

## Water Processes Theme Summary of Pilot Audit Technical Report

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## Preface

The Sustainable Rivers Pilot Audit (2002-2003) was set up to develop and agree on indicators and analytical procedures and identify costs and logistics of implementing a Basin-wide Sustainable rivers Audit. The Pilot project was completed at the end of 2003. The outcomes of the Pilot Audit are reported in 5 technical reports covering the major groups of indicators trialed in the Pilot Audit: fish, macroinvertebrates, hydrology, physical habitat and water processes.

This document is the Executive Summary only of the water processes technical report from the Pilot Sustainable Rivers Audit. The full technical report is available on CD by contacting the office of the Commission on 02 62790100. Copies of the reports can also be loaned from public libraries throughout the Basin.

This summary outlines the major conclusions and recommendations for the water processes theme. Subsequent to the Pilot Audit, partner governments to the Murray-Darling Basin Commission agreed to implement a Basin-wide Sustainable Rivers Audit from 2004/05 to 2010/11 with the following elements:

### Three groups of indicators (“themes”) for immediate implementation:

- Fish: 13 indicators derived from fish field sampling to be carried out once every 3 years in each of 23 valleys in the Basin;
- Macroinvertebrates: 3 indicators would be derived from field sampling once every 2 years in a single season in the 23 valleys of the Basin.
- Hydrology: 12 indicators to be derived from long term modeling sequences for modeled (largely regulated) areas only in each of the 23 valleys in the Basin, once each 6 years.

### Three groups of indicators (“themes”) for further development:

- Physical Form
- Riparian vegetation
- Floodplain ecosystems

Further information on the design and roll out of the Basin-wide Sustainable Rivers Audit will be released in the second half of 2004.

## Background

Murray-Darling Basin water reforms were introduced to improve water use efficiency and to provide protection for aquatic ecosystems across the Basin. The most significant reform, the introduction of the Cap on diversions, sought to balance protection of the riverine environment with the need for consumptive water use. In 2000, the Murray-Darling Basin Ministerial Council (MDBMC) noted the absence of a long-term Basin-wide assessment that could determine the effectiveness of current management practices, including the Cap, in sustaining river health. They agreed to initiate the development of a Sustainable Rivers Audit (SRA) that would assess river health using five themes: macroinvertebrates, fish, water quality, hydrology and habitat.

The primary aim of the SRA would be to provide consistent Basin-wide information on the health of rivers (through a rigorous systematic monitoring program) to drive high level, sustainable land and water management decisions. In 2001, the Cooperative Research Centre for Freshwater Ecology developed a framework for assessing the health of the Basin's rivers with the active involvement of jurisdictional representatives (Whittington *et al.*, 2001). However, before the SRA could be implemented on a Basin-wide scale, it was agreed that a Pilot SRA be conducted in four catchments in 2002/03 (Condamine, Lachlan, Ovens and Lower Murray) to trial and refine indicators and methods, and to identify logistical constraints and indicative costs.

The water processes theme intersects between 'drivers' (and 'modifiers') of river health and 'outcomes' of river health, as described by Whittington *et al.* (2001). Drivers and modifiers are processes that can change river health, while outcomes measure its resulting condition. Water quality is usually regarded as a driver of river health and all the biota living in it. Physico-chemical indicators of water quality characteristics can be seen as 'drivers' influencing important ecological processes. However they do not aid the quantification of river processes on the broad temporal and spatial scales proposed by the SRA. Water quality can also be regarded as an 'outcome' of health in its own right, a resulting sum total of water inputs, flow and in-stream ecological processes, and as a habitat medium for many organisms. Viewed from this perspective, its role in a river health assessment needs to be made explicit and be distinguished from traditional water quality assessments. This shifts the emphasis to the dynamic ecological processes taking place within the water column. These processes often determine sustainability of the water quality and it is now generally recognised that the focus of measuring in-stream health should be directed towards increasing our understanding of water column metabolic processes. The inclusion of these metabolic processes indicators is therefore considered essential for this theme, and has shifted the emphasis from water quality ('drivers') to water processes ('outcomes').

This report summarises the methods, results and recommendations, focussing on the technical factors, for:

- metabolic rates
- stable isotope ratio measurements
- water quality 'spot' measurements which largely contain the traditional water quality parameters.

The costs of implementing any of these groups of indicators in a Basin-wide Sustainable Rivers Audit (SRA) were considered subsequent to these technical considerations and are outside the scope of this report. Cost considerations are presented in the SRA Design report, along with a suggested efficiency rating of all potential Audit components (for instance – fish, macroinvertebrates, physical form etc). The analysis in that report suggests that standard water

quality indicators (i.e. spot measures) are unlikely to be an efficient input to assessing river health for the SRA. Furthermore, the costs of pursuing metabolic processes are marginal considering the current opinion about how useful the information is to assess river health at the relevant scale.

