

CATCHWORD

NO 120 SEPTEMBER 2003

A NOTE FROM THE DIRECTOR

**Professor
Rob Vertessy**

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A new internal review process for our CRC

A good research institution is one that submits itself to regular and challenging peer review. The Commonwealth CRC Program place a very high importance on the review of CRC's, mandating independent, external review at the end of the 2nd and 5th years of each CRC's life. Indeed, continuation of Commonwealth funding hinges on satisfactory performance of CRC's at these reviews.

In the case of our CRC, our Governing Board insists that we also undertake annual internal reviews of our projects to evaluate their quality and industry relevance. For the last four years we undertook these internal reviews progressively on a project-by-project basis. At each project review a panel of two to four experts, including industry representatives, would examine project achievements, culminating in the submission of an evaluation report to the Board. This method of internal review served us very well over the years but was quite expensive and time-consuming to administer. More importantly though, via this means we were unable to scrutinise our performance against the all-important integration objectives of our Centre. For these reasons we recently decided to adopt an alternative internal review method which we now refer to as a 'global internal review'.

Our first global internal review was held during 11-14 August 2003 at Monash University. The review panel comprised eight eminent specialists and was chaired by Professor Barry Hart, Director of the Water Studies Centre at Monash University. The other members of the panel were Dr Doug Boyle (Desert Research Institute, University of Nevada), Emeritus Professor Tom Chapman (University of New South Wales), Professor Wolfgang Geiger (University of Essen, Germany), Dr Chris Gippel (Fluvial Systems, Australia), Mr Steve Markstrom (United States Geological Survey), Dr Rory Nathan (Sinclair Knight Merz) and Dr Alistair Watson (Economics Consultant, Melbourne). Collectively, the panel were a powerhouse of talent and experience with the skills to drill into any component of our research portfolio.

The Terms of Reference for the review were to:

1. Scrutinise the central objective of the CRC: to produce an integrated, whole-of-catchment modelling capability for land and water managers and deliver this to them via the Catchment Modelling Toolkit;

2. Evaluate the scientific quality of the research being undertaken by each research program;
3. Assess the contribution of each Program to the target modelling capability; and
4. Evaluate the CRC's efforts with respect to Communication & Adoption and Education & Training.

Under each of these Terms of Reference was a series of questions such as 'Is there clear evidence of integration happening in the Program?' and 'How does the work compare on an international level?' All in all there were 16 discrete questions, giving the review panel a clear framework around which to assess our performance.

For the first three days of the review each of our Program teams gave presentations to back up the written material provided to the panel prior to the review. On the final day the review panel deliberated and began drafting their report. The final panel report was submitted on 25 August and runs to 25 pages. So, what does it say?

Fond as I am of quoting independent praise for our efforts, I'll let them do the talking:

'The overwhelming view of the Panel was that the CRC for Catchment Hydrology is undertaking high quality work that serves well the immediate needs of industry stakeholders in three eastern States. The Panel is confident that the web-based modelling Toolkit that will be produced by the end of this CRC will be of great value to the natural resource management industry in Australia (even if all the components presently envisaged are not available at that time). The extent of effective collaboration and involvement across different agencies, institutions, and disciplines is a particularly striking feature of the CRC. The Panel was most impressed with the highly effective communications and adoption program the CRC for Catchment Hydrology has in place.'

Mind you, whilst the panel gave us a solid 'thumbs up', their report was by no means saccharine, providing sage advice and raising some warning flags. Most of their concerns stemmed from a view that what we are attempting will be extremely challenging to deliver on. I'd have to agree; we have set ourselves a very ambitious mission. What we are attempting is



CRC PUBLICATIONS LIST

A complete list of all documents and products produced by the CRC since 1993 is available at our web site at www.catchment.crc.org.au/publications

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revolutionary and therefore risky, but my view is that you don't achieve great things unless you strive for them. In the lead up to next year's vital Fifth Year Review we will be implementing most of the panel's recommendations. This global internal review has been a great way to take stock of ourselves and fine-tune what we are doing.

I'd like to conclude by expressing my sincere appreciation to the review panel for their efforts. They did a superb job. I'd also like to thank John Molloy, Virginia Verrelli and Maeve O'Leary for the great logistical support they provided for the review. Finally, to the Program Leaders and researchers that participated in the review, my huge thanks for your continued hard work and excellence! The review panel report affirms my belief that we have a very talented and dedicated team of researchers attuned to the needs of the land and water industry.

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PROGRAM 1

PREDICTING CATCHMENT BEHAVIOUR

Program Leader
GEOFF PODGER

Modelling water regulation

Introduction

In the May 2003 edition of *Catchword* I discussed the short term strategy for integrating the CRC's industry participant's river models IQQM and REALM into the CRC's Catchment Modelling Toolkit. Work is continuing on this integration. However, in the longer term, components of the industry models will be ported across into TIME. IQQM and REALM have been specifically built to simulate the management of water in regulated systems and these management features are what we want to include in TIME.

Water management issues

Australia has one of the most variable climates in the world and consequently the management of water is extremely important. During extremely wet periods there are issues of managing floods, and, during the remaining periods, particularly droughts, there are issues of managing the scarce resources. In the past, management focused primarily on the delivery of water to consumptive uses such as irrigation, and monthly time step models were developed to simulate this. More recently the need to manage the river environment and health of our rivers has been a priority. The river environment is dependent upon the short term variability of flows, and consequently models need to operate at shorter time steps to simulate these processes. The current generation of models reflect this, operating at daily or sub-daily time steps. The current models also include complex environmental flow rules that aim to achieve a balance between maintaining the reliability of water supply to irrigators and restoring river health.

This article discusses river regulation and what needs to be considered in porting across some of the functionality of the existing industry models. I apologise to the other States, most of the focus of this article will be on NSW river regulation as this is the area most familiar to me. Despite this, there is some common ground on how each of the States manages their rivers.

River regulation

Basically river systems fall into two categories - those that have storages to regulate flow (regulated), and those that don't (unregulated). In regulated systems water is stored for several purposes: flood control, power generation, and releases for water users. Quite

often storages are used for all of these purposes. The storages used for flood mitigation are generally gated, whereby the gates are used to hold the flood surcharge behind the gates while water is released at a rate less than the inflow peak. Most NSW storages are used to supply water for irrigation and towns, and power generated is a by-product of water released for other purposes. The Snowy Scheme is an exception where releases are primarily made to generate power.

Both unregulated and regulated systems have rules that control the diversion of water. Access rules in unregulated systems are based on flow constraints that specify when pumping is allowed or are based on maintaining a downstream flow. The rate that water is diverted may also be a function of the amount of flow in the river or the intended use for the water e.g. for crops or to be stored in on-farm storages. The annual amount of water taken each year may also be capped. The rules in some unregulated systems can be quite complex when they are built up by a combining these rules across multiple classes of access.

In regulated systems water users are issued license entitlements that are used to determine a share that a water user has in the stored resource, as well as access to surplus flows (dam spills or unregulated inflows). There are usually two types of licences, high security and general security. High security entitlements are fully allocated prior to allocating any general security entitlement, and are typically reserved for town water supplies or permanent crops e.g. orchards. General security water is normally allocated to irrigators. Environmental water use may or may not be licensed. When licensed, it may be in combinations of high and general security water.

Accounting for water allocation

There are many different systems for allocating the stored water to water users. There are predominantly three systems used in NSW:

- Annual accounting,
- Annual accounting with carry-over, and
- Continuous accounting.

Annual accounting

Annual accounting is based on determining an allocation to water users on a water year basis. At the start of a water year the amount of active storage is determined (current storage less dead storage). Annual evaporation, delivery losses, high security requirements and high security reserves are deducted from the active storage. Allowance for annual minimum inflows and recessions of the current inflow are added to the active

storage. This is then divided by the entitlement in the system and turned into a percentage. This percentage is known as the annual allocation and when multiplied against a general security entitlement, the result specifies how much water a user has available for that water year. This percentage will be updated during the year as inflows above the minimum arrive. Note this percentage may increase but never decreases during the year. The maximum allocation may also be capped.

At the end of the water year the process starts again. Unfortunately this type of system does not favour water users that do not use all of their allocation. At the start of the next water year this water will get reallocated to all the other water users. This sort of system promotes a behaviour whereby irrigators will order water at the end of the water year to fill on-farm storages, rather than lose it. This is an inefficient practice and to overcome this problem, carry-over was introduced.

