CHAPTER 10

Monitoring and evaluation in riparian land management

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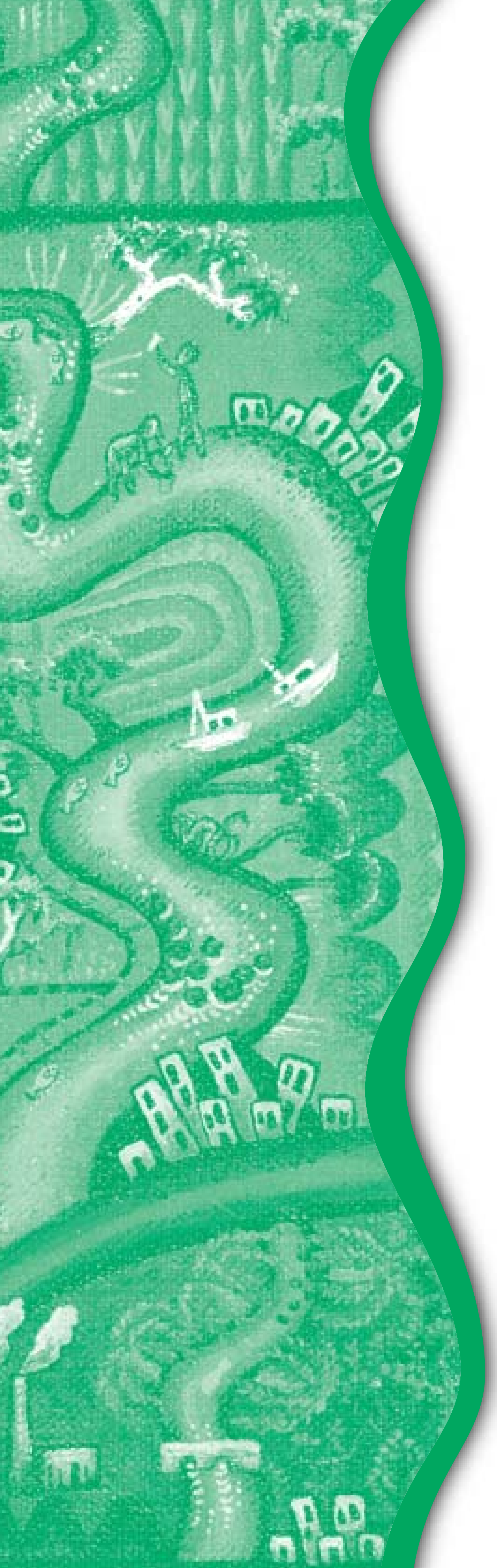
Summary

- Monitoring and evaluation (M&E) should be seen as an integral part of any riparian management project.
- M&E at a project or output level is straightforward, and methods for this are well developed. M&E at the outcome level, to determine whether, and the extent to which the project has met its objectives, is a more complex proposition and is likely to be expensive to undertake properly.
- Effective evaluation requires consideration of the scale and frequency of measurement, and potential difficulties of separating treatment effects from natural variability. Statistical comparison with control or reference sites is the preferred approach, but is not always possible. A before-and-after (BACI) approach requires adequate baseline data before treatments are imposed.
- Selection of indicators for monitoring programs should reflect the questions being asked in the evaluation, and the level of accuracy and precision therefore necessary.
- Methods for the rapid appraisal of riparian condition have been developed to meet the increasing need to assess whether riparian management is being effective, and to further adapt it if not.



10.1 The importance of monitoring and evaluation

Monitoring and evaluation (M&E) should be considered as integral components of any riparian land management project or program (Ladsen et al. 1999), and be funded and resourced accordingly. It is often claimed that 'you cannot manage it if you cannot measure it', and it is certainly difficult to be confident that management is effective if there is no supporting evidence. As well as helping to show whether management is achieving its objectives, M&E also provides a basis for adaptive management and continued improvement, and can assist in identifying priorities when resources are limited.

Despite this, the history of natural resource management in Australia (including river and riparian management) has involved little or no effective M&E activity, even for programs that involve the expenditure of substantial public funds (Australian National Audit Office 2001). Much overseas experience is similar (for example Lovett 2004), although there are also a few examples of well-developed M&E programs (United States Department of Agriculture 2001). M&E activities can be long-term and expensive, and should be designed to be commensurate with the scope and scale of the riparian management itself. There are also pitfalls to be avoided as described below. Despite these caveats, there is much to be gained for existing and future riparian land management work by including M&E as an integral component.

