NEWSLETTER OF THE COOPERATIVE RESEARCH CENTRE FOR CATCHMENT HYDROLOGY

CATCHWORD

NO 108 AUGUST 2002

A NOTE FROM THE DIRECTOR

Professor Rob Vertessy

Inside...

COOPERATIVE RESEARCH CENTRE FOR CATCHMENT HYDROLOGY

ONE STEP CLOSER TO A NEW SUITE OF PROJECTS

Our CRC devotes a lot of energy to project planning, via a carefully staged process requiring consultation and scrutiny at a range of levels. This can be exhausting but our experience is that the short-term pain always turns to long-term gain. We are now in the home stretch of the planning process for our next crop of three-year projects which are due to start in January, 2003. At the 29 July meeting in Canberra, our CRC's Governing Board considered 16 research proposal abstracts prepared by our research teams. Half of those proposals were endorsed by the Board for the next stage of development. The researchers leading those proposals now have a green light to prepare full project agreements for consideration by the Board at its 21 November meeting. A further six abstracts are undergoing various levels of revision and will be tabled at the 30 August Board meeting for re-consideration. We expect most of these will be endorsed by the Board at that meeting. Two of the sixteen abstracts presented to the Board were dropped from our portfolio, not for want of quality but because we have limited funds to allocate to new projects.

Although we are in the final stages of planning, the consultation and scrutiny will continue apace. During the writing of the project agreements, the project proponents will be actively communicating with their research teams and all of the CRC Parties. This time around there will be an extra level of consultation involved. In order to achieve our model integration objectives, Program 1 - Predicting Catchment Behaviour - will play a special role in brokering the definition and timing of deliverables for all projects. We are introducing this additional level of planning because it is vital that each project delivers appropriate outputs on schedule so that we can assemble our whole-of-catchment-scale, integrated modelling capability. So, the next few months will be busy for us all as we make a major investment in further project planning. It is a daunting but also exciting time, as there is clear evidence that we are on the verge of achieving something very special.

New management positions in the CRC

I am delighted to welcome three new members to our CRC's senior management team. Erwin Weinmann of Monash University has been appointed as a Deputy Director of the CRC. Erwin has made a major contribution to our flood prediction efforts over the years and is currently contributing to our Sustainable Water Allocation Program. Geoff Podger of the Department of Land and Water Conservation (NSW) takes over my old role as Program Leader of Program 1: Predicting Catchment Behaviour. Geoff is the Principal Hydrologist at DLWC and has been the lead developer of the IQQM model, used for water allocation planning in the states of New South Wales and Queensland. Tim Smith of Griffith University replaces John Fien as Program Leader of our Education and Training Program (Program 8). A specialist in estuarine management, Tim is also a Theme Leader in the Coastal Zone CRC and thus provides a valuable linkage role between our two CRC's. Erwin, Geoff and Tim bring added depth and great new ideas to our management team.

Strengthening ties with other Water Forum CRC's

We are fortunate that the Commonwealth is funding several CRC's related to different aspects of water management. Our own CRC is complemented by the CRC for Freshwater Ecology (CRCFE), the CRC for Coastal Zone, Estuary and Waterway Management (CRCCZEWM), the CRC for Waste Management and Pollution Control (CRCWMPC) and the CRC for Water Quality and Treatment (CRCWQT). Together we form the 'CRC Water Forum'. To date, we have worked fairly independently of one another, but increasingly we are recognising the merits of working more closely together as the need for a whole-of-water-cycle perspective is becoming apparent. Our linkages to CRCFE will revolve around coupling our hydrologic modelling capability to their knowledge of flow-biota interactions, both in rural and urban streams. Our linkages to CRCCZEWM will focus on linking our predictions of catchment pollutant budgets to their models of estuarine and coastal hydrodynamics. We are strengthening pre-existing relationships with these two CRC's, and we are now exploring linkages to a third CRC from the Water Forum. The CRCWQT has developed models of pathogen generation, transport and fate which are now ripe for coupling to our catchment hydrology models. Whilst our discussions have been limited and our ideas are still embryonic, it is obvious to me that there is a strong mutual benefit to be gained in working together.

Rob Vertessy
Tel: (02) 6246 5790
Email: rob.vertessy@csiro.au

NEW TECHNICAL REPORT

THE STATUS OF CATCHMENT MODELLING IN AUSTRALIA

by

Frances Marston
Robert Argent
Rob Vertessy
Susan Cuddy
Joel Rahman

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

New Program Leader

I am very honoured to be offered the position as Program Leader for Program 1. I would like to thank the Department of Land and Water Conservation, NSW (DLWC) for allowing me to take on this job. In particular, I would like to thank Dugald Black and Ross Williams for their efforts and support.

I have been told that I am the first industry participant to become a Program Leader. I think that this shows the CRC for Catchment Hydrology's commitment to working with industry over the next 3.5 years. I hope that with my industry experience I can assist in building much closer links between the CRC and industry.

Although I have a DLWC perspective, most of the State agencies have similar objectives, particularly with regard to the Murray-Darling Basin. The agencies are concerned with water rights, water allocation, water trading and water quality, and in particular salinity.

Industry cannot solve these problems in isolation; we need to work together accessing all of the skills necessary to address these issues. The CRC for Catchment Hydrology provides the means to bring together experts in a variety of fields from both industry and academia to address these issues.

Program 1 provides a particularly strong link between the CRC and industry, where research is turned into tools that can be used by industry.

Progress so far

After a very inspiring welcome to the new position from Rob Vertessy, came the crunch "by the way you need to write about Program 1 in August *Catchword*". Thanks Rob. However, I am not coming into this Program without involvement in the CRC, in particular, I have been closely involved in Program 1 through the various TAG meetings.

From the perspective of a TAG member, and an industry representative, it is apparent that there has been quite a lot of research over the past three years with some products delivered. Program 1 has investigated and evaluated modelling environments from around the world and has delivered some prototypes of the toolkit such as ICMS and EMSS.

I believe there are two major concerns for industry. Firstly, that the research is addressing their needs, secondly, that products are delivered that can be readily used by industry. Examples of these products are MUSIC and SEDNET.

Where to from here

Over the project period (to early 2006), the focus for Program 1 is going to be on delivery of products to meet industry needs. We now know how the modelling toolkit is going to be developed. Joel Rahman has reported (July *Catchword*) on the progress that has already been made with TIME. We hope to build on this by incorporating some of the research developed over the past 3 years, into TIME.

Program 1 will be looking for clear links with all of the other Programs within the CRC. This will be achieved by defining deliverables and linkages within the projects in these Programs. The project briefs have a requirement to identify the linkages to industry and other projects. Program 1 will be looking for deliverables from each of the projects such as methodologies, modules and parameter sets that can be incorporated into the toolkit. Program 1 will also provide a means of connecting together the various input and output data sets required and generated from each of the projects.

The toolkit will evolve over the project term, incorporating research from other projects as it is delivered. The toolkit will need to link with industry models. The initial linkage will be via data exchange but this will evolve over time with the toolkit absorbing more and more of the facilities out of the existing models. Hopefully the toolkit will reach a stage of development where most of the facilities that already exist in industry models, plus many more useful tools, will be available. This approach should encourage industry and others to use the toolkit.

Geoff Podger
Tel: (02) 9895 7480
Email: gpodger@dlwc.nsw.gov.au

PROGRAM 2

LAND-USE IMPACTS ON RIVERS

Program Leader
PETER HAIRSINE

Report by Peter Wallbrink

Using tracers to estimate how long fine sediment stays in river channels

Why is it important?

In Australia, fine grained sediment is recognised as a significant river contaminant. Catchment restoration efforts now often focus on revegetating gully networks or re-establishing riparian corridors in order to turn off the source of the pollutants. There is no doubt that such efforts will eventually improve downstream water quality. How long before such improvements are seen remains unanswered, and is difficult to quantify without realistic estimates of the residence time of the sediment in the channels. In this article we present a method for estimating such residence times.

How the method works

All soil surfaces have been labelled by radioactive fallout - esentially ^{137}Cs and ^{210}Pb. Caesium was deposited by above ground nuclear weapons testing during the 1950's and 60s and strongly sorbs onto fine grained particles. Fallout ^{210}Pb also binds strongly to fine grained particles and is the product of continuous atmospheric decay of a naturally occurring gas called radon (^{222}Rn). The two radionuclides have different half-lives, Caesium 30 years, and $^{210}Pb_{ex}$ 22.3 years. The useful thing about them is that i) the ratio of $^{210}Pb_{ex}$ to ^{137}Cs in soils varies with depth; and ii) the overall ratio between them in bulk soils is roughly constant from year to year allowing for decay and atmospheric inputs.

