NEWSLETTER OF THE COOPERATIVE RESEARCH CENTRE FOR CATCHMENT HYDROLOGY

CATCHWORD

NO 114 MARCH 2003

A NOTE FROM THE DIRECTOR

Professor Rob Vertessy

LANDSCAPE RENEWAL AND CATCHMENT PREDICTION

Anyone that reads *Catchword* will surely be aware of the elevated public interest in landscape renewal. Politicians and the media are now expressing great interest in water-related environmental problems, as the scale of our problems becomes increasingly evident. Incrementally, government is tightening the reins on the utilisation of land and water, and this has, on occasion, led to conflict with the community. And yet, the case is now being put for more fundamental change.

There are a number of articulate proponents for radical change in the way we manage Australia's land and water resources, and almost all of them argue for a stronger leadership role of government and greatly increased public investment in natural resources management. The instruments they advocate to guide such change vary, but include the redefinition of land and water rights, regulatory controls such as 'licences to pollute', the imposition of environmental levies on particular industries, excision and re-zoning of land, and the introduction of tax-incentives to stimulate particular commodity markets.

History tells us that the introduction of such instruments will most likely cause anxiety and conflict in the community, based on social justice and equity concerns. Unless particularly well conceived and implemented, some of these instruments may well be challenged by savvy interest groups in the courts. For these reasons, the advocates of land and water management reform rightly argue the case for the greater use of knowledge-based decision making and the engagement of regional communities. There is an acceptance of the fact that government is obliged to demonstrate the benefits of reform and to develop reform strategies in partnership with the communities that must bear the brunt of the change.

I believe that the science of catchment prediction should be a vital part of the landscape renewal process for many reasons. Firstly, it will allow us to extrapolate from our very limited data sets and erect, at minimum, a testable conceptual model of how catchment management actions impact on land and water values. In my view, it is essential that catchment stakeholders have access to a transparent version of this conceptualisation and are guided through the reasoning and data that underpins it. Secondly, the increased use of predictive models will impose on government and the community the discipline of assembling knowledge and data pertinent to catchment function and highlight areas of uncertainty that demand further data acquisition. Most people would agree that 'more data is needed' when it comes to catchment management, but few can agree on what kind of data is needed or where it should be measured and when. The routine application of models can assist in resolving these issues. Thirdly, not withstanding the limitations of models founded on modest data sets, catchment prediction provides a basis for government and community to conduct a dialogue on the development and evaluation of alternative land and water management strategies.

Our CRC is devoted to the mission of equipping government, and by extension the community, with the capability to predict the hydrologic and related consequences of land and water management actions. However, I want to stress that our mission entails much more than just building models; what we are attempting is revolutionary. We are encouraging multiple science teams to pool their knowledge and instantiate this in models cast at unprecedented spatial scale. We are engaging stakeholders in the model development process, responding to their recommendations and in so doing, instilling a sense of ownership in the tools that are produced. We are making the models more transparent by simplifying their scientific basis and communicating this to stakeholders. We are developing state-of-the-art software interfaces that enable more stakeholders to interact with the models, even if it is just as an observer in a workshop where a model is run. And finally, we are working with land and water management agency staff to build further modelling capacity within their organisations so that catchment prediction can be performed routinely.

The calls for radical landscape renewal are laudable in view of the environmental challenges we face. However, I feel that we are in danger of putting the cart before the horse if we don't first equip government and community with the capability to shape and responsibly implement the mooted instruments of land and water management reform.

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COOPERATIVE RESEARCH CENTRE FOR CATCHMENT HYDROLOGY

NEW TECHNICAL REPORT

THE STATUS OF CATCHMENT MODELLING IN AUSTRALIA

by

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Susan Cuddy
Joel Rahman

Technical Report 02/4

The CRC for Catchment Hydrology is developing a new generation of catchment models and modelling support tools, integrated within a system of software known as the Catchment Modelling Toolkit. The purpose of the Toolkit is to improve the standard and efficiency of catchment modelling, and to provide much-needed enhancements in predictive capability for catchment managers.

This report describes a vital element of the planning underpinning the development of the Toolkit concept. It summarises the results of three different surveys that gauged the opinions of catchment managers, model users and model developers with respect to the status of catchment modelling in Australia.

Copies are available through the Centre Office for $27.50

PROGRAM 1

PREDICTING CATCHMENT BEHAVIOUR

Program Leader
GEOFF PODGER

Report by Jean-Michel Perraud and Geoff Podger

Rainfall-Runoff Library

Lumped-conceptual rainfall-runoff models are a 'stock in trade' tool for those working in the water industry. There are many alternative models, each with its own requirements and operational features. Choosing an appropriate model for the task at hand can be very time-consuming. To address this issue, as part of the Catchment Modelling Toolkit, the CRC for Catchment Hydrology has developed a Rainfall-Runoff Library (RRL), built upon The Invisible Modelling Environment (TIME). The RRL allows modellers to trial different rainfall-runoff models to determine the one that is most appropriate for each catchment, taking into consideration model complexity versus adequacy of calibration. The initial release of this model is scheduled for late March 2003 and will be used to beta test the delivery of Toolkit products.

Background

The primary goal of this project is to deliver a powerful, easy-to-use product to support catchment modellers within the water industry. Product development began by talking to experts with experience in the design and implementation of rainfall-runoff models. This included valuable input from several persons including Walter Boughton, author of AWBM. On the completion of these discussions a short list of rainfall-runoff models to be included in the library was compiled. The code for each of these models was sourced from various locations. In some instances code was written based upon published papers. The software was developed in the TIME environment in such a way that it can be used by any other application as required and also builds on software already available within TIME.

Application overview

The library has its features categorised in six panels: Model, Input, Dates, Calibration, Sensitivity, and Simulation. There are currently five models available: AWBM, Sacramento, SimHyd, SMAR and the Tank model. The Input panel is context-sensitive, and data can be loaded from a library through simple drag and drop operations. The user can determine the appropriate periods of warm-up, calibration and verification, manually and with the use of tools, to improve the calibration robustness (Figure 1.1).

Three broad categories of calibration tools have been identified: generic, custom and manual. The generic optimisers work with any model, and include commonly used optimisation methods (Genetic Algorithm, Pattern Search, Shuffled Complex Evolution, and soon Rosenbrock's method), while optimisers that have

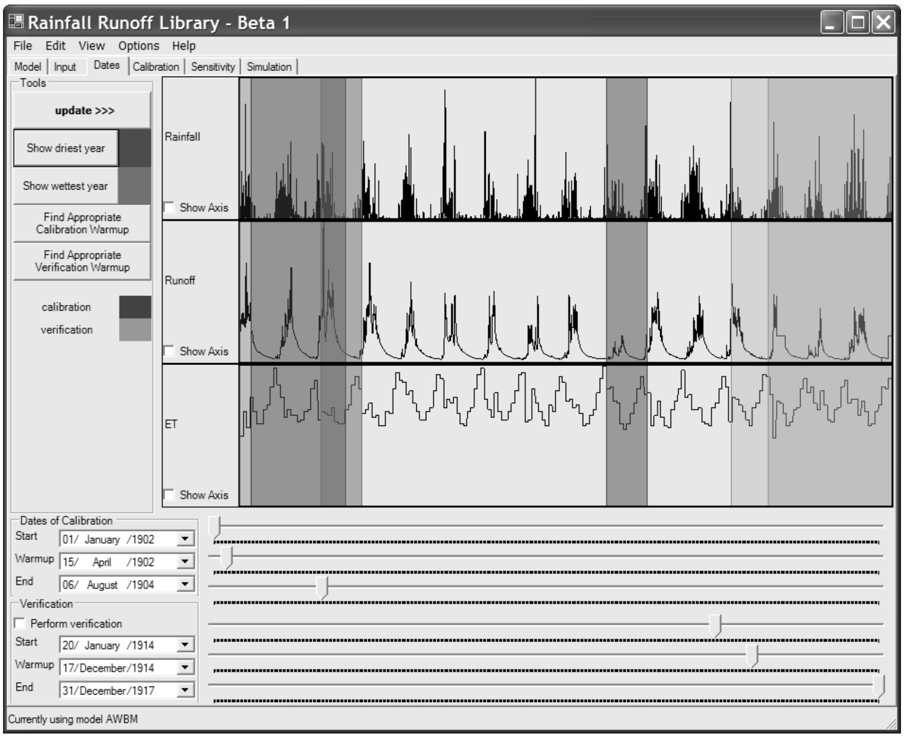

Figure 1: Selection of the calibration, verification and warm-up periods

intrinsic knowledge of a given model are in the custom section. Users can also modify parameters manually and see the dynamic effect in the model output, on scatter plots, duration curves and other standard plotting options (Figure 1.2). Calibration can be performed on runoff depth using one amongst a variety of objectives, or multiple objectives. Calibration can also be performed on the duration curve or the monthly runoff.

The Sensitivity panel includes additional tools to check the robustness of the calibration, and the Simulation panel is aimed at running the models using data where no flow records are available. Any intermediary results can be saved in a project file for archiving or later use.

Development aspects

The RRL is being developed using the Microsoft .NET platform that allows models to be written in many different languages. For example, the Sacramento model, based on Geoff Podger's implementation in IQQM, is written in Fortran. The cost of adding a new model is reduced to writing the core algorithm and "tagging" appropriately the variables as Parameters, Outputs, etc. which can require as little as half a day of work.

The definition of standard software interfaces also streamlines the somewhat more complex task of adding a calibration tool, since the library will discover at run-time the added feature and update its user interface accordingly. The same mechanism applies for adding new objective functions or input/output filters for handling additional data formats.