M&E programs should meet several essential criteria if they are to be successful and justify the resources committed to them. They must have a defined purpose and clear objectives, otherwise it will be difficult to decide what data should be collected and how often over what period. There should be an effective link between the program and the decisions it is to influence, for example

Using transects and quadrats to monitor regeneration of riparian vegetation. Photo Michael Askey-Doran.

through public reporting of the results and presentation to users. The design of the program must have the potential to detect changes and differences at the spatial and temporal scales anticipated. The attributes to be measured must reflect the outputs and outcomes to be achieved by the project, preferably linked via a conceptual model of riparian zone functions. There should be consistent and reliable protocols for measurement. Finally, the program must be funded adequately as there is little to be gained from ineffective M&E.

Before proceeding we must distinguish monitoring, which is the collection of information to demonstrate continuity or change (for example following treatment or over time), from evaluation, which is the assessment of whether aims, objectives or preferences are being achieved. The purpose of the evaluation will, in general, guide the type of monitoring required, and is therefore discussed first.

10.2 Evaluation

Riparian management projects, including on-ground works, can be evaluated at two levels. The first is what might be called project or **output** evaluation. This type of evaluation is used to show whether the project is following its agreed (or contracted) schedule, whether key stages (milestones) have been completed, and whether it is delivering or has delivered its outputs (specified products or services). This follows the standard form of project evaluation, primarily for purposes of accountability and reporting. There is a large literature available about how to undertake this type of evaluation and what sort of things to measure and record (what to monitor). This could include the reporting of achievement of process milestones by the required dates (e.g. appointment of staff, completion of fencing or replanting), the time taken or funds expended to reach these stages in the project, the delivery of outputs (e.g. length of fencing erected, number of trees planted, number of landholders engaged in the project), or some comparison (benchmarking) with equivalent projects. Projects can also be evaluated in this way for the extent to which they have met broader program goals.

This type of evaluation is straightforward, and should be considered as part of the minimum requirements for good project management. However, it tells us little about whether the project achieved its purpose and wider objectives, i.e. the **outcomes** sought. To do this requires a different approach to evaluation, one that is capable of measuring over time whether the required changes in condition (e.g. less bank erosion, lowered water temperature, increased in-stream habitat) have been achieved, and, just as importantly, whether they are the result of the project and the work undertaken. This type of evaluation is more complex and difficult, and as a result is rarely undertaken. Its difficulties include:

~ **Timescale**. The primary outcome sought from many riparian management projects is some change in physical, chemical or biological condition of a riparian area and/or of the stream. This may take many years to become apparent, even to fine-scale monitoring. For example, replanting an eroding streambank (even if it is the correct response) will require time for new plants to grow and extend their root system, and if the original bank erosion was due to infrequent flood events, it could be many years before treatment effects can be demonstrated with confidence, even with careful longitudinal and cross–section surveys. This timescale is well beyond the funding cycle of riparian projects (generally three years at most), and would require some form of long-term periodic monitoring to be maintained.

The area fenced and replanted or number of trees established could be used in output valuation of this project in Tasmania. Photo Michael Askey-Doran.

~ **Spatial scale**. Many outcomes (e.g. improved water quality, increased fish numbers) relate to factors that integrate riparian management over large areas, often the entire upstream network. A localised project could therefore be successful in dealing with some aspects of local condition, but have little or no effect on broader objectives. Spatial scale must be considered in designing both the project itself and for the effective monitoring of treatment effects.

~ **Signal to noise ratio**. Given the large climate variability found over much of Australia, it can be difficult to distinguish treatment effects from the (often much larger) effects of climate mediated through rainfall, seasonal conditions for plant growth or animal breeding, flood, frost, or fire. This must be considered when designing the spatial and temporal scales for a monitoring program.

~ **Frequency of measurement**. Several of the indicators that might be measured to demonstrate the effectiveness of riparian management (e.g. sediment and nutrient loads and concentrations) are driven by infrequent events, mainly related to flood flows. To be able to evaluate project effects on these attributes, it will be vital to capture information during the short period of such events, and this has implications for the type and expense of the monitoring system required.

