4. Rivers

Key Findings

- Four NRM regions provided information for river asset accounts, based on existing and, in some cases, long-standing state and regional river monitoring programs.
- It is possible for existing state and regional river health monitoring programs to produce high quality environmental asset condition accounts for regional purposes.
- The four monitoring programs used different suites of indicators. This presents challenges for national accounting and highlights the need for a national river condition accounting standard, such as that proposed in the 2011 Framework for the Assessment of River and Wetland Health.
- Two of the three jurisdictional river assessment programs changed their assessment methods between sampling periods, making it impossible to establish a reliable trend. Future assessments should be designed to enable comparison between accounting periods.
- The use of different aggregation methods and differences in estimating reference conditions further limit the ability for jurisdictional monitoring programs to be compared between regions.

Introduction

There has long been concern about the condition of Australia's rivers and associated wetlands and floodplains. Consequently, river condition assessments have been undertaken for nearly two decades, with specific programs developed for jurisdictional reporting needs (Abal *et al.* 2005; DNRE 1999; ERM in Healey *et al.* 2012) and for specific regions like the Murray Darling Basin (Davies *et al.* 2010) together with occasional reports at the national scale (NLWRA 2002). There is more experience in assessing the condition of Australian rivers than for any other environmental asset considered in these trials, and the methods for river condition assessment are more developed than for other assets.

These river condition assessment methods have been primarily developed in eastern Australia (i.e. Tasmania, Victoria, NSW and Queensland) (DEWHA 2009). They differ in the themes that they include (eg only some river assessment programs include riparian vegetation) as well as in the specific indicators used within each theme. While these differences are to be expected given the different purposes of the programs, it is recognised that developing a national river condition assessment program based on data collected in these state assessment programs is challenging (Norris *et al.* 2007a). In 2004, Commonwealth and state governments commenced a major program, the Framework for Assessing River and Wetland Health (FARWH), to develop a nationally consistent set of river and wetland condition indicators based on the various jurisdictional monitoring programs (Alluvium Consulting 2011).

The FARWH program is unique amongst the environmental assets considered in this report in that it specifically set out to conduct experiments to determine whether indicators from the disparate jurisdictional river condition programs could be combined to provide a national picture of river condition. Consequently, this chapter draws on both the river accounts developed in this trial and on findings from the FARWH program.

Rivers are listed as an asset in over 70% of the country's NRM regional strategic plans (GHD 2012) (**Supplementary Material 7**).

Accounting for Nature and the Framework for the Assessment of River and Wetland Health Trials

Rivers accounts were submitted by four trial regions: SEQ Catchments, North Central CMA, Queensland Murray-Darling Committee and NRM North. Queensland Murray-Darling Committee extended its boundaries to include the Condamine and parts of South West NRM to better capture the Queensland Murray-Darling Basin catchment (see **Chapter 1**, **Figure 2**), while NRM North only reported on the Tamar catchment within its region.

The FARWH program commenced some years earlier than the *Accounting for Nature* trials. It was developed as part of the 2005 Australian Water Resources Assessment (National Water Commission 2006) and subsequently funded and expanded by the National Water Commission (2008-2011). It had the aim of providing "assessments of the aggregate impacts of resource use on rivers and wetlands as the basis for reporting on waterway condition at a national scale from comparable state and territory-based assessments" for use in State of Environment reports, the annual National Water Account, and reports to fulfil international obligations (eg Convention on Biological Diversity). The $8 million program

was overseen by river and wetland experts from federal and state government agencies, universities and CSIRO.

FARWH took a comprehensive approach to river and wetland health (Norris *et al.* 2007b), using six key themes that together measured ecological integrity:

- Physical form
- Water quality and soils
- Aquatic biota
- Hydrological disturbance
- Fringing zone
- Catchment disturbance.

The design of indicators in *Accounting for Nature* echoed many of the features of the FARWH design. In common with *Accounting for Nature*, FARWH assumes that different indicators will be required in different parts of Australia for each theme because of different local issues. It also uses conceptual models of underlying processes to derive indicators and a reference condition based on pre-European conditions. FARWH scores condition on a scale of 0-1 (*Accounting for Nature* uses a scale of 0-100). It also allows for different methods for aggregating indices to measure overall river or wetland health. FARWH requires that quantity and quality of each asset both be reported for accreditation.

Initial trials of FARWH compared the Victorian Index of Stream Condition and the Tasmanian Conservation of Freshwater Ecosystem Values indices against standard FARWH river condition indices (Norris *et al.* 2007a). FARWH indicators were subsequently tested across a wider variety of climate zones and river types and State river monitoring programs in Queensland, southwest Western Australia and northern Australia (see Alluvium Consulting (2011) for details). FARWH was also tested in wetlands in five NSW NRM regions (reported in Chapter 8).

In regions with well-developed monitoring programs, such as Queensland, the FARWH trials used the existing monitoring programs supplemented by additional field sampling, modelling and remote sensing data. Thus, SEQ Catchments' Ecosystem Health Monitoring Program monitoring of water quality was augmented by remote sensing and modelling to include the Fringing Zone, Hydrologic Disturbance and Catchment Disturbance indicators required by FARWH. In regions without well-established aquatic monitoring programs (i.e. Northern Australia and Southwest WA) FARWH was used to undertake major field and desktop data collection exercises to populate the indicators.

Comparison of Approaches

Classification of Assets

Rivers are defined as freshwater aquatic systems contained within a channel and their associated streamside vegetation (Aquatic Ecosystems Task Group 2012). They may periodically or continuously contain moving water, and include both single channel and multi-channel systems.

For the purposes of these trials, the accounting units were defined by each region, for example reporting by catchments, subcatchments or river reaches. The environmental accounts trial relied on data from jurisdictional river assessment programs. Most data were reported at the site level, then aggregated to reaches and then to subcatchments.

Selection of Indicators

Data, methods and procedures for indicators used in the trial came from established river condition assessment programs within the relevant states (Table 26). River condition indicators usually fall into the following themes (Aquatic Ecosystems Task Group 2012):

- Hydrology
- Physical form
- Water quality (physical/chemical parameters)
- Riparian vegetation
- Aquatic biota (macroinvertebrates and/or fish)
- Recreational water quality (bacteria; nutrient cycling)
- Ecosystem processes

Indicator themes and measures were taken from jurisdictional assessment programs for use in the environmental accounts trial (Table 26). Although there are similarities in the types of indicators used within the themes, there is little consistency between assessment programs on the combination of themes used.

Table 26: Comparison of river theme condition indicators used in the environmental accounts trial.