The list of models available is expected to grow over time. It is likely, as is the case for most software products, that additional features will be suggested by users, and that the Rainfall-Runoff library (still looking for a suitable acronym or name...) will benefit from the output from other CRC projects.

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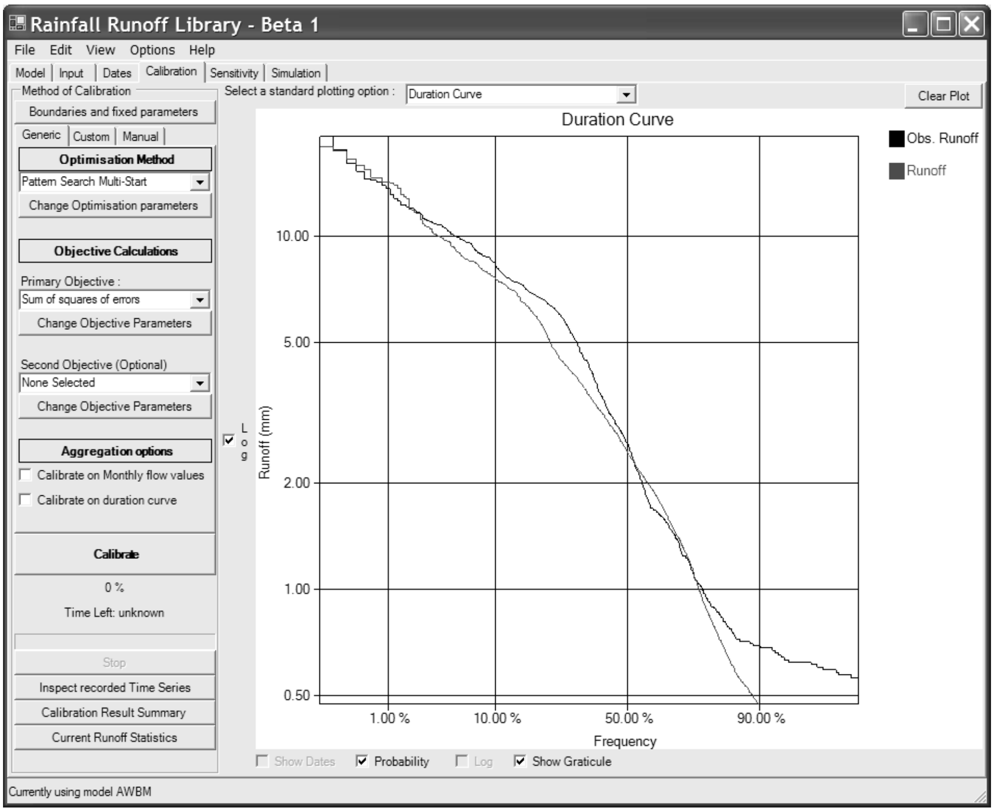

Figure 2: Duration curves of runoff depths with log-probability scale

FOREST MANAGEMENT WORKSHOP AND FIELD DAY - CANBERRA MAY 2003

EXPRESSIONS OF INTEREST SOUGHT.

A Forest Management workshop is being arranged for May 2003 through a partnership between the University of New South Wales, NSW State Forests, the Forest Science Centre and the CRC for Catchment Hydrology.

The workshop will be held in the Canberra region over three days and will include a field trip to discuss implications for forest management. The workshop is targeting researchers and professional forest and catchment managers.

Key themes for the workshop are likely to include:

- Forest Hydrology
- Sediment Delivery and Water Quality
- Fire Management
- Sustainable Forestry

If you are interested in participating in this workshop please send your contact details to this email address - workshop@ge.adfa.edu.au

Further details about the workshop as they are confirmed will be posted on the CRC website at www.catchment.org.au/news

OTHER OUTLETS FOR CRC PUBLICATIONS

In addition to the Centre Office, all CRC publications are available through the Australian Water Association (AWA) Bookshop in Sydney and the NRE Information Centre in Melbourne. They also stock a wide range of other environmental publications.

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PROGRAM 2

LAND-USE IMPACTS ON RIVERS

Program Leader
PETER HAIRSINE

Report by Nick Potter

Winter and summer - Australian catchments behave differently to those measured overseas

Catchments and runoff

Two catchments with the same annual rainfall need not produce equal annual runoff. There are many reasons why different catchments might produce more or less runoff. A flat catchment, with deep, permeable soils and populated with deep-rooted trees should produce less runoff than a mountainous catchment, with rocky soils and grasses as the predominant vegetation, even if they have the same annual rainfall.

Evapotranspiration

We recently modelled the effects of the seasonal timing of rainfall on the annual catchment-scale evapotranspiration process. The conclusion was that mean-annual evapotranspiration in Australian catchments is less if most of a catchment's rainfall occurs in summer, compared with catchments that have rainfall occurring in winter. This was somewhat unexpected and has implications for the choice of water balance models used in Australia.

The availability of moisture and radiative energy from the sun, or potential evapotranspiration, are the two primary factors that control the annual amount of actual evapotranspiration that takes place in a catchment. On an annual basis, evapotranspiration from a catchment can be assumed to be nearly equal to the difference between annual rainfall and annual river discharge. As such, knowledge of the mean-annual rainfall and annual potential evapotranspiration of a catchment allows a good 'first-order' estimation of the catchment's mean-annual water balance, or the partitioning of rainfall into evapotranspiration and runoff.

Other factors affecting runoff

There are countless other factors that determine the average amount of rainfall that becomes runoff, and it is a lot harder to incorporate these other variables into predictions of mean-annual water balance. There are many reasons why modelling mean-annual water balance has proved to be difficult, such as: a lack of reliable vegetation and soil data for many catchments, and the complexities of, and the non-linear interactions between, the hydrologic processes involved.

Water balance models

With the lack of much data relating to soils and vegetation in mind, it is natural to try to build water balance models that aim to exploit the most available form of data - that is, rainfall and potential evapotranspiration. We sought to use a climatic description of the catchment - the seasonal timing of rainfall relative to the timing of potential evapotranspiration - to describe the mean-annual water budget.

Runoff hypothesis

We adopted an hypothesis was that mean-annual runoff from catchments when most of the year's rainfall occurred during the summer months is likely to be less than runoff from catchments with winter-dominant rainfall, as more potential evapotranspiration, or radiative energy from the sun, is available in summer than in winter.

To test this hypothesis we modelled the soil-moisture dynamics with a lumped soil-moisture accounting model. We modelled the rainfall at each catchment as a simple stochastic process. This enabled us to easily characterise rainfall regimes with just a few parameters. The stochastic modelling also allowed rainfall records to be synthesised for arbitrary lengths of time as an input into the model.

Test data

The data we needed to test the hypothesis consisted of daily rainfall amounts, monthly potential evapotranspiration data and annual streamflow totals. This data was available for 331 gauging stations around Australia (Peel *et al.* 2000). Also required was an estimate of the soil-moisture capacity for each catchment. Values for the soil-moisture capacity for most of these catchments were available from CRC Project 2.3 (McKenzie *et al.*, 2003). In total, we were able to use 252 of these catchments for the analysis.

Model results versus data

The model results, as expected, had runoff ratios for summer-dominant catchments lower than the runoff ratios for winter-dominant catchments. However, we found that the data in fact showed the opposite behaviour. That is, we determined from the data that runoff as a proportion of rainfall was higher for Australian catchments with summer-dominant rainfall compared to the catchments with winter-dominant rainfall (see Figure 2.1). A non-parametric rank sum test showed that these effects were statistically significant.

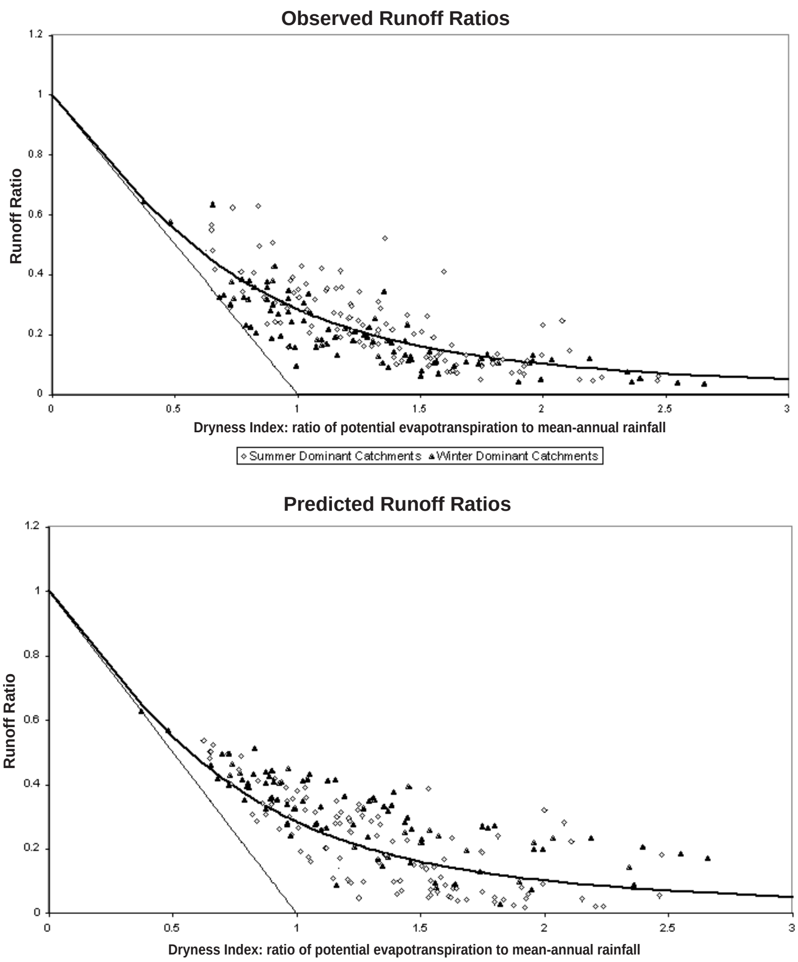

Figure 2.1: Comparison of observed and predicted runoff ratios.

