure vegetation in between the regular ISC monitoring timeframe – every 2 years.	8. Conduct Riparian Trend Assessment in between the ISC surveys as an interim indicator of change in Riparian Vegetation.	N/A

Recommended Indicator / Parameter	Methodology	Temporal and Spatial Scale	Recommendation	Influencing factors
Index of Stream Condition (ISC) Physical Form Sub-index	Of the five Sub-indices in the ISC, the Physical Form Sub-index assesses stream bank and bed condition, quality of and access to instream physical habitat. It consists of a list of indicators such as bank stability, bed stability, impact of artificial barriers on fish migration and instream physical habitat. As an ISC assessment has been done on the Broken River in 1999 and 2004, this has provided a benchmark of stream condition and monitoring should be assessed against these. For methods see White and Ladson (1999), "An index of stream condition: User's Manual (second edition)" and "An index of stream condition: Reference manual".	**Spatial: Location of sampling sites** There are 6 ISC reaches on the Broken River. The first two reaches are located in Management Unit L5, Reach 1 is between Gowangardie weir and the Broken Rivers confluence with the Goulburn River, Reach 2 is located between Gowangardie Weir and Casey's weir. Reaches 3 and 4 are located in Management Unit M1, Reach 3 is between Casey's weir and Benalla and Reach 4 is between Benalla and Lake Nillahcootie. Reaches 5 and 6 are located in Management unit M2, Reach 5 located directly above Lake Nillahcootie and Reach 6 is located further up in the catchment near Barwite. For more detail on the sites see the data warehouse website. **Temporal: Frequency of sampling** • Long Term - ISC is designed to be monitored every 5 years; a benchmark of stream condition was set in 1999, and then completed again in 2004.	9. The ISC monitoring is continued.	N/A
Fish Migration	A fishway has been installed at Casey's weir with a fish trap to assist in monitoring. Monitoring should be continued by ARI. A fishway is planned to be installed at Gowangardie weir but has not yet been completed, however once it is installed ARI should monitor it also.	**Spatial: Location of sampling sites** • Casey's weir. • Gowangardie Weir.	10. Continue with monitoring of Casey's weir fishway. 11. Compliance - Install fishway at Gowangardie weir. 12. Compliance - Investigate the installation of a fish way at Lake Nillahcootie.	N/A
Fish Community Assemblages	Fish have been sampled previously using a backpack electrofisher. This procedure should be continued for consistency. Backpack electrofishing can sample big	**Spatial: Location of sampling sites** The location of sites should, where possible, correspond with sites used for monitoring	13. Sampling for fish abundance and richness is	• You will need ethics approval to

Recommended Indicator / Parameter	Methodology	Temporal and Spatial Scale	Recommendation	Influencing factors

	and small fish but its use is limited to shallow (waist deep) water. The use of electrofishing in combination with bait traps is recommended (Baldwin et al. 2005). For methods see Baldwin et al. 2005.	other parameters. Fish are currently being monitored by MDFRC bi-monthly as part of the Broken River Rehabilitation Project. Sites are situated between Shepparton and Benalla, however do not include upstream of Benalla. It is recommended that the monitoring take place across 5 sections of River, each section containing 2 sites totalling 10 sites.
		
		Management Unit M2
		• Two sites above Lake Nillahcootie:
		  • Old Tolmie Road at Barwite:
		  • Lake Nillahcootie Road at Barjarg:
		
		Management Unit M1
		• Two sites between Lake Nillahcootie and Benalla:
		  • Swanpool Road at Moorngag;
		  • Yin Barun Road at Yin Barun.
		• Two sites between Benalla and Casey's Weir:
		  • Scholes Road;
		  • Casey's Weir Up Stream.
		
		Management Unit L5
		• Two sites between Casey's Weir and Gowangardie Weir:
		  • Quinn Road;
		  • Gowangardie Up Stream.
		• Two sites between Gowangardie Weir and confluence with Goulburn River:
		  • Cosgrove Road;
		  • Keats Road.
		
		Temporal: Frequency of sampling
		• Initial sampling should occur seasonally
			recommenced in M2.
			14. Sampling to be continued in M1 and L5.
			15. Sites to be established in M1 above Lake Benalla.
				conduct fish surveys.
				• All electrofishing operations must be carried out under the supervision and control of a Senior Operator who has been awarded a Certificate of Competency in Electrofishing Procedures and Safety for the Backpack Electrofishing unit.