~ **Lack of baseline data**. Although some baseline data about streams and riparian areas can be captured from historical sources (maps, aerial photographs and stored satellite images), the general lack of detailed condition data means that for most projects there will be at best only a short period of 'before treatment' data that can be used for later comparison. This problem is compounded by the spatial and frequency issues listed above, and by the short timescale available for most riparian projects. Even with adequate post-treatment monitoring, it is difficult to draw firm conclusions in the absence of an adequate set of 'before' data, except in the rare case where there are control (matched and untreated) sites available.

~ **Multiple variables**. In most riparian projects there are a mix of treatments aimed at addressing several identified problems at the same time, for example fencing to control stock access, replanting with native plant species, inclusion of trees to shade the stream, and possibly some reinforcing of the toe of the bank. It is then difficult to be sure about which of these treatment components is the cause of particular effects detected in the future.

These problems, and others outlined in Rutherfurd, Ladson and Stewardson (2004), help to explain the paucity of good evaluations of riparian management projects. The size of many projects would not warrant the expense of effective evaluation, but without such assessments it will be difficult to learn from past successes and failures in order to improve the effectiveness and efficiency of future projects. Evaluation, and the associated monitoring, must be incorporated into project design; it is rarely possible to return to past riparian projects and assess their success in achieving outcomes, for the reasons described by Rutherfurd, Ladson and Stewardson (2004).

One means of helping to overcome this apparent impasse would be to identify a small number of indicators of riparian condition (including surrogate indicators) that can be assessed easily and cheaply. These may not be suitable for all components of riparian management, but they can demonstrate at least the trend of changes following treatment, and they may be suitable for repeated assessment by non-technical people who have completed a short period of training. They may also enable some level of statistical analysis of the monitoring data to test for operator error and repeatability. Two examples, developed within the Riparian Lands Research and Development Program are listed later in this chapter.

Measuring change in ecosystem function (here, in-stream production and respiration) before and after rehabilitation can provide evidence about whether project objectives have been met. Photos Peter Davies.

10.3 Monitoring

Monitoring for project or 'output' evaluation of riparian management is fairly straightforward and can be based on published methods for project accountability and reporting. This discussion is more concerned with monitoring, that is the collection and analysis of information, which will enable an 'outcomes' evaluation to be undertaken.

The first question is "what type of monitoring system will best provide the data required?". The main requirement is to be able to detect change from the baseline condition, and to separate project or treatment effects from those due to natural spatial and temporal variability (Parr et al. 2003). It may be difficult to identify 'natural condition' if all local riparian areas have been affected to some extent by human disturbance. The effects of past changes (natural or human) may also be working through the system so that riparian zones are in transition rather than some stable equilibrium state.

Information (mainly field data) could be collected to demonstrate change over time, change from the base condition prior to treatment, change in relation to untreated control sites or to adjacent reference of 'natural condition' sites. Each approach can be valid depending upon the purpose of the riparian management and the resources available for monitoring. Statistically designed comparison of treated and control sites over an adequate timescale is the best option (the gold medal of Rutherfurd, Ladson & Stewardson 2004), but in practice has been uncommon. For many riparian rehabilitation projects, the emphasis will be on measuring change from the initial condition considered to be degraded or unsatisfactory, to one considered closer to natural or at least preferred. In the absence of a matching but untreated control site, comparison to an adjacent reference site is valuable to help distinguish treatment effects from natural background variability (the signal to noise issue discussed above).

Monitoring sites must be located to ensure that you can assess whether the project objectives have been achieved. Photo courtesy Tasmanian Department of Primary Industries and Water.

Where no comparison with other sites is possible, the collection of adequate baseline data from the treated site becomes paramount. Some type of before-after-control-impact (BACI) sampling design should be considered, with randomised or gradient sampling to take account of local spatial variability (Ellis & Schneider 1997). BACI monitoring systems are commonly used in environmental impact assessments, and for detecting the impacts of anthropogenic change. The length of the 'before' monitoring should be sufficient to provide information about the scale and direction of natural variability, and to capture the effects of significant natural events such as flood flows. In practice this is difficult due to the timing and funding processes for most riparian projects, although use may be made of local knowledge, oral histories, and past photographs or imagery.

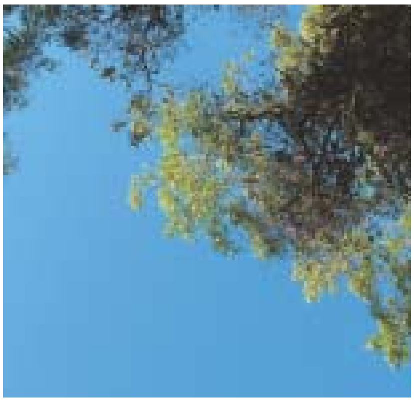
Landholders took these photographs to record their rehabilitation efforts over a period of nine years 1996 (left) and 2005 (right). Photos John and Sue Holt.

