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A method for determining Catchment Scale Priorities for Riparian Protection and Rehabilitation

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Abstract:

In Australia, river management decisions are increasingly being made at the catchment scale. There are well established procedures for setting restoration priorities, however catchment managers need objective assessments of catchment condition to help them prioritise restoration works. We describe the application of two catchment-scale assessment techniques, SedNet and the Rapid Appraisal of Riparian Condition (RARC), to determine priorities for protection (fencing) and rehabilitation (replanting) of riparian vegetation in the Murrumbidgee catchment. SedNet is a model that constructs sediment budgets, and the RARC is an assessment of the biodiversity and function of riparian zones. Priorities for bank erosion control were determined by bank erosion hazard, which accounts for stream power, the presence of erodible soil, and channel incision. Priorities for riparian condition were determined using a remotely sensed dataset of existing riparian vegetation cover. The techniques are demonstrated in the Murrumbidgee catchment, where they are being used to assist setting priorities for river restoration. A method for combining the priorities from SedNet and RARC is described, to address objectives of improving water quality and riparian condition.

Key Words:

Catchment management, water quality, sediment budget, modelling, river bank erosion, riparian condition

Introduction:

There is a growing interest in restoring rivers (White *et al*., 1999). In many river systems, the restoration work required exceeds the resources available. Consequently, management actions need to be targeted to achieve the greatest environmental benefit. Established procedures for maximising the effectiveness of stream rehabilitation are available (e.g: Rutherfurd *et al*., 2000). However, implementing such procedures requires assessments of stream condition that identify assets and problems, and provide the information to set priorities and measurable objectives. Where planning of stream rehabilitation is done at the regional scale, assessment of such large areas can be difficult, and requires a quantitative and systematic approach.

Spatially distributed process models provide one method for assessing river condition. Such models have the advantage of applying existing knowledge of catchment processes across large catchments, to identify causes of condition without the need for site assessments. They also provide the opportunity for quantitatively simulating the effect of management scenarios on system condition. An alternative method is to use field based classifications and assessments, such as the Index of Stream Condition (Ladson and White, 1999), and River Styles (Brierley *et al*., 2002). In comparison to modelling, these techniques can require extensive fieldwork, which can limit their application over large areas, particularly if detailed spatial resolution is required. Where application is possible, and if they are framed with catchment processes in mind, they can be useful. Another alternative method is an expert panel assessment of catchment characteristics. While rapid, at the regional scale this method generally does not provide the spatial resolution required for planning, and it may not provide the quantitative description of system behaviour necessary to identify causes of downstream impacts and compare the effect of different management scenarios.

In this paper we describe two catchment-scale techniques for assessing aspects of river condition, and their application to determining priorities for protection and rehabilitation of riparian vegetation. The first technique is SedNet (Sediment budgets for river Networks), a model that uses conceptual understandings of erosion and deposition processes to construct a sediment budget for each reach, or link in a river network. This technique can be used to identify dominant erosion processes, erosion 'hotspots', and the upstream causes of downstream sediment problems. The second technique is RARC (Rapid Assessment of Riparian

Condition), an assessment of the biodiversity and function of riparian zones (Jansen *et al.*, 2004; Jansen, this volume).

Data for assessing river condition using process-based models is today widely available. For example, the Australian Natural Resources Data Library (http://data.brs.gov.au/asdd/) houses national datasets on climate, terrain, geology, soils, vegetation cover and landuse are available. Many state and regional agencies have collected high-resolution data as part of their management planning and monitoring. The use of such data to model catchment condition is to be encouraged, so long as users have an understanding of model capabilities, and appropriate model use (Grayson, 2004). The assessments we describe assess trends in condition at the regional scale, which is useful for setting priorities, strategies and objectives. However, site-scale design still requires site inspections, or separate analysis of high-resolution datasets.

We demonstrate the SedNet and RARC techniques in the Upper and Middle Murrumbidgee catchment, upstream of Wagga Wagga (Figure 1). We also demonstrate a method for combining the priorities from SedNet and RARC, to develop priorities for protection and rehabilitation of riparian vegetation that address both erosion control and biological functions of riparian vegetation.