Once a particle is detached from the soil and transported into the fluvial system, it can then accumulate additional fallout ^{210}Pb by direct deposition. So, as storage time in the river increases, the sediments can attain higher ^{210}Pb activities and higher ^{210}Pb/^{137}Cs activity ratios than those of the catchment soils from which they were derived. If the additional amount of ^{210}Pb added to the sediment during its storage in the river can be estimated, then the time required to attain that amount can be calculated if the annual ^{210}Pb input rate is known.

Where did we try the method?

We applied this method to the Brisbane and Logan Rivers in SE Queensland. Their catchments adjoin one another, have similar land-uses, areas, lithologies, and are the predominant sediment sources to Moreton Bay. Their sediment yields increased rapidly in the 19th Century, particularly in the first three decades following settlement. In a detailed analysis of the catchment, Caitcheon et al. (2001) show that the primary sediment sources are subsoil erosion (75%) from the gullies and channels and surface erosion (25%) from cultivated land.

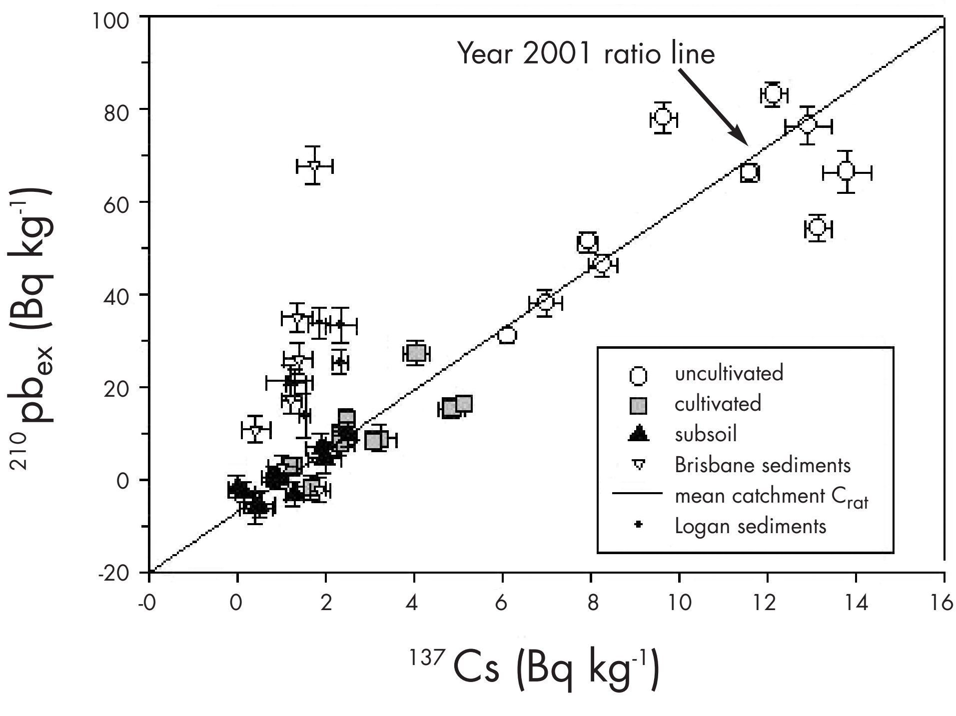

Figure 2.1: Concentrations of ^{137}Cs and $^{210}Pb_{ex}$ on <10 µm deposited sediments and erosion sources of the Brisbane and Logan River systems

RECENT TECHNICAL REPORT

CATCHMENT SCALE MODELLING OF RUNOFF, SEDIMENT AND NUTRIENT LOADS FOR THE SOUTH-EAST QUEENSLAND EMSS

by

Francis Chiew
Philip Scanlon
Rob Vertessy
Fred Watson

Report 02/1

In a jointly-funded study, the South East Queensland Regional Water Quality Management Strategy and the CRC developed an Environmental Management Support System (EMSS) to simulate runoff and pollutant movement across the South East Queensland region.

This report summarises a vital part of the research that went into the development of the EMSS. It describes the runoff and pollutant load model used in the EMSS and recommends model parameter values for use in the South East Queensland region.

Copies available through the Centre Office for $27.50.

RECENT TECHNICAL REPORT

ESTIMATION OF POLLUTANT CONCENTRATIONS FOR EMSS MODELLING OF THE SOUTH EAST QUEENSLAND REGION

by
Francis Chiew
Philip Scanlon

Report 02/2

In a jointly-funded study, the South East Queensland Regional Water Quality Management Strategy and the CRC developed an Environmental Management Support System (EMSS) to simulate runoff and pollutant movement across the South East Queensland region.

This report summarises a vital part of the research that went into the development of the EMSS. It recommends appropriate pollutant loading values for adoption in the EMSS. The work reported here is based on a very extensive data-mining exercise where the authors scoured reports and databases compiled by several organisations and scientists. In so doing, they have added significant value to work initiated by others.

Copies are available through the Centre Office for $27.50

For further information contact the Centre Office on 03 9905 2704

How we applied the method

Some 750 samples were collected from the Logan and Brisbane River catchments to characterise the ^{210}Pb and ^{137}Cs activities in recently eroded sediment. They were divided into three erosion source classes (i) uncultivated lands, (ii) cultivated lands and (iii) subsoil erosion from channels and gullies. Ten composite samples from each erosion class (representing 25 individual samples) were analysed. The <10 μm fraction was separated from each of the combined samples and then analysed for ^{210}Pb$_{ex}$ and ^{137}Cs. Sediments from the Brisbane and Logan rivers were collected from the river bed above the tidal limit during a period of low flow. The <10 μm fraction of these sediments was also analysed for ^{210}Pb$_{ex}$ and ^{137}Cs.

What did we find?

The ^{210}Pb$_{ex}$ and ^{137}Cs concentrations (Bq kg^{-1}) on the catchment samples from the three erosion source classes are shown in Figure 2.1. The mean ^{210}Pb$_{ex}$ and ^{137}Cs ratio of the different catchment sources is 4.1±1.4 (defined by the solid line). The fallout tracer concentrations on sediments from the Brisbane and Logan Rivers are also shown in Figure 2.1. Their mean ratios are 15.7±4.7 and 14.3±1.3 respectively; considerably higher than the catchment sources.

What does it all mean?

We believe that the higher ^{210}Pb$_{ex}$ to ^{137}Cs ratio on the sediments results from the storage of sediment in the channel combined with the direct addition of ^{210}Pb$_{ex}$. Using the following assumptions:

i) no desorption of ^{137}Cs from the sediments occurs during transport,

ii) the catchment sampling characterises the range of erodible ^{137}Cs and ^{210}Pb soil activities,

iii) the ^{210}Pb$_{ex}$ is thoroughly mixed within the sediment layer,

iv) constant deposition of ^{210}Pb$_{ex}$ occurs over the sediment storage time; and

v) the active sediment layer in the river channels is less than 20 mm thick

we construct the series of residence time curves, given in Figure 2.2.

These plot the predicted residence time of the river sediment in years versus the measured values of ^{210}Pb$_{ex}$ (C_t) on the sediments themselves.

As an example of the effect of sediment thickness on residence time, the most downstream value of ^{210}Pb$_{ex}$ activity in the Brisbane River sediment (C_t = 26.3±3.4 Bq kg^{-1}) yields a value of t = 6 yrs for a sediment thickness of 20 mm and t = 0 years for thickness of 1 mm. Using the relationship of Figure 2.2, the range of measured C_t concentrations provide residence times of 0 - 21 years for the Brisbane and 0 - 9 years for the Logan. Their mean residence times (derived from the average of their C_t values) is 5.1 and 5.7 years respectively, assuming a sediment thickness of 20 mm.