Where even adequate BACI monitoring is not possible (this includes most on-ground riparian projects), effort should be made to collect monitoring data from randomly selected locations within the treated zone (helps reduce effects of spatial variability) and data collected periodically over as long a time period as possible (to reduce effects of temporal variability). Rapid assessment tools for monitoring riparian condition have been developed to meet exactly this need.

The next question is "what to monitor?" The two general approaches to this are the condition-pressure-response framework and the ecosystem framework (Whittington 2002). In the first, indicators are chosen to provide information about riparian condition (e.g. extent, structure and floristic diversity of native vegetation), including the pressures affecting that condition (e.g. proportion of area unfenced and open to continuous grazing), and about the responses to those pressures (e.g. uptake of incentive payments for riparian fencing). Pressures to be considered include climate change, changed hydrology, drought flood and fire, pollution and contamination, erosion, dams and water abstraction, vegetation management, grazing, invasion by exotic species, and direct effects of human access.

Under the ecosystem framework, indicators are selected to reflect the crucial characteristics and functions of the riparian zone (e.g. channel size and shape, or shading of the stream surface and water temperatures). These need to be considered in the context of the catchment's geology, topography, climate and land use, as well as position within the landscape, which together set the bounds for riparian characteristics.

Repeated in-stream monitoring is one method of measuring change over time. Photos: (top left) David Kelly, (top right) Guy Roth, (bottom left) Mick Rose, (bottom right) Wayne Tennant.



Indicators of physical condition such as canopy cover may respond faster and be easier to measure than changes in animal populations. Changing canopy cover can be viewed using a 'fish eye' lens to look up from the stream. Photos: (above) Ian Dixon, (below left) Australasia Grebe, Neville Male, (below right) *Litoria caerulea*, Angus Emmott.

Choosing which framework to use should be determined by the purpose of the evaluation being undertaken (e.g. is it important to include policy or management responses), and the availability or ease of collection of the data required. In practice, a mix of indicators from the two frameworks is often selected. It is crucial at this stage of designing your monitoring system to make sure that the data to be collected will support the evaluation intended; not doing so is a frequent cause of failure to evaluate outcomes.

The next question will be "what indicators should be measured?". Some important characteristics of useful indicators are that they: are linked directly to a key aspect of condition, function or pressures (stressors); detect change at the required spatial and temporal scales; can be interpreted without ambiguity; are sensitive to the changes anticipated following riparian treatments; can be measured easily and cheaply with a high degree of accuracy and repeatability; can be measured using existing methods; and, useable data already exists or is being collected. In practice, few if any riparian indicators meet all these requirements, but several meet more than one and are suitable for inclusion in a M&E program.

It is generally preferable to include a mix of indicator types. It can be argued that the terrestrial and aquatic biota associated with riparian zones are the ultimate indicators of change, but it may take time for biotic change to become measurable (e.g. a slow decline in riparian vegetation condition), whereas physical (e.g. area fenced) or chemical (e.g. soil nutrient status) indicators could show likely trends much sooner. As well, because biotic indicators tend to integrate effects across all aspects of the ecosystem, it is often difficult to determine cause and effect relationships with confidence, e.g. there are many potential causes of vegetation decline.

Indicators should also be capable of measurement over the required temporal and spatial scales. Repeated measurement will be required over a timescale sufficient for physical, chemical, and biological changes to occur and be detected, as well as to take account of the affects of natural variables such as floods and fire. Riparian zones are influenced by surrounding land uses and upstream condition, so data for some indicators may need to be collected from these areas as well. Repeated measurement is valuable in confirming or changing the management being used, that is, it supports an adaptive management approach (Walters 1986).

The degree of shading of a stream is a relatively easily measured surrogate indicator for some in-stream processes. Photos Peter Davies.