Limitations of model

Rainfall intensity and infiltration-excess runoff (Hortonian flow), which are not included in the model, may be important for Australian catchments. Milly (1994) used a similar model to predict annual runoff quantities for the United States east of the Rocky Mountains with much greater success. The assumption in both Milly's model and our model is that rainfall occurs as an instantaneous event. Without a measure of the duration and intensity of the rainfall, it is impossible to model runoff that occurs when storms are more intense than the rate at which the water can infiltrate the soil. If infiltration-excess runoff is the predominant hydrologic mechanism controlling the soil-moisture dynamics then it is to be expected that a model that does not include this as a process would inadequately describe the annual water budget.

Other reasons for the poor runoff predictions could be:

- over-sensitivity of the predictions to the soil-moisture capacity estimations,
- lack of inter-annual variability in the rainfall model, and
- use of too simplistic a rainfall model, which may be non-representative of the rainfall process.

We are currently investigating all of these possibilities. It is expected that this model will give us greater insight into the effects of land-use change on the mean-annual water budget after more work is done on selecting a better model.

This research is currently being prepared for presentation at the EGS-AGU-EUG Joint Assembly being held in Nice, France during April 2003.

References

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McKenzie, N.J., Gallant, J.C. and Gregory, L.J. (2003). Estimating water storage in soil at catchment scales. Cooperative Research Centre for Catchment Hydrology Technical Report (in press).

Peel, M.C, Chiew, F.H.S, Western, A.W. and McMahon, T.A. (2000). Extension of Unimpaired Monthly Streamflow Data and Regionalisation of Parameter Values to Estimate Streamflow in Ungauged Catchments. Report prepared for the National Land and Water Resources Audit. In Australian Natural Resources Atlas website, http://audit.ea.gov.au/anra/water/docs/national/Water_Streamflow.htm.

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Report by Jon Olley

Project 2.1: Sediment movement, physical habitat and water quality in large river systems

Project end

Last month marked the end of Project 2.1: 'Sediment movement, physical habitat and water - quantity in large river systems' and the end of my time with the CRC for Catchment Hydrology. As Project Leader I have been delighted with the efforts of the project team and have enjoyed my time with the CRC.

Over the last three years researchers working on this project have done some remarkable science, producing

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more than thirty papers and reports. They have significantly improved our understanding of how land-use change in large catchments affects the transport of sediment and associated nutrients; the distribution of physical habitat; and form of the channel. The project was developed to improve techniques for targeting river remediation efforts, and as with all CRC for Catchment Hydrology projects we focused not only on doing research, but getting that research incorporated into management actions.

Research results and application

In the Coxes River catchment we assessed changes in sediment supply and sediment transport capacity relative to changes in land degradation, climate, and dam closure. Dam closure was thought at the time to be the largest cause of river degradation. We showed that changes in sediment supply resulting from land-use change and the formation of gully networks, was the single largest contributor to the poor state of the river. This work is now incorporated into the Coxes River catchment management.

In a two-year study for the south east Queensland (SEQ) Regional Water Quality Management Strategy we used a multi-faceted approach that included analysis of existing water quality and climate data, catchment scale modeling (using SedNet), and sediment tracing, to determine the origins of sediment delivered to Moreton Bay. The results showed that gully and stream bank erosion is the dominant form of erosion in the SEQ catchments, and that 90% of the sediment comes from only 30% of the catchment area. The study demonstrated the benefits of a combined modeling and tracing approach for targeting catchment remediation efforts and the finding is now the basis of the remediation plan.

In the Murrumbidgee catchment analysis of the historical rainfall, stream flow and turbidity data and catchment scale modeling (using SedNet) showed that the tributaries below the dams are the major source of the suspended sediment to the lower river, with Jugiong Creek the largest. Analyses of the turbidity data also show that over the last 20 years the turbidity in the river at Wagga Wagga has been falling in response to decreased flows from the tributary catchments. Jugiong Creek, with a catchment area of 2200 km^2, was also the focus of a more detailed modeling and sediment tracing exercise which identified the primary source areas in this sub-catchment, and identified gully and channel erosion as the dominant process supplying sediment.

National Land and Water Resources Audit (NLWRA)

The NLWRA showed that sand was a major issue in most Australia Rivers. Lack of data on the distribution of sand slugs was hampering our ability to predict their occurrence and to plan remediation actions. To provide a database that can be used to improve the model predictions, the distribution of coarse sediment slugs and riparian vegetation along the Murrumbidgee River channel was mapped from aerial photographs (for both 1944 and 1998). This data is now being used as part of the new CRC for Catchment Hydrology Project 6B 'Predicting spatial and temporal variations in channel form' to improve the prediction of sand distribution in our river networks.

Other research outputs for the Murrumbidgee

In addition fifty sites in the upper Murrumbidgee were surveyed for planform, water elevation, bed sediments, pool-spacing, and channel type. From this data:

- A model was developed that predicts physical habitat along the river
- Changes in the flux of sediment in the Upper Murrumbidgee catchment since European settlement were assessed
- A major report on sediment erosion in the Murray-Darling Basin was produced
- Meander bends along the Murrumbidgee River were dated to assess channel erosion and migration rates.
- Nutrient and organic matter sources and transport in the Murrumbidgee was examined
- Two PhD students, Rebecca Bartley and Scott Wilkinson, studied this area for their thesis
- SedNet was incorporated into the CRC for Catchment Hydrology Catchment Modelling Toolkit by Program 1.

All in all a great three years.

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PROGRAM 3

SUSTAINABLE WATER ALLOCATION

Program Leader
JOHN TISDELL

Report by Bofu Yu

Modelling water trading in the Murrumbidgee

Background

For historical reasons, water entitlements in many river basins in Australia were allocated on the perceived requirement at the time of issue. Water markets are developing as part of a Council of Australian Governments initiative to promote an efficient use of Australia's water resources. Full evaluation of the benefits and spatial externalities of trade and agricultural extraction in general requires integrated hydrologic and economic modelling. Such modelling is in its infancy. Most economic models of the benefits and costs of trade to date rely on static exogenous hydrologic constraints. While all the economic models require agronomic and hydrologic data for water demand and water availability, none interacts dynamically with hydrologic models.

Daily water management model - IQQM

The integrated Quantity and Quality Model (IQQM) was developed for water resources planning and management. IQQM operates on a daily basis and is used to assess the impacts of changes in water management policies on water users and the environment. The model contains complex river management rules that allow it to simulate the delivery and allocation of water resources. For the past ten years, IQQM has been progressively implemented for all the major river basins in NSW and Queensland. IQQM is purely a hydrologic model, and currently does not take into account temporary water trade among irrigation nodes driven by market processes. In IQQM, water trade or adjustment to the existing water allocation and crop patterns is treated as given rather than unknown. To be able to successfully model the movement of water within systems, it is important to adjust crop patterns based on an economic rationale. For example, in resource-constrained years, water will be traded from the less profitable crops to the higher return crops. Water trade therefore occurs when the buyers perceive positive returns while the sellers are adequately compensated to maximise some form of aggregate social welfare, subject to a wide range of biophysical and social economic constraints.

Water reallocation model

To develop integrated tools to assess the impact of changes to climate, land-use, and policy instruments at the whole-of-catchment scale, a hydrologic and economic modelling project was initiated early this year to provide a dynamic link with hydrologic water allocation models such as IQQM and economic water trading models. A water reallocation model, WRAM, was developed for this purpose. WRAM is currently being implemented for the Murrumbidgee River in close connection with IQQM as implemented for the same basin.

Reallocation of water to irrigation nodes

A Linear Programming (LP) problem was formulated to reallocate the limited water supply among regulated irrigation nodes. Constraints on water and land availability, crop feasibility and crop rotation were taken into consideration. Output from the LP can be used to inform hydrologic water allocation models such as IQQM in terms of crop pattern at each irrigation node and modified allocations based on water requirements as a result of water trade among irrigation nodes in the basin. The LP problem was solved using callable routines from NAG Fortran library. The code was written in Fortran 95 and compiled with Lahey Fortran version 5.7 to be consistent with IQQM. The code has been verified with GAMS (General Algebraic Modeling System) and one of the most effective stand-alone LP solvers, PCx. A Windows interface was also developed with VB.NET in the .NET framework for eventual migration and integration into the Toolkit being actively pursued in Program 1 (see J Rahman's article in *Catchword*, issue no. 113, Feb. 2003).

Modelling irrigation nodes and crops

There are 49 irrigation nodes to represent the irrigation area in IQQM for the Murrumbidgee Valley. 11 distinct crops were modelled in IQQM for the Murrumbidgee. 46 separate crops were considered in WRAM for water allocation and trade because of the regional difference in water requirement and production costs. For WRAM, we estimated crop yield and price, water charge and other variable costs for these crops from farm budget information made available through NSW Agriculture. For this version of WRAM for the Murrumbidgee, there are 419 decision variables, and 1670 non-zero cells. Computational time is of the order of 0.1 sec per LP solution on a Toshiba Satellite Pro 6100. If two planting decisions are called for per year for summer and winter crops, we estimate an additional computational cost of 3-4 min when WRAM is invoked by IQQM for long-term (about 100 years) simulations.