A check of the method

A simple manipulation of the known river sediment loads and channel dimensions can be used to check our method. Approximately 400,000 t yr^{-1} (or 200,000 m^3 yr^{-1}) of fine sediment is delivered to the mouth of the Brisbane river annually (Caitcheon *et al.*, 2001). A conservative estimate of total channel length in the

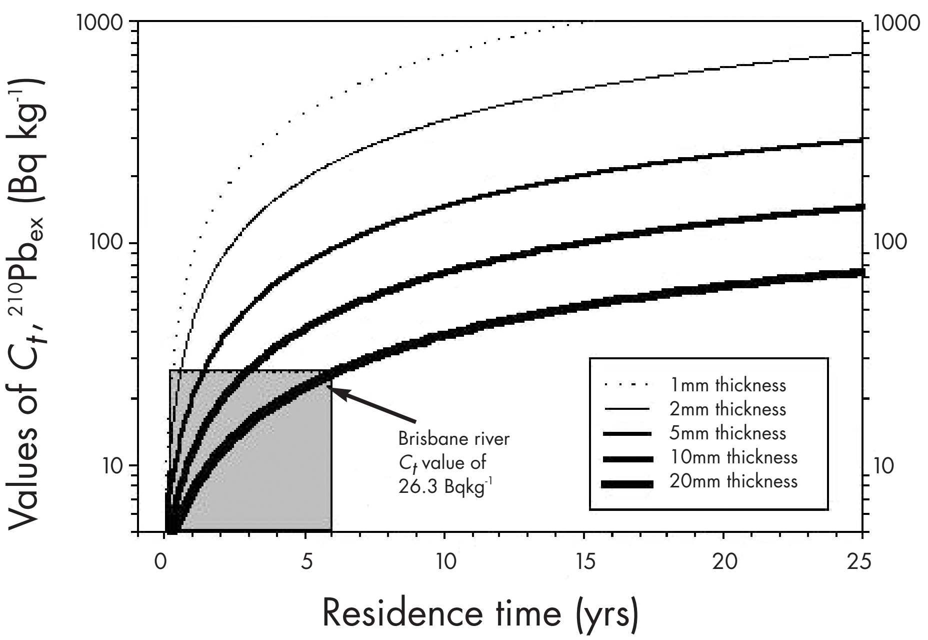

Figure 2.2: Postulated residence time for sediments of different thickness to acquire the C_t concentration measured on deposited Brisbane river sediments.

catchment is about 1000 km, average width is about 100 m. If we assume a mean residence of 5 years (see above) then on average, an amount equivalent to the annual sediment load should be stored on about 200 km of river channel length per year. By dividing the annual sediment mass by this area of channel we derive a value of 10 mm sediment depth. This is within the range of our field observations and within a factor of 2 of the sediment thickness value used in deriving the residence time estimate. Given the uncertainties in both approaches, we believe they are in reasonable agreement.

Implications

Our residence time estimates for the fine sediments in the Brisbane and Logan Rivers imply that the impact of catchment works aiming to decrease sediment loads will probably be observed on a time scale of years to decades. We also believe our method can be applied to most river systems characterised by high - or frequent - flow events. The exception may be dryland rivers with very infrequent (>80 years) transport or flood events. Future work aims to apply this method to rivers of differing spatial scale and catchment form. The benefit of this information is that catchment managers will have a realistic time-frame over which anticipated benefits from rehabilitation efforts may occur. A more detailed explanation of this method can be found in Wallbrink *et al*., (2002) in the upcoming IAHS, redbook series.

We should thank

We acknowledge the support and assistance from CSIRO Land and Water, Mr Danny Hunt (field sampling of catchment samples-laboratory processing of samples); Dr Gary Caitcheon (collection of sediment samples); Mr Haralds Alksnis (radionuclide analyses of catchment sediment soil and sediment samples).

References

Caitcheon, G.G., Prosser, I., Douglas, G., Wallbrink, P.J. Olley, J.M., Hughes, A., Hancock, G. Scott, A., & Stevenson, J. (2001) Sources of sediment in Southeast Queensland: Report on Project SS, Phase 3 for the Southeast Queensland regional Water Quality Strategy, *CSIRO Land and Water Consulting Report*, September 2001.pp1-67.

Wallbrink, P.J. Olley, J.M. and Hancock, G. Estimating residence times of fine sediment in river channels using fallout Pb-210, *In The structure function and management implications of fluvial sedimentary systems*, IAHS Red Book Publ. 276, 425-432.

Peter Wallbrink
Tel: (02) 6246 5823
Email: peter.wallbrink@csiro.au

NEW TECHNICAL REPORT

OPTICAL PROPERTIES OF LEAVES IN THE VISIBLE AND NEAR-INFRARED UNDER BEAM AND DIFFUSE RADIANCE

by
Iain Hume
Tim McVicar
Michael Roderick

Report 02/3

Land-use impacts on the water balance and regional hydrology through vegetation. Agricultural and natural resource managers therefore need to know the amount of understorey and overstorey vegetation in these woodlands. Remote sensing has a role in this assessment.

This report describes laboratory studies to determine if the remote sensing signature of tree and grass leaves differ enough to allow them to be unmixed using broad-band satellite data. Additionally, further understanding of the way understorey and overstorey leaves absorb diffuse and beam light was developed. These results provide an avenue forward for remote sensing in this difficult area.

Copies are available through the Centre Office for $27.50

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

CRC PUBLICATIONS LIST

Copies of the Publications List are available on request from the Centre Office on 03 9905 2704 or can be downloaded from the CRC website at

www.catchment.crc.org.au

All prices listed include GST, postage and handling.

The Centre's products can be ordered through the Centre Office.

Contact Virginia Verrelli on:
tel 03 9905 2704
fax 03 9905 5033
email
crcch@eng.monash.edu.au

Centre Office Postal Address:
CRC for Catchment Hydrology
Department of Civil
Engineering
PO Box 60 Monash University
Victoria 3800

PROGRAM 3

SUSTAINABLE WATER ALLOCATION

Program Leader
JOHN TISDELL

Report by John Ward and Nadine Brodeur

Reinforcing Communication and Adoption pathways through workshop evaluations in focus catchments

Adoption - a major performance measure

The level of adoption of research outcomes is the major performance measure of the CRC for Catchment Hydrology. In drafting the communication and adoption strategy for Project 3.2, delegates from the investor group were identified as playing a pivotal role as enthusiastic advocates and communicators of the project outputs. The experimental economic methods used in the research of the project are also proving to be excellent communication and adoption instruments.

Testing water market views

Experimental economic methods are employed in Project 3.2 to test the reactions and attitudes of water market participants in formalised and repeatable water market experiments in both laboratory and field settings. It is envisaged that such methods will become a widely adopted in facilitating:

1) the rapid and formalised assessment of water reform measures and policy initiatives at both the institutional and physical scales and to;

2) provide a primary educational tool to promote irrigator understanding of and competence in market based water transfers in addition to mitigating the high levels of water market scepticism and mis-understanding observed in the responses to the Projects' 2000 survey program.

Workshops for stakeholders

To support the industry advocates in their promotion of the methods and the project's outputs, several workshops have been organised involving irrigator and management stakeholders in the Murrumbidgee and Goulburn-Broken catchments. The workshops run simulated yearly water trading sessions for 12 participants, with differing farm characteristics, under various market conditions. Although not a representative sample, the results provide a quantifiable evaluation of the methodology by participating irrigators and irrigator group representatives. The quantified enthusiasm shown by workshop participants will help to reinforce the identified communication pathways and the promotion of the research outputs by industry advocates. In addition the workshops:

- partially fulfil the evaluation of Project 3.2's Communication and Adoption strategy;
- through irrigator participation, enhance the understanding of market procedures and processes, helping to ensure water markets do not become thin and consequently subject to poor performance and distortion;
- provide valuable data to calibrate the market behaviour of laboratory (university students) and field (irrigators) experimental participants;
- provide an opportunity for irrigators to develop water trading strategies over relevant farm time frames without risk to their farm assets;
- enable a longitudinal comparison of anecdotal irrigator attitudes to water markets and trading.

Workshop format and approach

Full day workshops were held at the Yanco Agricultural College on the 15 and 16 July and Goulburn- Murray's training facility at Tatura on the 18 July. Up to 14 people attended the Yanco sessions, comprising irrigators and industry representatives (Coleambally Irrigation Pty Ltd, MIA Council of Horticulture Association, Murrumbidgee Irrigation Pty Ltd, Murrumbidgee Private Irrigators, NSW Farmers Association and the Rice Growers Association).

Following orientation and an explanation of the experimental market rules and procedures, workshop participants were provided with farm-specific spatial characteristics, crop watering schedules, water values and variable rainfall.

The experimental method encourages players to develop and implement farm management strategies incorporating various flexible combinations of water trading, irrigation rates and cropping levels.

Economic outcomes are measured as group and individual aggregate farm income (comprising crop and net market income) calibrated to an optimising algorithm. As a metric of environmental flow, the volume of monthly aggregate water extractions is compared to historic mean natural flows. The experimental treatments reflect two levels of market information; either suppressed or disclosed monthly bid prices and volumes.