	SEQ	North Central	QMDC	NRM North
Assessment Program	Ecosystem Health Monitoring Program (EHMP)	Index of Stream Condition and Sustainable Rivers Audit (ISC)	Sustainable Rivers Audit (SRA)	Freshwater Ecosystem Health Assessment Program (FEHAP)/ Tasmanian River Condition Index (TRCI)
Asset units	13 catchments	57 subcatchments; 4 catchments	4 catchments	11 subcatchments
Intended scale of assessment program	Reach-catchment	Reach - subcatchment	Reach – Zone- Valley	Subcatchment
Purpose of Monitoring Program	Used to advise councils and land managers on areas of declining health, report on the effects of different land uses, and evaluate the effectiveness of management actions aimed at improving and protecting aquatic ecosystems.	A monitoring program that benchmarks the condition of Victoria's major rivers and streams; used to help prioritise CMA work programs.	Surveillance, detecting and reporting on the signs of change. Provides independent information on the health of the river ecosystems within the MDB and to support the Basin Plan monitoring and evaluation framework to assess the success of the Basin Plan in reaching identified targets and objectives	TRCI: to inform understanding of river condition; prioritise investment and set strategic objectives; FEHAP (Tamar Estuaries and Esk River): to improve scientific understanding of issues impacting on the health of waterways to better identify and target priority areas requiring investment in on-ground works.
Assessment period (and number)	2003-2010 (10)	1999-2010 (3)	2004 -2010 (2)	2012 (1)
Hydrology	n/a	ISC Report 1: Amended annual proportional flow deviation; catchment permeability; daily flow variation due to hydroelectric power stations ISC Report 2: Low flows; high flows; zero flows; seasonality; variability ISC Report 3: Number of priority watering actions achieved (where available); low flows; high flows; zero flows; seasonality; variability (where priority watering actions not available)	SRA Report 1: High-flow events, Low- and zero-flow events, Variability, Seasonality, Gross volume calculated for specific gauging sites SRA Report 2: High-flow events; Low- and zero-flow events; Variability; Seasonality; Gross volume; median annual discharge calculated for significant hydrological nodes, weighted for stream length	n/a (not used but available through TRCI)
Physical Form	n/a	ISC Report 1: Bank stability, bed stability, artificial barriers, instream physical habitat ISC Report 2: Bank stability, bed stability, artificial barriers, instream physical habitat	SRA Report 1: n/a SRA Report 2: Bed dynamics, channel form, bank dynamics, floodplain form	n/a (not used but available through TRCI)
Water Quality	pH, conductivity, Diel (24hr) range and maximum temperature, Diel range and minimum dissolved oxygen; Ratio of 15N to 14N stable isotopes	ISC Report 1: Total phosphorous, turbidity, salinity (EC), pH ISC Report 2: Total phosphorous, turbidity, salinity (EC), pH	n/a	EC, pH, Turbidity, TP, TN

Fish	Proportion of native species expected, ratio of observed to expected species, proportion of alien fish	n/a	SRA Report 1: Expectedness; Nativeness SRA Report 2: Expectedness; Nativeness; Recruitment	n/a (not used but available through TRCI)
Macroinvertebrates	Number of macroinvertebrate taxa, PET richness (number of stonefly, mayfly and caddisfly families), average SIGNAL score	ISC Report 1: AUSRIVAS, SIGNAL ISC Report 2: AUSRIVAS, SIGNAL	SRA Report 1: Observed to expected ratio; observed to expected SIGNAL ratio SRA Report 2: simOE (i.e. community compositional similarity to Reference Condition)	O/E score (AUSRIVAS)
Riparian	n/a	ISC Report 1: Width, longitudinal continuity, structural intactness, cover of exotic vegetation, regeneration of native species, billabong condition ISC Report 2: Width, longitudinal continuity, structural intactness, cover of exotic vegetation, regeneration of native species, billabong condition	SRA Report 1: n/a SRA Report 2: vegetation abundance and diversity; vegetation quality and integrity, vegetation nativeness, vegetation fragmentation	Extent of vegetation, organic litter, logs, weeds, recruitment, canopy cover, number of species, cover, longitudinal continuity, large trees, patch size, neighbourhood, distance to core area
Ecosystem Processes	Growth rate of algae, ratio of ^{13}C to ^{12}C stable isotopes, respiration (R24), gross primary production	n/a	n/a	n/a

Indicators were chosen based on the known or expected relationships between external drivers that affect the environment and the condition of rivers within the catchment. Conceptual diagrams, that elucidated the key interactions within and between assets, were drawn up as part of the design of two of the four river assessment programs presented here. The diagram developed for the Sustainable Rivers Audit is shown below (**Figure 25**).

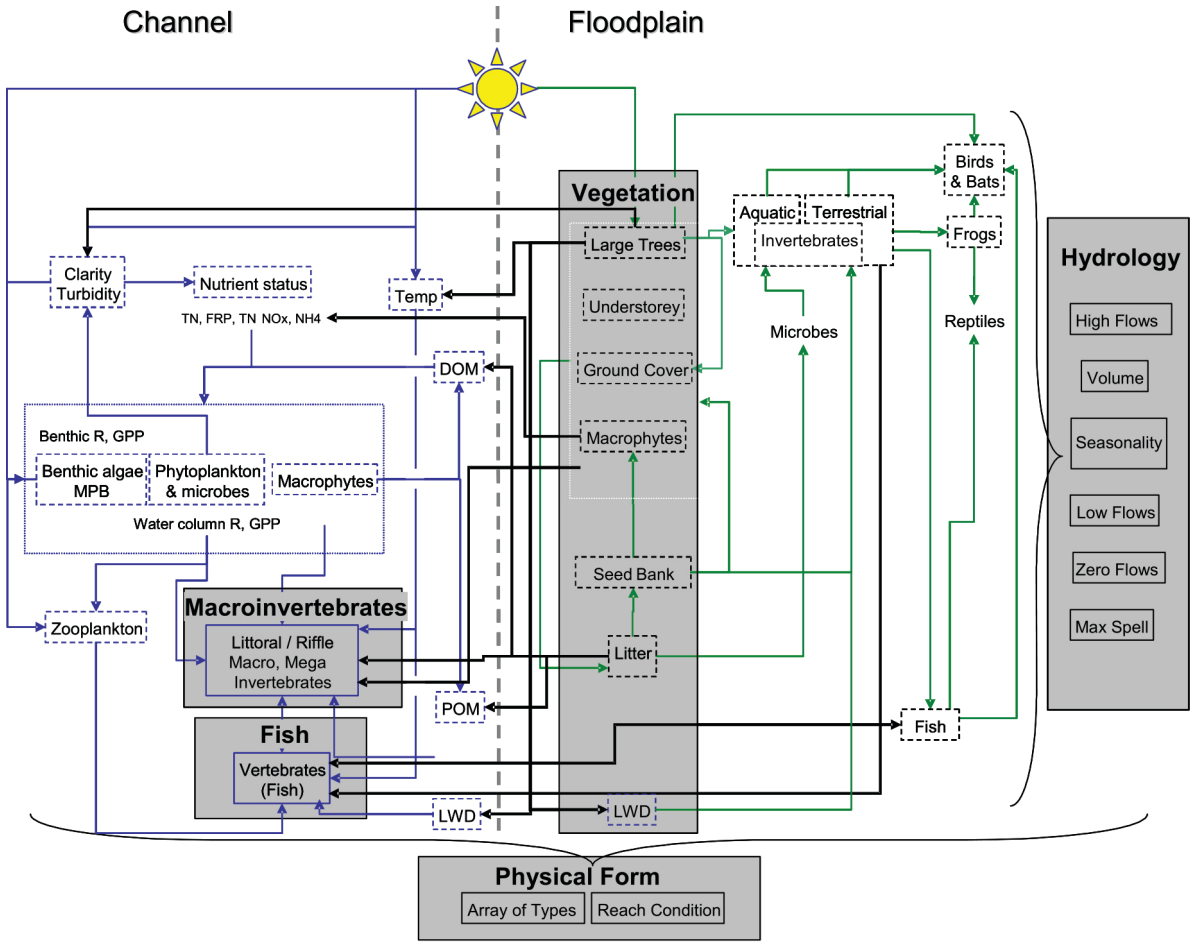

Figure 25: The River Ecosystem Function Model for a channel-floodplain ecosystem, developed for the Sustainable Rivers Audit of the Murray–Darling Basin, Australia. The model articulates the interactions between components of the system (grey windows) and the relationship to the theme indicators (shown as arrows) (Davies *et al.* 2008).