Model validation and capabilities

A mature market is yet to be established for water trading in the Murrumbidgee basin. As a result, the opportunity to validate the water reallocation model is actually quite limited. We use some simulation results on water trading

NEW TECHNICAL REPORT

WATER TRADING IN THE GOULBURN-MURRAY IRRIGATION SCHEME

by

Wijedasa Hewa Alankarage
Hector Malano
Tom McMahon
Hugh Turral
Garry Smith

Technical Report 02/9

This CRC report presents the outcomes of a study of permanent and temporary water trading in irrigation areas within the Goulburn-Murray Irrigation Scheme (GMIS). The study is based on a survey of permanent and temporary water traders in the GMIS from March to May 2001 and past water records of the GMIS. Outcomes of studies in the area based on two previous surveys conducted in 1994 and 1996 and an irrigation farm census conducted in 1997 have also been compared.

Printed and bound copies of this technical report are available from the Centre Office for $27.50 (includes GST, postage and handling) or an Adobe .pdf file can be downloaded at www.catchment.crc.org.au/publications

For further information contact the Centre Office on 03 9905 2704 or email crcch@eng.monash.edu.au

NEW INDUSTRY REPORT

WATER SENSITIVE URBAN DESIGN: A STORMWATER MANAGEMENT PERSPECTIVE

by
Sara Lloyd
Tony Wong
Chris Chesterfield

Industry Report 02/10

In response to the need for reliable, cost-effective, environmentally-friendly, robust and aesthetically-pleasing stormwater treatment measures, the CRC for Catchment Hydrology undertook research to develop new and existing stormwater quality improvement practices. The integration of these and other water conservation practices into urban design is referred to as Water Sensitive Urban Design (WSUD) and its principles can apply to individual houses and streetscapes or to whole catchments.

Fundamental to successfully applying WSUD principles to urban development is an understanding of the performance capabilities of structural stormwater management strategies, their life cycle costs and market acceptance. This report centres on the design process, construction activities and monitoring of environmental, social and economic performance indicators associated with Lynbrook Estate's Demonstration Project.

This report is available through the Centre Office for $33.00 (includes GST, postage and handling).

for the Murrumbidgee to illustrate model capabilities. Figure 3.1 gives an example of the magnitude of water trade among all the 49 nodes at a particular level of allocation of 1700 GL. The amount of spatial variation is considerable with up to 63 GL traded. At this level of trade, there are 21 'buyers' out of these 49 nodes and the rest are 'sellers'. The average trade volume is 15 GL/node for the year. Figure 3.2 shows the simulated volume of trade relative to total amount of allocation as a function of total allocation. As the total allocation decreases, water becomes scarce and the volume of trade in general increases. The minimum level of trade is about 20% of total allocation for the Murrumbidgee from Figure 3.2. The level of trade is considerably higher than the actual intra-valley trade recorded for the Murrumbidgee in the past few years.

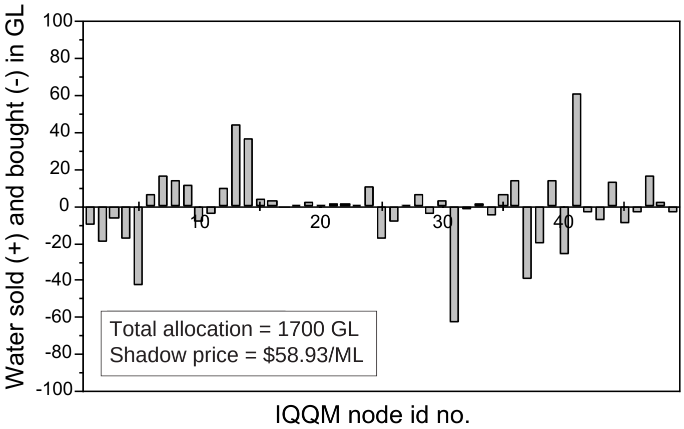

Figure 3.1: Simulated water trading volume among the 49 IQQM regulated irrigation nodes in the Murrumbidgee basin.

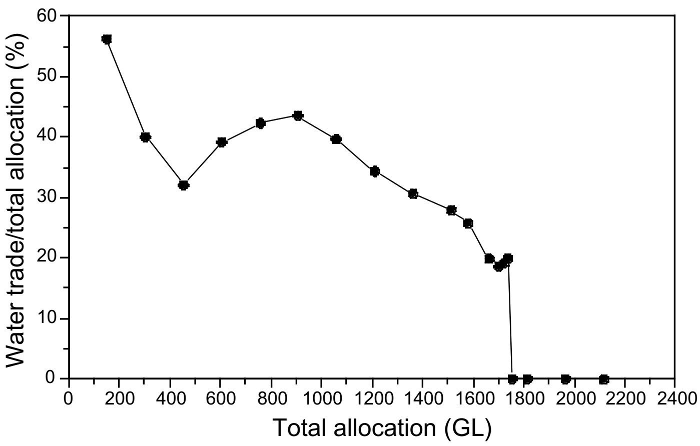

Figure 3.2 Simulated level of water trade as a function of total allocation for the Murrumbidgee Valley.

Assumptions in water reallocation model

When discussing these simulation results, we need to consider the assumptions underlying this water reallocation model. A perfectly competitive water market is assumed to exist, and water traders have perfect information to make rational decisions. Water requirement and allocation are deterministic. There are negligible transaction costs, and the short-term net benefit can represent social welfare. When a well-developed water market does not exist, water trade occurs at suboptimal levels, resulting in the historical water trade being considerably less than the optimal level of trade for the Murrumbidgee. Sub-optimal reallocation outcomes have been explored using trading experiments in a previous CRC for Catchment Hydrology project on an evaluation of the temporary water market (see J Tisdell's article in *Catchword*, issue no. 113, Feb. 2003).

Linking hydrologic and economic models

In the current project on hydrologic and economic modelling for water allocation, we are to make the first genuine attempt to dynamically link hydrologic water allocation models such as IQQM with economic models for optimal water allocation. Data required to determine water demand for each crop at each irrigation node were sourced entirely from IQQM for the Murrumbidgee. Simulated water allocation and crop pattern as a result of incentive-based water trade can be fed back to IQQM in a seamless manner when needed.

Additional features

WRAM is currently being refined to introduce additional features to improve its modelling capabilities. Hydrologic constraints due to channel or pumping capacities consistent with the IQQM implementation for the Murrumbidgee will be added. Model users will be able to select an arbitrary collection of irrigation nodes to participate in water trading to simulate the trade volume. The shadow price of water can be determined for any combination of irrigation nodes among which water trading is allowed. We believe that a spatially limited trading block is necessary in order to reduce the amount of trade to realistic levels. It may also be necessary to limit the extent to which the existing crop pattern can be adjusted because of the persistence of cropping patterns at the nodal level in the basin.

(This article is an extended summary of MODSIM2003 paper 'A hydrologic and economic model for water trading and reallocation using linear programming techniques', by B. Yu, J. Tisdell, G. Podger, and I. Salbe. They are all researchers in the CRC for Catchment Hydrology.)

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PROGRAM 4

URBAN STORMWATER QUALITY

Program Leader
TIM FLETCHER

Report by Thomas Kasper and Graham Jenkins

Determining the Background Concentration of Suspended Solids in a Stormwater Treatment Wetland

Introduction

Constructed wetlands are now a widely accepted means for retaining fine sediment and reducing nutrients, and have become a major part of urban stormwater management and landscape planning. However, wetlands require a significant area of vacant land, which often is in short supply in urban developments. The effective design of urban stormwater wetland systems requires a detailed understanding of the treatment processes taking place both during storm events, as well as during the period between storm events. It is these inter-event processes that influence and determine the background concentration of contaminants within the wetland.

A wetland monitoring program has recently been completed in which water samples were collected from an artificial surface water wetland, both within storm events and over the following dry weather period. The aim of this program has been to describe the background concentration and the processes taking place during the inter-event periods. The wetland was sampled on a daily basis over a period of four and a half months. During this period, three major and some smaller storm events were observed. The water samples were analysed for total suspended solids (TSS) and total volatile solids (TVS). An example of the data collected at the wetland outlet is shown in Figure 4.1.

Bridgewater Creek stormwater treatment wetland

The Bridgewater Creek Wetland is a constructed stormwater treatment surface-flow wetland installed by the Brisbane City Council between May and October 2001. The wetland's catchment is approximately 180 ha in area and is dominated by residential land use. The wetland itself has a surface area of about 0.8 ha.

The wetland contains three main elements - gross pollutant traps at the inlet, followed by sedimentation ponds, and finally a large macrophyte zone. The litter traps remove trash, litter and gravel, whilst the sedimentation ponds allow coarse sediment to settle out of the stormwater, before it enters the shallow macrophyte zone. Made up of five ponds (the last two of which are densely vegetated), the macrophyte zone is designed to filter out fine sediment and nutrients.

During high intensity storm events, the stormwater can bypass the macrophyte zone via an overflow bypass channel, leaving the sediment pond and flowing around the wetland. The high flow bypass, which re-enters Bridgewater Creek downstream of the wetland outlet, protects the wetland vegetation from being damaged during high flow events and reduces resuspension of captured sediment.

Background concentration of TSS in the wetland

Within the sampling period, three major storm events were observed between September and December 2002. For all of the sample sites in the wetland, the major reduction of TSS was completed within the first 24 hours following each storm event. After that period a further reduction took place at a much slower rate. Approximately eleven days after each storm event, we observed that the concentration of both the organic and inorganic fractions of suspended solids began to grow. During one of the storm events the flow through the system was so large that the embankment between the sediment pond and the macrophyte zone was overtopped. Erosion of the clay embankment occurred, causing the embankment material to be washed into the wetland. This resulted in higher TSS values than usual being observed at all sampling sites. The resulting background concentrations following this event were significantly higher than for the other previous two events.