Market trading views and behaviour

Anecdotally, there was an increased acceptance of water trading by the Murrumbidgee participants compared to the 2001 workshop, reflected in part by the aggressive market activity in concert with an increased willingness to trade water in lieu of growing a crop. The vigorous market trading was associated with substantially increased and sustained market prices.

Trading levels at the Tatura workshop, measured as equilibrium prices and volumes, were comparable with the 2001 workshop, reflecting a generalised attitude of risk aversion and market familiarity.

At all workshops, the level of trading activity was substantially enhanced following an explanation of the determination of market prices. Most participants considered this as a seminal workshop outcome, indicating a widespread lack of understanding of fundamental water market processes, corroborating one of the 2000 survey findings.

Table 3.1 summarises the workshop assessment by participants at Yanco and Tatura. The responses to an open-ended question inviting personal comments indicate a very positive response to the market simulations, to the workshop format, to the method of facilitation and the degree of information exchange.

Insights from workshop

In the context of the Project 3.2's research agenda, the primary objectives of the catchment workshops were the compilation of data for field and laboratory comparison, software field-testing and an appraisal of anecdotal comments indicative of catchment-specific attitudes to water markets and trading in general.

Evaluation of the communication and adoption strategy, whilst initially a subsidiary workshop objective, has assumed increasing importance and status.

Additionally, the workshops have yielded insights into the:

- identification of alternate communication and adoption pathways and
- an indicative quantifiable stakeholder endorsement of the main communication pathway proposed in Project 3.2's Communication and Adoption Strategy

It is envisaged that the endorsement of the workshops and the experimental methodology by participant irrigators provides encouragement and motivation to industry delegates, for the continued promotion, advocacy and adoption of the research outcomes and tools developed by Project 3.2. The Communication and Adoption Strategy developed for Project 3.2 articulates an adoption vision and provides a structured forum and focus for interaction between project researchers and identified stakeholders, thus improving the level of successful adoption. The workshop outcomes reinforce the notion that the interaction is likely to be fluid and iterative.

John Ward
Tel: (07) 3875 7308
Email: john.ward@mailbox.gu.edu.au

Nadine Brodeur
Tel: (07) 3875 5506
Email: s2121889@student.gu.edu.au

Table 3.1 Participant appraisal of Project 3.2's water market workshops

Table 3.1 Workshop Assessment

	Murrumbidgee (15 July 2002) (n=14)*			Murrumbidgee (16 July 2002) (n=14)			Murrumbidgee (18 July 2002) (n=12)		
Question	**very**	**somewhat**	**not really**	**very**	**somewhat**	**not really**	**very**	**somewhat**	**not really**
Did you feel the workshop was informative?	8	6	0	12	2	0	12	0	0
Do you feel more confident in your understanding of water markets?	8	6	1	11	3	0	11	1	0
Would you recommend future workshops to colleagues	13	1	0	12	2	0	12	0	0

* *The responses to the Yanco 15 July 2002 session reflect software and computer delays initiated by players trading beyond their experimental means, a feature now rectified that may not have been readily detected without the workshop interaction.*

NEW TECHNICAL REPORT

THE DEVELOPMENT OF WATER REFORM IN AUSTRALIA

by
John Tisdell
John Ward
Tony Grudzinski

Report 02/5

The first phase of the CRC Project 3.2 'Enhancement of the Water Market reform Process' was to gather background information on water management in Australia, and water reform and water trading in particular. Part of this important process is to gain an overview of the nature of water, a history of water management in Australia, and current literature on water reform. This report is a summary of that overview and contributes to a greater understanding of water management in Australia and its future.

This report is now available from the Centre Office for $33.00.

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

UPCOMING CONFERENCE

SECOND NATIONAL CONFERENCE ON WATER SENSITIVE URBAN DESIGN

2-4 September 2002 Brisbane, Australia

The Second National Conference on Water Sensitive Urban Design (WSUD) will be held on 2-4 September 2002 at the Brisbane Convention and Exhibition Centre, Brisbane in Queensland. The conference has been programmed to precede the River Symposium (4-6 September 2002).

Who should attend?

- Water managers (eg. state and local government)
- Development industries
- Consulting and development engineers
- Environmental scientists
- Asset managers
- Urban planners
- Academics and researchers
- Landscape architects

Further detail and a registration form is available at www.catchment.crc.org.au/news

For further information about the program, themes or sponsorship opportunities contact the Queensland Branch of the Australian Water Association on tel: (07) 3397 5644, fax: (07) 3397 5283 or email: awaq@powerup.com.au

PROGRAM 4

URBAN STORMWATER QUALITY

Program Leader
TIM FLETCHER

By Lucy Peljo and Tim Fletcher*

** with contributions from Jodie Fielding, Anne Simi and Catherine Papa*

Brisbane City Council's Stormwater Quality Monitoring Program

Background

Over the past decade, the quality of stormwater runoff from urban catchments has become of increasing public and scientific interest. Initially, the vast majority of investigative work in this area was carried out in southern states by government authorities and universities in Victoria, New South Wales and the Australian Capital Territory. To ensure that stormwater strategies are based on local information, Brisbane City Council commenced a monitoring program in 1994 to obtain data on stormwater quality in South East Queensland. Since its inception, the monitoring program has gradually expanded to become one of the most comprehensive of its type in Australia.

Consultants and government bodies throughout Queensland use the results of the program for a variety of purposes, including water quality modelling. As such, Brisbane City Council has developed a set of guidelines to assist with this modelling. These are the 'Guidelines for Pollutant Export Modelling' in Brisbane. In the past these have focussed on pollutant export relationships for use in the water quality model AQUALM. However, with the release of MUSIC these guidelines are being updated to incorporate calibration parameters and default pollutant concentration parameters. An updated version of the guidelines incorporating MUSIC parameters will be released in the next three months. Some preliminary estimates of these parameters are presented in this article. However, the estimates are subject to further verification, and should be utilised with caution until then.

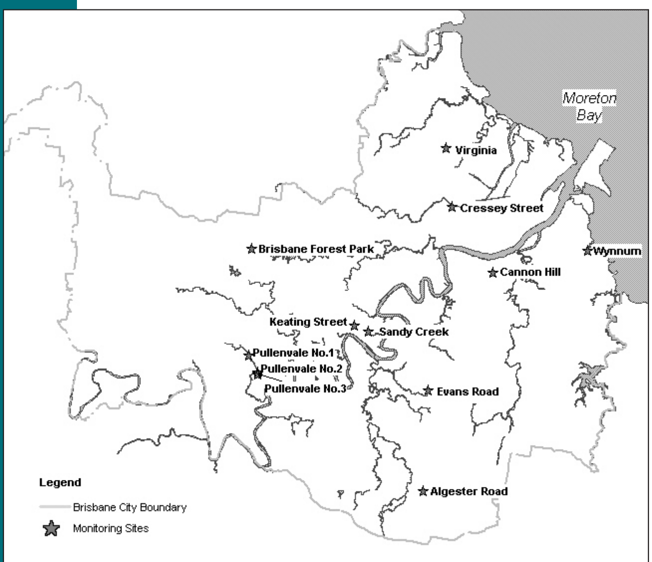

Figure 4.1 Location of sites.

Sampling

Since the monitoring program commenced in 1994 data has been collected from twelve sites across Brisbane with a variety of upstream land uses (Figure 4.1). These include:

- urban residential (2 sites)
- commercial (2 sites)
- industrial (2 sites)
- rural residential (2 sites)
- forested (1 site)
- developing - change in land use (3 sites).

This article details the results from the urban residential, commercial, industrial and rural residential land uses only. There have been limited data collected for the forested land use to date, and the results from the 'developing land use' sites are yet to be fully analysed.

Automatic samplers have been installed at each site to collect event mean concentrations (EMC) during storm events. Base flow (or low flow) monitoring has also been undertaken regularly at each site. Samples from both the storm and base flows are analysed for total suspended solids (TSS), total nitrogen (TN) and total phosphorus (TP).

In addition, a refrigerated sampler is being rotated between the different land uses to gather data on a wider range of pollutants, including nutrient speciation, heavy metals, pesticides, hydrocarbons and particle size distribution of TSS. Samples are also being analysed to determine the distribution of contaminants over the particle size range of TSS (refer to the February 2002 edition of *Catchword* for similar research being undertaken in Melbourne).

To date, the refrigerated sampler has been installed to monitor runoff from a commercial catchment and an industrial catchment. The refrigerated sampler will next be installed at one of the urban residential catchments.

Results

A summary of pollutant concentrations for both storm events and low flows to date is presented in Table 4.1.