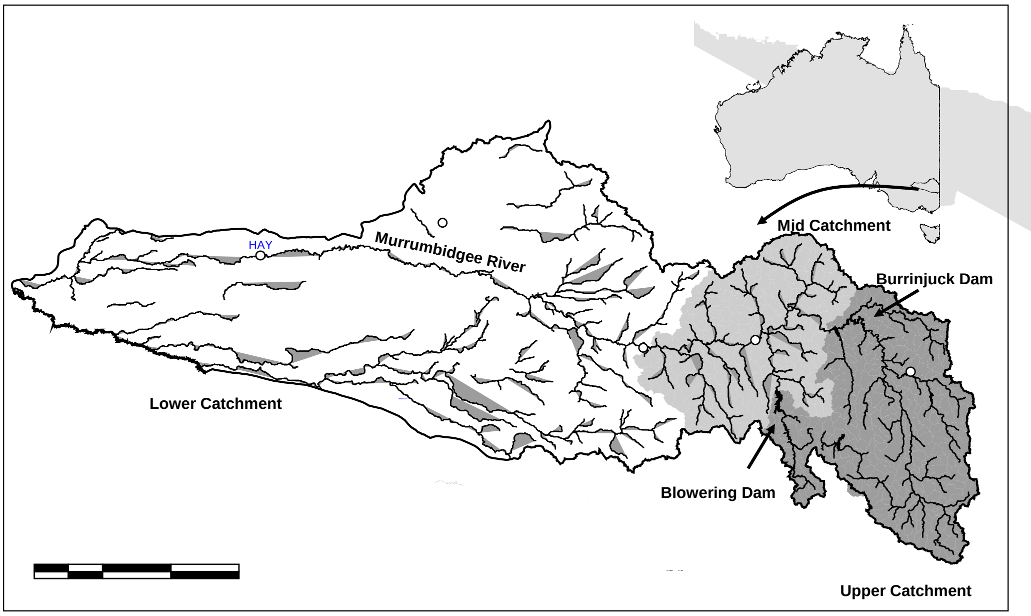

Figure 1: Location of the Upper and Middle Murrumbidgee catchment.

Priorities for Bank Erosion Control using SedNet Assessment of Sediment Budgets:

SedNet is a physically-based process model that identifies the major sources, sinks and loads of sediment for each link, or reach, in a river network. Budgets (mass balances) of bedload and suspended sediment are constructed for each reach link in a river network. SedNet was originally developed for continental-scale assessments for the National Land and Water Resources Audit (Prosser *et al*., 2001). It has been progressively refined to improve its suitability and accuracy for catchment-scale (10^3 – 10^6 km^2) assessment (Wilkinson, 2004). SedNet is available as software in the Catchment Modelling Toolkit (www.toolkit.net.au/sednet), and details on the technique are available in Wilkinson *et al.* (2004a).

Table 1: Relative proportions of sediment sources and losses in the contemporary budget, totalled across the upper-mid Murrumbidgee Catchment

Inputs	% of total	**Outputs**	% of total
Hillslope suspended supply	18	Floodplain suspended deposition	9
Gully suspended supply	12	Channel bedload deposition	21
Gully bedload supply	24	Reservoir suspended deposition	20
Riverbank suspended supply	23	Reservoir bedload deposition	16
Riverbank bedload supply	23	Export suspended sediment	24
		Export bedload sediment	10
Total supply	100%	Total Export and Deposition	100 %

SedNet modelling for the Murrumbidgee catchment indicates that riverbank and gully erosion are the dominant sources of sediment to the river (Table 1), a finding supported by radionuclide tracer observations (Wallbrink *et al.*, 1998). The long-term average suspended sediment load at Wagga Wagga predicted by SedNet modelling is 578 kt/y; which compares well with the observed load of 600 kt/y (Olive *et al*., 1996). The datasets used to apply SedNet to the Murrumbidgee are detailed in Wilkinson *et al*. (2004b).