Two of the river assessment programs used in the regional environmental accounts changed indicators and methodologies between sampling periods.

- The second iteration of the Sustainable Rivers Audit (2008-10, the data of which were used in the Queensland Murray-Darling account), includes vegetation and physical form condition indices; these were not present in the first SRA (2004). There were modifications to components of the fish and macroinvertebrate themes and major revision of the hydrology index.
- The Index of Stream Condition (Victoria, used for North Central's rivers account) although keeping the same indicator themes, changed methods and indicator measures over the three sampling periods recorded in the account.

The institutions managing these programs warn against comparing trends over time between the accounting periods (DEPI 2013).

Estimation of Reference Benchmarks

Reference condition benchmarking has a long history in river science: the concept was first established through pivotal work in the field of aquatic bio-assessment, where rivers are assessed using fish and macro-invertebrate assemblages (Karr 1981; Reynoldson *et al.* 1997) which are compared to reference sites or expected pre-development levels. Use of a reference condition makes allowance for endemic differences between ecosystems when comparing different rivers.

Australian Water Quality Guidelines (ANZECC and ARMCANZ 2000) provide guidance on marine and freshwater monitoring programs, including derivation of water quality guidelines for a range of environmental values (aquatic ecosystems, primary industries, recreational, drinking, cultural and industrial). Water quality guidelines for aquatic ecosystems are intended to represent limits based on known ecological thresholds of condition or human health. Determining what a pre-development guideline or limit for water quality would look like is difficult and often limits are determined through best estimates based on long-term studies of sites (ANZECC and ARMCANZ 2000).

Although the *Accounting for Nature* design suggests that all indicators use a pre-development reference condition, these trials are dependent on the reference conditions incorporated into jurisdictional monitoring programs. Three of the four river assessment programs (Ecosystem Health Monitoring Program, Index of Stream Condition, Tasmanian River Condition Index) used a combination of reference benchmarks. These may represent guidelines for purposes other than assessing the condition of an aquatic ecosystem (eg water quality). There are examples where pre-development conditions are relevant as reference benchmarks (macroinvertebrates, fish, riparian, hydrology[1], physical form). The Sustainable Rivers Audit used only pre-development reference conditions.

Data Sources and Analysis

Data for the trial rivers accounts used to calculate *Econds* were obtained from existing jurisdictional river assessment programs (Table 26). Data were not consistently available for all indicators for some programs (NRM North, North Central). Missing data were filled using procedures adopted for jurisdictional assessment programs. In the case of the Index of Stream Condition, used by North Central CMA, missing values were synthesised from nearby, similar sites (DSE 2004). This ensured a full suite of data for aggregation. The program used by NRM North ignored missing variables, resulting in some *Econds* being calculated from a reduced set of observations.

Indicator Condition Scores

Raw scores for each indicator were standardised against the reference benchmark on a scale between 0-100.

Standardised indicator scores were then integrated for a particular indicator theme at the site or reach scale, then these integrated scores were aggregated to higher scales, such as zone or valley. Regions used the integration techniques inherent in the jurisdictional programs. Sustainable Rivers Audit used expert rules to integrate scores, the Ecosystem Health Monitoring Program used unweighted indicators, and programs in Victoria and NRM North used weighted indicators (Table 27).

1 The 2010 ISC assessment used a mixture of pre-development and flow targets for the hydrology indicator.

Table 27: Methods for developing theme scores (intermediate indices) in river assessment programs used in the Australian regional environmental accounts trial.

	SEQ	North Central	QMDC	NRM North
Assessment Program	Ecosystem Health Monitoring Program	Index of Stream Condition	Sustainable Rivers Audit	Freshwater Ecosystem Health Assessment Program
Aggregation scale	Site - Catchment	Site - Reach - Subcatchment	Site – Zone - Valley	Site - Zone
Hydrology	n/a	The Hydrology Sub-index score is calculated out of 10 according to the following formula: Hydrology sub-index = (Low Flow + High flow + Zero Flow + Variability + 2 (Seasonality)) / 6 The final hydrology sub-index score is based on a uniform weighting of the individual indices, except the seasonality index, which is given twice the weight of the other individual indices.	Expert systems (**Table 29**) used to integrate indicators at reach scale, then aggregated to the zone and valley scale, using a length-weighted average, producing two aggregated index values at the zone or valley scales. This was done separately for the mainstem and headwater part of the stream network. Index values are combined to calculate the final zone- or valley-scale Hydrology Condition Index (SR– HI), where mainstem values represented Lowland zones, headwater values represented Montane zones, a combination represented Slopes and Upland zones, and the valley-scale.	n/a
Physical Form	n/a	To integrate the sub-indicators at the reach scale, fish barrier indicators were ranked, Wood scores were averaged, and the minimum bank stability score was used. The Physical Form Sub-index score is calculated out of 10 according to the following formula: Physical form sub-index = 10/8 x ((large wood score + fish barrier score)/2 + bank stability score).	Metrics and indicators were spatially aggregated across all LiDAR-surveyed sites using a combination of length-weighted and simple averaging. Scores were aggregated from the zone to the valley scale by averaging and weighting zone values, based on total stream length within each zone (AusHydro digital river network). Four indicators were combined using Expert Systems to yield SR–PI scores for each zone and valley.	n/a
Fish	Three standardised sub-indicator scores (PONSE, O/E50, Proportion alien) were averaged for each monitoring episode (spring or autumn). Averaged site scores were summed for each monitoring episode per catchment to get average spring/ autumn catchment scores. These were averaged to give a final Native Fish index score per catchment per reporting year.	n/a	Median scores for each site are given as the zone score. Averaging the zone scores provides a valley score which is then stream-length weighted. Indicator scores are also integrated through a process of Expert Systems at the zone and valley scale.	n/a