Analysis conducted on the raw data for all sites indicated that the data were log-normally distributed, consistent with the findings of Duncan (1999). Therefore, the data were transformed (Log_{10}) and checked for normality prior to further statistical analysis.

Calibrating MUSIC parameters for Brisbane City - preliminary analysis

The current default pollutant concentration parameters in MUSIC are based on the means of the EMC data from a

Land Use	Parameter	Total Suspended Solids (mg/L)		Total Phosphorus (mg/L)		Total Nitrogen (mg/L)	
		Base Flow	Storm Flow	Base Flow	Storm Flow	Base Flow	Storm Flow
Urban Residential	No. Samples	244	205	224	180	217	174
	Mean	14.6	240	0.14	0.45	1.79	2.12
	Std Deviation	17.7	288	0.17	0.47	1.59	1.21
Commercial	No. Samples	120	105	119	103	120	102
	Mean	12.6	209	0.52	0.68	2.94	3.23
	Std Deviation	27.1	229	1.06	1.44	3.49	3.24
Industrial	No. Samples	84	63	84	62	84	62
	Mean	14.3	156	0.16	0.40	1.50	2.67
	Std Deviation	44.1	191	0.20	0.39	0.87	2.87
Rural Residential	No. Samples	97	44	97	44	97	44
	Mean	<5	376	0.06	0.36	0.42	2.76
	Std Deviation	4.16	351	0.16	0.22	0.28	2.00

Table 4.1 Summary of pollutant concentrations

Table 4.2: Preliminary base and storm flow concentration parameters for MUSIC

Land Use	Parameter	Total Suspended Solids (Log_{10}mg/L)		Total Phosphorus (Log_{10}mg/L)		Total Nitrogen (Log_{10}mg/L)	
		Base Flow	Storm Flow	Base Flow	Storm Flow	Base Flow	Storm Flow
Urban Residential	Mean	0.99	2.18	-0.95	-0.47	0.19	0.26
	Std Deviation	0.38	0.39	0.34	0.30	0.19	0.23
Commercial	Mean	0.82	2.17	-0.66	-0.40	0.35	0.37
	Std Deviation	0.40	0.39	0.49	0.35	0.30	0.33
Industrial	Mean	0.78	1.96	-1,15	-0.56	0.12	0.28
	Std Deviation	0.44	0.44	0.44	0.37	0.19	0.33
Rural Residential	Mean	0.54	2.36	-1.52	-0.52	-0.52	0.36
	Std Deviation	0.24	0.51	0.41	0.27	0.42	0.25
EXISTING MUSIC DEFAULTS (after Duncan, 1999)							
Urban	Mean	1.10	2.20	-0.82	-0.435	0.32	0.42
	Std Deviation	0.17	0.32	0.19	0.25	0.12	0.19
Agriculture	Mean	1.40	2.30	-0.88	-0.27	0.07	0.59
	Std Deviation	0.13	0.31	0.13	0.30	0.13	0.26
Forest	Mean	0.90	1.90	-1.50	-1.10	-0.14	-0.07
	Std Deviation	0.13	0.20	0.13	0.22	0.13	0.24

world-wide literature review undertaken by Duncan (1999). However, the nature of the data reviewed by Duncan results in standard deviations that reflect mainly the spatial variation (ie. variation between sites), rather than temporal variation (ie. variation within a site, over time). Ideally, the calibrated standard deviations in MUSIC should reflect the variations over time.

Brisbane City stormwater monitoring data provide a valuable resource to estimate mean and standard deviation (in the log domain) concentrations (under both event and base flow conditions) of TSS, TP and TN, for calibrating MUSIC to Brisbane conditions.

The log-transformed data were used to calculate the mean and standard deviation (separately for base flow and event flow conditions) for each land use and pollutant. The mean concentrations were calculated by combining all data within each land use. However, the standard deviation was derived from the mean of the two standard deviations, calculated separately for each of the two sites within a land use. This approach ensures that the standard deviation represents only variation within a site (ie. temporal variation), and not between sites (ie. spatial variation). This approach should be utilised by others wishing to calibrate MUSIC's pollutant concentration parameters for their own region.

The preliminary base and storm flow parameters for use in MUSIC are shown in Table 4.2, along with the existing default parameters from MUSIC (after Duncan, 1999). In general, the Brisbane results are similar to the default MUSIC parameters These preliminary estimates will be reviewed, and published in the updated 'Guidelines for Pollutant Export Modelling in Brisbane.'

Conclusions

The commitment of Brisbane City Council to collecting long-term data for predicting urban stormwater quality is now paying dividends, and providing a valuable resource for guiding stormwater quality management models and strategies throughout the region. The use of these data to calibrate MUSIC to local Brisbane conditions highlights the benefits of collaboration between the CRC's researchers and Brisbane City Council. Continued collaboration over the next four years of the CRC will ensure Brisbane City Council's management of urban stormwater impacts is based on the best available science.

References

Brisbane City Council, (2001/2002). *Stormwater Quality Monitoring Program 2001/2002*, City Design, July 2002.

Duncan, H.P. (1999) *Urban Stormwater Quality: A Statistical Overview*, Report 99/3, Cooperative Research Centre for Catchment Hydrology, February 1999.

Lucy Peljo
Tel: 07 3403 6882
Email: wc1@brisbane.qld.gov.au

Tim Fletcher
Tel: (03) 9905 2599
Email: tim.fletcher@eng.monash.edu.au

WORKING DOCUMENT

GENERATION OF SPATIALLY AVERAGED DAILY RAINFALLS FOR THE YARRA REGION

by

Lionel Siriwardena
Ratnasingham Srikanthan

Working Document 02/1

This document describes the data preparation and the generation of areal average rainfall for the Yarra catchment.

Two daily rainfall generation models, the Transition Probability Matrix (TPM) model and a modified Wang-Nathan Model (WNM), were used to derive spatially averaged daily rainfall sequences for a region encompassing the Yarra catchment in Victoria, one of the focus catchments in the CRC for Catchment Hydrology. The performance of the two data generation models was evaluated with respect to their ability to preserve various important rainfall characteristics at daily, monthly and annual time scales.

Copies are available through the Centre Office for $22.00.

PROGRAM 5

CLIMATE VARIABILITY

Program Leader
FRANCIS CHIEW

Report by Sri Srikanthan

Project: 5.2: National data bank of stochastic climate and streamflow models

Approaches for monthly rainfall and streamflow data

Monthly rainfall data are generally needed in the simulation of water resources systems, and in the estimation of water yield from large catchments.

Monthly streamflow data generation models are usually applied to generate monthly rainfall data. These models, however, do not work for sites which have a significant number of months of no rainfall.

In an earlier study, Srikanthan and McMahon (1985) recommended the method of fragments to disaggregate the annual rainfall data generated by a first order autoregressive model. The main drawbacks of this approach are the inability to preserve the monthly correlation between the first month of a year and last month of the previous year and the repetition of similar patterns from a short length of historic data.

Using streamflow as the example, Maheepala and Perera (1996) proposed a modification to the selection of fragments that preserves the year-end monthly correlation to improve on the first drawback.

Porter and Pink (1991) used synthetic fragments from a Thomas-Fiering monthly (streamflow) model to overcome the second drawback. For sites with considerable number of zero rainfall months, there will be problems with the application of the Thomas-Fiering monthly model. Hence, historical data were used to obtain the fragments, but during data generation process they are selected by using the criterion given in Maheepala and Perera (1996).

Non-parametric method for streamflows

Recently, Sharma and O'Neill (2001) developed a non-parametric approach to model the inter-annual dependence in monthly streamflows. The non-parametric model (NP) preserves both the short term (month to month) as well as the inter-annual (month to year, year to year) dependencies in simulated rainfalls. The model adopted in this study uses only the dependence on the previous month and the previous 12 months rainfall total

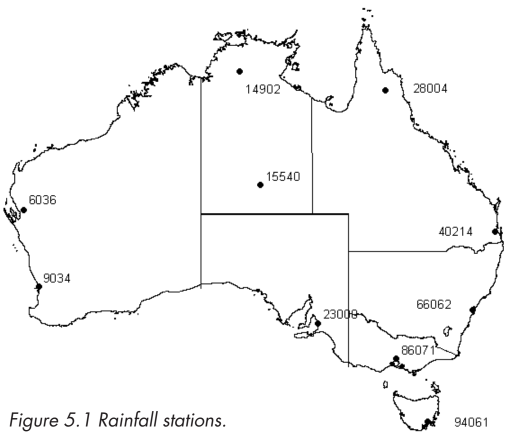

Figure 5.1 Rainfall stations.

