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Catchment assessment techniques to help determine priorities in river restoration

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Principal Investigator

Scott Wilkinson
CSIRO Land & Water
GPO Box 1666
Canberra ACT 2601

Email: scott.wilkinson@csiro.au
Telephone: 02 6246 5774

Collaborators

Arthur Read, Yun Chen and Briohny Davey
CSIRO Land & Water

Robyn Watts and Amy Janson
Charles Sturt University

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Postal address:	GPO Box 2182, Canberra ACT 2601
Office location:	Level 1, The Phoenix, 86-88 Northbourne Ave, Braddon ACT
Telephone:	02 6263 6000
Facsimile:	02 6263 6099
Email:	enquiries@lwa.gov.au
Internet:	www.lwa.gov.au

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1 Project Objectives

Through the following steps, develop and apply catchment assessment techniques to help regional catchment agencies to determine priorities for rehabilitating riverine water quality, habitat sedimentation and riparian condition:

1. Identify 3 or 4 focus catchments where the above three stream problems are issues for management agencies and where management agencies are keen to apply catchment assessment techniques to assist their river restoration and management plans
2. Determine the data available to assess those management issues, working closely with agencies and communities
3. Adapt and further develop catchment assessment techniques to data available at the regional scale and the management issues using current knowledge and test them against independent field observations
4. Undertake the assessments to identify where in the catchment (rivers or reaches) rehabilitation actions are most likely to result in significant improvement in the management issues. These actions may include erosion and pollutant control, flow management and riparian restoration. Identify the magnitude of improvement
5. In each focus region, demonstrate the use of the techniques for identifying rehabilitation priorities, given a specified management vision and investment scenario
6. Evaluate the benefits of the techniques in achieving river rehabilitation goals. Examine the effectiveness of planning of past rehabilitation projects, and how using the catchment assessment techniques developed might assist such projects
7. Prepare protocols for wider use of the techniques by agencies, catchment authorities and community groups (eg Rivercare). Explore how agencies can best routinely use the methods, through avenues such as technical consultants

2 Summary of methods

This report summarises the outcomes of the catchment assessment techniques project. The intent is for the assessment techniques described to provide an improved rational basis for setting stream rehabilitation priorities.

Focus catchments were chosen that had issues aligned with those in the project objectives. Two existing assessment techniques; SedNet (Prosser et al., 2001) and RARC (Jansen et al., 2004a), were selected to be developed for regional scale priority setting, based on the project team's expertise with these techniques. These techniques were developed using data from the focus catchments. The assessments were then applied at the catchment scale and tested against independent observations. Priorities for rehabilitation activities were determined from the assessments, and implementation of the priorities simulated to demonstrate the benefit of the techniques in achieving river rehabilitation goals. Specified investment scenarios were also simulated. Data were gathered on past rehabilitation projects and used to examine the effectiveness of those projects.

3 Results against each objective

3.1 Objective 1

Through the following steps, develop and apply catchment assessment techniques to help regional catchment agencies to determine priorities for rehabilitating riverine water quality, habitat sedimentation and riparian condition:

Objective 1: Identify 3 or 4 focus catchments where the above three stream problems are issues for management agencies and where management agencies are keen to apply catchment assessment techniques to assist their river restoration and management plans

Members of the National Rivers Consortium Board were invited to suggest focus regions from their jurisdictions and further discussion with regional managers refined that list to select three catchments 6,000 – 30,000 km^2, that had management agencies interested in prioritising stream rehabilitation at a regional scale, that had data available to develop the assessment techniques, and had issues aligned those in the project objectives. The upper Murrumbidgee (NSW), Goulburn-Broken (VIC) and Mt Lofty Ranges (SA) catchments were selected.

3.2 Objective 2

Objective 2: Determine the data available to assess those management issues, working closely with agencies and communities

Following project workshops in each focus catchment, the management agencies were responsive to data requests. For SedNet, high-resolution data were collected including vegetation cover, landuse, stream flow, digital elevation models and water quality data. These data provided the potential to considerably improve predictions over those made in the NLWRA SedNet assessment. In the Mount Lofty Ranges, regional data on gully erosion were available only for the Torrens catchment and parts of the neighbouring catchments. Field reconnaissance indicated that the NLWRA gully assessment (Hughes et al., 2001) was inadequate at this scale, and so SedNet assessment in this focus catchment was confined to the area for which regional data were available.