Recommended Indicator / Parameter	Methodology	Temporal and Spatial Scale	Recommendation	Influencing factors
		to assess variation in catch throughout the year. • After two years, sampling frequency should be scaled back to twice per year between 1st November and 30th April.		
Macroinvertebrates	EPA Rapid assessment.	• The EPA has conducted monitoring throughout all three Management Units, for a period of 10 years.	16. Continue with existing monitoring program.	N/A

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Appendix A

Consultancy Brief

Development of a Monitoring Program for the Broken River

MARCH 2007

Project Aim

To develop a monitoring program to evaluate and assess the management actions, resource condition targets and vision of the Regional River Health Strategy (GB CMA 2005) in the Broken River catchment.

Study area

The study area includes the Broken River from the Goulburn River to its most upstream point, just north of Mansfield. It includes the management units described in the Regional River Health Strategy as:

- L5 Lower Broken River
- M1 Mid Broken River
- M2 Upper Broken River

It excludes the Broken Creek and Lake Mokoan catchments:

- L2 Lower Broken Creek
- M4 Lake Mokoan
- M6 Upper Broken and Boosey Creeks

Tributaries of the Broken River will be considered in the context of their influence on the main trunk of the river. However, the design of the monitoring program does not apply to the tributaries themselves:

- M3 Ryans and Hollands Creeks
- M5 Warrenbayne Creek

Background

The Goulburn Broken Regional River Health Strategy (RRHS) (GB CMA 2005), a sub-strategy of the Regional Catchment Strategy (RCS 2002) sets the vision for the management of waterways in the Goulburn Broken region. It identifies environmental, economic and social values associated with the catchment waterways, threats to those values and priority actions to mitigate threats, protect values and work towards resource condition targets.

The GB CMA, with the community and partner agencies, has been implementing actions under the GB CMA Waterways Program and the "Improving Flow and Habitat in the Broken River" project. The RRHS requires that an effective monitoring, evaluation and reporting program be developed to enable clear feedback into the decision-making process.

The RRHS does not detail the design of the MER program but does identify key environmental assets for monitoring under Program A of the RRHS (pp 90-91), and provides guidelines for monitoring and evaluation of other RRHS programs.

To inform the project and river health program the monitoring program should enable evaluation of:

- implementation of actions;
- effectiveness of works to achieve expected effects;
- progress towards resource condition targets; and
- overall effectiveness in reaching the vision.

The monitoring program also needs to fulfil the requirements of funders (State Government, NHT, NAP and other funding bodies), be effectively conveyed to the community, maintain scientific rigour and be able to be applied, where appropriate, to other areas in the catchment.

Related projects and issues

The project should complement related projects and align with national and state policies and other GB CMA strategies, including:

- National Natural Resource Management Monitoring and Evaluation Framework.
- National Framework for Natural Resource Management Standards and Targets.
- Monitoring, Evaluation and Reporting Strategy for the Goulburn Broken Catchment (2004)
- State Environment Protection Policy (Waters of Victoria)
- GB CMA project: Development of a Program to Monitor Ecological Response to Environmental Flows in the Goulburn and Broken Rivers.
- From the Fringe to the Mainstream: A Strategic Plan for Native Biodiversity
- Goulburn Broken Water Quality Strategy 1996 – 2016.

Other Considerations

The decommissioning of the storage Lake Mokoan will result in changes to irrigation water delivery which may have significant implications for water quality in the Lower Broken River. Such implications should be considered I the design of the monitoring program, specifically the monitoring of water quality.

Objective

The primary objective of this project is to develop a monitoring program for the Broken River which will evaluate and assess the management actions, resource condition

targets and vision of the Regional River Health Strategy (GB CMA 2005). Additionally the monitoring program should:

- Fulfil National and State GB CMA obligations for monitoring and reporting;
- Be effectively communicated to funders, GB CMA staff and management, partner agencies and the community;
- Feed back into the strategic river health management decision-making processes; and,
- Be applicable to other areas of the Goulburn Broken catchment.

Task Brief

The project should build on the direction and findings of *A Review of Historic Monitoring (river health and water quality) and Research within the Broken River System* (Williams *et. al.* 2005), and be aligned with the RRHS MER guidelines.

The primary outcome of the study will be a program to monitor waterway works and activities and the health of the Broken River. It is expected that the major tasks will include:

- Identifying the vision for the Broken River catchment (in keeping with the vision of the RRHS);
- Identifying the resource condition targets for the Broken River;
- Identifying the management actions relevant to the resource condition targets, as per the Regional River Health Strategy;
- Defining the temporal and spatial scale of the monitoring program;
- Identifying potential indicators to be monitored and assess against "SMART" criteria (Specific, Measurable, Applicable, Realistic and Timely);
- Identifying standard indicators under the National Natural Resource Management Monitoring and Evaluation Framework;
- Providing recommendations of locations, methods, frequency and reporting of indicators;
- Commenting, where appropriate, on the reliability of methods and statistical power of data sets;
- Providing recommendations on appropriate data analysis, interpretation and reporting tools and formats.
- Describing the overall monitoring program within an adaptive management framework.