One approach to improving water quality using SedNet, and the approach we will demonstrate here, is to target erosion control activities to erosion "hotspots". To determine priorities for controlling bank erosion that are independent of existing woody vegetation cover, we calculate the predicted rate of bank erosion in the absence of riparian vegetation. This is termed "*bank erosion hazard*" and is determined by stream power (product of channel slope and bankfull flow rate), and the amount of erodible soil along each link (Wilkinson *et al*., 2004a). Priorities for protecting existing riparian vegetation, and revegetating cleared riparian zones, are based on bank erosion hazard. Figure 2 indicates three bank erosion hazard priority levels. The first priority level contains 1,000 km of river length, or approximately 20% of the total network. Links with greater than 50% of their length inside reserves make up a 4th priority level, since we assume that fencing and replanting are not required in these areas.

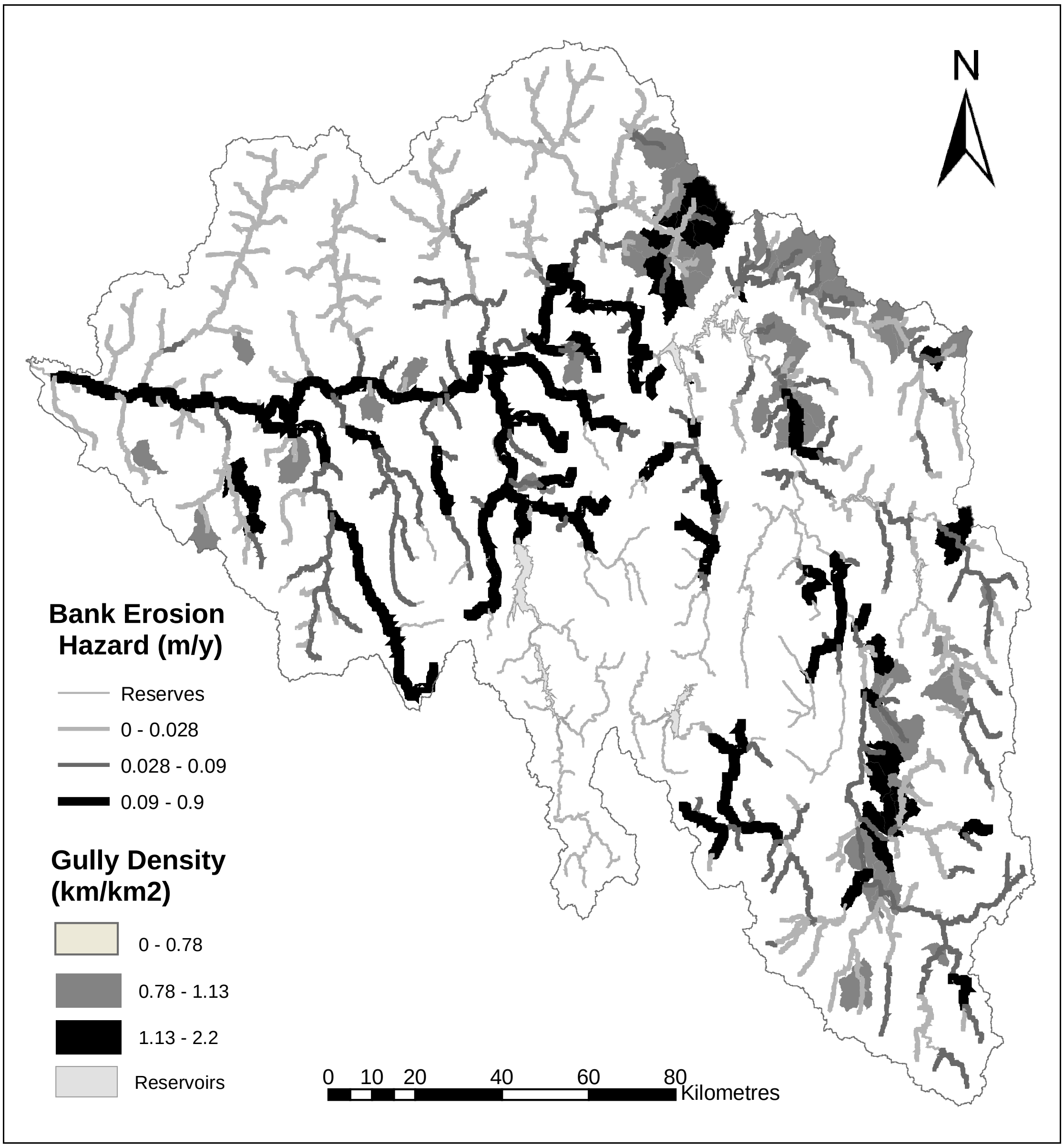

Figure 2: Priority levels for bank and gully erosion control in the Upper and Middle Murrumbidgee catchment.