Datasets adequate for assessing riparian condition were available for the Goulburn-Broken Catchment and the Mt Lofty Ranges, based either on SPOT satellite imagery with a 5m pixel resolution or on aerial photography. However, in the Murrumbidgee catchment, the only dataset available was the BRS landcover data, which is available for all of Australia and has a 25m pixel resolution. This was adequate for the upstream sections of the Murrumbidgee Catchment but has limitations in areas with few trees.

3.3 Objective 3

Objective 3: Adapt and further develop catchment assessment techniques to data available at the regional scale and the management issues using current knowledge and test them against independent field observations

3.3.1 SedNet

Prior to the project, demonstration of SedNet at the regional scale (DeRose et al., 2003a, 2003b) indicated the potential of SedNet for setting regional priorities. A prerequisite for this use is certainty in the predicted spatial patterns in erosion and sediment delivery. For targeting erosion control, several limitations for using the model at the regional scale for catchment planning were obvious; the algorithms were not adapted to higher-resolution regional data, there was unknown uncertainty in the predicted spatial patterns at the regional scale, and the priorities were not specific to available management actions.

Several model components were selected to improve certainty in prediction. These are reported in detail in Wilkinson et al. (2004a, 2005a, 2005b, in press):

- Bank erosion; A new explanatory variable was adopted; stream power. The capacity to determine channel slope and to predict erosion levels was improved. Along with this, a definition of the riparian zone was developed, reducing noise and uncertainty in prediction of bank erosion. Testing predictions against rates measured from historical aerial photos showed an improvement in spatial pattern of predicted bank erosion. A potential bank erosion rate was defined to assist targeting riparian protection and rehabilitation of riparian vegetation.
- Gully erosion: A method for representing recent declines in gully activity was developed.
- Hillslope erosion: An improved method for predicting vegetation cover was developed. This better discriminated between different land uses, and enabled paddock-scale scenario modelling of landuse change.
- Hydrology: A physically based hydrology model reduced uncertainty.

The capacity of SedNet to predict spatial patterns in sediment delivery was tested using water quality data from 9 locations across the Goulburn catchment; the above developments resulted in a significant reduction in error compared with two SedNet assessments carried out prior to the project (Wilkinson *et al*., 2005a). A transient model for predicting the distribution of bedload accumulation was refined and tested against data collected in the Murrumbidgee catchment, showing improved capacity to predict the location of sand slugs (Wilkinson and Prosser, in prep). The model now uses the best data available at the regional scale, and the value of such data has been demonstrated.

3.3.2 Riparian condition

Remotely sensed data on vegetation cover in riparian zones was used to estimate canopy cover in these zones. This was tested in all three catchments against field data collected using the Rapid Appraisal of Riparian Condition (RARC). The RARC has already been shown to be a good indicator of the biodiversity and functioning of riparian zones (Jansen et al., 2004a). In the three catchments, canopy cover measured from the remotely sensed data explained between 5% and 66% of the variance in the on-ground RARC scores (Wilkinson et al., 2004a; Jansen, 2005). The better results were obtained with higher resolution imagery. It was considered that canopy cover, measured from remotely sensed data, was a good indicator of riparian condition in all three catchments. Using the protocol outlined in Appendix 1, riparian condition could thus be assessed across each of the catchments.