The scope of the tasks may be further defined at the project initiation meeting.

Consultation

Stakeholder consultation, if required, will be managed through the Mid Goulburn Broken Implementation Committee.

Role of Consultant

The consultant shall be responsible for the complete conduct of the study, including:

- Consultation and liaison
- Compilation of all available information and data
- Field surveys (if required)
- Preparation of cost estimates
- Organisation of meetings and workshops (if required)
- Correspondence
- Distribution of documents
- Project management
- Report writing

Background Information / Reports

The consultant should draw on information from all relevant sources. Suggested references include:

- Chee, Y.E., Webb, A., Cottingham, P. and Stewardson, M. (2006). *Victorian environmental flows monitoring and evaluation program: Monitoring and evaluation of environmental flow releases in the Broken River.* eWater Cooperative Research Centre: Canberra.
- Cottingham P., Stewardson, M., Roberts, J., Metzling, L., Humphries, P., Hillman, T. and Hannan, G. (2001) *Report on the Broken River Scientific Panel on the Environmental Condition and Flow in the Broken River and Broken Creek*. Technical Report 10/2001. Cooperative Research Centre for Freshwater Ecology: Canberra
- DeRose, R.C. (2003) *Assessment of reductions in suspended sediment and Total P loads as a consequence of riparian rehabilitation in the Goulburn-Broken Catchment*. CSIRO Land and Water: Canberra.
- DeRose, R.C., Prosser, I.P., Wilkinson, L.J., Hughes, A.O. and Young, W.J. (2003) *Regional Patterns of Erosion and Sediment and Nutrient Transport in the Goulburn and Broken Catchments, Victoria*. CSIRO Land and Water: Canberra.
- Garrett, B. and McLennan, J.R. (2004) *Monitoring, Evaluation and Reporting Strategy for the Goulburn Broken Catchment*. Goulburn Broken Catchment Management Authority: Shepparton, Victoria.
- Goulburn Broken Catchment Management Authority (2005) *Regional River Health Strategy.* Goulburn Broken Catchment Management Authority: Shepparton, Victoria.
- Goulburn Broken Catchment Management Authority (2004) *From the Fringe to the Mainstream: a Strategic Plan for Integrating Native Biodiversity 2004-2007.* Goulburn Broken Catchment Management Authority: Shepparton, Victoria.
- Goulburn Broken Catchment Management Authority (2002) *Regional Catchment Strategy*. Goulburn Broken Catchment Management Authority: Shepparton, Victoria.
- Goulburn Broken Catchment Management Authority (2002) *Goulburn Broken Water Quality Strategy*. Goulburn Broken Catchment Management Authority: Shepparton, Victoria.
- Natural Resource Management Ministerial Council (2002) *National Natural Resource Management Monitoring and*

Evaluation Framework. Natural Resource Management Ministerial Council: Canberra.

- Rundle, A.S. and Rowe, R.K. (1974) *A Study of Land in the Catchment of the Broken River*. Soil Conservation Authority: Victoria, Australia.
- Williams, J., Mitchell, A. and Gawne, B. (2005) *A Review of Historic Monitoring (river health and water quality) and Research within the Broken River System.* Murray-Darling Freshwater Research Centre: Wodonga, Victoria.

Management Arrangements

Study Principal

Goulburn Broken Catchment Management Authority.

Project Management

Sue Botting (until March 30th 2007)

Water Quality and River Health Coordinator

Goulburn Broken Catchment Management Authority

P.O. Box 1752, Shepparton, Victoria

Phone (03) 5820 1113

Mobile: 0407 369 060
Facsimile: (03) 5831 6254

E-mail: sueb@gbcma.vic.gov.au

Wayne Tennant (post March 30th 2007)

Manager, Strategic River Health

Goulburn Broken Catchment Management Authority

P.O. Box 1752, Shepparton, Victoria

Phone (03) 5820 1100

Mobile: 0407 369 060

Facsimile: (03) 5831 6254

E-mail: sueb@gbcma.vic.gov.au

Project Meetings

The consultant will be expected to work closely with the Goulburn Broken Catchment Management Authority during the study. The consultant's Project Manager will be required to meet with the GB CMA Project Manager to confirm project schedule (Project Initiation Meeting), and then at regular intervals (draft report and final report submission) to coordinate the study work plan and review progress.

Reporting Outcomes

The final report is to include a non-technical summary. Technical matters are to be dealt within the body of the report or subsidiary reports as necessary. All data compiled for the study is to be made available in computer readable form. The report is to include sufficient detail for the work to be replicated.