In this study, this recent method is compared with the modified method of fragments. Ten rainfall stations were selected to cover the Australian continent. The locations of the selected rainfall stations are shown in Figure 5.1. The number of months of no rainfall varies from 0 to 90%. The large percentage of no rainfall months renders the application of the Thomas-Fiering model to be very difficult.

Advantages of non-parametric method

One hundred replicates, each of length equal to the historical length, were generated and various monthly and annual characteristics were calculated for model comparison. From the results, both models were found to preserve the annual and monthly characteristics adequately. However, the non-parametric model has the following advantages over the method of fragments:

1. It eliminates the need for choosing a starting month for forming annual totals as it uses only the monthly data.
2. It also eliminates the need for having a separate model that simulates the annual rainfall values.
3. It does not repeat the same yearly patterns as in the method of fragments.
4. Minimum rainfalls were generated better than the method of fragments.

Overall comment

In conclusion, the non-parametric model performed marginally better than the modified method of fragments. The work reported here will be published as a CRC for Catchment Hydrology Technical report.

References

Maheepala, S. and Perera, C. J. C., 1996. Monthly hydrologic data generation by disaggregation. J. Hydrol. 178, 277-291.

Porter, J. W. and Pink, B. J., 1991. *A method of synthetic fragments for disaggregation in stochastic data generation*. Hydrology and Water Resources Symposium, Institution of Engineers, Australia, 187-191.

Sharma, A. and O'Neill, R., 2001. A nonparametric approach for representing interannual dependence in monthly streamflow. Submitted to Water Resources Research.

Srikanthan, R. and McMahon, T.A., 1985. *Stochastic generation of rainfall and evaporation data*. AWRC Technical Paper No. 84, 301pp.

Sri Srikanthan
Tel: (03) 9669 4513
Email: sri@bom.gov.au

PROGRAM 6

RIVER RESTORATION

Program Leader
IAN RUTHERFURD

Report by Tony Ladson

Project 6.2 : Optimising urban stream rehabilitation planning and execution

Evaluating stream rehabilitation planning

Background

This month continues the discussion of the urban stream restoration work that is being undertaken by Program 6. Project 6.2 aims to improve urban stream rehabilitation planning and execution. Last month I wrote about one of the parts of Project 6.2,'An adaptive experiment into controls on urban stream health'. In summary, we are proposing to test the effectiveness of constructed wetlands in improving stream health. We expect to see improvements in water quality, some attenuation of small floods and perhaps, some improvement in macroinvertebrate indicators.

The other part of 6.2 is 'Evaluating the effectiveness and feasibility of a stream rehabilitation planning procedure'. Here we are aiming to review urban stream planning techniques and strengthen the methods that are currently used by Melbourne Water. Recent work includes participation in a review of Melbourne Water's strategic waterway management plan and contributions to workshops aiming to improve the STREAMS model of priority setting for waterway activities. These two activities are being led by the Cooperative Research Centre for Freshwater Ecology. We are also planning to contribute to the development of indicators that can be used to assess the condition of urban streams - an urban Index of Stream Condition.

Activities in work on evaluating stream rehabilitation

One of the key activities of this study has been the work undertaken by Josef Kiessner, a visiting student from the University of Agriculture in Vienna, Austria. Josef came to the University of Melbourne to complete his final year project and worked for 9 months from September, 2001 to May, 2002 on urban stream restoration planning. He has now returned to Austria and is writing up his thesis.

Monbulk Creek - research focus

Josef's focus was on Monbulk Creek which flows through an interesting mix of urban and rural development in Melbourne's eastern suburbs. The upper reaches are in a relatively natural condition, draining the Dandenong Ranges National Park around Kallista and Sherbrooke. Downstream there is urban development through Belgrave. Then the creek flows through agricultural land in Lysterfield and new urban areas in Ferntree Gully and Rowville before joining Corhanwarrabul Creek and onto Dandenong Creek just north of Wellington Road.

The lower reaches of Monbulk Creek are subject to many of the pressures that are typical of urban streams, yet there are also opportunities for rehabilitation. This is because there is limited development on some of the floodplain, areas of rural land upstream, and a retarding basin that has the potential to protect the creek from the changes to hydrology caused by urban development around Belgrave. Melbourne Water has also recently been rehabilitating the creek in parallel with construction of a golf course. Willows have been removed, and a series of rock chutes has been built to control bed erosion and to provide in-stream habitat for the aquatic life in the clay-bedded Monbulk Creek.

Research task

Josef's task was to look at planning approaches that could be used to further improve the health of Monbulk Creek. In particular his work involved an application and assessment of the type-specific approach (Leitbild concept), a planning approach that has been developed in Austria to re-establish ecological integrity in riverine landscapes (Jungwirth et al. 2002). This approach focuses on restoring some of the natural attributes of a particular stream rather than providing generic recommendations for restoration. The Leitbild concept was developed in response to deficiencies in past restoration projects that include poor project design and planning, lack of integration of different disciplines, or scaling issues, and inadequate monitoring.

A Vision

The first task in this approach is to define a vision or 'leitbild'. This vision is based on what the stream was like before European settlement and is reconstructed from historical records and, if available, current less impacted sites. For Monbulk Creek, data were available from historical maps and descriptions of the area from early settlers. Early Parish plans from 1855 and 1856 indicate that the lower Monbulk Creek, downstream of Nixon Road (Melway 83J2) to the confluence with Ferny creek, was a vast Tea-tree swamp. There was no defined stream channel in some sections. Early settlers describe the area as being poor and scrubby (Coulson 1959).

Status quo condition

The next step is to assess the status quo, or current condition, and to compare it with the reference conditions to determine deficits and demands. Data on the status quo condition were available from

CONFERENCE PROCEEDINGS

THE THIRD AUSTRALIAN STREAM MANAGEMENT CONFERENCE - THE VALUE OF HEALTHY STREAMS

27-29 August 2001

Brisbane, Queensland

Copies of the Stream Management Conference proceedings are now available for sale from the Centre Office.

The 700+ page, two volume set contains over 120 papers. Copies cost $110 (includes GST and postage) and can be ordered by contacting the

CRC Centre Office
tel 03 9905 2704
fax 03 9905 5033
email
virginia.verrelli@eng.monash.edu.au

Note: Limited copies of the Second Australian Stream Management Conference ($104.50 including GST and postage) are also available.

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.

AWA Bookshop (virtual)
contact Diane Wiesner
Bookshop Manager
tel: 02 9413 1288
fax: 02 9413 1047
email: bookshop@awa.asn.au
web: www.awa.asn.au/bookshop/

NRE Information Centre
8 Nicholson Street (cnr Victoria Parade)
PO Box 500
East Melbourne
Victoria 3002 Australia
publication.sales@nre.vic.gov.au
Phone: 03 9637 8325
Fax: 03 9637 8150
www.nre.vic.gov.au
Open: 8.30-5.30, Monday to Friday

investigations of Melbourne Water Corporation that include a report on geomorphology and a Waterway Activity Plan. Additional investigations were made through field work which comprised mapping, photo documentation, discharge measurements, and the application of an Austrian field protocol to evaluate the geomorphology. Josef modified this protocol as necessary to make it suitable for Australian conditions.

Quantitative data, including cross sections, width to depth ratio, width and depth variance, were collected in the field. The draining of the Tea-tree swamp, catchment clearing, construction of a defined stream channel, rural and urban development is revealed by changes in parish plans, historical documents, a sequence of aerial photographs and the annual updates of the Melway street directory.

Assessing the status quo included a detailed assessment of stream hydrology and hydraulics to predict channel stability from the frequency of bankfull flow, and the corresponding stream power and shear stress. Bankfull discharge was estimated from field measurements of channel size and slope, along with selection of a Manning's n value. Bankfull discharge frequency was determined from a partial flood frequency analysis of flows from the gauge on Monbulk Creek in Tecoma, which is upstream of the retarding basin at Birdsland Reserve. For a given recurrence interval, the discharge downstream of the retarding basin was calculated using a RORB model.

Bankfull flow is expected to occur with a frequency of 1 to 2 years for streams that are in balance with their water and sediment inputs. Similarly, bankfull stream power is expected to be about 35 W/m^2 for stable streams (Brookes, 1988) while critical values for bankfull shear stress can be calculated from bed material size. Where the actual values depart from the critical values, stream processes are likely to alter the size and slope of the channel. Although these methods are all approximate, in combination they are likely to be a reasonable approach to predicting where channel adjustment is most likely. These areas have now been mapped along Monbulk Creek.