3.4 Objective 4

Objective 4: Undertake the assessments to identify where in the catchment (rivers or reaches) rehabilitation actions are most likely to result in significant improvement in the management issues. These actions may include erosion and pollutant control, flow management and riparian restoration. Identify the magnitude of improvement

3.4.1 SedNet

Budgets of bedload and suspended sediment were assessed for each focus catchment using SedNet. Bank and gully erosion were identified as major sediment sources in all focus catchments. Across each focus catchment spatial priorities for erosion control and riparian restoration were defined in descending order of potential bank erosion (in the absence of riparian vegetation), gully density and hillslope erosion rate. Separate spatial priorities for each erosion control activity were shown to be most efficient at reducing sediment yields. Sediment delivery through the network accounting for losses to reservoirs and floodplains was calculated to provide priorities for reducing suspended sediment export. Simulation of erosion control demonstrated that suspended sediment export could be reduced by the order of 20-50% by implementing riparian revegetation (Wilkinson *et al.*, 2004a, 2005a).

3.4.2 Riparian condition

Riparian condition was assessed for all stream links in each catchment using the protocol. This assessment was used to set priorities for protection and rehabilitation of riparian vegetation to improve riparian condition. The magnitude of improvement is difficult to estimate (or even quantify) for riparian condition. There is little data on how long riparian restoration can take, and what functions/biodiversity values will be restored. We assume that, given best-practice rehabilitation methods and sufficient time, protection and rehabilitation of riparian vegetation will eventually restore all riparian functions and biodiversity values in the treated riparian zones.

3.5 Objective 5

Objective 5: In each focus region, demonstrate the use of the techniques for identifying rehabilitation priorities, given a specified management vision and investment scenario

3.5.1 Murrumbidgee catchment

At the request of the Murrumbidgee Catchment Management Authority (MCMA), priorities were provided for the $1M River Restoration project (Wilkinson et al., 2004a). To match the project goals, a report was presented to the MCMA containing primary erosion control priorities and nested secondary riparian condition priorities. The response of suspended sediment supply to implementing the recommended priorities was simulated.

3.5.2 Goulburn-Broken catchment

In the Goulburn-Broken Catchment a number of high and very high priority reaches had been identified by the Catchment Management Authority as part of the Goulburn-Broken Regional River Health Strategy (GBCMA, 2004). For each of the 13 reaches where water quality had been identified as a high or very high priority threat to condition, spatial priorities for erosion control were provided in descending order of suspended sediment contribution (Wilkinson et al., 2005). Jurisdictional separation between "catchment" and "riverine" management was handled by providing separate priorities for bank erosion control and gully/hillslope erosion control. Riparian condition was assessed in all of the priority reaches and information on which reaches should be rehabilitated first was provided, as well as estimating the area of plantings and the length of fencing required to address the identified threats of stock access and degraded riparian vegetation for each reach.

3.5.3 Mt Lofty Ranges catchments

A management scenario was not provided by the management agencies in this region. The defined region spanned several catchment and water management boards, which are shortly to amalgamate into one entity.

3.6 Objective 6

Objective 6: Evaluate the benefits of the techniques in achieving river rehabilitation goals. Examine the effectiveness of planning of past rehabilitation projects, and how using the catchment assessment techniques developed might assist such projects

A reliable prediction of the spatial pattern of erosion and sediment delivery is required to achieve river rehabilitation goals related to sediment. The improved performance in predicting spatial pattern of sediment yield in the Goulburn-Broken catchment (Wilkinson *et al.*, 2005a) is a measure of the benefit of using the improved SedNet for achieving catchment-scale river rehabilitation goals.

There is demand for regional scale assessment of erosion and sediment delivery, and for targeting erosion control activities. SedNet has now provided a rational basis for assessing sediment sources and delivery, and setting spatial priorities for erosion control at the whole of catchment scale. A measure of benefit is that the Murrumbidgee Catchment Management Authority has used the outputs of our study (Wilkinson *et al*., 2004a) to assist setting spatial priorities for erosion control in the current River Restoration project and to assist setting targets for future sediment loads. Another measure is the response of the GBCMA, who report that this approach "has enabled us to target areas for riparian protection, bank erosion, catchment erosion activities, to address the source of erosion and sediment problems, rather than using a random approach throughout the catchment. This targeted approach has been accepted by the CMA's partners in land management. The results are also being used to target grant proposals." (Tennant, pers. comm. 2005).