The linear extent of gully erosion in the Murrumbidgee catchment has been well mapped from aerial photos by the NSW Department of Infrastructure, Planning and Natural Resources. This mapping includes all small streams that are incised. As have no data on the spatial variation of gully activity, or gully size, the model assumes that all gullies produce sediment at the same rate per kilometre. In the model therefore, all gullies have equal priority for stabilisation. For several practical reasons, we recommend that gully erosion control targets areas in decreasing order of gully density:

1. Treating a large number of gullies in a small area, and across a few land-holdings, is more efficient than treating isolated gullies.
2. It is likely that areas of high gully density will contain a higher density of actively eroding gullies, and they may also be larger.
3. Gullies in high-density areas may also more likely to be well connected to the stream network.

Three priority levels of gully stabilisation are illustrated in Figure 2. The highest priority has a gully density of >1.13 km/km^2. Due to its size, the third priority level (<0.78 km/km^2) is split into two classes.

Links within each priority level are regarded as having equal priority for erosion control. In reality, the levels are merely classes along a continuous spectrum of erosion hazard. While there is some uncertainty in ranking the hazard potential of individual links, there is much greater certainty that, as a group, the 1st level of bank or gully erosion control has considerably higher erosion than the 2nd level. Treatment will include protecting existing riparian vegetation to prevent bank erosion developing, rehabilitating (revegetate and protect) vegetation to reduce bank erosion, and stabilising gullies by vegetation or other means.

Priorities for Improving Riparian Condition as Measured by the RARC:

The RARC was originally designed as a site-based assessment (Jansen *et al.*, 2004). We have extended this method to a whole of catchment scale assessment, by using satellite imagery to calculate the percent cover of remnant riparian vegetation in each river link. Riparian condition is related to tree cover extent, as described by Jansen (this volume). Using this catchment-scale assessment, a separate set of priorities for protection and rehabilitation of riparian vegetation are developed based on a principle of ‘protect and conserve first, restore and rehabilitate second’ (eg. Rutherfurd *et al.*, 2000). This approach assumes that it is more efficient to protect sections of rivers that are in good condition, than it is to restore badly damaged reaches. Five priority levels are defined. The first priority level has the highest riparian zone canopy cover (>80% canopy cover), with subsequent levels being 60-80%, 40-60%, 20-40%, and finally <20% canopy cover. River links in reserves are excluded from the priorities, because they are already protected. Other threatening processes, such as feral animals, weeds and fire, may be more important in these areas.

These regional-scale RARC priorities have the following limitations:

- Due to its extent, vegetation in links with a high percentage canopy cover is assumed to be in better condition than in less vegetated links. In reality, some small remnants of riparian vegetation may also be valuable. Also, small amounts of vegetation in one link may be contiguous with larger areas in adjacent links.
- Being based on canopy cover, this method does not identify rare or endangered communities, or areas of heath or grassland that should be protected. It also does not discriminate between native and exotic tree species, such as Willows.
- The BRS landcover data (Barson *et al.*, 2000) used in this assessment has a pixel size of 25 metres, so does not detect narrow strips of trees or sparsely scattered trees.
- The extent of existing protection is not known, and the assessment identifies priorities for protection and rehabilitation, assuming that fencing or revegetation has not already been carried out.

Combining SedNet and RARC Priorities for Riparian Protection and Rehabilitation:

The priority levels for bank erosion control and the RARC priorities based on canopy cover can be combined to provide an overall priority ranking for protection and rehabilitation. If it is assumed that erosion control is a primary objective of riparian works, we propose that the bank erosion control priorities be used to define primary priority levels (Figure 2). If improving the biological functions of riparian vegetation is a secondary objective, then the five RARC priority levels can be nested within each of the primary priority levels. Thus, protection and rehabilitation would be implemented on all links in the 1st priority level before moving to the 2nd priority level. Within each level, work would proceed in order of the RARC priority by starting with links having greatest proportion of existing vegetation and proceeding to those links with least existing vegetation.