Target view for Monbulk Creek

The next step in the type-specific approach to stream restoration is to develop an "operational leitbild" or target view. This aims to move the stream toward reference conditions while recognising that it may not be desirable or achievable to make the stream completely natural. This target view guides the development of a rehabilitation design that takes account of the specific characteristics of the stream and aims to restore key features that have been lost. The operational leitbild considers the social and economic constraints that may prevent complete restoration. It is also important to identify the features that should be protected from further degradation and the current geomorphic trajectory.

For the Monbulk Creek, Josef is developing a target view and rehabilitation plan to restore some of the features of the stream that existed under natural conditions. In particular this involves increasing the frequency of connection between the stream and the floodplain and restoring some of the wetlands and Tea-tree swamps. Unfortunately, it's a little late to incorporate these features into the new Waterford Valley golf course but perhaps they could guide the next development upstream.

As well as developing his Monbulk Creek plan, Josef is evaluating the type-specific approach, commenting on its suitability for Australian conditions and identifying any modifications that may be required. One finding is that the formal assessment of reference conditions provides a method to overcome the difficult step of setting goals for stream rehabilitation. The approach has also confirmed the need to identify, and if possible address, the processes leading to stream degradation (see Hobbs and Norton. 1996). It is not enough to just provide a list of activities required to restore streams, as these will never be successful unless the cause of the degradation is mitigated.

References

Brookes, A. (1988). Channelized rivers: perspectives for environmental management. Chichester, Wiley.

Coulson, H. (1959) Story of the Dandenongs: 1838-1958. F.W.Cheshire, Melbourne.

Hobbs, R. J. and D. A. Norton (1996). Towards a conceptual framework for restoration ecology. *Restoration Ecology* 4: 93-110.

Jungwirth, M. Muhar, S. Schmutz, S. (2002) Re-establishing and assessing ecological integrity in riverine landscapes, *Freshwater Biology*, 47: 867-887.

Tony Ladson
Tel: (03) 9905 4983
Email: tony.ladson@monash.edu.au

PROGRAM 7

COMMUNICATION AND ADOPTION PROGRAM

Program Leader
DAVID PERRY

The Flow on Effect - August 2002

Report by Sara Lloyd and David Perry

AT A GLANCE - A SUMMARY OF THIS ARTICLE

The CRC is publishing another report in our industry report series targeting urban catchment managers. This report - CRC Report 02/10- is entitled 'Water Sensitive Urban Design: A Stormwater Management Perspective'.

Written by Sara Lloyd, Tony Wong and Chris Chesterfield, it will be available through the centre office in early September at a cost of $33.00 (includes GST, postage and handling).

Introduction - Water Sensitive Urban Design

In response to the need for reliable, cost-effective, environmentally friendly, robust and aesthetically pleasing stormwater treatment measures, the Cooperative Research Centre (CRC) for Catchment Hydrology is undertaking 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). WSUD principles can apply to individual houses and streetscapes or to whole catchments.

Water Sensitive Urban Design is a philosophical approach to urban planning and design that aims to minimise the hydrological impacts of urban development on the surrounding environment. Stormwater management is a subset of WSUD directed at providing flood control, flow management, water quality improvements and opportunities to harvest stormwater to supplement mains water for non-potable uses (that is, toilet flushing, garden irrigation etc.).

Responding to industry needs

Regular readers of *Catchword*, particularly those interested in the CRC's Urban Stormwater Quality research Program led by Tim Fletcher will be familiar with Water Sensitive Urban Design as a concept and focus of CRC research.

WSUD has been promoted since 1994 but industry was reluctant to apply the concept without a sound technical basis. Over recent years, the CRC's Urban Stormwater Quality Program team, Melbourne Water, Brisbane City Council, the Urban and Regional Land Corporation and other similar organisations including local government groups have been addressing the key issues in incorporating WSUD principles into stormwater management. This work has resulted in a technical underpinning of WSUD principles and techniques enabling government and commercial organisations to confidently apply the WSUD philosophy.

In response to regular requests for detailed information by urban catchment managers, Sara Lloyd, Tony Wong (Monash University) and Chris Chesterfield (Melbourne Water) have prepared a CRC Industry Report entitled 'Water Sensitive Urban Design: A Stormwater Management Perspective'.

Industry Report overview

The Industry Report is in three sections:

- Developing a Stormwater Management Scheme
- Implementation of a Stormwater Management Scheme: The Lynbrook Estate Demonstration Project
- The Current Status of Water Sensitive Urban Design in Australia

The first section addresses key issues in stormwater management in the context of an integrated urban water cycle. The section structure follows the broad approach to the development of a stormwater management scheme outlined in the document Urban Stormwater: Best Practice Environmental Management Guidelines (Victorian Stormwater Committee, 1999) (Figure 7.1)

The second section uses the Lynbrook Estate Demonstration Project south east of Melbourne in Victoria to demonstrate the implementation phase of a stormwater management scheme. Research findings are presented that quantify water quality improvements attributed to bio-filtration systems and the level of market acceptance and perceptions of changes in urban drainage using WSUD.

The third section briefly discusses key barriers to widespread adoption of WSUD in Australia. The focus is on creating an effective planning framework and examining the performance of hypothetical structural stormwater management strategies and associated life cycle costs.

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 the Lynbrook Estate Demonstration Project in Victoria.

NEW 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 crcch@eng.monash.edu.au

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

UPDATED EVAPOTRANSPIRATION AND RAINFALL MAPS FOR AUSTRALIA

Where to get them!

The CRC for Catchment Hydrology and the Bureau of Meteorology have recently completed a project to produce national maps of evapotranspiration for Australia.

The map set is now available for $33 plus postage and packaging.

They can be purchased from:

1. Publications Section, Bureau of Meteorology, 9th floor, 150 Lonsdale St Melbourne. tel: 03 9669 4000 main switch) and ask for Publications

OR

2. Bureau Regional Offices (all capital cities) Contact details for each Regional Office are available at http://www.bom.gov.au/inside/contacts.shtml

Information about the climate atlas map sets and the digital map data sets can also be obtained from: National Climate Centre Ph: 03 9669 4072 Email: webclim@bom.gov.au

Technical queries about the evapotranspiration modelling can be referred to Dr Francis Chiew at The University of Melbourne email f.chiew@civag.unimelb.edu.au

Any technical queries about the mapping should be referred to Graham de Hoedt tel 03 9669 4714

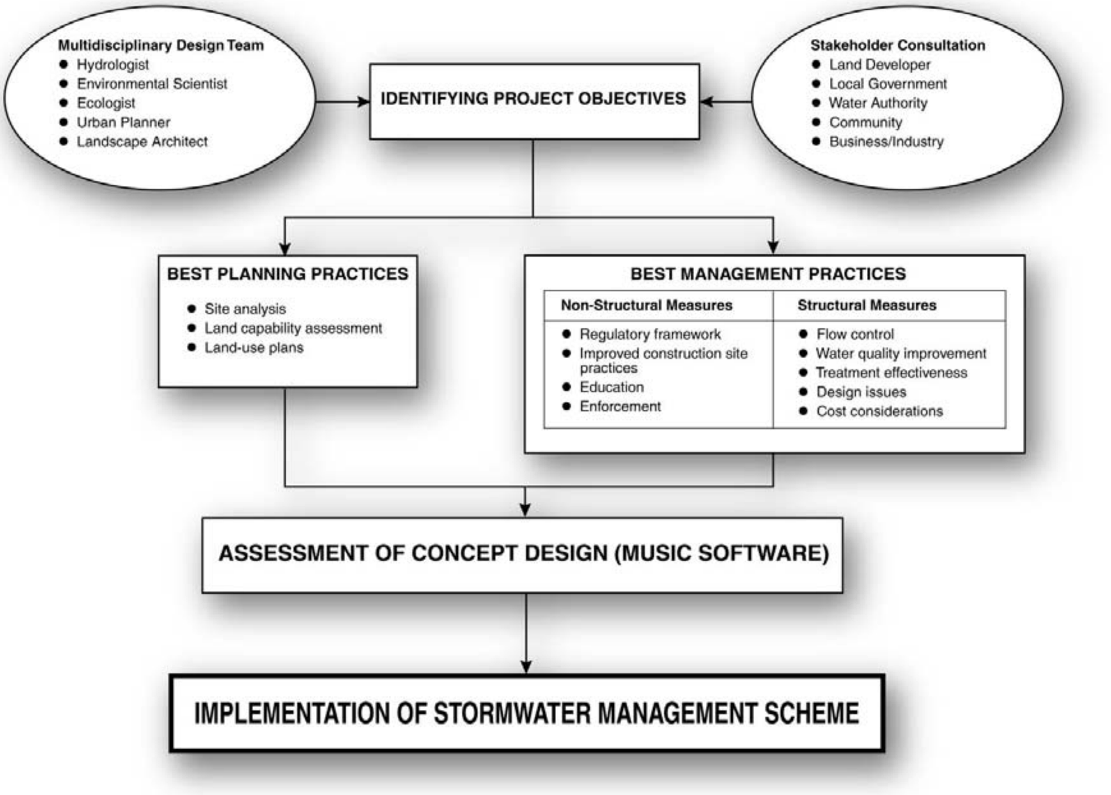

Figure 7.1 Key considerations in the planning, design and assessment of a stormwater management scheme; aspects covered in CRC Industry Report 02/10

Report Availability

Copies of the CRC Industry Report 02/10 will be available from the Centre Office for $33.00 in September 2002. Please contact Virginia Verrelli on 03 9905 2704 or by email crcch@eng.monash.edu.au

If you would like further information about the CRC's research and water sensitive urban design please visit www.catchment.crc.org.au/search. Searching on the term 'water sensitive urban design' results in nearly 70 matches, many of which link to reports and earlier Catchword articles on this theme.