	SEQ (cont.)	North Central (cont.)	QMDC (cont.)	NRM North
Water Quality	Four standardised sub-indicator scores (pH, conductivity, temperature, DO) are averaged for each monitoring episode (spring or autumn) for each monitoring site. Missing data was ignored (i.e. average was determined for three rather than four sub-indicators). These scores were then summed for each monitoring episode per catchment to get average spring/autumn catchment scores for the physical/chemical indicator. Scores were then averaged to give a final physical/chemical index score for each catchment in the reporting year.	The water quality rating for a monitoring site uses the 75th percentile for total phosphorus, turbidity and EC and the 25th and 75th percentiles for pH. The percentile value for each indicator is assigned a rating by comparison to reference condition. The total sub-index score is a score out of 10 and is calculated by summing the scores (0-4) for each of the four indicators as in the following formula: Water quality sub-index = 10/16 x (Total Phosphorus rating + Turbidity rating + EC rating + pH rating).	n/a	Medians were calculated and compared using threshold and trigger values determined by an expert panel. A category value (1 - 4) was assigned for indicator sites (**Table 8**, NRM North Information Statement). Values were averaged to calculate a Category Score for the reporting zone. A final score was then calculated by dividing the reporting zone average Category Value by 4. Water quality scores were calculated by dividing the final score by the number of indicators (meaning sub-indicators) used. (No grade was given if < 3 sub-indicators were used). Scores (0 – 1) were converted to a qualitative grade.
Macroinvertebrates	Three standardised sub-indicator scores (# taxa, PET richness, SIGNAL score) were averaged for each monitoring episode (spring or autumn), then summed for each monitoring episode per catchment to get average spring/autumn catchment scores. Scores were then averaged to give a Final Aquatic Macro- invertebrates index score for each catchment in the reporting year.	For each site assessed, ratings are given to each of the two indicators (SIGNAL and AUSRIVAS). Each indicator is given a rating on a scale of 0-4. The Aquatic Life Sub-index score is calculated out of 10 according to the following formula: Aquatic life sub-index = 10/8 (AUSRIVAS rating + SIGNAL rating)	Median scores for each site are given as the zone score. Averaging the zone scores provides a valley score, which is then stream-length weighted. Indicator scores are also integrated through a process of Expert Systems at the zone and valley scale.	For each site the average of all AUSRIVAS O/E scores was calculated, the average score for each reporting zone was then used to assign a grade. The results of each year were then used to calculate the overall reporting zone grade, which is the mean of all results for that reporting zone.
Riparian	n/a	Not all streamside zone indicators carry the same weight in the calculation of the sub-index (SZ). SZ = (US + W + LC + Wd +LT + R + TC + LIT + LOGS) / 10	Median scores for each site are given as the zone score. These scores are averaged to a valley score, which is stream-length weighted. Indicator scores are integrated using Expert Systems at zone and valley scales.	Mean SZV scores for each reporting zone were calculated by taking the mean score using all sites in each reporting zone.
Ecosystem Processes (Nutrient Cycling)	Two standardised sub-indicator scores (d15N and algal bioassay3) were averaged for each monitoring episode (spring/ autumn), then summed for each monitoring episode per catchment to get average spring / autumn catchment scores. These scores were averaged to give a Final Nutrient Cycling index score for the catchment for the reporting year.	n/a	n/a	n/a

A subset of indicator condition scores are presented for rivers in the Queensland Murray-Darling Basin (**Table 28**). The full set of indicators is available online (NRM Regions Australia 2015). Indicator condition scores for the Queensland Murray-Darling Basin are nearly all 50 or above in 2010 (**Figure 26**).

Table 28: Indicator condition scores, measures and *Econds* for four river valleys in the Queensland Murray-Darling Basin for 2007 and 2010.

Class	Indicator (unit)	Reference Benchmark	2007			2010		
			Measure	ICS	*Econd*	Measure	ICS	*Econd*
Paroo Valley					100			90
	Macroinvertebrates condition (index)	100	64	64		86	86	
	Hydrological condition (index)	100	100	100		100	100	
	Fish condition (index)	100	78	78		83	83	
	Vegetation condition (index)	100				100	100	
	Physical form (index)	100				99	99	
Border Rivers Valley					65			50
	Macroinvertebrates condition (index)	100	66	66		68	68	
	Hydrological condition (index)	100	70	70		83	83	
	Fish condition (index)	100	60	60		63	63	
	Vegetation condition (index)	100				52	52	
	Physical form (index)	100				74	74	
Condamine and Balonne Valley					75			50
	Macroinvertebrates condition (index)	100	55	55		77	77	
	Hydrological condition (index)	100	44	44		74	74	
	Fish condition (index)	100	63	63		65	65	
	Vegetation condition (index)	100				83	83	
	Physical form (index)	100				71	71	
Warrego Valley					53			70
	Macroinvertebrates condition (index)	100	93	93		86	86	
	Hydrological condition (index)	100	49	49		100	100	
	Fish condition (index)	100	56	56		50	50	
	Vegetation condition (index)	100				100	100	
	Physical form (index)	100				89	89	

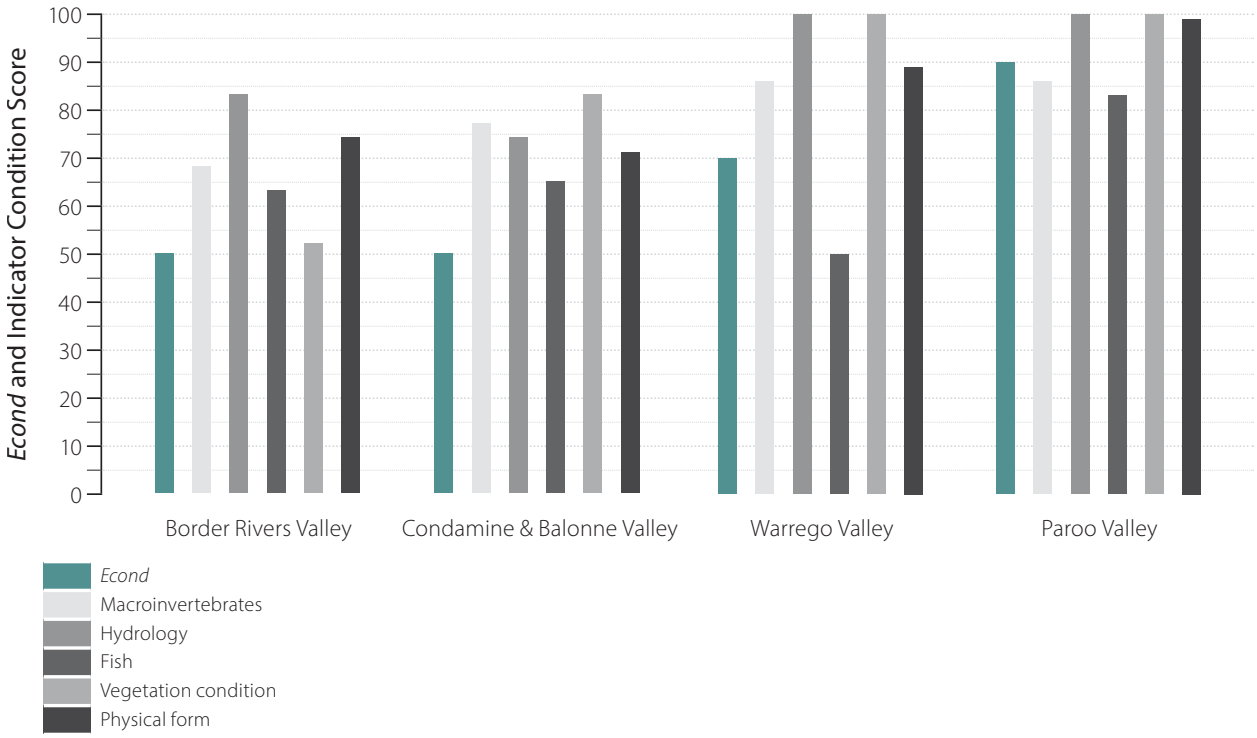

Figure 26: *Econds* and Indicator condition scores for four river valleys in the Queensland Murray-Darling Basin for 2010.