The result is that neither of these components were advocated for inclusion in the first stage of implementation of the SRA. A further consideration was the substantial overlap of a potential water quality/process component of the SRA with existing State water quality monitoring programs. While these existing programs can provide useful information into the Auditing process (possibly to support or interpret assessments based on other indicators), it was not considered appropriate to attempt to make water quality assessments based on current State data programs meet the SRA objectives. The process by which this could happen is yet to be scoped and will depend on the adoption of a Basin-wide Audit. Recommendations are therefore limited to components of this theme that can be incorporated into the SRA without incurring the high costs associated with high intensity field sampling. Further conclusions of the Pilot study are also presented in the event that this theme would be included in a future stage of the SRA.

## **Design and methods**

A referential framework has been adopted for the SRA. The aim is to express current river health relative to ‘the condition that would exist now in the absence of human influence experienced during the past two centuries.’ This ‘natural reference condition’ is used to facilitate comparisons across the Basin. Its use does not equate with the objective of returning rivers to a natural condition.

Sampling for the Pilot focused on the main river network excluding two important components of riverine ecosystems: aquatic habitats on the floodplain and ephemeral systems. It is expected that these systems will be considered for inclusion in the full SRA given their importance to fish and macroinvertebrate communities.

The four river valleys were divided into three valley process zones (VPZ’s) based on geomorphic characteristics: sediment source, sediment transport and sediment deposition. The total number of sites was based on the need for adequate reporting at the valley scale. Results can be reported at finer resolutions but with lower confidence. The number of sites allocated to each zone was based on the area of the zone. Sites were located at random within a zone to ensure that the sampling was unbiased and measurements could therefore be combined to infer the condition of the entire valley.

The water processes theme was developed to generate indicators that would enable an assessment of in-stream metabolic processes. The suitability of existing methods for measuring ecological processes - gross primary production (GPP) and respiration (R) were investigated, as was the potential for stable carbon (C) and nitrogen (N) isotope ratios as indicators of river health. Spot measurements of water quality were also included – they were viewed as important ‘drivers’ of change but less informative than process measures (which are ‘outcomes’). Both groups include indicators that are subject to high temporal and spatial variability.

Data were collected at approximately 40 assessment sites per valley which generally overlapped with the Pilot Audit fish assessment sites. Although sites are listed in

*Table 1* as source, transport and deposition, the latter two categories were assumed to behave similarly under base-flow conditions. This was important with regard to the development of reference condition. No ‘best available’ sites were selected for the Murray and Ovens

catchments. The sites selected for metabolic processes and stable isotope ratios are subsets of the water quality spot measurement sites.

**Table 1. Number of sites selected for water quality per VPZ (source, transport, deposition, numbers in italics) and for entire valley (total, best available and assessment), metabolic rates (whole-stream, pelagic and benthic) and stable isotope sampling**

Valley	Water quality						Metabolic rates			Stable Isotopes
	<i>Source</i>	<i>Transport</i>	<i>Deposition</i>	<b>Total</b>	Total best available	Total assessment	Whole-stream	Pelagic	Benthic	
Condamine	<i>12</i>	<i>16</i>	<i>26</i>	<b>54</b>	16	38	9	-	-	-
Lachlan	<i>12</i>	<i>12</i>	<i>36</i>	<b>60</b>	17	43	11	6	4	28
Murray	-	-	<i>42</i>	<b>42</b>	-	42	-	-	-	-
Ovens	<i>21</i>	<i>9</i>	<i>13</i>	<b>43</b>	-	43	12	-	-	32
<b>Total</b>	<b>45</b>	<b>37</b>	<b>117</b>	<b>199</b>	<b>33</b>	<b>166</b>	<b>32</b>	<b>6</b>	<b>4</b>	<b>60</b>

Substantive attempts were made to define reference condition for metabolic process indicators (GPP and Respiration), for isotope ratios of  $\delta^{15}\text{N}$  and  $\delta^{13}\text{C}$  of submerged algal and plant material, and for spot measurements (temperature, conductivity, pH, dissolved oxygen, turbidity, total phosphorus, total nitrogen, NO<sub>x</sub> and chlorophyll-a). The Pilot project aimed to investigate suitable methods for monitoring water processes and characteristics at the Basin scale. At that scale, it proved difficult to define reference conditions for those nine water quality indicators with great confidence. As a result, an assessment of river health was not made against reference and only raw results have been reported. Reference condition values have been presented together with results, but no attempt was made to use these to assess water quality condition.