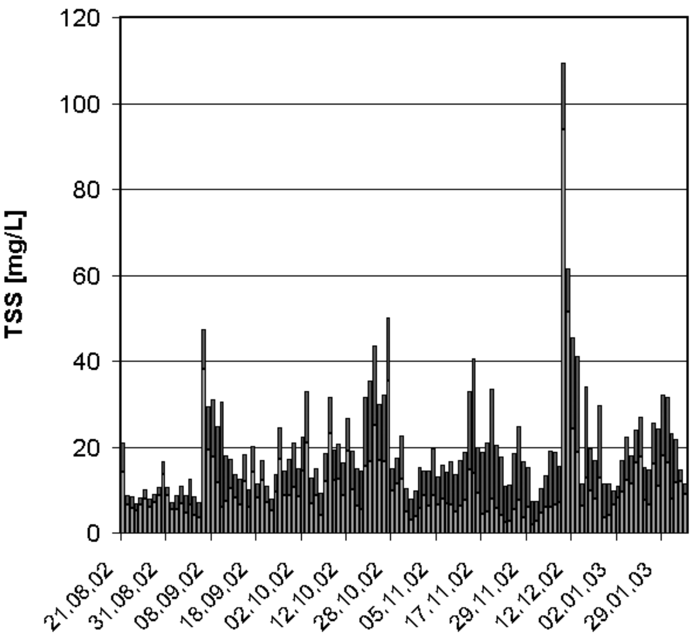

Figure 4.1: TSS time series measured at the wetland outlet.

NEW TECHNICAL REPORT

NON-STRUCTURAL STORMWATER QUALITY BEST MANAGEMENT PRACTICES - AN OVERVIEW OF THEIR USE, VALUE, COST AND EVALUATION

By

André Taylor
Tony Wong

Technical Report 02/11

This report presents an overview of a CRC project co-funded by EPA Victoria that investigated the use, value, life-cycle costs and evaluation of non-structural best management practices (BMPs) for improved urban stormwater quality and waterway health.

The report costs $27.50 and can be ordered through the Centre Office by contacting Virginia Verrelli on 03 9905 2704 or email crcch@eng.monash.edu.au

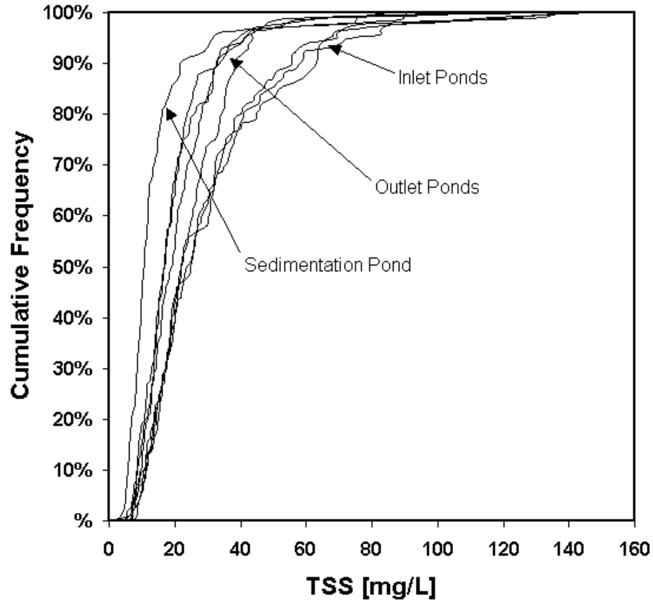

Figure 4.2: Cumulative Frequency Analysis of TSS Samples

Results

A comparison of the cumulative frequency analysis for the entire time series of observed data for all of the ponds, as shown in Figure 4.2, demonstrates that there is a relationship between TSS concentration and the distance from the wetland inlet. It is apparent that the sedimentation pond consistently has the lowest concentration of TSS. The concentration decreases on the way through the wetland to reach a minimum in ponds 5 and 6, which are also the most densely vegetated ponds. The concentration of TSS in ponds 2, 3 and 4 generally appear to be between the values observed in the first and last pond.

Analysis of results

A first-order kinetic reaction (*k* - *C**) model was fitted to the observed data to determine the background concentration *C**. The TSS concentration approaches the background concentration *C**, which represents the lowest concentration possible in the pond due to settling of suspended particles. The decay of TSS after each storm event is dominated by precipitation of the inorganic suspended particles. The growth phase observed is primarily due to algae growth and resuspension, caused by wind or other influences, such as birds.

The background concentration determined from fitting the (*k* - *C**) model to the observed data showed no significant variation from one pond to another. This suggests that variations in vegetation density have only a minor influence on the background concentration. The average background concentration determined for all ponds during these storm events was 14.2 mg/L and 14.6 mg/L. The TSS concentrations at all sites in the third storm event were significantly higher than in the two previous events. This is possibly due to erosion of the embankment during the storm, resulting in a higher concentration of fine sediment being deposited in the wetland. The average background concentration *C**, for this event was 26.7 mg/L. An example of the decay and growth of suspended solids observed in the wetland is shown in Figure 4.3.

Conclusions

It is clear from this preliminary data that the sedimentation pond plays a major role in the treatment of TSS through the wetland system. Further analysis also suggests that some deterioration in the quality of TSS occurs in the following ponds. However, wetlands also play a significant role in the treatment of nutrients such as phosphorus and nitrogen, which were not sampled as part of this study. Further sampling and analysis is currently being undertaken to provide a more complete understanding of the treatment processes related to other contaminants that occur in the system during these inter-event periods.

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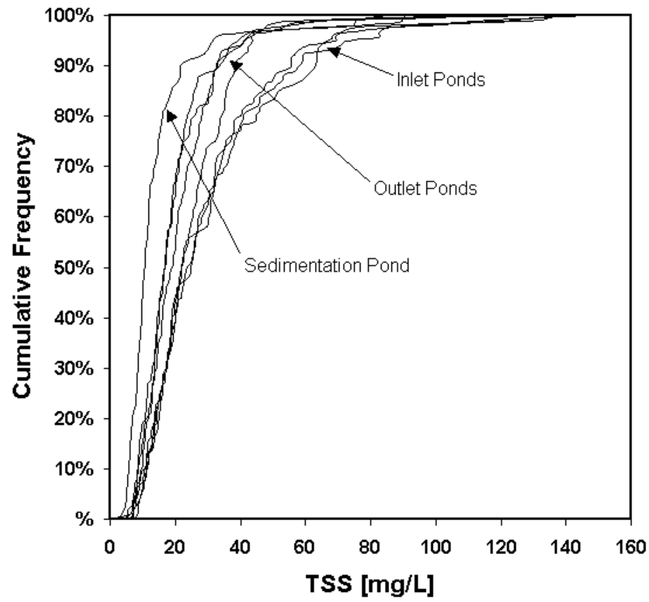

Figure 4.3: Observed Data for Pond 2, Showing Decay and Growth Models

NEW WORKING DOCUMENT

PREPARATION OF A CLIMATE DATA SET FOR THE MURRUMBIDGEE RIVER CATCHMENT FOR LAND SURFACE MODELLING EXPERIMENTS

by
Lionel Siriwardena
Francis Chiew
Harald Richter
Andrew Western

Working Document 03/1

This report describes the preparation of a climate data set for ten locations in the Murrumbidgee River Basin; Balranald, Hay, Griffith, Yanco, West Wyalong, Cootamundra, Kyeamba, Adelong, Canberra and Cooma.

The data will be used as forcing data for land surface modelling experiments. The locations coincide with the sites in the CRC's Murrumbidgee River Basin soil moisture monitoring program.

Printed and bound copies of this working document are available from the Centre Office for $22.00 (includes GST, postage and handling) or an Adobe .pdf file can be downloaded at www.catchment.crc.org.au/publications

PROGRAM 5

CLIMATE VARIABILITY

Program Leader
FRANCIS CHIEW

Report by Sri Srikanthan

Stochastic generation of climate data

Uses for climate data

The generation of point rainfall data at annual, monthly and daily timescales were described in earlier issues of *Catchword*. The generation of point climate data completes the first round of the CRC for Catchment Hydrology Project 5.2 'National data bank of stochastic climate and streamflow models' and this is described here. One major use of climate data in conjunction with rainfall data is in computer simulation of rainfall-runoff processes, crop growth and water supply systems. Rainfall-runoff models require evaporation data along with rainfall as input. Crop growth models require, in addition to rainfall, net radiation or evaporation as a measure of energy input. In irrigation simulation studies, both rainfall and evaporation are required. In demand calculations for water supply systems, maximum temperature is generally used and hence evaporation and maximum temperature data are required in addition to rainfall for water supply system simulation.

Scope of stochastic generation models

In generating more than one variable, the cross correlations between variables must be preserved. This article describes the stochastic data generation models for rainfall, evaporation and temperature data at yearly, monthly and daily time scales. The models developed were applied to 10 sites located in various parts of Australia (Figure 5.1) to generate 100 replicates of length equal to the corresponding historical record and the generated climate data were evaluated using a number of statistics. These statistics include the first three moments and correlations at daily, monthly and annual time scales.