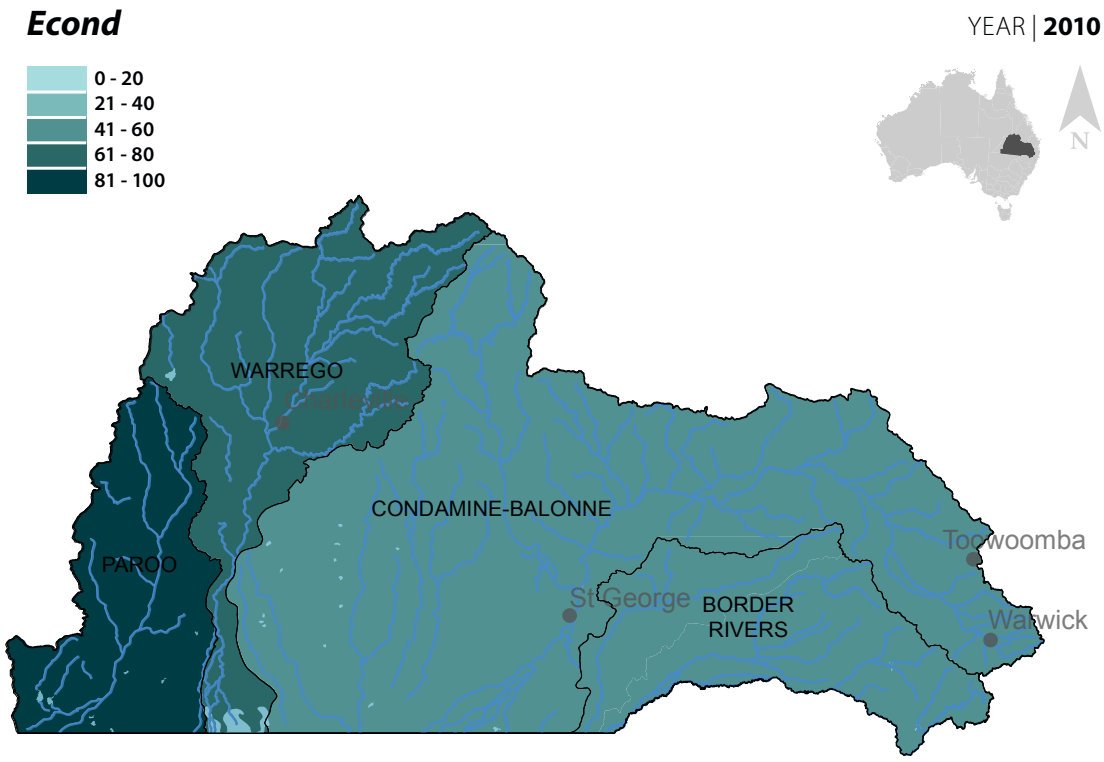

Figure 27: Map of the condition of four river valleys in the Queensland Murray-Darling Basin for 2010.

Environmental Condition Index (*Econd*)

Like the indicator condition scores (theme indices), *Econds* were combined in a number of different ways according to the methods inherent to the jurisdictional monitoring programs used by the regions in the trial (Table 29). *Econds* based on data from the Index of Stream Condition and Ecosystem Health Monitoring Program were generated by aggregating reach or zone indices to the catchment scale. The Sustainable Rivers Audit scores are calculated by integrating scores at each of the spatial scales (zone, valley, basin).

Table 29: Methods for producing the Rivers Account ***Econds***, environmental accounts 2014

	SEQ	North Central	QMDC	NRM North
Assessment Program	Ecosystem Health Monitoring Program	Index of Stream Condition	Sustainable Rivers Audit	Freshwater Ecosystem Health Assessment Program
Method of aggregation	Indicator theme scores are averaged.	ISC Report 1, ISC Report 2: The sub-asset *Econds* were calculated by doubling the reach ISC score (as they were originally out of 50). The reach *Econds* were then summed, weighted by length, to calculate an overall river *Econd*.	SRA Report 1: Indicator condition scores for fish, macroinvertebrates and hydrology are combined to create an ecosystem health rating using Expert Systems. SRA Report 2: The indicator condition scores for fish, macroinvertebrates and riparian vegetation are integrated to the ecosystem health rating using Expert Systems. The Sustainable Rivers Audit does not integrate the hydrology and physical form indices into its overall ecosystem health rating but they are used to inform on drivers of river health.	Categorical scores between 1 and 5 are allocated for indicator condition scores and taking the average of these categorical results multiplied by 20 to create a condition score out of 100.
Weightings applied if applicable (%)	No (equal) weightings applied.	Inverse ranking weightings applied, eg Lowest score receives highest weighting	SRA Report 1: Fish (>macroinvertebrates) Macroinverts (>hydrology) Hydrology (lowest weighting) SRA Report 2: Fish (>macroinvertebrates Macroinvertebrates (>riparian) Riparian (lowest weighting) Hydrology (0%) Physical form (0%)	No (equal) weightings applied

Expert rules express the professional judgement of experienced ecologists on how to construct an integrated index from constituent indicators. Thus, the integrated index for the Sustainable Rivers Audit (used by the Queensland Murray-Darling Committee) was based on expert rules because known interactions and non-linear relationships between the indicators could not be captured through mathematical methods such as Euclidean distance or an arithmetic mean (Murray-Darling Basin Authority 2012). In this, the Independent Sustainable Rivers Audit Group (Davies *et al.* 2008) employed their knowledge of the rivers to combine different indicators to yield an overall numerical index of ecosystem health (0-100) which was then assigned to one of five possible categories from Extremely Poor to Good Health (Table 30).

Table 30: Expert rules establish how different combinations of condition ratings (Good, Poor, Extremely Poor) for three indicators (Fish, Macroinvertebrates, Hydrology) are combined into the *Econd* (Ecosystem Health Index) (Davies *et al.* 2012a).