Annual accounting with carry-over

Carry-over allows water users to carry over an amount of unused allocation into the next water year. The carried over amount may be subject to certain rules that discount the carry-over water if it is not used within a certain period and it is lost if the dam spills. Note the carry-over water is released prior to the current year's allocation.

Continuous accounting

Unfortunately both annual accounting and carry-over systems favour water users that consume their allocation each year. Users that require reliable supply, e.g. dairy farmers, are bound into the valley-wide allocation despite their water usage, which might be small. There are two ways of dealing with this, capacity sharing and continuous accounting. In continuous accounting systems each general security irrigator has a defined share of the storage. This share is determined by considering the maximum active storage volume, less high security entitlement, high security reserve and allowance for delivery loss (which is a function of the stored resource). This is divided by the total general security entitlement in the system to determine a ratio that gets multiplied by the licence entitlement to determine the storage volume share. Under this system there is no water year and the resource available to each water user is the amount stored in that water user's storage share.

Capacity sharing is similar to continuous accounting but differs in that high security has a share and losses are not socialised. This system has not been implemented in NSW as it is too difficult to define equitable shares and is much more difficult to manage.

NEW TECHNICAL REPORT

Estimating Water Storage Capacities in Soil at Catchment Scales.

By

**Neil McKenzie
John Gallant
Linda Gregory**

Technical Report 03/3

Landscapes vary in their capacity to store water. Estimates of water storage capacities in soil are required to allow a better analysis of interactions between vegetation and stream flow from local to regional scales. This is particularly relevant to simulation studies relating to dryland salinity, farm forestry and water security. This report investigates how land resource data can be used to improve estimates of water storage capacities in soil at catchment scales.

Printed and bound copies of this report are available from the Centre Office for \$27.50. Contact Virginia Verrelli on 03 9905 2704 or email crch@eng.monash.edu.au

www.toolkit.net.au

The Catchment Modelling Toolkit web site has been completely revised. The Toolkit web site will be used to deliver for the CRC for Catchment Hydrology's modelling software and supporting documentation over the next three years.

MUSIC users can now access a range of supporting information at www.toolkit.net.au/music

For further information visit www.toolkit.net.au

Comments and queries can be directed to
David Perry
tel: 03 9905 9600
email: david.perry@eng.monash.edu.au

Modelling considerations

Most river basin models employ a headwater to outlet approach (top-down) for modelling flows in the river system. If river regulation is to be modelled then multiple passes are required to allow for the allocation of water resources.

Passes are required to:

1. Determine available resources
2. Pass orders from water users to storages
3. Share surplus flows
4. Carry out flow routing and water balance

These passes are necessary to determine what water users can order, what releases are made subject to orders, and what access to surplus flow water users are allowed.

The determination of available resources is typically done by river operators when above-minimum inflows into storages occur. This is done in IQQM by specifying a calculation frequency and time frame. The typical frequency is every seven days and the time frame can be from nine months to all of the water year.

Order passing is done from bottom to top and is done by accumulating the orders from water users. Allowance is made for losses and tributary contributions as the orders propagate towards the storage. The order at the storage is then subject to release constraints and is subsequently used in the water balance pass to control the storage release.

The water balance pass, as well as releasing water from storages, routes water, calculates open surface water evaporation losses and rainfall gains, accumulates water from tributaries and at junctions, and subtracts water diverted by irrigators and other water demands.

Surplus sharing is used to share unregulated water equitably (based on license) throughout the system. This is done by doing multiple passes on the system on a reach by reach basis. The amount that is allocated to water users dictates how much surplus water may be extracted in the water balance pass.

Concluding remarks

This article covers relatively simple systems with a single supply storage. I have tried as much as I can to keep this extremely complex topic simple, I hope I have succeeded. There is still much more I could discuss:

1. Systems with multiple storages
2. Systems with state/country sharing of resources
3. Environmental flow rules
4. Water ordering (in particular irrigation orders)

If there is some interest in discussing these other topics this could be covered in a future *Catchword*. I look forward to your feedback.

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PROGRAM 2

**LAND-USE
IMPACTS ON
RIVERS**Program Leader
PETER HAIRISINE**Report by Alice Best and Lu Zhang****Project 2.23 (2E) - Modulating daily flow duration curves to reflect the impact of land-use change***Background*

In last year's September edition of *Catchword*, an article by Lu Zhang and Warrick Dawes entitled "Afforestation and Water Security: An example for Goulburn-Broken Catchments" highlighted the need to be able to predict the impacts of afforestation on finer times scales than the previous annual and annual average estimates.

Our project team is working on the prediction of changes to a stream's flow duration curves (FDC) as a result of changes to vegetation in the contributing catchment. Flow duration curves are cumulative frequency curves that show the percentage of time that specified flows are equalled or exceeded. As such they provide an easy way of displaying the complete range of flows. Being able to modulate a daily flow duration curve for changes in land use would allow the impacts for land use change to be incorporated into models such as IQQM and REALM, as shown in Figure 2.1.

Vegetation impacts

Our understanding of the impacts of vegetation on flow duration curves (FDCs) comes primarily from small experimental catchments in which large percentage

changes in vegetation have occurred. In these small experimental catchments, two types of responses in FDCs have been identified (Lane *et al.*, 2003). Figure 2.2 shows contrasting responses in the FDC due to changes in vegetation (grass to pine plantation) in two experimental catchments. Figure 2.2(a) shows a much larger proportional reduction in low flows, leading to a large decrease in the percentage of time flow occurs, while Figure 2.2(b) shows a catchment in which the proportional reductions in low and high flows are similar.

Modifying flow duration curves for vegetation changes

To modify the FDC for changes in vegetation, two main steps have been identified. Step one involves the parameterisation of the FDC, while step two links these parameters to the current understanding of the impact of vegetation on the mean annual water balance (Zhang *et al.*, 2001) and catchment characteristics. The water balance developed by Zhang *et al.* (2001) calculates mean annual evapotranspiration from mean annual rainfall and potential evapotranspiration. In estimating catchment average water yield, it is assumed that there is no net change in catchment water storage over a long period. As a result, catchment water yield can be calculated as the difference between long-term average rainfall and evapotranspiration. In order to predict changes in the FDC, the parameterisation of the FDC has been done in such a way that the parameters can be easily linked to the outputs from the mean annual water balance model.

With the parameterisation of the FDC achieved, the next step in Project 2E is to develop relationships between these parameters and our understanding of the impacts

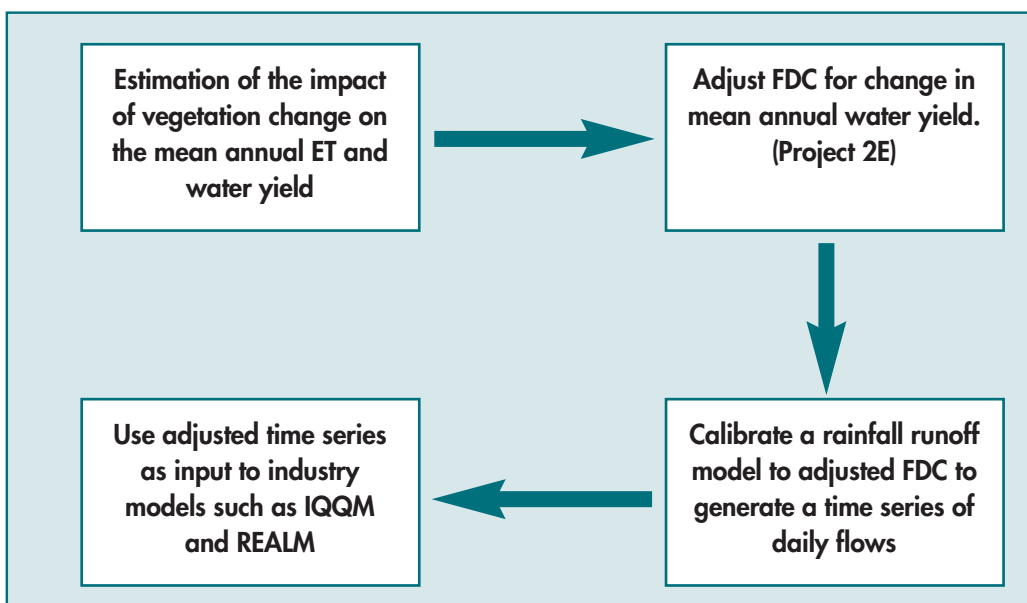


Figure 2.1: Linking the outputs of Project 2E to industry models

**MDBC-CSIRO-CRC
TECHNICAL REPORT
SERIES****A Critical Review of Paired
Catchment Studies with
Reference to Seasonal
Flows and Climatic
Variability.**

By

Alice Best
Lu Zhang
Tom McMahon
Andrew Western
Rob Vertessy

Technical Report 03/4

This report focuses on the use of paired catchment studies as a means for determining long-term changes in water yield as a result large scale changes in vegetation. Current knowledge gaps in relation to the impacts of broad scale vegetation changes on flow regime and seasonal flows are highlighted and possible methods of addressing these gaps are suggested.