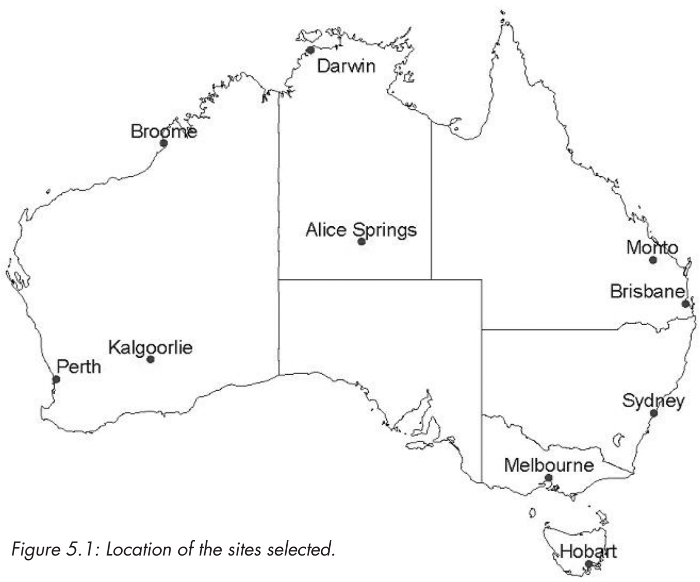

Figure 5.1: Location of the sites selected.

Annual climate data generation model

Because the variability, skewness and lag one autocorrelation of annual climate data is low, a first order autoregressive multivariate model with Wilson-Hilferty transformation is adequate for the generation of annual rainfall, evaporation and temperature data.

A multivariate model to generate annual rainfall, evaporation and maximum temperature data is of the form

$$X_t = AX_{t-1} + B\varepsilon_t$$

where

X_t (3x1) matrix of standardised annual climate data for year t

A, B (3x3) coefficient matrices to preserve the correlations, and

ε_t random component with zero mean and unit variance.

A comparison of the historical and generated annual statistics showed that the model performed adequately.

Monthly climate data generation model

The modified method of fragments can be used to generate monthly climate data. The observed monthly climate data are standardised year by year so that the sum of the monthly climate data in any year is equal to unity. This is carried out by dividing the monthly climate data in a year by the corresponding annual total. In the case of maximum temperature, the mean annual maximum temperature is multiplied by 12. By doing so, from a record of n years, one will have n sets of fragments of monthly climate data. The generated annual climate data are disaggregated by selecting a fragment whose annual values are closer to the generated annual values by using the indices suggested by Maheepala and Perera (1996). A comparison of the historical and generated monthly and annual statistics showed that the model performed adequately.

Daily climate data generation model

Unlike the case of annual and monthly climate data, the correlation coefficient between daily rainfall and daily climate data is small. However, the daily climate data has been found to depend on the state of the day (dry or wet) and multivariate models have been usually used to generate

NEW WORKING DOCUMENT

THIN PLATE SMOOTHING SPLINE INTERPOLATION OF PARAMETERS OF THE AR(1) ANNUAL RAINFALL MODEL ACROSS THE AUSTRALIAN CONTINENT

by
Penny Hancock
Michael Hutchinson

Working Document 02/7

A first order autoregressive, or AR(1), model was found by Srikanthan and McMahon to be appropriate for simulating annual rainfall amounts at a given location. The objective of this project was to develop thin plate smoothing surfaces that spatially interpolate the parameters of the AR(1) model across the Australian continent.

The study considered AR(1) parameters including the mean, the standard deviation, the skewness coefficient and the lag one autocorrelation coefficient.

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climate data (Srikanthan, 1985; Richardson, 1981). The rainfall was considered as the primary variable and was generated first. Multivariate models were then conditioned on the state of the days and were used to generate the remaining climate variables. The results showed that the annual standard deviation of evaporation and maximum temperature were considerably underestimated. A number of modifications were made to the model resulting in varying degrees of success. Finally, it was decided to modify the model so that the generated daily data is adjusted at the monthly and annual time scales to match the historical values. This modification performed satisfactorily and this modified model was adopted as the model for the generation of daily climate data.

Conclusions

In conclusion, stochastic models have been developed for the generation of annual, monthly and daily climate data and evaluated using data from 10 sites located in various parts of Australia. The work reported here will be published as a CRC for Catchment Hydrology technical report.

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PROGRAM 6

RIVER RESTORATION

Program Leader
MIKE STEWARDSON

Report by Bob Keller and Frank Winston

Design of Rock Chutes for the Stabilisation of Channel Beds

River and channel stability

The stability of rivers and channels is often linked to the stability of the channel bed. Channels may be de-stabilised by (for example) the draining of a downstream swamp, which can initiate an erosion head which, unchecked, will migrate upstream with substantial subsequent bank collapse.

Hydraulic design of rock chute

This article describes a computer program which carries out the hydraulic design of a rock chute for stabilising channel beds. An earlier program was developed by ID&A Pty Ltd and the present study has drawn heavily from the theory of the earlier study.

A rock chute is a relatively short and steep section of the bed of a channel which has been armoured with rock. It is normally intended to either stabilise an erosion head, preventing it from moving upstream in the channel or to reduce the overall grade of a channel by providing a weir within the channel bed.

Although the concept of a rock chute is simple, proper hydraulic design is very important to ensure that the chute geometry and rock size are matched with the expected flow conditions such that the rock remains stable under all expected flow conditions. In addition, appropriate rock chute design requires that the abutments are treated to prevent failure by outflanking of the crest, and that the grading of rock sizes within the rock mixture minimises the presence of voids.

Typical rock chute

A typical rock chute is shown schematically in Figure 6.1, together with an illustration of the various terms used in describing and designing a rock chute. From a hydraulic point of view, the primary elements are the chute face and the apron, since these provide protection to the bed from the erosive forces of the water.

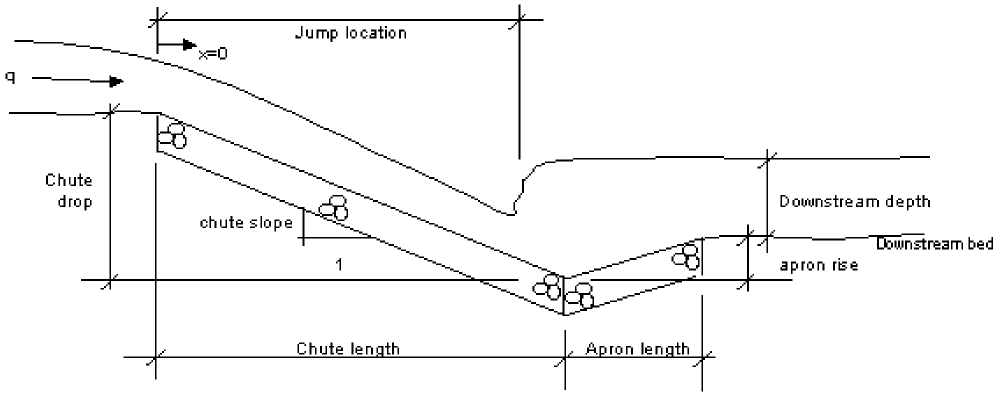

Figure 6.1: Schematic of a typical chute with explanation of terms

Rock size and water surface profile

The primary design output is the rock size required to ensure a stable structure. Because the rock size is dependent on the bed shear stress, which, in turn, is dependent on the flow profile over the chute, a key element in the design process is the determination of the water surface profile.

Bed shear stress

The location of the point of maximum bed shear stress can be shown to coincide with the location of the minimum depth. Typically, the chute design flow rate - that for which the required rock size is a maximum - will be lower than the channel design flow rate - that for which the required channel capacity is a maximum. This is a most important distinction in the design of a rock chute.

Design program

The design program is set up as a Microsoft Excel workbook, with separate sheets devoted to inputs, downstream channel conditions and results. Because the water surface profile is a critical component of proper design, the downstream conditions must be properly identified. The program permits a range of options for the downstream water level, including a pre-established rating table and uniform depth.

Figure 6.2 shows an example of a graph of the calculated required value of D50 against the flow rate per unit width passing through the structure for a typical design where the maximum unit flow in the channel was $4m^3/sec/m$.

It is evident that the critical flow with respect to rock size is substantially less than the peak design flow.

Factor of safety

One important design input parameter is the factor of safety. Issues which govern the choice of value include the consequences of failure, the reliability of the input parameters, the quality and consistency of the available rock, and the likelihood of eventual stabilisation by vegetation.

Guidelines for rock chute structures

Guidelines for the design of rock chute structures using the computer model are presently being developed. It is expected that these will be released shortly, together with the model.

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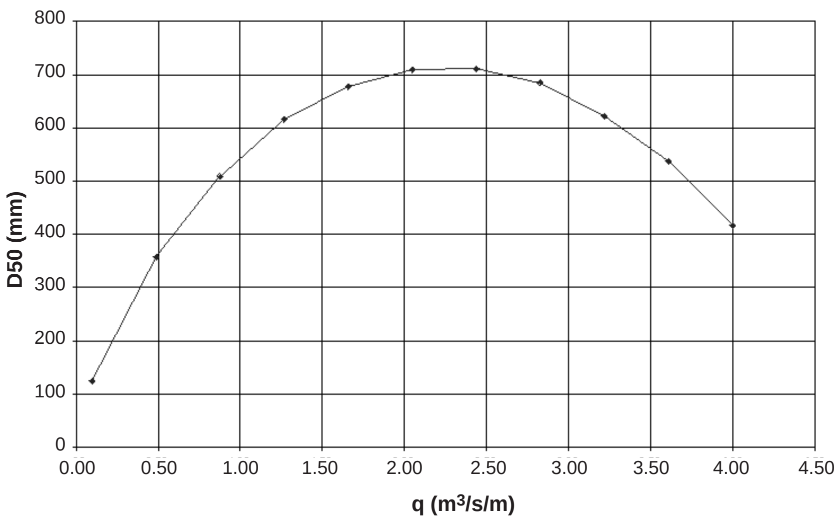

Figure 6.2: Typical plot of calculated D50 size against flowrate per unit width

HYDROLOGIC IMPACTS OF BUSHFIRES WEBSITE

In response to many requests for information about the hydrologic impacts of the recent bushfires, the CRC has established a website to deliver relevant information to catchment and water supply managers.