Condition Rating			Ecosystem Health	
Fish	Macroinvertebrates	Hydrology	*Econd* (Ecosystem Health Index)	Label
Good	Good	Good	100	Good Health
Good	Good	Poor	93	
Good	Good	Extremely Poor	85	
Poor	Good	Good	75	Moderate Health
Good	Poor	Good	75	
Poor	Good	Poor	69	
Good	Poor	Poor	69	
Good	Poor	Extremely Poor	63	
Poor	Good	Extremely Poor	63	
Poor	Poor	Good	53	Poor Health
Good	Extremely Poor	Good	50	
Extremely Poor	Good	Good	50	
Poor	Poor	Poor	47	
Good	Extremely Poor	Poor	45	
Extremely Poor	Good	Poor	45	
Poor	Poor	Extremely Poor	43	
Good	Extremely Poor	Extremely Poor	40	
Extremely Poor	Good	Extremely Poor	40	
Poor	Extremely Poor	Good	28	Very Poor Health
Extremely Poor	Poor	Good	28	
Extremely Poor	Poor	Poor	24	
Poor	Extremely Poor	Poor	24	
Poor	Extremely Poor	Extremely Poor	20	
Extremely Poor	Poor	Extremely Poor	20	
Extremely Poor	Extremely Poor	Good	5	Extremely Poor Health
Extremely Poor	Extremely Poor	Poor	3	
Extremely Poor	Extremely Poor	Extremely Poor	0	

Two additional themes – physical form and riparian vegetation – which were added in the second audit, were modified to give riparian vegetation and fish condition greater influence on the Ecological Health Index than macroinvertebrate condition because "vegetation and fish respond to, integrate and influence processes over a wider range of temporal and spatial scales than macroinvertebrate communities" (Davies *et al.* 2012b). Despite the significance of native vegetation, there was less confidence in the data used for measuring this indicator than in the macroinvertebrates and fish indicators, and so the relative weighting of the vegetation indicator was reduced compared to the other two themes (Davies *et al.* 2012b). Hydrology and physical form are not included in calculating the final index.

The Index of Stream Condition, used by North Central, is calculated by inverse ranking, which placed the five theme scores in ascending order, multiplying the lowest score by 5, the next lowest score by 4, and so on, and the highest score by 1. The totals are then added together to produce a score out of 150. This score is then divided by 3 to produce a final ISC score out of 50. For the trial, this was converted to a score out of 100 (DEPI 2013).

Econds for NRM North in Tasmania were calculated by averaging a set of categorical scores. As explained earlier, this is not mathematically correct. These *Econds* are not reliable because of the errors likely to be introduced by this procedure.

Table 31 shows *Econds* for three regions for periods up to 11 years. Data from NRM North were insufficient to develop an *Econd* and will not be discussed further. Changes in methodologies between time periods make it impossible to draw conclusions about changes in condition in North Central and Queensland Murray-Darling Basin.

Econds for a given region can be compared across different time periods as long as consistent methods were used for their formulation. This is the case for South East Queensland since the method did not change (**Figure 28**). However, the scores in North Central cannot be compared between the three collection periods because the method changed significantly each time (DEPI 2013), and the *Econds* for Queensland Murray-Darling Basin, based on Sustainable Rivers Audit, also cannot be compared between 2007 and 2010 because of the change in methods (MDBA 2011). MDBA (2011) discusses some expected differences between indices constructed using different methodologies, and compatibility between the SRA and the ISC indicators was further examined as part of this project in the North Central CMA (see below).

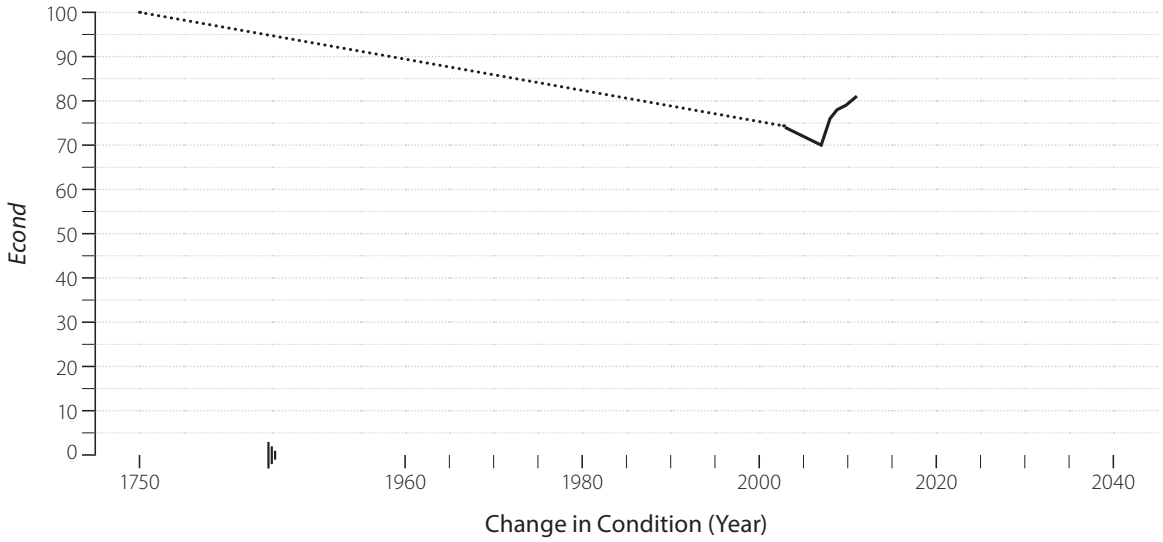

Figure 28: Trend in rivers *Econds* for SEQ

Table 31: Rivers accounts for three regions between 1999 and 2011.

REGION	*Econd*/Year												
	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
North Central CMA (VIC)	48					34						48	
Queensland Murray-Darling Basin (QLD)									64			68	
SEQ Catchments (QLD)					74				70	76	78	79	81

Although comparisons cannot be drawn between time periods for the river *Econds* in North Central and Queensland Murray-Darling Basin, it is possible to compare catchments and sub-catchments within an NRM region in each of the time periods in which data were available. Thus, **Figure 29** shows that the Paroo catchment had the highest river *Econds* of each of the four catchments in Queensland Murray-Darling Basin in each of the two sampling periods of the Sustainable Rivers Audit. The Paroo catchment is noted in the audit reports (Davies *et al.* 2008; Davies *et al.* 2012a) as being in the best condition of any river valley in the Murray-Darling Basin largely because of the absence of infrastructure and the low level of development of the catchment.

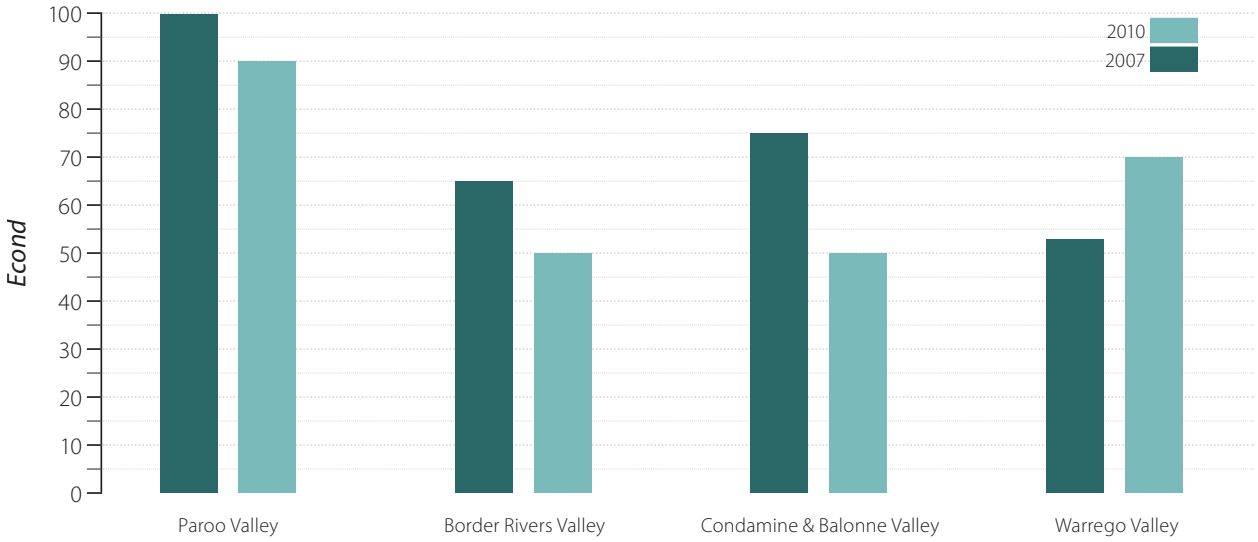

Figure 29: *Econds* for catchments within the Queensland Murray-Darling Basin for two time periods (SRA 1 and SRA 2). Note that *Econds* cannot be compared between years.