This report is available as an Adobe .pdf file only.

Visit www.catchment.crc.org.au/publications and search under 'Land-use Impacts on Rivers'

MDBC-CSIRO-CRC TECHNICAL REPORT SERIES

Impact of Increased Recharge on Groundwater Discharge: Development and Application of a Simplified Function using Catchment Parameters.

By

Mat Gilfedder
Chris Smitt
Warrick Dawes
Cuan Petheram
Mirko Stauffacher
Glen Walker

Technical Report 03/6

This report describes the development of a simple approach towards estimating the response of groundwater systems to changes in recharge that arise from changes in land-use. The emergent properties of a groundwater system are examined using scaling arguments, by combining the effect of aquifer properties into a single dimensionless groundwater system similarity parameter (G).

This report is available as an Adobe .pdf file only.

Visit www.catchment.crc.org.au/publications and search under 'Land-use Impacts on Rivers'

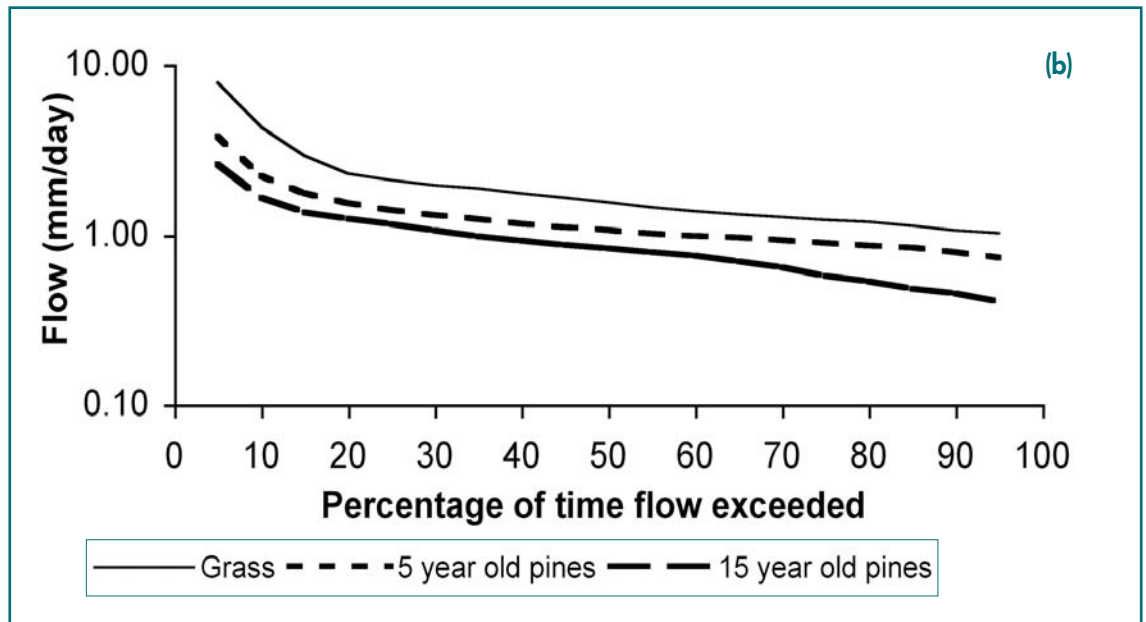
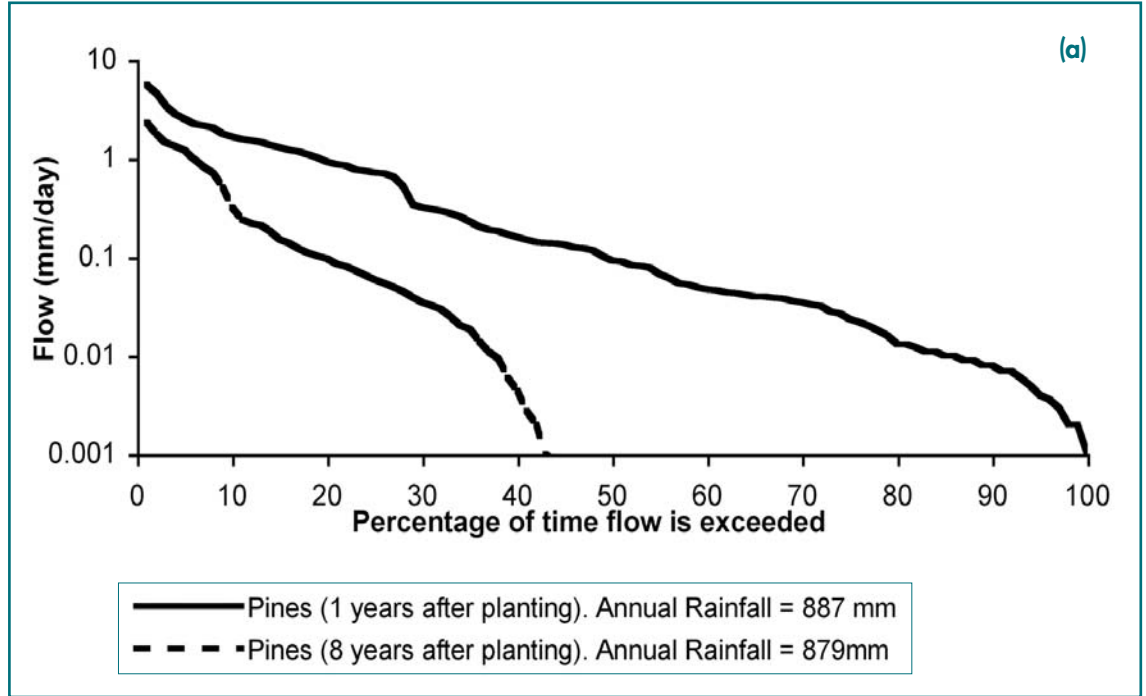


Figure 2.2: Flow Duration curves for the (a) Redhill catchment, near Tumut, New South Wales, Australia (Mean annual Rainfall = 876mm) and (b) Glendhu experimental catchment, New Zealand (Mean annual rainfall = 1330mm) showing the change in FDC following the conversion from grass/pasture to pine plantation.

of vegetation on the water balance. Two methods are proposed for linking the mean annual water balance model to the FDC parameters. One is appropriate for gauged catchments and the other for ungauged catchments. Initial work linking the FDC parameters to the mean annual water balance model in small experimental catchments has been promising. Results from the upper and middle Murrumbidgee basin also indicate that the FDC parameters can be regionalised.

Project 2E has made some good progress in being able to adjust the FDC for changes in vegetation. In the coming months we hope to improve our ability to predict how the number of no-flow days change as a result of changes in vegetation in the upstream contributing areas and the regionalisation of the FDC parameters.

References

Best, A.E., Zhang, L. McMahon, T.A., and Western, A.W. (2003). Development of a model for predicting the changes in flow duration curves due to altered land use conditions. MODSIM 2003, Townsville 14-17 July 2003. 861-866

Lane, P., Best A., Hickel K., and Zhang, L (2003). The effect of afforestation on flow duration curves. Technical Report No. 03/13, Cooperative Research Centre for Catchment Hydrology. In press.

Zhang, L., Dawes, W.R., Walker, G.R. (2001). Response of mean annual evapotranspiration to vegetation changes at catchment scale. *Water Resources Research*, 37: 701-708.

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MDBC-CSIRO-CRC TECHNICAL REPORT SERIES

Modelling the Effectiveness of Recharge Reduction for Salinity Management: Sensitivity to Catchment Characteristics.

By

**Chris Smitt
Mat Gilfedder
Warrick Dawes
Cuan Petheram
Glen Walker**

Technical Report 03/7

This report describes the use of modelling to investigate the sensitivity of groundwater and other characteristics on the effect of recharge reduction on salinity management.

This report is available as an Adobe .pdf file only.

Visit www.catchment.crc.org.au/publications and search under 'Land-use Impacts on Rivers'

MDBC-CSIRO-CRC TECHNICAL REPORT SERIES

Testing In-Class Variability of Groundwater Systems: Local Upland Systems.

By

Cuan Petheram
Chris Smitt
Glen Walker
Mat Gilfedder

Technical Report 03/8

This report assesses the extent information can be transferred between hydrogeologically similar catchments, by investigating in detail one set of similar catchments.