The consultant shall produce the following:

- A draft report suitable for reproduction
- Final report in the following forms:
  - Stand alone Executive Summary
  - Electronic copy (CD or DVD) of report in pdf, Microsoft Word and Microsoft Excel formats
  - Electronic files (CD or DVD) of all mapping, shapefiles to be ArcView 9.1 compatible and in GDA 94 projection
  - 3 bound copies in A4 format (Printed on both sides of the page)

Project Timetable

The final report is to be completed within 3 months of the consultant being notified of acceptance.

The following indicative project timetable is proposed:

- Seek submission (2nd March 2007)
- Closing date for submission of brief (14th March 2007)
- Consultant appointed (15th March 2007)
- Project initiation meeting (16th March 2007)
- Draft report completed (4th May 2007)
- Final report (31st May 2007)

Form of Response

The Proposal will need to clearly demonstrate that the Consultant has the necessary capacity, skills and experience to achieve the project objectives. To establish a consistent basis of comparison, it is mandatory that the Proposal be submitted in the following standard format:

A covering letter referring to the three Attachments and dated and signed by a person authorised to enter into a contract. The letter should identify the key contact person for further information.

Attachment 1 - Experience in work of this nature, Nominated Resources - names, qualifications and relevant experience of key personal.

Attachment 2 - Detailed costs associated with performance of the tasks; fee structure for appointment, plus itemised costs for support / disbursements (vehicles per km rate as used when directed by the Authority, etc.)

Attachment 3 - Details of Occupational Health and Safety Management Systems should be provided as a separate attachment.

Proposals should be short and concise, with the minimum of superfluous marketing information.

Proposals that do not conform to the required format may be excluded from the selection process at the Steering Committee's discretion.

Fee Basis

A detailed fee basis for this consultancy is to be provided. Any specialist sub-consultants should be detailed and costed into the proposal. The fee should be inclusive, including reimbursable, travel and accommodation costs. A fixed fee proposal is preferred.

Funding for the study is expected to be up to $20 000. The final funding allowance will be approved by the Project Manager after consideration of the submitted proposals.

Payments will be made by the Principal at monthly intervals up to 50% of the total fee. A further 25% of the fee will be paid on receipt of the draft report. A final payment of 25% of the total fees payable will be made after acceptance of the final report by the Project Manager.

Lodgement of Response

One hard copy of the proposal is to be sealed in an envelope or package, which should be endorsed *CONFIDENTIAL* and clearly marked:

Goulburn Broken Catchment Management Authority

Consultancy Proposal

Development of a Monitoring Program for the Broken River

The envelope should be addressed to:

Sue Botting (Confidential), Goulburn Broken Catchment Management Authority, P.O. Box 1752, Shepparton 3632

The proposal must be provided with a covering letter certifying the accuracy of all information supplied, providing the name of the authorised contact, and signed by a senior officer of the organisation.

Proposals may be delivered by Australia Post or lodged in person at 168 Welsford Street, Shepparton, prior to the closing date. In lodging a proposal the organisation is deemed to have accepted the terms and conditions of the Consultancy Brief. All responses shall become the property of the Goulburn Broken Catchment Management Authority.

Closing Date

The closing time for the lodgement of responses is

4:00 pm on Wednesday 14 March 2007.

Late responses will not be considered.

Confidentiality

The Goulburn Broken Catchment Management Authority undertakes to treat all information received in Proposals as strictly confidential and commercial-in-confidence. The information will only be made available to the sub-committee of the Steering Committee. On completion of the selection process, only one copy of the information will be maintained on a secure file and all other copies will be destroyed. The intellectual property contained in Proposals remains the property of the consultant that lodged the submission.

Terms of Engagement

The terms of engagement will be the Goulburn Broken Catchment Management Authority's standard conditions of engagement as specified in the contract.

This Brief and the Consultants Proposal will form part of the contract documentation.

Any contract awarded or entered into by the Goulburn Broken Catchment Management Authority with any other person or corporation shall be on the basis that all outputs produced directly or indirectly from the work or services the subject of the contract shall become and remain the sole property and copyright of the Goulburn Broken Catchment Management Authority and shall be freely available for the Goulburn Broken Catchment Management Authority to use in its absolute discretion in any of its projects or works, reporting requirements and/or as the basis for follow-on consultancies. All such outputs shall be provided to the Goulburn Broken Catchment Management Authority by the contractor in such forms or formats as the Goulburn Broken Catchment Management Authority shall reasonably require and without fetter or restriction by password or code or otherwise. The consultant and partner organisations will be able to access and publish all data following approval by the Authority.

Further Information

The point of contact for further information of a technical or explanatory nature should be the GB CMA Project Manager.

Requests for further information will only be responded to if submitted in writing. Every endeavour will be made to respond in writing to questions within two working days of receipt.

Date of Brief

The date of this Consultancy Brief is 1st March 2