The site is a modest resource at this point and will evolve as more contributions are made. The site initially features a FAQ section designed for land and water managers, an overview of the hydrologic impacts of fire, a news page for information about related activities and reference lists that will be of particular interest.

The site can be found at www.catchment.crc.org.au/bushfires

The CRC welcomes contributions from all individuals and organisations to the site to expand its value to land and water managers.

If you can contribute to this site please contact david.perry@eng.monash.edu.au

NEW WORKING DOCUMENT

NON-STRUCTURAL STORMWATER QUALITY BEST MANAGEMENT PRACTICES - GUIDELINES

by

André Taylor

Working Document 02/6

This working document presents a new evaluation framework for measuring the effects and life-cycle costs of non-structural BMPs. This framework defines seven different styles of evaluation to suit the needs and budgets of a variety of stakeholders involved with stormwater management. In addition, monitoring protocols and data recording sheets have been developed to support each style of evaluation.

A printed and bound copy of this report is available from the Centre Office for $22.00 including GST, postage and handling.

The report is also available as an Adobe pdf file and can be downloaded from http://www.catchment.crc.org.au/publications

PROGRAM 7

COMMUNICATION AND ADOPTION PROGRAM

Program Leader DAVID PERRY

The Flow on Effect - March 2003

At a glance - a summary of this article

A special type of non-profit marketing called social marketing has significant potential for application in the natural resource management industry - its ultimate objective is to influence action.

Introduction

Society, through taxes, invests in publicly funded government agencies to manage natural resources such as water, land and air to provide a range of benefits for individuals, groups and businesses. Traditionally local, state and federal government agencies have had three key 'levers' with which to influence the management of our natural resources: through formal Acts of Parliament, regulation and associated disincentives (for example, fines or penalty infringement notices); through incentives to encourage desirable behaviour; and communication based programs. Communication based programs are commonly used to either support government based regulation and incentive schemes, or are delivered independently to influence target groups.

Using regulation and behavioural incentives to manage our natural resources has serious limitations. The scale, and hence cost, of enforcement and incentives required to effectively address natural resource management issues guarantees that governments will never have sufficient resources to ensure adherence to responsible natural resource management principles. Consequently government agencies regularly turn to communication based programs.

Education or action?

Within the natural resource management sector, education based communication programs are common. The result is that the target audience might know more but do they change their behaviour? Certainly, some communication programs are designed simply to draw the community's attention to an issue and its impacts, for example a change in law or policy. But in the context of natural resource management, I argue that simply gaining acceptance of an idea without inducing action cannot be considered success. Accepting that behavioural change is the desired outcome of many natural resource management programs then the traditional education campaign might be considered largely ineffective.

Marketing and the public sector

Marketing is a societal process by which individuals and groups obtain what they need and want through creating, offering, and freely exchanging products and services of value with others (Kotler 2000). Organisations engage in marketing to promote fulfilment of their mission. For businesses the fundamental mission is the earning of profits, while for non-profit corporations it is accomplishing the social and/or economic goals they pursue. For public sector administrative agencies, the basic mission is implementation of their public policies (Snavely 1991).

Marketing involves setting measurable objectives, undertaking market research, developing products and services to meet consumers needs, creating demand through promotion, and finally delivering them through a network of outlets at a cost that make it possible to achieve the marketing objectives. Over the last decade there has been a growing interest in marketing and public policy issues (Arbor and Mazis 1997). On this basis then it is reasonable to assume that the marketing discipline offers an alternative perspective for designing and delivering more effective communication programs to improve natural resource management. Marketing however, is commonly associated with commercial interests and its application in the public sector is often subject to debate. This stems from the perception that marketing is strictly a commercially oriented discipline.

Relevance of marketing to the natural resource management sector

Many generic marketing tools are potentially useful to government organisations when divested of their commercial characteristics arising from the supplier's self interest, and when adjusted to the administrative and political requirements of government action in society. Buurma (1999) describes the most relevant elements of commercial marketing for the public sector as:

- A clear differentiation of stakeholders involved in the marketing process and their interests.
- The marketing mix (a set of marketing tools) as a means to match consumers with products
- Need and demand patterns of citizens in their capacity as customers as a basis for the matching process
- Market segmentation as a way of anticipating different need patterns amongst stakeholders

- A marketing information system including market surveys to determine the characteristics of different market segments
- Marketing organisation and strategic marketing planning

It is reasonable then to expect that these commercial marketing principles will require some modification to fit the uniqueness of the natural resource management sector but does this type of marketing exist?

Social marketing

Social marketing is a special approach within the larger arena of non-profit marketing. In broad terms it is the design, implementation, and control of programs seeking to increase the acceptability of a social idea, cause or practice in a target group(s). Social marketing utilises the elements of commercial marketing listed above to maximise target group response but is distinguished from other fields of marketing by its emphasis on so-called non-tangible products - ideas and practices - as opposed to the tangible products and services that are the focus of commercial marketing. Target audiences may extend well beyond the people directly engaged in negative behaviours to include policy-makers, the media, even the government agencies own staff and management.

Principles of social marketing

The ultimate objective of social marketing is to influence action. Social marketers argue that action - for example an exchange of current behaviour for more desirable behaviour - will occur whenever target audiences believe that the benefits they receive through the exchange will be greater than the costs they incur. It follows then that programs to influence action will be more effective if they are based on an understanding of the target audience's own perceptions of the proposed exchange. Of course target audiences are seldom uniform in their perceptions and/or likely responses to marketing efforts and so can be partitioned into groups of people with similar characteristics. This grouping process is called segmentation and allows communications to be developed to meet specific needs within the target market.

Like the commercial marketers, natural resource managers and communicators must create an enticing 'product', that is the package of benefits associated with the desired action. They must minimise the financial and other costs to the target audience associated with the exchange of behaviours and as much as possible ensure that this exchange and its opportunities is available in a range of places that reach the audience and fit its lifestyles. The exchange opportunity should be promoted with creativity and through media and tactics that maximise desired responses.

Naturally, recommended behaviours always have competition, which must be understood and addressed to create value for the target audience in the proposed exchange. The marketplace is constantly changing and so program effects must be regularly monitored and management must be prepared to rapidly alter strategies and tactics (Social Marketing Institute, 2003).

Wouldn't incorporating these principles result in markedly different and more effective natural resource management communication programs?

Examples of application

Andreasen (2002), an American social marketer, describes the most significant development in social marketing over the last two decades as the migration of social marketing from its initial close identification with the marketing of products involved in social change such as condoms, pills and oral rehydration solution to a broader conception of its potential areas of application. Nevertheless, social marketing continues to have the greatest application in the health care fields. Well known Australian examples include the Quit and Victorian Traffic Accident Commission (TAC) campaigns.

In reviewing the literature for this article, I struggled to find any documented application of social marketing in the natural resource management sector. Perhaps most relevant was Johnson and Graber's (2002) investigation into the potential for social marketing in the public decision-making process surrounding the removal of dams from waterways. The authors concluded that social marketing practices held great promise for influencing change in decision makers and opinion leaders in local communities toward the support of sustainable ecosystems.

Conclusion

Social marketing's key advantage over traditional education programs is its emphasis on the need to identify and then listen to the target audiences and learn what may motivate them to change. I believe the discipline of social marketing offers great potential to improve natural resource management communication programs in Australia. It is, however, a new area for our industry and a critical mass of expertise and application is required before benefits can accrue.

For more information about social marketing and case studies please visit http://www.social-marketing.org/

As always any feedback on this article is very welcome.

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POSTGRADUATES AND THEIR PROJECTS

Josephine Brown

Before beginning my PhD I completed a Bachelor of Science majoring in physics at Sydney University, and honours in astrophysics at the Australian National University. After honours I decided to apply my background in physics and interest in environmental issues to understanding and modelling the climate system. I started my PhD in the School of Earth Sciences at Melbourne University in 2000, working with Dr Ian Simmonds as part of the meteorology and oceanography group.

I also had the opportunity to visit the Laboratoire des Sciences du Climat et de l'Environnement (LSCE) in Paris for a month in 2002 working with Georg Hoffmann in the glaciology group, as well as visiting the Meteorology Department at the University of Reading and the British Antarctic Survey in Cambridge.

The topic of my PhD is "Modelling stable water isotopes in the atmosphere and ocean surface". Isotopes of oxygen and hydrogen in water are used to reconstruct past climate from records such as ice cores from Antarctica and Greenland, as well as tropical records from carbonate skeletons of coral and foraminifera in the ocean. My project involves using a computer General Circulation Model (GCM) of the atmosphere with a scheme which traces the different isotopic species through the hydrological cycle, calculating the isotopic fractionation during phase transitions according to known physical processes.

The ratio of isotopes in precipitation is a function of the temperature difference between the moisture source and the site of precipitation, as well as the transport path and amount of precipitation. However isotopic records in polar ice cores are commonly interpreted as simple proxies for local (or global) temperature. Studies using GCMs with isotopic tracer schemes can be used to test this assumption by examining the isotopic response to influence of changes in atmospheric circulation and precipitation distribution under different climate conditions.

Tropical isotopic records from coral and foraminifera are commonly interpreted as records of both local sea surface temperature (SST) and changes in the local precipitation-evaporation balance as well as changes in the mean ocean isotopic ratio over longer (glacial) time-scales. For example, such records can be used to identify the magnitude of cooling in tropical SST under ice age conditions, or to investigate changes in precipitation associated with El Nino-Southern Oscillation (ENSO) over several centuries prior to the availability of instrumental records.