Similarly, *Econds* can be spatially mapped to visualise condition of these assets across a region. *Econds* are presented for subcatchments (**Figure 30**) and catchments (**Figure 31**).

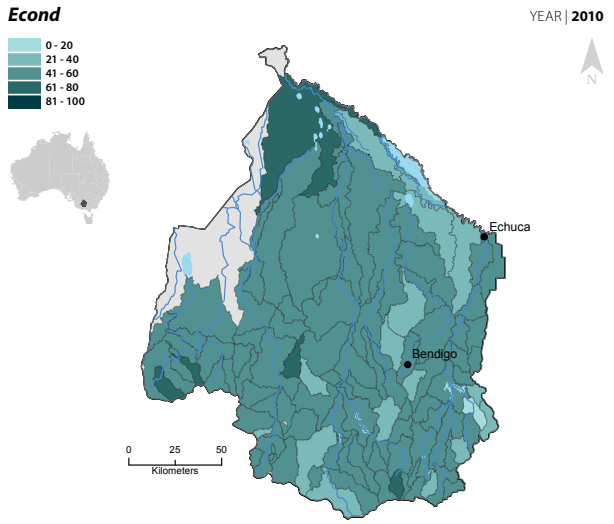

Figure 30: Condition of sub-catchments in North Central CMA, VIC.

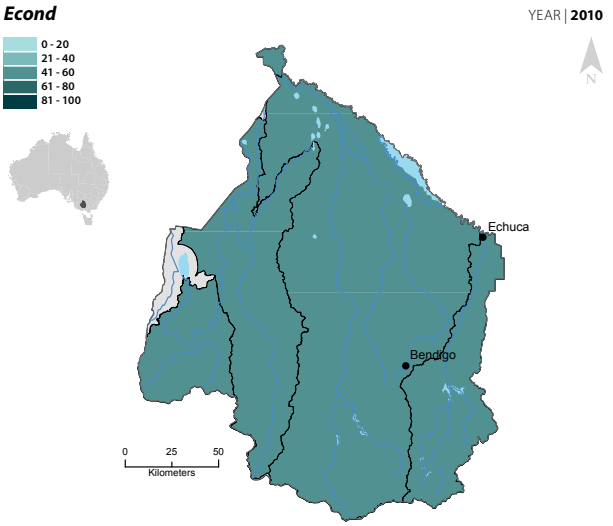

Figure 31: Condition of catchments in North Central CMA, VIC.

The Ecosystem Health Monitoring Program in South East Queensland has been designed to be comparable between years and the methods employed in calculating the indicators have not changed substantially (Fisk 2010). Consequently, the monitoring results can be compared between catchments and between years up to 2011 (as shown in **Figure 32**). The results show an improvement in condition between years for most of the catchments within the region.

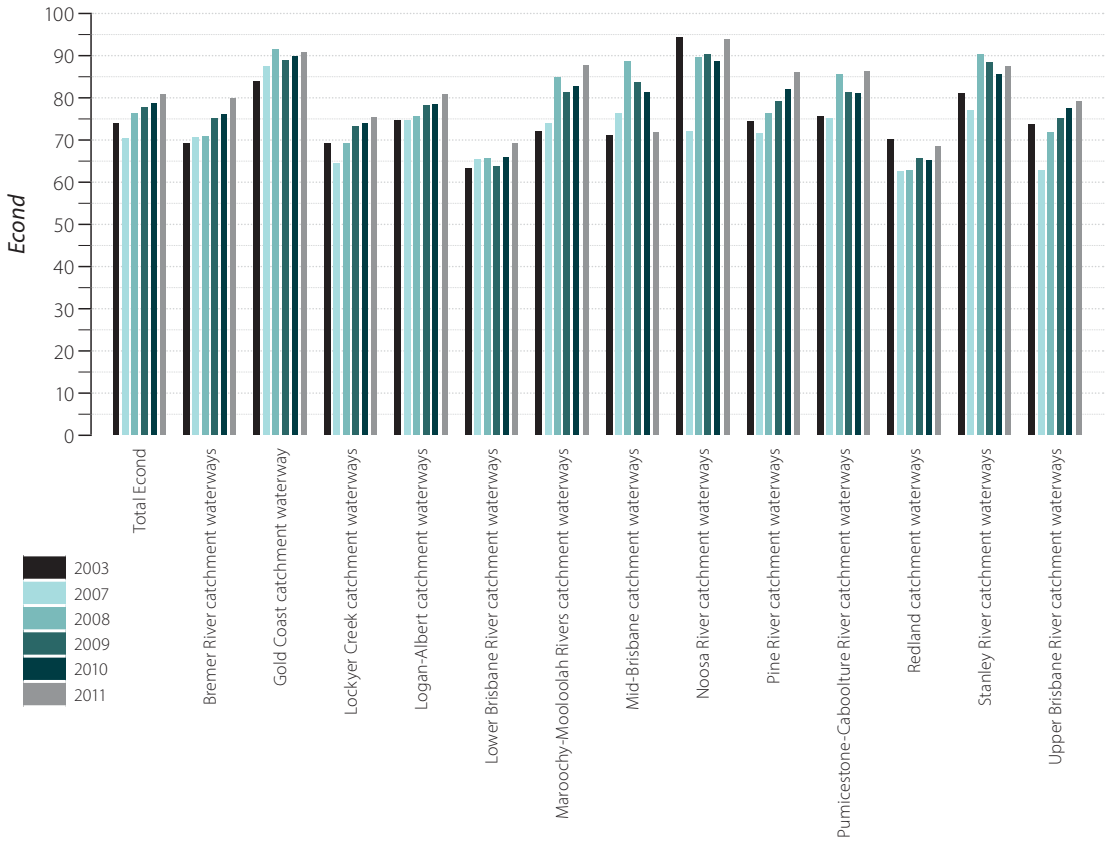

Figure 32: Change in catchment *Econds* for 13 catchments in SEQ, 2003-2011

Discussion

Selection of asset boundaries: Rivers accounts should report at subcatchment scale, based on measures at reach scale (Norris *et al.* 2007b; State of the Environment Committee 2011). The environmental accounts trial shows that it is possible to reformulate data from existing state and regional environmental monitoring programs at the subcatchment scale to provide information on river condition within regional NRM boundaries.