We compared the simulated effect of targeted revegetation against a spatially random pattern of revegetation, as a measure of the benefit of using the techniques. While rehabilitation has never been randomly implemented, setting priorities at the site scale in conjunction with and in response to landholders, with catchment managers trying to consider a range of site issues and ensure an even spread of investment across the region may be approximately random at the regional scale. In the Murrumbidgee and Goulburn-Broken catchments, a comparison of simulations of targeted and random revegetation indicate that targeted erosion control results in reduction in sediment export several times larger than that resulting from random revegetation over the long term. (Wilkinson *et al*., 2004a, 2005a).

The effect of past rehabilitation can be simulated using the assessment techniques. In general, we were unable to obtain sufficient details on past projects to specifically assess their impact due to inadequate record keeping. Often these projects had a range of objectives not related to sediment or riparian condition. One exception is the Bidgee Banks project, where the spatial extent of fencing and revegetation was obtained. Simulating the effect of the project on sediment export indicated a negligible effect. However, this was partly due to difficulties representing the revegetation in SedNet.

For evaluation of past projects, it is recommended that the modelled stream network be positioned using topographic stream lines rather than directly from the Digital Elevation Model (Wilkinson et al., 2005a); that the extent of the topographic stream network match that of perennial eroding streams in the catchment so that simulating riparian revegetation affects bank erosion rather than gully erosion in SedNet, and its effect on riparian condition is captured. Representing narrow widths of riparian revegetation in a regional-scale model also requires careful treatment when defining the riparian zone and selecting data resolution. While the techniques are certainly helping to target actions, responses to the current increase in rehabilitation have still to be evaluated. Evaluation of benefits should also include site-scale surveys.

SedNet, and the riparian condition assessment, are designed to provide priorities at the regional scale, and identify areas of the catchment to focus effort. They are not a substitute for field inspections when designing management actions at the site scale. Access issues and variability in condition and threat within each reach must also be considered. The temporal response to rehabilitation is also not explicitly considered by SedNet and the riparian condition assessment. In general, it will take 10-30 years for vegetation to fully stabilise erosion and there are little data to predict temporal improvement in riparian condition following revegetation. Reductions in erosion and sediment delivery will in general be much smaller than inter-annual variability caused by climate (Olley and Scott, 2002); necessitating sophisticated analysis of water quality data to test model predictions of sediment loads (Wilkinson and Olley, in prep).

Evaluating the economic benefits of targeting river rehabilitation, and weighing biophysical priorities against resource constraints should consider the unit costs of each management activity (bank revegetation, gully stabilisation and hillslope vegetation cover management), as well as the extent of implementation. For targeting erosion control, this is described in Lu *et al.* (2004). A model, such as the SedNet software (Wilkinson *et al*., 2004b) could be extended to provide a decision support system that considers both the costs and benefits of rehabilitation.

3.7 Objective 7

Objective 7: Prepare protocols for wider use of the techniques by agencies, catchment authorities and community groups (eg Rivercare). Explore how agencies can best routinely use the methods, through avenues such as technical consultants

SedNet and riparian condition assessments and priorities should be used in the context of a broader catchment planning process that considers a range of other condition assessments (e.g: Rutherfurd et al., 2000). Users should also ensure that the management actions undertaken will specifically address the root cause of, or threat to current condition. For example; SedNet priorities can assist in reducing mean annual suspended sediment loads. However, high turbidity at low flow may also be caused by disturbance by carp, flow management, stock access, or industrial point sources.

3.7.1 SedNet protocols

SedNet is available as free software at www.toolkit.net.au/sednet . Users should have experience in spatial data analysis, and in assessing erosion. Consultants, and regional agency staff who can access support from other modellers should obtain training before using the software. Users should carefully follow the guidance for data preparation and model use and interpretation given in the User Guide (Wilkinson *et al*., 2004b). The priorities should be interpreted at the regional scale. Rather than targeting erosion control to individual links, it should be targeted to groups of links. The considerable uncertainty in model predictions, particularly simulations of future condition, should be considered. As the model continues to improve, numeric predictions will likely change, and the core model results should be regarded as the general spatial patterns. Results should be tested against observations of erosion rates and sediment yields in every catchment application.