This report is available as an Adobe .pdf file only.

Visit www.catchment.crc.org.au/ publications and search under 'Land-use Impacts on Rivers'

PROGRAM 3 SUSTAINABLE WATER ALLOCATION

Program Leader
JOHN TISELL

The National Water Initiative

Introduction

On 29 August 2003 the Council of Australian Governments (COAG) agreed on the scope of the National Water Initiative. The initiative aims to achieve:

- nationally compatible water access entitlements
- nationally functioning water markets
- integrated management of environmental water
- improved measurement, monitoring and information on catchments
- urban water reform.

This article briefly outlines the essence of the initiative and how the work in Program 3 will contribute to addressing a number of the initiative's key goals.

Water access entitlements – redressing inequities

The first objective of the initiative is to establish nationally compatible water access entitlements. The ownership of water resources has historically been vested with the States and each State has developed its own institutional structures and associated entitlement structures for water use. Moving to nationally compatible water access entitlements is necessary in order to redress inequities in the over-allocation of rights to both surface and ground water that have arisen. The notion is to establish perpetual rights. This will require significant changes to current entitlement arrangements and it is proposed that compensation mechanisms be established for those affected by such changes.

Establishing national water markets

Establishing nationally compatible water access entitlements is a necessary prerequisite for establishing national water markets. It is important to keep in mind that establishing such entitlements is a necessary but not sufficient condition for efficient markets. Operationalising the requirements for efficient water markets across large spatial and temporal scales will not be simple. It will require elegant market design tested in laboratory and field trials, but a challenge worthy of CRC researchers.

Trading for environmental management

The initiative also aims to develop new arrangements to manage water at a basin, aquifer or catchment scale to deliver agreed environmental results. It is proposed that a Murray-Darling basin-wide environmental water manager trade in the national water markets to achieve environmental results. It could be envisaged that the objective of such a trader will incorporate both bulk water requirements for wetlands and timed aggregate extraction targets within water years at specific locations in the basin.

Modelling by CRC Program 3 researchers suggests that water trading is likely to exacerbate differentials between extraction timings and natural flow patterns. It is highly unlikely that an environmental water trader will be able to effectively manipulate such flow patterns under existing water market structures without significant transaction costs. In concert with the development of nationally compatible water access entitlements and nationalised water markets, serious consideration will need to be given to how an environment trader can effectively operate in such markets without high transaction costs or creating distortions arising from perceived or actual market concentration. The challenge will be to create elegant designs for what could prove to be quite complex markets and associated entitlement structures.

CRC activities

Program 3 is able to make a significant contribution by providing thought on the design of entitlement structures, both extractive and environmental, and national water markets. Researchers plan to work with national bodies, such as Environment Australia, in the development of water trader options. At a higher level, the timing of the initiative is critical for the CRC, which is at the crossroads of developing the re-bid strategy. The CRC could choose to keep a strong hydrological focus and make a significant contribution to improved measurement, monitoring and information on catchments or alternatively it could give greater emphasis to the development of institutional structures and market designs in the formation of entitlements and water markets; an area in which the CRC at present has a small but very committed research group.

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PROGRAM 4

**URBAN
STORMWATER
QUALITY**Program Leader
TIM FLETCHER**Report by Stefan Ahlman & Tim Fletcher****Verification of a process-based stormwater
pollution model for Brisbane conditions***Background*

Stefan Ahlman is a second year PhD student from Chalmers University of Technology, Gothenburg, Sweden. Stefan is working with Tim Fletcher in the CRC for Catchment Hydrology's Urban Stormwater Quality Program. Stefan will be undertaking a project to improve the prediction of pollutant loads from Brisbane's various land-use types, utilising data collected as part of Brisbane City Council's Stormwater Quality Monitoring Program.

Currently, the Monitoring Program data are used for two main purposes:

- for the development of pollutant export relationships in AQUALM

- for calibrating MUSIC's stochastic pollutant generation algorithms.

Brisbane City Council and the CRC for Catchment Hydrology have identified weaknesses in both approaches. Ideally, a more reliable, process-based prediction is necessary if we are to be able to accurately predict pollutant concentrations and loads. This is important in assessing performance against Brisbane's Water Quality Objectives.

Stefan will develop a process-based model for Brisbane, using a previously developed model (SEWSYS) from Sweden. The results will be used to calibrate and refine MUSIC for use in Brisbane. This is one of several projects the CRC is undertaking, utilising Brisbane's Stormwater Quality data. The project will run for three months, ending in October 2003.

Swedish and European Union research

Stefan's research is affiliated with two overseas research programs, Urban Water and DayWater. Urban Water is a Swedish program with 16 PhD students and about 10 senior researchers from eight universities, all working in trans-disciplinary research projects related to sustainable urban water management. The projects cover water supply, wastewater and stormwater

**MDBC-CSIRO-CRC
TECHNICAL REPORT
SERIES****Assessment of Salinity
Management Options for
Kyeamba Creek, New
South Wales: Data
Analysis and Groundwater
Modelling.**

By

Richard Cresswell
Warrick Dawes
Greg Summerell
Geoff Beale
Narendra Tuteja
Glen Walker

Technical Report 03/9

This report describes a study of the hydrogeological factors influencing salinity in the Kyeamba catchment, located within the uplands of the Lachlan Fold Belt of south-eastern Australia.

This report is available as an Adobe .pdf file only.

Visit www.catchment.crc.org.au/publications and search under 'Land-use Impacts on Rivers'

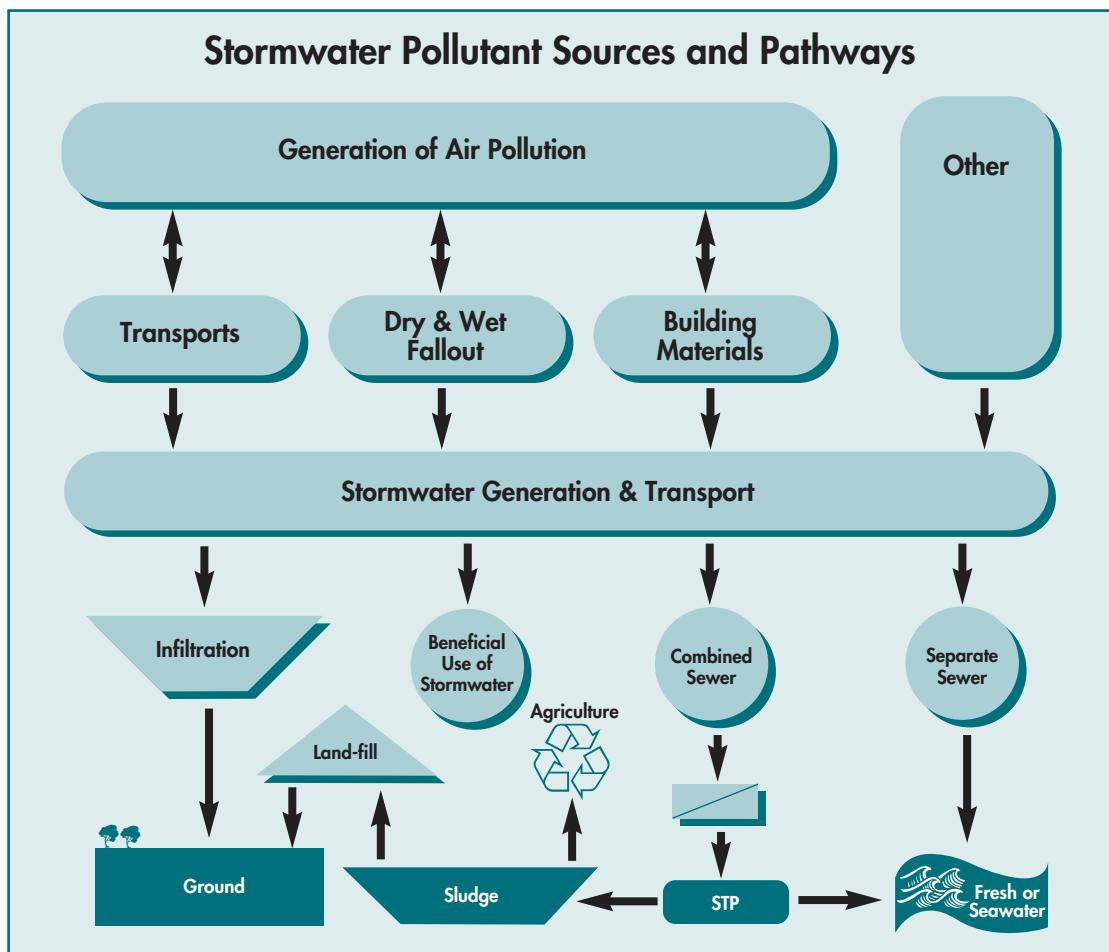


Figure 4.1. Stormwater pollutant sources and pathways.

management (www.urbanwater.org). DayWater is a research program funded by the European Union, with a total of 10 partners spread over eight countries including UK, France, the Netherlands, Greece, Germany, Czech Republic, Denmark and Sweden. The aim of DayWater is to develop an adaptive decision support system for the integration of stormwater source control into sustainable urban water management strategies, at different spatial levels within Europe (www.daywater.org).