It is also necessary to determine the degree of accuracy (how close the measured data is to the actual value) and precision (how close are repeated measurements) required of the indicators. Accuracy is important in relation to the effects of detecting a false positive (recording change when in fact there is none) or a false negative (recording no change when in fact there is one). As there is often a power relationship between accuracy and the number of data measurements needed (e.g. four times as many measurements may be needed to halve the sampling error), it is important to pre-determine the level of confidence required in the results to trigger a management or policy decision. Is 100% confidence required, or is 90% or even only 20% sufficient? The answer will depend very much on the questions being asked — this will also determine whether false positives or negatives are the most dangerous. Determining a required level of precision is important when measurements made by different people, or measurements repeated over time, are to be compared. Statistical methods are available to help determine required levels of accuracy and precision.

Although indicators that are linked directly to condition, function or stressor are generally to be preferred, they can be difficult and expensive to measure. As a result, there is often a role for surrogate indicators, that is, something that is indirectly linked to the factor of interest. The frequency of large woody pieces protruding from the water column could be used as a surrogate indicator of complexity in flow velocity, which would be much more difficult to measure directly. Native plant canopy cover and presence of regeneration could be used as a surrogate for vegetation condition. There is often a trade-off between ease of measurement and accuracy in using surrogate indicators, but depending upon the level of confidence required in the data, this may be acceptable.

Combining a range of riparian indicators to give a single score can be useful when you wish to quickly compare different sites. The components may be weighted to determine the composite index, according to their relative importance to the overall assessment required. It is essential to make sure that the different indicators can be combined so that they are all measured at the same scale, otherwise the differences or similarities may be artificial. Some information is inevitably lost in this process of 'averaging' across the individual indicators, and sites that look and behave very differently may end up with the same score. Although a single index is useful for comparative purposes, it should be unbundled back into its components before management or policy decisions are made.

A final point about indicators is that you do not have to measure everything. A small number of well-chosen indicators can be quite sufficient to indicate the direction and size of change over time, and for many purposes this will be all that is required. It is generally far better to focus limited resources on measuring thoroughly a few carefully selected indicators, than to attempt to cover all possible factors but with less replication or limited frequency.

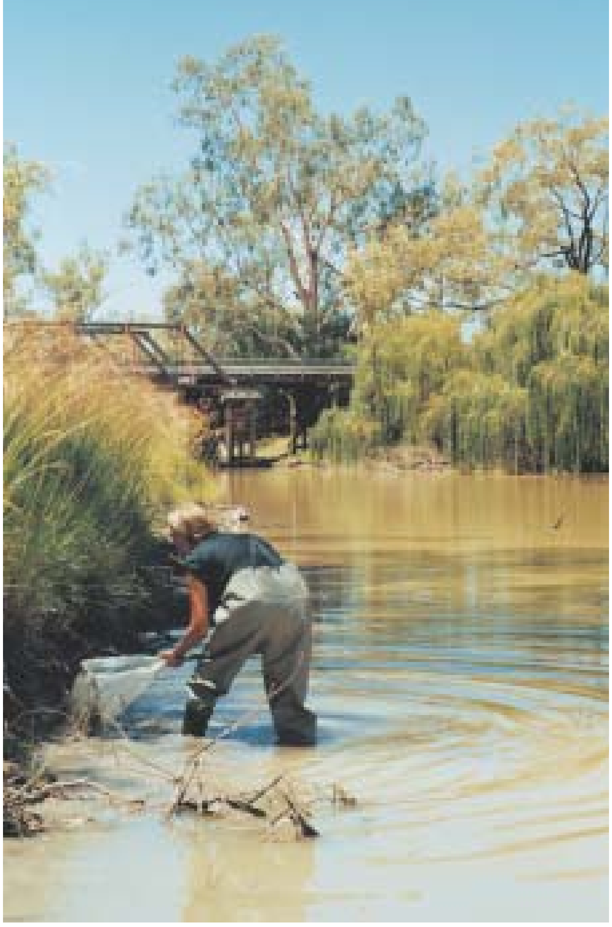


Photo Monika Muschal.

10.4 Monitoring programs

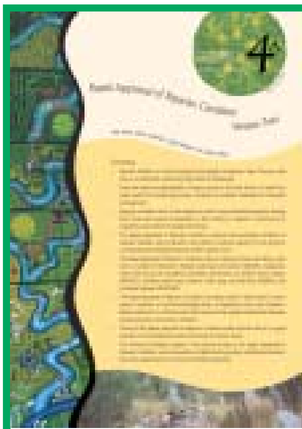
Many national, state and territory, regional, and local programs have been established in recent years for assessment of catchments, rivers, and riparian zones. Several are primarily concerned with monitoring and reporting change in extent, condition or ecological status (e.g. State of the Environment reporting), but some use the collated data for evaluation purposes related to management or policy (e.g. the National Land and Water Resources Audit). These programs use different approaches to assessment, a wide range of indicators, and different measurement methods. A list of programs and of websites with stored data is provided by Whittington (2002).