My project has involved adding a slab ocean scheme to the model to calculate the isotopic balance at the ocean surface, as well as adding a river runoff scheme to include the isotopic signature associated with runoff into the ocean. This allows the surface ocean isotopic ratio to be calculated for different climate conditions, and the modelled values compared with those inferred from observational records.

The runoff scheme calculates the runoff rate and direction from the topography used by the model, and transports excess soil moisture at each time-step. Such a scheme, while highly simplified, allows the isotopic ratio of the runoff to be estimated and the influence of runoff to be included in the ocean surface water budget. The impact of seasonal variability of runoff, including snow melt at high latitudes, is seen at coastal grid points in the slab ocean scheme, where increased runoff produces smaller surface ocean isotopic ratios (depletion of the heavy isotopic species). Comparison with observational runoff datasets including those available through the CRC for Catchment Hydrology is being used to test the sensitivity of the model.

The focus of the project is on tropical climate and the isotopic signals associated with interannual (eg. ENSO) as well as longer term (eg. glacial) variability. Understanding how tropical climate responds to changes in global conditions is highly relevant to anticipating the likely response to human-induced climate change in the region where the majority of the world's population live.

A simulation of present day climate using observed SSTs and sea ice concentration data for the period 1950-1999 has been completed. Interannual variability such as El Nino-Southern Oscillation and the Pacific Decadal Oscillation was identified in the amount of precipitation and in the isotopic ratios of both precipitation and the surface ocean. This means that the model reproduces the major modes of tropical climate variability, and can be confidently used to simulate past climate.

The model was then forced with SST and sea ice concentrations for the Last Glacial Maximum (21,000 years ago) in order to simulate the climate conditions of that period. The changes in both surface temperature and precipitation produce significant changes in the isotopic ratios, which are compared with available observational records. Some of the questions to be addressed include the influence of changes in SST gradients on precipitation patterns, the relative magnitude of precipitation/evaporation signals (used to reconstruct palaeo-salinity) and SST signals in records such as fossil coral and foraminifera and the influence of tropical isotopic changes on polar isotopic records.

As an increasing number of researchers are extracting coral and sediment cores from sites across the tropics and using these to reconstruct past climate, climate models play a complementary role in testing the assumptions used by the palaeoclimate community.

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OTHER OUTLETS FOR CRC PUBLICATIONS

In addition to the Centre Office, all CRC publications are available through the Australian Water Association (AWA) Bookshop in Sydney and the NRE Information Centre in Melbourne. They also stock a wide range of other environmental publications.

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CRC PROFILE

Our CRC Profile for March is:

Joel Rahman

My Early Years (Fitzroy Focus Catchment)
I started life, and my current obsession with computers, in a sleepy street in Rockhampton as the (very much) youngest of five kids. With seven years to the day between me and the next eldest, it's hard to know whether I was an accident or the result of impeccable timing - I'm promised it's the latter. Starting out in Rockhampton gave me some strange expectations of the world that have not been met - I was quite shocked when I moved to Canberra to begin Year 4 in a school that wasn't over 100 years old.

I have a strange mix of memories from those days, not the least of which being the transformation of our sleepy street into a major thoroughfare for travel to the Dire Straits concert at the rugby field. My main memory of the Fitzroy is clinging for dear life to the front of a mate's mother's wind surfer out on the river and being told not to dangle my feet in the water because of the crocodiles - now you tell me! That same friend had a Commodore 64 on which I made a little turtle (actually it was a triangle) draw a pattern wherever it went, thereby cementing my long running interest in all things nerd.

I used to say that I was moving back to Rocky first chance I got. Regrettably, I think I have to give that dream away, as I've become quite a humidity wimp in recent years.

Most of my Years (Murrumbidgee Focus Catchment)
My family left Rockhampton when I was nine and moved to Canberra as my mother had landed a programming job with the Australian Bureau of Statistics. Despite the evidence, my mum is not to blame for my becoming a computer nerd, as she tried on numerous occasions to gently nudge me towards a career in real engineering.

I've now spent most of my life living in Canberra, in the Murrumbidgee Focus Catchment. I remember being shocked when I realised I'd lived half my life here, and even more shocked that the occasion had passed unnoticed!

On finishing school, I ended up at the University of Canberra (UC) studying (you guessed it) Computing. Computer Engineering to be exact, although who am I kidding, it's not real engineering. I initially enrolled in a double degree (fashionable thing to do) with Law which, in all honesty, was just a way to meet girls. With a major under my belt, and a lovely law student (Chantal) by my side, I ditched law in preference to straight computing and finished in 1999.

Along the way I joined CSIRO Land and Water, at the tail end of the first life of the CRC for Catchment Hydrology. Working for Richard Silberstein and Rob Vertessy as a vacation scholar for the summer of '98, I got to play around with Matlab and help create a new visualisation system for TOPOG. This was probably my first interaction with a model that wasn't made of balsa wood.

Something happened then and I didn't leave at the end of the summer, and, after hanging around on a part time basis during my final year of uni, I landed a full time job with the new life of the CRC and the toolkit project in 2000. The toolkit was easily the most interesting project I could have landed straight out of uni, and the fact that I could wear shorts and a t-shirt to the office certainly helped sell me the idea.

Since then I've worked on all things toolkit, cutting my teeth (and banging my head) on the Environmental Management Support System (EMSS), which, if you haven't heard about, you obviously spend too much time reading the profiles in *Catchword* without ever reading the Program 1 reports. Shame on you. The creatively titled "Local EMSS" followed in 2002, along with The Invisible Modelling Environment (TIME) which I tell people about whenever they'll listen - you've probably heard of both of them too. Most recently, I've been given the reigns to lead Project 1A (the software development side of the whole toolkit deal) in the second round of projects. I must have caused so many bugs that someone thought that needed to stop me writing code! Seriously though, 1A gives me the chance to work with a great team of software developers and delivery experts as well as getting a taste for the range of disciplines within the CRC.

I married that fellow law student in September 2001, around two weeks after the EMSS delivery. I was a bit preoccupied with software delivery in the lead up to the big day, so I just turned up when and where I was told and was pleased to see that Chantal turned up as well! Things haven't changed much, with Chantal willingly managing the fact that I'm a disorganised klutz!

So that's me, to date. Will I stay in this catchment, or move to the big lights of, say, the Yarra or the Brisbane? This is where I cop-out and say 'TIME will tell'.

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WHERE ARE THEY NOW?

Report by Lucy McKergow

Well, I'm still in the same place I've been for the last five years. I submitted my PhD thesis in October 2002 and in late November reappeared as a 'real person'. I'm a post-doc working in the Rivers and Estuaries group at CSIRO Land and Water, with Ian Prosser. The main focus of our current work is prioritising catchments requiring sediment and nutrients controls in the Great Barrier Reef World Heritage Area. We're using the SedNet and Annex models and so I have rediscovered the joy of working with ArcInfo.

I investigated riparian buffer performance at hillslope and small catchment scales in Western Australia and Far North Queensland for my PhD thesis. Thankfully when it was 'all stations go' in the wet tropics nothing was happening in WA, and vice versa. To cut a long story short...

Dense grass riparian buffers on planar slopes in the wet tropics are a good last line of defence. Even with high soil loss (>40 t/ha) more than 80% of the incoming bedload, and between 30 and 50% of total nitrogen, total phosphorus and suspended sediment loads were trapped. The story was not so great for a remnant rainforest buffer, which was a sediment and nutrient source area. Similarly, in a highly convergent catchment, runoff channelised upslope of the buffer and during larger storms scoured the buffer, limiting its effectiveness.

Now, transport yourself from the wet tropics to the Mediterranean climes of the far south-west of WA. If you are ever lucky enough to fly from Perth to Albany you'll be amazed by the sea of blue gums in the south-west. Many of these trees have been planted on riparian lands, but are they good water quality buffers? At our field site, surface runoff filtering was reduced to a minor role due to large volumes of subsurface flow, so the buffers didn't see much action. Nevertheless, between 10 and 50% of the sediment and nutrient loads were retained within a 10m blue gum buffer. An adjacent grass buffer trapped between 50 and 60% of incoming suspended sediment, total nitrogen, total phosphorus and filterable reactive phosphorus loads. Despite all this, these buffers are still important for displacing polluting activities, such as cattle and fertiliser applications from streams.

In 1997 riparian buffers were established in a small catchment where a water quality station had been operating since 1991, making a before and after study possible. The stream channel was fenced to exclude stock and the riparian area planted with native species. Stream suspended sediment concentrations and loads were 90% lower after the riparian buffers were created, largely due to reduced bank erosion. The nutrient story was not so dramatic or clearcut. While no reductions in total phosphorus or total nitrogen exports were evident, the proportion of phosphorus moving as filterable reactive phosphorus increased.

Many people helped me navigate through the thesis minefield. I'd like to thank my supervisors Ian Prosser and Rodger Grayson for their support and David Weaver (WADA) for sharing his data, local knowledge, and expertise. Finally, much of my data was collected by Adrian Reed and John Grant (WADA), and Dale Heiner (QDNRM). Thank you for spending endless hours in the rain. IOU big time!

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OUR MISSION

To deliver to resource managers the capability to assess the hydrologic impact of land-use and water-management decisions at whole-of-catchment scale.

OUR RESEARCH

To achieve our mission the CRC has six multi-disciplinary research programs:

- Predicting catchment behaviour
- Land-use impacts on rivers
- Sustainable water allocation
- Urban stormwater quality
- Climate variability
- River restoration

The Cooperative Research Centre for Catchment Hydrology is a cooperative venture formed under the Commonwealth CRC Program between:

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