Urban pollutant approaches

The common approach in stormwater quality models is to use standard pollutant concentrations for different land uses. This makes the models easier to work with since it requires less input data. However, to be able to achieve quality source control, i.e. reducing the pollutants at the source, it would be necessary to have a larger resolution in the pollutant transport model. The sources for pollutants from different activities in the urban area have to be separated in their respective origin: material corrosion, brake wear, tyre wear etc. The pollutants in stormwater, especially the heavy metals, contribute to a large extent to the total pollutant mass flow in the sewerage system (Boller 1997). The appropriate long-term strategy would be to avoid, replace or reduce the sources for stormwater pollution.

The different stormwater pollutant sources and pathways are summarised in Figure 4.1. This descriptive concept has formed a framework in the development of the substance flow modelling tool SEWSYS discussed below.

Stormwater pollution load model, SEWSYS

A model for simulation of urban sewerage systems has been developed in the computer program package MATLAB/Simulink (Ahlman and Svensson, 2002a). The model is called SEWSYS and handles sources and

fluxes of substances within the urban sewerage system. SEWSYS consists of a stormwater module, sanitary wastewater module and a wastewater treatment plant with nitrogen removal. Simulation of stormwater treatment by sedimentation in wetland ponds is possible. Both separate and combined sewer systems can be simulated. In this project we are only using the stormwater pollution load module of SEWSYS.

The catchment specific input data that the model requires is listed in Table 4.1.

In addition, the model requires background data such as atmospheric deposition and corrosion rates. This kind of data will be provided from an initial literature study, with a focus on the conditions in Brisbane.

SEWSYS has thus far been used in a study to compare different strategies for stormwater management in an urban catchment in Gothenburg (Ahlman and Svensson, 2002b). From this study it was concluded that all the studied measures individually lead towards a high reduction of the discharge of pollution to the local water body. Additionally, the substance flow model SEWSYS

Table 4.1. Catchment specific input data

Description	Units
Total impervious area	m ²
Road area	m ²
Total Roof area	m ²
Zinc roof area	m ²
Copper roof area	m ²
Annual precipitation	mm/year
Total traffic load	vehicle_km/day
Heavy vehicles	%
Baseflow	m ³ /s

Table 4.2. Relevant catchments for SEWSYS verification

Station	Land use	Catchment area (ha)	Impervious (%)
Wynnum ¹⁾	Commercial	35	68.9
Keating Street	Commercial	15	72.4
Virginia ¹⁾	Industrial	37	94.7
Evans Road	Industrial	17.5	74
Cannon Hill	Developing	17	30.4
Cressey Street	Urban residential	107	42.3
Sandy Creek	Urban residential	220	48.6
Algerster Road	Rural residential	282	26.9

¹⁾ Includes mobile sampler data.

was considered useful for understanding the processes of generation and spreading of the studied substances.

Site selection and methods

Based on data availability, a selection of the Brisbane catchments has been chosen for the verification process. Table 4.2 shows the chosen catchments in order of relevance. The SEWSYS model only accounts for fast surface runoff, hence the impervious area must occupy a high proportion of the catchment. In addition, the mobile sampler used at Wynnum and Virginia makes it possible to verify the heavy metal loads; not only TP and TN.

Background data literature study

An initial literature study will be undertaken to provide background data such as atmospheric deposition and corrosion rates. The literature study will focus on the atmospheric conditions in Brisbane.

Monitored stormwater data

Brisbane City Council has the monitored stormwater data stored in the HYDSYS database management system. Every site has rainfall, flow measurements and quality data for about 60 rain events, respectively. At first, quantity data (measured rainfall and hydrographs)

for the selected catchments will be extracted. The quantity data will be used for calibration of SEWSYS' rainfall-runoff model. Figure 4.2 shows the correlation between measured and modelled runoff volume for 12 selected rainfall events out of a total of 79 from the Wynnum catchment. Figure 4.3 shows the calibration result for the rain event of 04/10/1999 from Wynnum.

Relating to Table 4.1, the input data SEWSYS requirements, the total impervious area of the catchments has previously been calculated by Brisbane City Council using GIS. Impervious area here includes roads, roofs and car parks. The GIS method gives an estimate, and the impervious area will be refined in the runoff calibration process, taking into account the part that is connected to the drainage system. This method also gives the required distribution of impervious area in roads, roof and other impervious area.

Traffic data for the different catchments is provided from the Transport Planning group within City Design, Brisbane City Council. The Brisbane Strategic Transport Model (BSTM) is used to give annual average daily traffic (AADT) volumes and % of Commercial Vehicles (CVs) for the individual streets in the catchments.

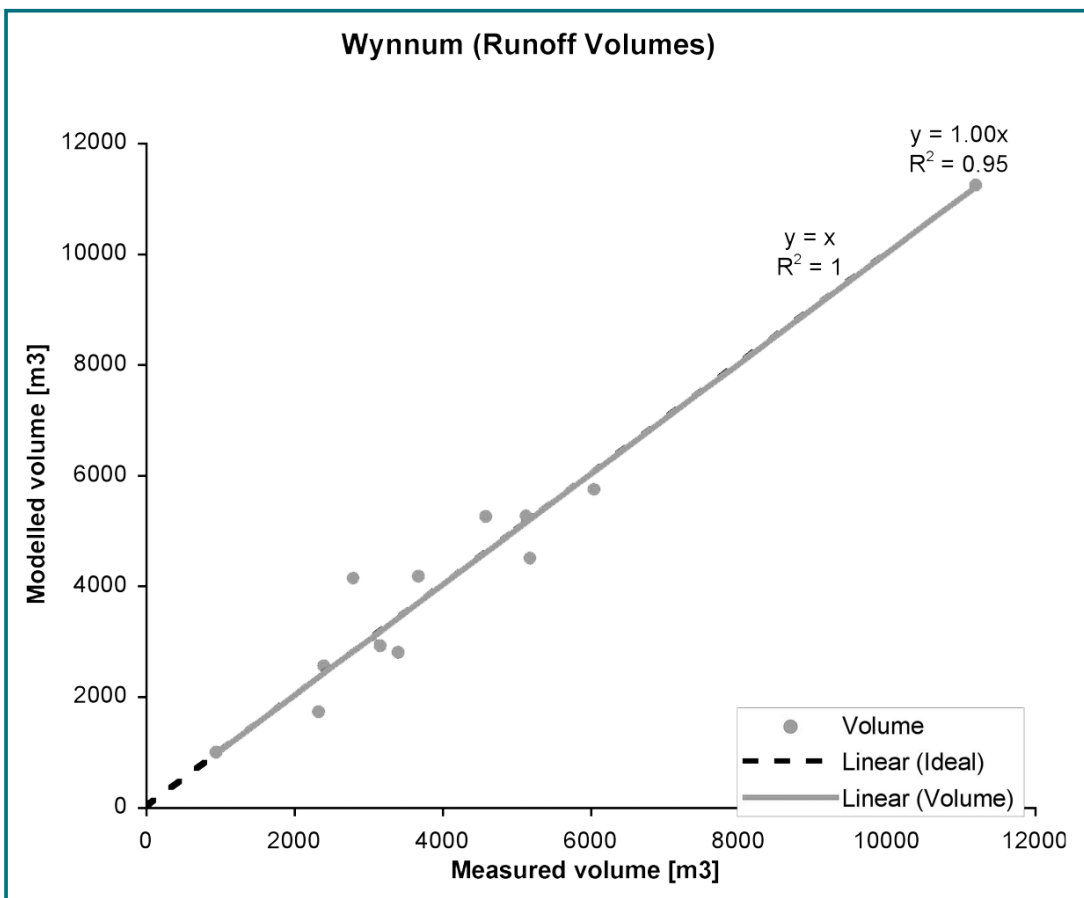


Figure 4.2. Correlation between measured and modelled runoff volume for 12 rainfall events

WEATHER RADAR CONFERENCE

Sixth International Symposium on Hydrological Applications of Weather Radar

2-4 February 2004
Melbourne, Australia

The major theme of this conference is 'The successful implementation of radar technology for hydrological and quantitative rainfall applications'.