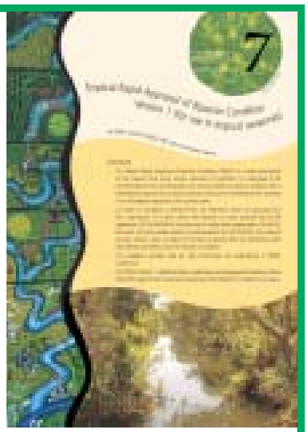
Undertaking the TRARC. Photo Ian Dixon.

10.5 Rapid appraisal methods

In response to the increasing demand for monitoring and evaluation at the outcome level, several methods have been developed for rapid appraisals of environmental condition. These are especially valuable where repeated assessments are required, using non-technical assessors, and over a large number of sites. They often use surrogate indicators for ease and speed, and are suitable for situations where trends over time are more important than absolute measures.

Two such methods have been developed and tested as part of the Land & Water Australia National Riparian Lands Research and Development Program. These are the Rapid Appraisal of Riparian Condition (RARC) method described in Jansen, Robertson, Thompson and Wilson (2003), and the Tropical RARC (or TRARC) reported in Dixon, Douglas, Dowe, Burrows and Townsend (2005). Details of both methods, including their use in practice, are available from the website — www.rivers.gov.au





For further information

Jansen, A., Robertson, A., Thompson, L. & Wilson, A. 2005, 'Development and application of a method for the rapid appraisal of riparian condition', *River & Riparian Land Management Technical Guideline*, no. 4A, Land & Water Australia, Canberra.

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Details about both methods are available on the website www.rivers.gov.au

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GLOSSARY

A

Adventitious roots	With reference to roots emerging from an unusual place on a plant, and which function in a secondary manner to those roots which are produced in the normal places on the plant.
Aerenchyma	A form of plant tissue with large spaces between cells in which gases are stored and diffused.
Aggregate	Cluster of soil particles which adhere to each other and consequently behave as a single mass.
Allochthonous	See autochthonous.
Anabranch	A secondary channel of a river which splits from, and then later joins the main channel.
Anaerobic decomposition	The breakdown of complex organic molecules in the absence of free (gaseous or dissolved) oxygen.
Anoxic	Deficient or absence of free (gaseous or dissolved) oxygen.
Arboreal	Living in trees.
Autochthonous production	Organic matter produced within a stream or river (in contrast with allochthonous matter that is produced outside of it).
Autogenic	Processes operating within the system.

B

Basal (area)	Part of the bed or lower bank that surrounds the toe of the bank.
Basal scour	Erosion of the base of a stream bank by the shear stress of flow.
Benthic	Pertaining to the bottom or bed of aquatic environments.
Biofilm	An organic matrix comprised of microscopic algae, bacteria and other microorganisms that grow on stable surfaces in water bodies (for example, on submerged logs, rocks or large vascular plants).
Buffer strip	A vegetated strip of land that functions to absorb sediment and nutrients.

C

Cantilever failure	Undercutting leaves a block of unsupported material on the bank top which then falls or slides into the stream. A type of mass failure.
Carbon flux	Input and movement of organic carbon.
Channelisation	Topography forcing the runoff flow to converge in the hollows or by large objects such as fallen trees.
Cyanobacteria	Uni-cellar organisms such as blue–green algae. Probably the first oxygen producing mechanisms to evolve.

D

Desiccation	Drying and cracking of bank materials causing the bank to erode more easily.
Detritus	Organic debris from decomposing organisms and their products. A major source of nutrients and energy for some aquatic food webs.
Detritivore	Animal that feeds on dead plant or animal matter, e.g. leaf litter, woody debris, dead grass, dead insects.
Diatoms	The common name for the algae of the division *Bacillariophyta*.
Drip line	The limit of a tree canopy, defined by the pattern of drips from the canopy.

E

Entrained sediment	Sediment that has been incorporated into a flow by rain drop and flow processes.
Eutrophication	An increase in the nutrient status of a body of water. Occurs naturally with increasing age of a waterbody, but much more rapidly as a by-product of human activity.