**The indicators considered for the water processes theme are listed in**

*Table 2.* Indicators related to in-stream processes have the greatest value in increasing our understanding of the in-stream ecology. The Pilot project investigated the use of metabolic process indicator methods and their suitability for routine monitoring purposes on a Basin wide scale. Routine monitoring on a Basin-wide scale for water quality and processes is currently non-existent. Three methods for measuring metabolism rates were trialled: whole-stream metabolism, benthic chambers and pelagic chambers, and their use and compatibility as monitoring tools were discussed on the basis of the experiments, technical problems and results obtained.

**Table 2. List of indicators trialled in the Pilot SRA for the Water Processes theme**

Indicator / Indicator Type		Classification
<b>Rate Measures</b>		<b>Note: calc = used in calculation of process, Interp = used in interpretation of process</b>
1	Respiration / Gross Primary Production 1a. Benthic domes 1b. Water column 1c. Total channel	Primary Ecological Process
2	Stream diurnal DO, pH and temperature	Primary Ecological Process
3	External Light	Modifier, GPP and respiration (calc)
<b>Standing Stocks – Spot measures</b>		

1	Macrophyte delta C <sup>13</sup> and delta N <sup>15</sup>	Primary Ecological process indicator
2	Pelagic chlorophyll-a	Primary Ecological process indicator
3	Phosphorus (TP, FRP)	Secondary ecological process indicator Modifier, GPP (Interp)
4	Nitrogen (TN, NO <sub>x</sub> , NH <sub>4</sub> )	Secondary ecological process indicator Modifier, GPP (Interp) Calc Redox (NO <sub>x</sub> :NH <sub>4</sub> )
5	Turbidity	Secondary ecological process indicator Modifier, GPP (calc)
6	Clarity – PAR extinction, Secchi depth	Modifier, GPP (calc)
7	Electrical Conductivity	Modifier, GPP (calc)
8	Alkalinity	GPP (calc)
9	Temperature	Modifier, Total respiration (calc)
10	Instantaneous velocity and flow	Modifier, GPP/respiration (calc) and Standardisation to reference

## Results

### Metabolic rates

The whole-stream method shows the greatest potential for developing a routine monitoring tool, despite the inaccuracies with determining re-aeration coefficients, one of the three components in the change of dissolved gas concentration. The accuracy with which the other two components, production (photosynthesis) and respiration can be determined is affected by this re-aeration coefficient. The problems with estimating re-aeration coefficients are greater in the upstream regions than in the lowland areas, due to the higher turbulence and more complex mixing regimes characteristic of those uplands. To some extent greater accuracy can be achieved by using the ‘two-station’ method, but this would be more costly and not directly comparable to a ‘one station’ measurement in a lowland area. Deployment of data loggers in upland areas could also be constrained by shallow depths and fluctuating water levels, especially at base-flow conditions.

However, compared to chamber methods the whole-stream method is preferred, due to its relative ease of sampling, lower potential for equipment failure or breakdown and the data collected being an integrated measure of GPP and respiration. A model exists to validate diurnal production and respiration rates (Grace and Harper, 2003), which was used to verify and screen data collected in the Pilot. This model may need further refinement (including defining its limitations) and could be used to develop a routine monitoring protocol.

The chamber methods are only measuring parts of the metabolic processes taking place in the water column, and therefore direct comparisons between data collected with the chambers and the whole-stream method are not possible. In contrast to the whole-stream method, exchange rates of oxygen between the atmosphere and the water column can be measured fairly accurately in enclosed chambers, but there are possible distortions of the metabolic processes due to light fractionation and reduction within the chambers. The distortions and the limits imposed by the enclosures mean that measured rates do not necessarily reflect what is happening in the surrounding water column. Benthic and pelagic chambers only measure certain aspects of total metabolic processes and cannot be compared directly. Comparisons between chambers and whole-stream methods reveal that chambers consistently underestimate metabolic rates, but the proportion of underestimation can vary considerably, making calibration between both methods problematic (Poirier *et al.*, 2003).

Reference conditions were developed for GPP/R ratios and include a decision tree model (Bormans, 2003). Although these reference conditions can be used to assess stream condition, it

is not clear whether it would be useful to make a cross-Basin assessment. Therefore, it is recognised that reference condition will need to be refined further before valid assessments and cross-valley comparison of condition can be made.