For more information on the symposium, please visit www.bom.gov.au/announcements/conferences/hawr2004 or email hawr2004@bom.gov.au

The conference is supported by the Commonwealth Bureau of Meteorology, the CRC for Catchment Hydrology and the Australia Meteorological and Oceanographical Society

URBAN STORMWATER SOFTWARE

Model for Urban Stormwater Improvement Conceptualisation (MUSIC)

MUSIC is a decision-support system. The software enables users to evaluate conceptual designs of stormwater management systems to ensure they are appropriate for their catchments. By simulating the performance of stormwater quality improvement measures, music determines if proposed systems can meet specified water quality objectives.

MUSIC is available from the Centre Office for \$88.00

Individuals will need to sign a Licence Agreement (available from the Centre Office and website: www.catchment.crc.org.au)

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

Please note: MUSIC version 1.00 is a development version and will be valid until September 2003. The CRC for Catchment Hydrology is committed to updating MUSIC annually until at least 2006. Subsequent versions of MUSIC may be charged for.

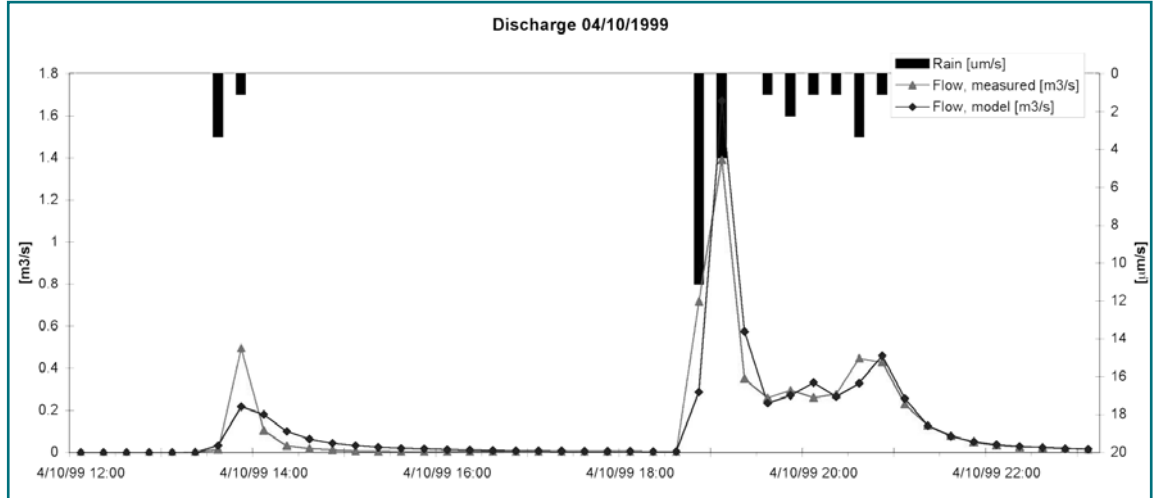


Figure 4.3. Calibration results for rainfall event on 04/10/1999 (Wynnum).

The stormwater quality data, i.e. measured pollution load, from the selected catchments will be compared with modelled pollution load. SEWSYS uses continuous modelling to take into account the build up and wash off processes that occur on impervious areas.

Study findings to date

The initial literature study has revealed some differences in catchment characteristics between the different cities. Brisbane has much higher atmospheric pollution, which relates to higher traffic loads and combustion of fossil fuels. The atmospheric conditions, mainly salt deposition, also affect the corrosion rates, where the iron corrosion in Brisbane is found to be several times higher than in Gothenburg. The final results of the research project will be reported in a scientific publication, submitted to an international journal.

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Ahlman, S., and Svensson, G. (2002b). "Substance flow analysis of the stormwater system in Vasastaden, Göteborg." In: Strecker, E. W. and Huber, W. C., Proceedings of the 9th International Conference on Urban Drainage, Portland, Oregon, USA, September 8-13. ISBN 0-7844-0644-8.

Boller, M. (1997). "Tracking heavy metals reveals sustainability deficits of urban drainage systems." *Water Science and Technology* 35(9): 77-87.

Links

Swedish research program, Sustainable Urban Water Management: <http://www.urbanwater.org>

European Union research program, DayWater: <http://www.daywater.org>

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PROGRAM 5

**CLIMATE
VARIABILITY**Program Leader
FRANCIS CHIEW**Report by Andrew Frost and Sri Srikanthan****Stochastic generation of point rainfall data at sub-daily timescales***Background*

The generation of point rainfall and climate data at annual, monthly and daily timescales were described in earlier issues of *Catchword*. The generation of point rainfall data at sub-daily timescales is one of the activities in the second round CRC for Catchment Hydrology project, Project 5.06 (5B): "Stochastic rainfall data generation models". Subdaily rainfall data is required in urban hydrological models (eg. MUSIC) and in continuous simulation models used in flood studies. Given that there is typically less than 20 years of sub-daily data at most rainfall stations in Australia, stochastic rainfall models provide an important tool for risk based design.

A number of stochastic sub-daily rainfall models are available in the literature and a literature review is being carried out. Of the models reviewed, two better performing but conceptually different models have been selected for trial and comparison:

- the Disaggregated Rectangular Intensity Pulse (DRIP) rainfall model, a refinement of the model proposed by Eagleson (1978), developed jointly by the University of Adelaide and the University of Newcastle (Heneker *et al.*, 2001), and,

- the Neyman-Scott Rectangular Pulse (NSRP) cluster model proposed by Rodriguez-Iturbe (1987) and further developed by Paul Cowpertwait of Massey University, Auckland (eg. Cowpertwait and O'Connell, 1997).

Comparison of models

Within DRIP, rainfall is conceptualised as a series of events – with associated random dryspell time, storm duration and storm intensity – and as such is termed an event-based model. Conversely, the NSRP model is an example of a cluster-based model, with rainfall represented as clusters of rain cells associated with storms. Each cell is considered as a pulse with a random duration and random intensity which is constant throughout the cell duration. Overlapping of cells is allowed both within the same storm and across different storms. The NSRP differs from DRIP in that events are not identified (as storms can overlap). The different conceptual bases (event vs. cluster) require differing calibration methods.

Both models have previously shown good reproduction of extreme rainfall statistics and aggregation statistics (daily/monthly/yearly rainfall distributions) and where applied. See Figure 5.1 for an initial calibration of DRIP applied to Sydney. Note that like most short-timescale models, DRIP underestimates annual variability in rainfall. Time permitting, future work will address this (for both DRIP and the NSRP) using the methods employed by Frost *et al.*, (2002).

Proposed calibration and evaluation of models

For the purposes of evaluation, the above two models are to be calibrated at sites where there is sufficient pluviograph data. This means predominantly capital

**NEW TECHNICAL
REPORT****Predicting the Effects of Large Scale Afforestation on Annual Flow Regime and Water Allocation: An Example for the Goulburn Broken Catchments.**

by

**Lu Zhang
Trevor Dowling
Mark Hocking
Jim Morris
Geoff Adams
Klaus Hickel
Alice Best
Rob Vertesy**

Technical Report 03/5

This report bridges part of the gap between the science of catchment water balances and the management of catchments. The language has moved from "annual average yield" to "water security". Afforestation and water remains a contentious issue. This report sets out an important case study to underpin future decision-making.