F

Facultative	Able to adapt from one ecological mode to another, and not strictly bound to one environment.
Fluvial	Pertaining to water flow and rivers.
Filter strip	See buffer strip.
Frost heave	In cold climates bank moisture temperatures fluctuate around freezing, promoting the growth of ice crystals that dislodge bank material.

G

Granivore	Animal that feeds on seeds.

H

Headcut	Sharp step or small waterfall at the head of a stream.
Heterotrophic	Organism or ecosystem dependent on external sources of organic compounds as a means of obtaining energy and/or materials.
Hydrochory	Dissemination of seeds through water.

I

Isotopic signatures	Naturally occurring ratios of stable isotopes in plant or animal tissue. (Isotopes are atoms of the same element with the same chemical properties, but differ in mass.)

J

Julian day	Day based on a calendar year (365 days per year and every fourth year 366 days) introduced by Julius Caesar.

L

Lentic	Standing waterbodies where there is no continuous flow of water, as in ponds and lakes (of freshwaters).
Littoral	The shallow margin at the edge of a lake or wetland. Usually characterised by rooted aquatic plants that are periodically exposed to the air due to fluctuating water levels.

M

Macrophytes	Large vascular plants.
Mass failure	A form of bank erosion caused by blocks of material sliding or toppling into the water.
Mesic	Found in areas with regular availability of water.
Microtopography	Variations in topography of the ground surface at the scale of centimetres to metres.
Monocots	An abbreviation of *monocotyledon* (*mono*, single; *cotyledon*, leaf), which is one of the two major classes of plants, and typified by seedlings with a single leaf; an absence of cambium (i.e. wood); stems with thickened basal portions forming corms, rhizomes, and bulbs; linear leaves with parallel venation; and flowers parts usually in multiples of threes (i.e. commonly six sepals, six petals, etc.).
Morphological	The external structure of a plant (or animal) based on degree of differentiation between species.
Myrtaceous	Belonging to the family Myrtaceae, which includes genera such as *Callistemon*, (bottlebrushes), *Eucalyptus* (gums and bloodwoods) and *Melaleuca* (paperbarks).

O

Obligate	Limited to a particular ecological mode, i.e. confined to a particular habitat.
Organic colloids	Small, low-density particles that can be transported easily by overland flow.

P

Ped	See aggregate.
Periphyton	Algal communities that grow on hard surfaces (such as rocks and logs) or on the surfaces of macrophytes.
Photic zone	Upper portion of a lake, river or sea, sufficiently illuminated for photosynthesis to occur.
Planform	Shape of a river as seen from the air.
Primary production	1. The total organic material synthesised in a given time by autotrophs of an ecosystem. 2. Rate at which light energy is converted to organic compounds via photosynthesis.
Propagules	A dispersive structure, such as a seed, fruit, gemma or spore, released from the parent organism.

R

Rain splash	The dislodgment of sediment by rain which travels down the bank and into the flow.
Rheophytic	A plant adapted to fast flowing water, most often inhabiting stream banks or stream beds, and may have certain morphological or reproductive characteristics.
Rhizome	More or less horizontal underground stem bearing buds in axils of reduced scale like leaves. Serves in vegetative propagation.
Riparian zone	Any land which adjoins, directly influences, or is influenced by a body of water.
Rill erosion	Small, often short-lived channels that form in cropland and unsealed roads after intense rains.
Rotational failure	A form of bank erosion caused by a slip along a curved surface that usually passes above the toe of the bank.

S

Scour	A form of bank erosion caused by sediment being removed from stream banks particle by particle. Scour occurs when the force applied to a bank by flowing water exceeds the resistance of the bank surface to withstand those forces.
Senescent	Old trees with some dead limbs.
Sheet erosion	Erosion on hillslopes by dispersed overland flow.
Slab failure	A type of mass failure caused by a block of soil toppling forward into the channel.
Slaking	Occurs as a result of the rapid immersion of banks. The soil aggregate disintegrates when air trapped in aggregates escapes.
Slumping	The mass failure of part of a stream bank.
Snags	Large woody debris such as logs and branches that fall into rivers.
Stable isotope analysis	A technique to measure naturally occurring stable isotopes (typically of carbon and nitrogen), increasingly used in food web studies.
Stomata	Microscopic perforations consisting of a unique arrangement of cells on a leaf surface through which exchange of gases and transpiration of water vapour occurs between a plant and the environment.
Stratigraphy	The sequence of deposited layers of sediment.
Stream order	Classification of streams according to their position in the channel network, for example, a first order stream has no tributaries. Streams become larger as their order rises and an increasing number of segments contribute to the flow.
Subaerial erosion	Erosion caused by exposure of stream bank to air.
Substrate	1. Substance upon which an enzyme acts. 2. Ground and other solid object on which animals walk, or to which they are attached. 3. Material on which a microorganism is growing, or a solid surface to which cells in tissue culture attach.
Succession	Directional and continuous pattern of colonisation and extinction of a site by populations or plants and/or animals. (Not to be confused with seasonal shifts in species composition.)
Surcharge	The weight imposed on a bank by vegetation.