There is also flexibility to share the weighting between the bank erosion control and biological functions of riparian vegetation (Wilkinson *et al*., 2004b). A higher weighting on riparian biodiversity can be achieved by protecting links in the 2nd and 3rd priority levels that are in good condition (high proportion of existing vegetation) before links in the 1st priority level that are in poor condition.

The assessment techniques described provide quantitative, regional-scale priorities. Site-scale planning of works in high-priority areas should be based on field inspections. Several practical considerations mean that only part of each riparian zone or sub-catchment gully length may need treatment:

- The majority of erosion reduction may be achieved by treating the most active erosion. Bank erosion hazard will vary within each link, due to variations in channel slope, bank height, soil erodability, and location relative to the inside or outside of channel bends. Gully activity will also vary.
- Some bank vegetation will already be protected.
- Not all landholders will want to be involved in riparian management and access to some parts of the riparian zone may be difficult due to topography.
- Treating only part of each river link may also be sufficient to demonstrate the value of these activities across the catchment, and encourage voluntary completion of these activities.

Simulating management scenarios

We simulated scenarios where 100%, 50% or 20% of each river link was protected and restored. That is, 100%, 50% or 20% of existing riparian vegetation is protected, and 100%, 50% or 20% of the presently non-vegetated riparian zone is revegetated and protected. In these simulations, only revegetation has an effect on bank erosion, with protection only preventing a future increase in bank erosion. The impact on sediment supply from bank erosion for each scenario is shown in Figure 3. A large reduction in bank erosion is predicted when all the links in the first priority level have been fenced or replanted. Implementing works within the 2nd and 3rd priority levels further reduces the predicted amount of bank erosion, but the improvement per kilometre of works is less. Not surprisingly, if only 50% or 20% of the links are fenced or replanted the model predicts there would be a more limited response. These models do not consider the type of within link prioritising described above and it is possible that targeting works within links, under the 50% or 20% scenarios, could have a greater impact on sediment supply then shown.

The results for the Murrumbidgee catchment will be used in the implementation of a river restoration project that is intended to address water quality management targets as specified in the Murrumbidgee Catchment Blueprint (MCMB, 2003). A similar method is soon to be applied in the Goulburn-Broken catchment.

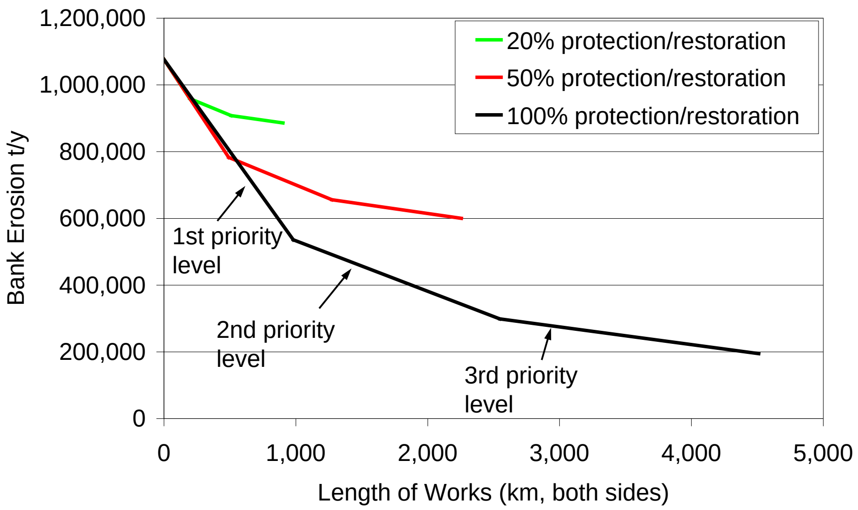

Figure 3: Predicted change in sediment supply from bank erosion following the protection and restoration of different percentages of each river link. Each priority level is labelled on 100% line.

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