Printed and bound copies of this report are available from the Centre Office for \$27.50. Contact Virginia Verrelli on 03 9905 2704 or email crch@eng.monash.edu.au

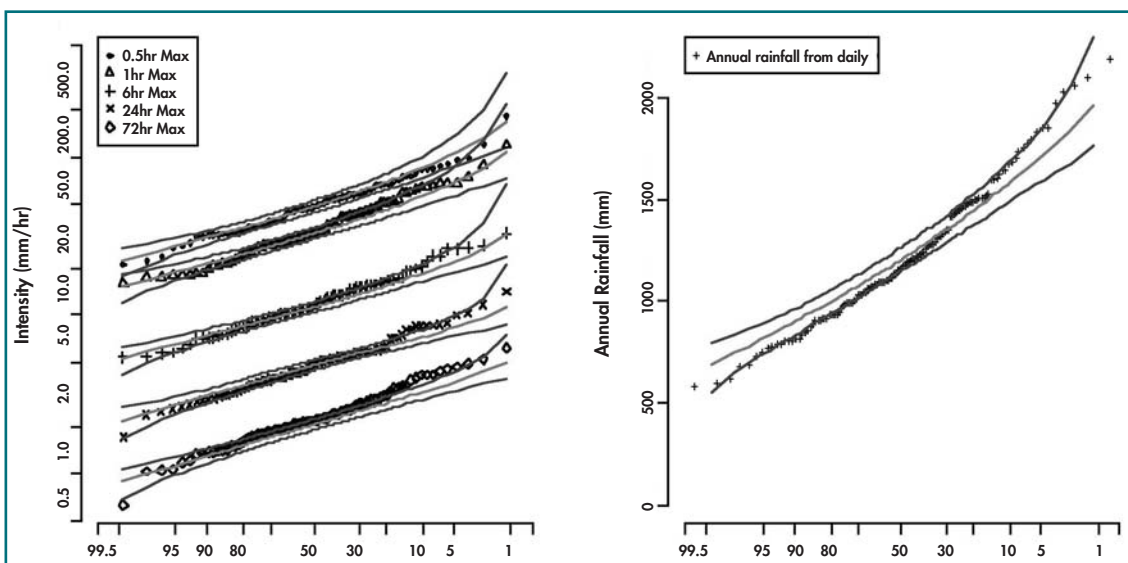


Figure 5.1. Intensity-Quantity-Duration curves and the distribution of annual rainfall for Sydney.

CATCHMENT MODELLING SCHOOL 9-20 February 2004

The CRC for Catchment Hydrology is proposing to hold a Catchment Modelling School during 9-20 February 2004 in Melbourne, Victoria.

The workshop based School aims to equip participants with the skills required to undertake and interpret a range of modelling activities relevant to catchment management. Individual workshops based around the latest modelling principles, practices and products will be held during the two-week School and will vary in length from a few hours up to three days.

Over the next few months, CRC staff will be seeking your views as to what specific content should be included in the Catchment Modelling School. We will require broad-based input from the land and water industry to make this important event a success.

You can send your ideas and/or register your interest in learning more about the Catchment Modelling School by contacting David Perry via email: david.perry@eng.monash.edu.au

cities (Adelaide, Canberra, Brisbane, Darwin, Hobart, Melbourne, Perth, Sydney), some regional cities (Cairns, Townsville, Alice Springs) and possibly some other key stakeholder sites.

CRC Toolkit links

Model(s) will be recommended, based on the Australia wide comparison, for inclusion into the CRC's Catchment Modelling Toolkit. Model(s) simulation executable files will be included into the Toolkit, with the parameter files used in the comparison being available for simulation. Further site calibrations will be added at later dates in cooperation with the model authors.

The next task is to develop methods to generate subdaily rainfall data at sites with limited or no pluviograph data. The regionalisation methods for both DRIP (Jennings, 2003) and the NSRP (Cowpertwait and O'Connell, 1997) will be evaluated.

Further collaboration

In a recent visit to the Australia (June 2003), Paul Cowpertwait had a meeting with us at the Bureau. We will be collaborating with him in using the NSRP model for a single site and later extending it to multiple sites (Cowpertwait *et al.*, 2002). Likewise, collaborations continue between the University of Adelaide (Martin Lambert, Andrew Metcalfe) and the University of Newcastle (George Kuczera) towards improving and spatially generalising DRIP.

We encourage any comments, along with future collaborations with industry partners or other interested researchers.

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Rodriguez-Iturbe, I., Febres de Power, B. and Valdes, J. B. (1987) Rectangular pulse point process models for rainfall: analysis of empirical data. *J. Geophys. Res.* 92,N.D8: 9645-9656.

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PROGRAM 6

**RIVER
RESTORATION**Program Leader
MIKE STEWARDSON**Report by Michael Stewardson and Brian
Finlayson****Re-using Channel Data: The Case for a National
River Channel Database***Victorian data*

As a part of our project on channel geomorphology [Project 6.12(6B): "Predicting spatial and temporal variations in channel form"], Susan Hayes (a research assistant at The University of Melbourne) is searching through archives of various agencies and consulting companies to collate river channel surveys from throughout Victoria. We're planning to use these survey data to explore variations in channel form and physical habitat conditions throughout river networks across the State. By the time Susan finishes up next month there could be up to 100 river surveys in the database. These surveys were undertaken for flood studies, geomorphic assessments and environmental flow projects. They have been provided by our Industry Affiliates (Earth Tech and Sinclair Knight Merz), the Department of Sustainability and Environment, and personal archives of various researchers. These surveys are just the tip of the iceberg of Australian river surveys. Our initial purpose in collating these data was for research in the River Restoration Program. We're now wondering if there is merit in establishing a database of river channel surveys for industry use.

Wider purposes for river channel data

Until recently, channel surveys were mostly for flood studies. With increasing emphasis on environmental management of river channels and flow, these data are being used for a wider range of purposes including monitoring river condition, channel restoration design and environmental flow studies. Multiple surveys can provide a valuable resource for regional planning and research. Surveys from a region can be used to explore variations in channel properties throughout river networks to guide catchment planning activities. Where the same reach has been surveyed on several occasions, we can evaluate the impact of catchment activities on channel properties through time. Where channel disturbances are relatively recent, historical surveys can be a valuable record of the natural state of the channel. An adequate understanding of the

behaviour of a river is only possible when it is viewed over a long period. Putting together the historical data on river behaviour and continuing that into the future would provide researchers and management agencies with the best possible basis for understanding any river system. Australia is extremely well placed to establish such a database. Historical river channel surveys often date back to the very first occupation by Europeans settlers and there are often many subsequent surveys to provide a time series over quite long periods.

Flood plain data

Many river surveys, particularly those undertaken for flood studies, include transects across floodplains. Floodplain topography can be derived from ground surveys, photogrammetry and more recently using Airborne Laser surveying techniques. Such data has long term value for a range of projects including flood management, floodplain land-use planning, environmental flow assessment and research. Victoria already has a statewide flood database which includes floodplain surveys and GIS-based flood inundation maps. Other States may have similar resources. Because of the higher cost of surveys, floodplain surveys are more likely to be preserved in an accessible form. Maybe a National River Survey Database could identify which floodplains have been surveyed, the type of survey and who holds these data.

Advantages of a national database

The advantages of a national database are:

- reducing the cost of accessing prior surveys;
- storing data in a consistent format to simplify processing of survey data;
- avoiding the need to re-survey rivers because prior surveys are not available;
- preserving historic channel surveys for assessing rates of channel change; and
- providing a resource for riverine research.

Need for support

The development of the database will require some investment from resource management agencies as will ongoing maintenance of the database, including the addition of future surveys. A river channel database would need to be supported by a range of State agencies including those with responsibility for the management of water resources, catchment management authorities, environment and heritage, wildlife and fisheries, and ports and harbours. In the private sector, river engineering and environmental

**NEW SOFTWARE -
CHUTE**

www.toolkit.net.au/chute

CHUTE carries out the hydraulic design of rock chutes for stabilising channel beds and is designed for use by professional engineers and managers involved in stream rehabilitation and restoration.

CHUTE is the first of many products that will be available to the land and water industry via the Catchment Modelling Toolkit website at www.toolkit.net.au

The CHUTE software can be downloaded from the Toolkit Members area now at www.toolkit.net.au/members.

For further information including copies of the Rock Chute Design Guidelines, please visit www.toolkit.net.au/chute

consultants would have an interest in the establishment and maintenance of such a database.

If you have a particular interest in this proposal, please contact Michael Stewardson: mjstew@unimelb.edu.au. We are interested in hearing your comments.

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Email: mjstew@unimelb.edu.au

Brian Finlayson

Tel: (03) 8344 6333

Email: brianf@unimelb.edu.au

**COMMUNICATION
AND ADOPTION
PROGRAM**Program Leader
DAVID PERRY**The Flow on Effect – September 2003****At a glance – a summary of this article**

The CRC has committed to holding a Catchment Modelling School in Melbourne during 9-20 February 2004. The School comprises a series of targeted training workshops designed to assist professionals in the natural resource management sector to improve their hydrologic modelling skills. Further details will be made available at www.toolkit.net.au/school as they are confirmed

A Catchment Modelling School?

If your idea of school is uniforms, asphalt playgrounds, morning assembly and a freckly-faced boy who steals your lunch most days then you'll be pleased to know that the CRC's Catchment Modelling School planned for February 2004 will be very different!