### **Stable isotope ratio measurements**

Stable carbon (C) and nitrogen (N) isotope analysis of in-stream vegetation (vascular plants and filamentous algae) has been trialled in the Pilot project as indicators of river health. Stable nitrogen isotopes have been used as tracers of anthropogenic sources of nitrogen in aquatic ecosystems, while stable carbon isotopes have been used in identifying sources of organic carbon that support food webs. During the Pilot project, a number of samples of algal and vascular plant material were collected from the streambed at sites sampled for other water quality indicators within the Condamine, the Lachlan and the Ovens catchments during spring 2002 and summer 2003. The material was collected according to the protocols developed for the Pilot project (APPENDIX 3) and the samples were analysed by mass spectrometry for stable C and N isotope ratios.

The results indicate that considerable variation in stable nitrogen (and carbon) isotope signatures was found among samples of aquatic plants in river sites in NSW and Victoria, collected in the SRA Pilot.  $\delta^{15}\text{N}$  values for the Lachlan ranged from  $-6.2$  to  $13.3$  ‰ and those for the Ovens ranged from  $-1.1$  to  $12.2$  ‰. The high level of variation in isotope values recorded among 'replicate' samples within sites/times is associated with a broad range in ‰ C and N values. This, together with the noted variety of plant samples processed in the laboratory suggests that a wide range of material was collected, including filamentous algae, N-fixing biofilms and emergent C4 macrophytes. Although the Pilot study has highlighted some strong evidence of correlations between land use and N isotope signatures, this work is in a preliminary stage and will need further development before the inclusion of isotope ratios as an indicator can be considered. This indicator would potentially be useful in establishing the relationship between land and water interactions with regard to modification of nutrient cycles.

The C isotope ratio has the potential to be used as an indicator of river health, but further research is needed to establish if confounding factors can be eliminated. C isotope ratios can be used as a check on extreme values of GPP, and may be a useful aid in developing methods for accurate GPP measurement. The collection of primary consumers has the potential for integrating these indicators over different time scales. Collection and analysis of the data can be done at low cost, but training is required to ensure quality assurance of the data collected in the field.

### **Water quality spot measurements**

Water quality indicators may be regarded as 'diagnostics' to explain river health condition if they can capture 'driver' mechanisms, but their explanatory value is likely to be limited by the ability of the sampling design and frequency of the program to capture trends for indicators with small and/or variable temporal scales. Water quality sampling sites for the Pilot project were selected and sampled according to a protocol agreed upon during the initial technical workshop and involved a limited number of 'best available' sites and a larger number of assessment sites. These sites are a subset of fish and/or macro invertebrate sampling sites and the sampling was undertaken during base-flow conditions. Samples were collected during winter 2002 (limited sites), spring 2002 and summer 2003. Data were collected and substantive attempts made to define reference condition for nine water quality indicators: temperature, conductivity, pH, dissolved oxygen (DO), turbidity, total phosphorus, total nitrogen, NO<sub>x</sub> and chlorophyll-a.

The results of nine indicators are presented in the report for best available sites and assessment sites. Spot measures of physico-chemical indicators can have interpretive value for several of the SRA themes, including the metabolic processes indicators.

Defining reference condition for water quality spot measurements would need to be determined and refined before the first assessment of river health condition could be conducted. This would need to be done for all Basin valleys, and would require a coordinated approach. The confidence levels in reference condition of 'natural' may be limited and difficult to quantify, due to the difficulties in using best available sites and in limited data being available. However, as more information and data become available, reference condition can be tighter defined and informing on targets may become possible over time. Reporting against targets and on long-term trend detection would gain importance over time and gradually replace assessment against reference condition.

## Recommendations

As a result of the water processes theme not being recommended for inclusion in the SRA, only three main recommendations have been formulated:

1. A water quality assessment (including GPP, R and Chlorophyll-a) be included in the Remote Sensing Pilot Study objectives which will be undertaken as part of methods development for floodplain assessment, riparian vegetation and physical form. Part of the field verifications and calibrations undertaken for the other themes could include water quality measurements, perhaps by telemetry.
2. ISRAG to develop guidelines for assessing:
  - a. interpretive datasets from State and other programs, including nutrient budget models (Young *et al.*, 2001 and Prosser *et al.*, 2001) and equilibrium models (Lawrence, 2002)
  - b. water quality data to be collected as part of SRA fish and macroinvertebrate sampling, to assist in the interpretation of data collected for biotic themes for the SRA.
3. The SRA to keep a watching brief over research related to metabolic processes and the development of GPP/R24 as a routine monitoring tool.

The report also lists a number of conclusions resulting from the Pilot project which could be regarded as recommendations in the event that the water processes theme would be included in the SRA at some point in the future (section 10.2).