Appropriate applications for SedNet include: Catchment assessment of sediment loads, and nutrient loads using in addition the Annex model (Young et al., 2001), and assisting in assessing ecological condition or naturalness; Targeting erosion control at the catchment scale; simulating erosion control to conservatively set targets for future end-of-valley suspended sediment loads; preliminary assessment of sites for suitability for gravel extraction; helping to design water quality monitoring programs.

3.7.2 Riparian condition assessment

See Appendix 1 for the riparian condition assessment protocol. This should be able to be applied by any technical officer with GIS skills. Quality of the assessment increases with increased resolution of the vegetation data used.

3.7.3 Communication and adoption activities

The project findings have been widely communicated:

- Workshops in each focus catchment; project reference panel meetings including focus catchment representatives; presentations to the MCMA and DIPNR. Catchment agency response has been to request output data and use the recommended priorities (Section 3.6). SedNet is now used by 10 regional catchment agencies to assist prioritising erosion control.
- SedNet workshops at the Catchment Modelling School 2005 and 2005, the Hydrology and Water Resources Symposium 2005, to CRC for Catchment Hydrology focus catchment staff, and to agency staff modelling the Great Barrier Reef catchments (approximately 70 modellers in total). Software is being used by two environmental consulting companies and 5 regional agencies.
- Industry journal articles (Wilkinson, 2004; Jansen et al., 2004b)
- Conference presentations (Wilkinson et al., 2004c, 2005c, 2005d; Jansen, 2003, 2005), Victorian Water Quality forum (November 2004).
- Reports (Wilkinson et al., 2004a, 2004b, 2004, 2005a, 2005b; Jansen et al., 2004a)
- Scientific papers (Wilkinson et al., in press, in prep, 2005c, Jansen, 2005).

3.7.4 Recommendations for adoption role of NRC

There are ongoing roles for the NRC in supporting adoption of the project outcomes in industry forums. Supporting sensible use of catchment models will assist in maintaining the reputation of this approach to prioritising rehabilitation. Supporting evaluation of rehabilitation actions would also assist evaluation of a rational, targeted approach. Further research into incorporating outcomes into catchment planning frameworks, including risk assessments, will assist in application of the assessment techniques. There are several opportunities to further develop the assessment techniques developed in this project, to improve their performance.

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Appendix 1 - Protocol for estimating riparian vegetation condition from remotely sensed data

Start with the following data:

(1) SedNet stream network with data on channel width for each link. Alternatively, it is possible to use any stream network and divide it into sections as required, providing there is data on channel width for each section.
(2) Tree coverage data for the region of interest – preferably at 5m resolution (e.g. Victoria's TREEDEN25 dataset). It is possible to also use 25m resolution data, such as the BRS landcover dataset which is available for all of Australia. The dataset must contain pixels or shapes designated as tree cover.

Steps for each link:

(1) Calculate half the channel width, and then create a buffer around each link based on this width. This will create a channel rather than a line.
(2) Calculate four times the channel width, then create a buffer around each channel link (i.e. around the half channel width buffers) based on this width. This will represent the riparian zone adjacent to the channel. Note that for channels less than 10m wide, the riparian zone should be 40m wide rather than four times the channel width. Ensure that each buffer has an ID corresponding to the original links. Calculate the total area of each riparian buffer.
(3) Intersect the riparian buffers with the tree cover dataset.
(4) Calculate the area of each riparian buffer intersected by trees. There are different procedures for doing this depending on whether the tree data is points or polygons:
(a) For polygons – calculate the area of each intersection then sum for each link ID
(b) For points – determine the number of points with trees and the total number of points for each buffer.
(5) Some links will be missing if there was no tree cover – these must be manually assigned a "0".
(6) Calculate tree cover/total area (or points with trees/total number of points) for each buffer to give an index of riparian condition.
(7) For prioritisation, the links can be sorted according to condition
(8) For mapping, condition can be assigned into categories, e.g. <0.2, 0.2-0.4, 0.4-0.6, 0.6-0.8, >0.8.