The concept of a Catchment Modelling School has arisen from the CRC's experience with training workshops over recent years. Program teams regularly receive requests from many organisations and individuals for training in aspects of catchment hydrology and, in particular, hydrologic based models. Providing training on demand however, is very challenging for CRC staff as we are already committed to a very tight schedule of research and adoption activities. So that we can balance industry's needs and CRC resources, we will host a two week school in Melbourne to assist participants to improve their hydrologic modelling skills and its application.

During Monday 9 to Friday 20 February 2004, the CRC will run the Catchment Modelling School covering a set of modular workshops on aspects of catchment modelling. The School will equip participants with the expertise required to undertake and interpret a range of modelling activities relevant to catchment management. Individual workshops based around the latest modelling principles, practices and products will be held varying in length from a few hours up to three days.

Workshops will be scheduled according to streams of interest, with a range of relevant and related workshops available over a few days. This will enable participants to complete a range of training in a short time. Some of the workshops will be held more than once, subject to demand.

The School will target people in the hydrologic modelling community as well as a range of model users and those

commissioning modelling studies, specifically:

- Technical staff from natural resource management agencies
- Water policy makers
- Water quantity and quality modellers
- Water allocation modellers
- Water economists
- Consultants
- Ecologists

Many workshops will be based around some of the Catchment Modelling Toolkit products that will be familiar to regular *Catchword* readers. These include MUSIC (Version 2.0.0), RAP (River Assessment Program), RRL (Rainfall Runoff Library), TIME (the modelling platform supporting the Toolkit), SEDNET, BC2C and EMSS, just to name a few.

Whilst one of our objectives is to introduce participants to the Catchment Modelling Toolkit software, the School also represents an opportunity for workshops on other models to be delivered. There have been suggestions to hold workshops on HEC-RAS, RORB, IQQM and other industry standards, and we will be inviting appropriate presenters to join the School.

In addition to a series of model-focussed workshops, a series of mini-workshops will be included that address the broader needs of participants. Current suggestions include 'modelling for managers' and 'the art of calibration, verification and validation'.

Planning for the Catchment Modelling School is now underway. To decide the specific program, we will be asking potential participants (for example our *Catchword* readers!) what their most important training needs are. We want to make the School as relevant as possible to industry needs while keeping participants' costs to a minimum. We are hoping to attract more than 200 professionals over the fortnight. No doubt that will also give rise to some social occasions where the finer aspects of modelling and model use can be debated amongst colleagues!

I welcome any feedback or ideas about the Catchment Modelling School. Please contact me by email or phone – see below. Details of arrangements will be published at the Toolkit website as they are finalised (www.toolkit.net.au/school).

I look forward to your participation in what might well become a regular event.

David Perry

Communication and Adoption Program
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POSTGRADUATES AND THEIR PROJECTS

Margot Biggin

It was just over fifteen months ago when I decided to leave a perfectly good job, move from Canberra to Melbourne and launch myself into the world of postgraduate research. Growing up in various parts of New South Wales and spending seven years studying (environmental science) and working in Canberra, moving to Melbourne was not something that was considered until this opportunity for further study came up. I must say it is a really pleasant relief living somewhere that has a pulse. To make things even better, Victorians aren't half as wacky as what they seem when you're looking in from the other side of the border.

When I first started my PhD I knew I wanted to do two things: something on the development of environmental flow methods, and secondly, something on how these environmental flow methods are integrated into water resource allocation and distribution within a catchment. So this led me to be involved with both the water allocation and river restoration programs of the CRC for Catchment Hydrology and carrying out a study that will evaluate the impact of water allocation proposals on hydraulic habitat conditions.

During the first few months of reading literature on the fine art of determining environmental flow allocations and discussions with supervisors, it became apparent that there is a need for the integration of a hydraulic habitat assessment method into water allocation and distribution processes in Victoria. It also became clear that in recent years the emphasis in Australia has been on using hydrological indices or getting together a scientific panel to recommend adequate environmental flow scenarios. While these two methods have a lot of merit, both methods have been found to not adequately quantify the allocation requirements for different instream habitats. This is where hydraulic habitat characteristics come in handy.

Hydraulic habitat characteristics are important in freshwater systems as they determine habitat availability and its condition. This in turn determines what aquatic species can live within that habitat. This study will consider how natural hydraulic habitat characteristics have been altered in rivers subject to irrigation in Victoria. Undertaking this study at a regional scale will lead to a definitive list of hydraulic and hydrological

parameters for use in a preliminary habitat assessment tool. This study will assess how this preliminary assessment tool can be integrated into current water resource allocation planning and distribution processes to not only quantify the impact of proposed allocations on instream habitat, but also aid in the monitoring of the ongoing ecological impacts.

So fifteen months on, the plan for my project is in place and I still love Melbourne's busy but laidback nature. More importantly, I am still enjoying the challenge of my PhD.

Margot Biggin

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CRC PROFILE

Our CRC Profile for September is:

Ross Williams

The last 30 years in the public sector has seen my involvement with several agencies in NSW including: the State Pollution Control Commission, Department of Water Resources, Environment Protection Authority, Department of Land and Water Conservation, and the Department of Sustainable Natural Resources, but the consistent thread over this period has been water. More particularly I have focussed on water quality issues spanning marine, coastal and freshwater.

My career started in 1975 with the NSW State Pollution Control Commission as a scientist in their research branch. This was back in the heady old days when the environment was the new topic on the block – poorly understood and feared by many. Over the years the revolution has turned into evolution with a strong emphasis these days on integrated planning and natural resource management.

My current role is with the newly formed NSW Department of Infrastructure, Planning and Natural Resources (DIPNR) as the General Manager, Centre for Natural Resources (CNR). CNR provides strategic science to support the delivery of DIPNR functions through:

- Effective, efficient, and integrated solutions to complex natural resource issues; where possible utilising collaborative relationships;
- Decision support tools; community accessing the latest scientific/social/economic knowledge and process tools to make effective decisions and trade offs;
- Modelling and mapping; improved natural resource knowledge of status, condition, behaviour, understanding and process models available statewide;
- Standard setting and bench marking based on scientific values;
- Scientific frameworks for natural resource information and data collection;
- Scientific coordination, best practice and quality processes; and
- Laboratories: quality analytical services to support DIPNR and other clients (limited access).

Decisions about planning at an urban and infrastructure level and the allocation and use of natural resources are

frequently contentious – and becoming more so. Science has an important contribution to make to the acceptance and adoption of such decisions by demonstrating that they are well informed, rational, and credible and by providing tools to underpin their implementation.

The establishment of DIPNR provides the opportunity to develop and implement an integrated, leading edge research/science capacity. The scope of science in DIPNR needs to cover biophysical, social and economic considerations that build on our knowledge and understanding.

Science should provide the basis upon which policy is made and create the momentum for issues to be addressed by the policy agenda at an operational level.

Science provides answers to key questions such as:

- What is needed where?
- How much is there?
- How does it work? and
- If we make a change, what effect should it have, and when?

Science can tell us how much risk is involved and how we may learn. It is important to give the community confidence in planning and natural resource management decisions. In our decision making process the level of uncertainty in our knowledge should not prevent us proceeding with solutions. The adaptive management approach has allowed us to proceed with robust solutions while supporting learning.

The above leads to the point that there is an insatiable appetite for knowledge and it is my view that the CRC Catchment Hydrology provides an ideal vehicle for collaborative research servicing water interactions at a catchment level and beyond. As a CRC Catchment Hydrology Board member over the last 4 years I have been particularly interested in promoting an integrated approach to catchment processes/modelling and building strong partnerships between the agencies, industry and universities.

It is an exciting and busy time in all facets of my life at the moment with a young delightful family; new focus within NSW on integrated planning and natural resource management, and greater devolution of decision making to the community; and the CRC Catchment Hydrology embarking on an bold new round of projects and a potential rebid. What more could one want in life?

Ross Williams

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NATIONAL CONFERENCE ON INTEGRATED CATCHMENT MANAGEMENT (ICaM - 2003)

**26-27 November 2003
Parramatta, NSW**

ICaM - 2003 aims to bring together practising scientists, engineers, policy makers, community educators and academics in the field of environment and catchment management.

Case studies from around Australia are especially encouraged, providing delegates with opportunity to share their problems and solutions with the wider water resource community.

For further information about contributing papers or attending please email your query to icam2003@awa.asn.au



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

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- Predicting catchment behaviour
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- Urban stormwater quality
- Climate variability
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The Cooperative Research Centre for Catchment Hydrology is a cooperative venture formed under the Commonwealth CRC Program between:

Brisbane City Council
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