Indicator selection: Determining which indicators contribute to an understanding of the condition of an asset relies on articulating the known or expected relationships within the catchment (ANZECC and ARMCANZ 2000). The use of conceptual diagrams to elucidate these key relationships by three of the four jurisdictional monitoring programs gives confidence that the indicators are well selected for the purposes of the jurisdictional monitoring programs. However, if that program does not have an ecological focus, the indicators and data provided to the accounts may not suit the purpose of asset condition accounting.

One of the NRM regions (NRM North Tasmania) did not include sufficient indicators from the jurisdictional monitoring programs (Freshwater Ecosystem Health Assessment Program and Tamar River Condition Index) to provide an adequate measure of environmental condition for the rivers within its area. These jurisdictional programs do contain additional data and it should be possible to strengthen the *Econds* for this region to meet the necessary standards in future if they choose to do so.

In South East Queensland, the Ecosystem Health Monitoring Program was designed to report on water quality and so omits water flow information. A review of this program suggested that hydrology indicators would complement the sampling design by providing information on drivers and pressures (Fisk 2010). While the *Econds* submitted by SEQ Catchments were provisionally accepted in the trials, it is important that the water quality indicators be augmented with relevant flow indicators for environmental accounting.

The Sustainable Rivers Audit also omits river flow indicators in its assessment of overall river health. The Audit's expert panel judged that ecosystem health is indicated primarily by biological changes, often caused by changes in physical drivers such as changes in flow regime. Consequently, information on flow regime and physical form is reported alongside the overall condition index (Murray-Darling Basin Authority 2012), but not used in the final index.

This discussion illustrates that the indicators selected for the purposes of the jurisdictional monitoring programs do not always suit the needs of measuring asset condition for environmental accounts. Apart from regions which use the Index of Stream Condition, NRM regions would need to augment the selection of indicators to provide an adequate assessment of river condition for regional NRM use.

Reference condition benchmarking: While the *Accounting for Nature* model requires reference benchmarks that reflect, as closely as possible, pre-development conditions, not all jurisdictional monitoring programs used here adopt such reference conditions. This also affects the extent to which different *Econds* can be compared.

These differing interpretations of reference condition further limit the extent to which the *Accounting for Nature* design can be implemented using existing diverse government monitoring programs.

Combining indicators: Methods of calculating *Econds* varied between assessment programs and between frameworks as described in previous sections. While each method can be justified for the purposes of the jurisdictional monitoring program, the use of different aggregation methods limits the extent to which *Econds* based on data from different monitoring programs can be compared.

Detecting change over time: Because of the long history of river health monitoring in Australia, it was assumed that river assets would be able to be reported for multiple time periods. The Index of Stream Condition had three periods, the Sustainable Rivers Audit two periods, and the Ecosystem Health Monitoring Program 10 periods.

It was not possible to establish reliable trend analyses for either the Index of Stream Condition or the Sustainable Rivers Audit due to changes in methods which affect the comparability of results between time periods (Davies *et al.* 2012a; DEPI 2013). To enable interpretation of trend data, changes in method should always be accompanied by methods to hindcast data for 'new indicators' so they can be compared to previous datasets, and/or preserving raw data from field sampling so that some common indicators can be calculated from different sampling periods. The results from South East Queensland show the power of maintaining a consistent set of indicators over a 10 year period.

River condition at national scale: These trials did not include an assessment of whether the various *Econds* provide comparable measures of riverine condition for use in national policy and investment decisions. However, the FARWH trials did set out to test whether disparate state level river condition indicators could be combined to provide a national rivers and wetlands condition assessment. This experience provides helpful direction to any future regional environmental accounting for river assets.

The results for Victoria were mixed, with three Index of Stream Condition components (aquatic biota, fringing zone and hydrology) being well correlated with their FARWH equivalents while two (physical form and water quality) were weakly correlated. Nevertheless, the overall Index of Stream Condition scores were well correlated with the FARWH scores. Tasmanian Conservation of Freshwater Ecosystem Values indicators were less well correlated with the FARWH indicators than were Index of Stream Condition indicators, with the CFEV hydrologic disturbance and the aquatic biota indices being notably different from their FARWH equivalents.

The subsequent trials in three Queensland regions showed that, with supplementary data obtained from fieldwork, remote sensing and modelling, the Stream and Estuary Assessment Program and Ecosystem Health Monitoring Programs could be adapted to meet the FARWH requirements. However, there were problems obtaining valid reference conditions in all Queensland regions and concerns were raised over the costs arising from on-ground field assessment programs at the intensity required by FARWH.

The trials in the data poor regions of Southwest WA and northern Australia showed that the FARWH concepts could provide reasonable and defensible assessments of river issues in those regions. However, the boundaries of reporting regions need to be more carefully delineated than was the case in the Southwest WA trials. In both Southwest WA and northern Australia there needed to be better methods for determining reference conditions. Testing of the FARWH indicators in northern Australia also raised questions about the assumed links between the degree of catchment disturbance and physical form, fringing zone, water quality and aquatic biota indices. FARWH chose to refrain from integrating scores into a final river condition index (Dixon *et al.* 2011).

While these FARWH trials raised many technical and conceptual issues that still needed to be resolved, a national approach to river assessment may be possible under the proposed FARWH framework (Alluvium Consulting 2011).

Conclusions

Three of the four regions were successful in modifying existing jurisdictional river condition programs to create a regional river asset condition account that was potentially suitable for regional accounting purposes. However, there were significant problems in tracking changes in the condition of the river assets over time and space, because of changes in indicators and methods.

The technical support for constructing regional river condition accounts mainly reside in state agencies and research organisations. Data collection obligations of federal authorities may also assist in the construction of river condition accounts. Implementing regional river condition accounts will require a greater degree of cooperation to better homogenise information relevant to management activities of the NRM regions.

Development of nationally compatible *Econds* that would allow inter-regional comparisons could not be tested in these trials. Nationally compatible *Econds* will first require a national standard for developing a consistent set of indicator themes, and methods for developing indicators that are sensitive to regional issues within those themes, determining pre-development reference conditions, and integrating and aggregating indicators. The FARWH trials show that this is technically possible and is the logical starting point on which to develop a national standard for regional river asset condition accounts. Consistent with the testing of the *Accounting for Nature* methodology, the FARWH trials brought agreement amongst federal and State agencies that nationally consistent river condition reporting could be implemented using existing monitoring programs (Wentworth Group of Concerned Scientists 2008). For these reasons, further development of indicators of river condition should be based on the FARWH design.

The areas that require further technical development include:

- Further testing of the compatibility of different river condition monitoring programs in order to develop a national river accounting standard
- Ensuring that new river condition monitoring programs, particularly in western and northern Australia, are compatible with FARWH or a new national river accounting standard
- Developing methods to bridge changes in procedures in existing programs (for example Sustainable Rivers Audit and Index of Stream Condition) so that changes over time can be determined whilst still supporting refinements and development of new methods.
- Undertaking sensitivity testing of integration and aggregation methods.
- Further developing methods for estimating appropriate reference conditions Build national capacity in remote sensing, remote monitoring and modelling to provide data in a cost effective manner, especially for riparian vegetation and catchment disturbance

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