T

Tensile stress	The force per unit area acting to pull a mass of soil or tree root apart.
Toe	Bottom of the bank.

W

Windthrow	Shallow-rooted, stream-side trees are blown over, delivering bank sediment into the stream.

X

Xeric	Adapted to arid conditions.

RESOURCES

For river and riparian management the most comprehensive range of fact sheets, technical guidelines and manuals can be accessed at www.rivers.gov.au. This website also has a number of interactive catchment diagrams that show well-managed and poorly-managed riparian areas in relation to a particular topic.

www.rivers.gov.au website

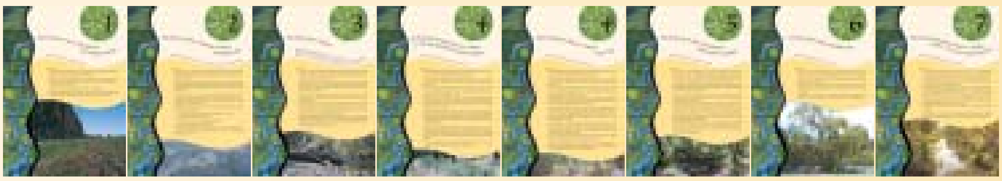
The www.rivers.gov.au website is the best place to visit for up-to-date information and tools designed to assist people working in rivers and riparian lands across Australia. The website has full details of all the products listed here, with most able to be downloaded or ordered in hard copy from CanPrint Communications (freecall 1800 776 616).

Fact sheets

These fact sheets aim to set out the general principles and practices for sound management of rivers and riparian lands. They are grouped according to whether they deal with riparian land, in-stream health, river contaminants or other management issues.

Technical guidelines

These guidelines are aimed at a more technical audience and provide detailed information about the science underpinning recommended best practice in river and riparian management. They have become central reference documents for most catchment management organisations in Australia, as well as providing the most up-to-date river and riparian science for researchers working in the area.



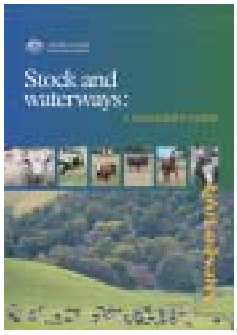
RipRap

This newsletter provides information about new research, products and case studies. It is the best way of staying up-to-date with what is happening in rivers research across Australia. Editions are based around a particular management theme and written in easily understood language to update policy makers, catchment groups and landholders about the most recent developments in river management.

Industry specific guidelines

These guidelines provide different commodity based industries with river and riparian management information specific to their needs. Two guidelines — 'Managing riparian lands in the sugar industry' and 'Managing riparian lands in the cotton industry' have already been produced. The wool industry now has its own set of guidelines that brings together the latest science and recommended management approaches for riparian areas within the context of a commercial wool growing property. The wool guides are available for high rainfall regions (above 600 mm) and sheep/wheat regions (300–600 mm). In addition there is an accompanying summary document and checklist.

Stock and waterways: a manager's guide



The aim of this book is to help farmers identify their riparian land and understand the role it plays in maintaining a healthy waterway. It offers practical advice on how to manage riparian land both productively and sustainably. It also includes a number of case studies from farmers throughout Australia who have seen the benefits of changing their management practices.

CDs and stories

We have CDs containing all of our publications in the one spot, as well as CDs that tell stories about how people are managing their rivers for future generations. Our "Legacy" CD (released in December 2006) covers scientific findings, PowerPoint presentations and all the products that have been developed by the National Riparian Lands R&D Program over the past 13 years.

All these products are available on the Rivers website at www.rivers.gov.au
They are also available from CanPrint Communications on freecall 1800 776 616.

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RiverLandscapes

RiverLandscapes

Together...
We can restore, protect and enhance our river landscapes for present and future generations.