Reference

Victorian Stormwater Committee (1999) Urban Stormwater Best Practice Environmental Management Guidelines, CSIRO Publishing, 268p.

[To obtain copies of this publication tel 03 9662 7666 or visit http://www.publish.csiro.au]

Sara Lloyd
Tel: 03 9905 3837
Email: sara.lloyd@eng.monash.edu.au

David Perry
Communication and Adoption Program
Tel: 03 9905 9600
Fax: 03 9905 5033
Email: david.perry@eng.monash.edu.au

POSTGRADUATES AND THEIR PROJECTS

Subhadra Jha

Hi, my name is Subhadra Jha and I am from Nepal.

It seems like a long time ago that my career began. After an Intermediate in Science (I.Sc) degree from Nepal, in 1978 I completed a B.Sc.Ag. (Hons. in Soil Conservation) with distinction from Punjab Agricultural University, Ludhiana, India.

Following the degree I returned to Nepal and in 1979 started my career as an assistant Soil Conservation Officer with the Department of Soil Conservation and Watershed Management (DSCWM). This Government of Nepal department has responsibility for mitigating soil and water erosion problems. For the first five years I was engaged in planning, designing, and implementing Soil and Water Conservation (SWC) programs for donor-funded projects (USAID and Asian Development Bank projects). These projects were located in ecologically different settings: Himalayas, middle mountain, and plain where issues of SWC were different. There were huge practical field challenges; for instance it took four full days by foot to reach one of the projects from the nearest vehicle access point!

Later on the DSCWM offered me a chance to undertake in 1990 a Masters degree in Forest Hydrology from the University of Georgia, Athens, Georgia, USA. This broadened my knowledge and upgraded my skills. After completing the Masters degree, I resumed work with the DSCWM - this time with different responsibilities and challenges.

I was assigned to various projects for mitigating the soil and water erosion problems of fragile mountain catchments, problems that are triggered by monsoon rain and complex farming systems. There was seldom a match between the degree and complexity of the problems and the availability of resources - especially finance and human resources. However this varied field experience helped me to design a Soil Conservation and the Watershed Management Plan for a district. Later on, I designed a SCWM component of the Land Resources Management Project, the first of its kind focusing on the soil and watershed problems of the entire siwalik and Terai(plain) regions of Nepal. This was part of a World Bank undertaking.

Finally, I took a particularly challenging job as National Co-director of the Bagmati Integrated Watershed Management Project (Phase-II), a European Union undertaking and the biggest project of the DSCWM. The project aimed at improving the livelihood of the rural people through managing 21 sub-catchments. There were major issues to be worked out and developed in order to be able to fulfil the objectives of the project.

In the second year of the project I decided that I should tackle one of the project aims by pursuing PhD studies. I applied to a couple of overseas universities for admission and I was very lucky enough to be offered an International Postgraduate Research Scholarship (IPRS) and a Melbourne International Research Scholarship (MIRS) at The University of Melbourne. Many thanks to Assoc Prof Rodger Grayson, and Prof Tom McMahon of the Department of Civil and Environmental Engineering for making it happen! I arrived in Melbourne and began as a PhD student on the 20 August 2001.

The huge array of research projects of the CRC for Catchment Hydrology gave me an excellent opportunity to choose a project that suited my interests and objectives.

My PhD project has the title "modeling streambank erosion at basin scale" and is co-supervised by Rodger Grayson and Ian Rutherfurd.

The aim of my project is to predict the contribution of sediment from streambank erosion into a river system at basin scale. In order to make the model widely applicable, a generic model will be developed. The extensive Australian databases e.g. gauging records of rivers, the ATLAS of Australian Soils, data recorded for developing the Index of Stream Condition (ISC), State of the Stream Survey (SOS), and Ausrivas are some of the lists that will be explored as potential data sources - aided, of course, by field datasets in developing the proposed model.

It is hoped that the model could be applied in a variety of situations and that it can predict the channel size of stream networks under different riparian conditions in a basin. The project is anticipated to be completed by August 2004.

Subhadra Jha
Tel: (03) 8344 7237
Email: subhadra@civag.unimelb.edu.au

PREFER YOUR *CATCHWORD* BY EMAIL?

Almost one third of *Catchword* readers receive their copy by email. Each month the Centre sends out a pdf copy of *Catchword* to email subscribers as well as a link to the CRC website from which *Catchword* can be downloaded.

If you would like to reduce the paper on your desk please contact the Centre Office on 03 9905 2704 or email virginia.verrelli@eng.monash.edu.au

Over 1200 people receive *Catchword* each month.

WORKING DOCUMENT

GENERATION OF ANNUAL RAINFALL DATA FOR AUSTRALIAN STATIONS

by

Ratnasingham Srikanthan
Tom McMahon
Geoff Pegram
George Kuczera
Mark Thyer

Working Document 02/3

The work reported here forms part of CRC Project 5.2 - National Data Bank of Stochastic Climate and Streamflow Models - of the Climate Variability Program. The literature review (CRC Technical Report 00/16) carried out as part of the project recommended an autoregressive time series model or the Hidden State Markov (HSM) model to generate annual rainfall data.

In this working document, these two models are applied to 44 stations located in various parts of Australia. The performance of the models is assessed using a number of basic and other statistics. Based on this, recommendations are made as to the appropriate model for the generation of annual data.

Copies are available through the Centre Office for $22.00.

CRC PROFILE

Our CRC Profile for August is:

Geoff Podger

I grew up in south-western Sydney until my teenage years when my parents decided that they would prefer the country life. So they bought into a shop, Post Office and telephone exchange in a small country town, Gilgai. The town is located about 500 km north of Sydney and about 10 km south Inverell. This was a bit of shock for a Sydney boy moving to a town of about 300-400 people where everybody knew everybody. Looking back on this, it really was good. I can still go back and bump into many friends.

This is a little scary, as I am showing my age. It is a long time since people relied upon calling a telephone exchange (our house) to make phone calls. Needless to say I can still remember the phone numbers for all of the Doctors, Hospitals and the radio station in Inverell.

All of my family have decided they like the country life, but I chose to move on and go to University and become a Civil Engineer. I rapidly realised that I did not like design and roads and all that traditional civil stuff. I much preferred to punch holes in cards and get a huge metal box to solve quadratic equations. I also found I liked the water subjects - little did I realise where this might head.

Despite the distractions of University life I graduated and decided to find a Civil Engineering job and hopefully go out and design or build things. However, I could not find a good job so I decided on a job with the Maritime Service Board of NSW. They looked at what I had done at University and decided I would be suited to the Hydraulic Research Lab. I think they knew more about me than I did.

I then spent nine years at the Lab doing physical model studies, coastal engineering and writing computer software. I wrote wave refraction, wave diffraction; wave erosion; vessel movement and realtime wave, wind and tide recording systems. This is where I learnt a lot about assembler and Fortran IV and all those bad programming practices that engineers develop.

Getting annoyed with constant restructuring I decided I needed to do some real engineering and I opted for the country life and set up an engineering consultancy in Inverell. However, after two or three portal frame designs, a couple of sub-divisions and many house slabs, I decided writing code was much more rewarding (I must be a computer nerd). Then I started to work with other languages writing commercial code in Pascal and C.

After that I took on a 6-12 month project to develop a daily time step water allocation model for the Department of Water Resources NSW , later to be known as the Integrated Quantity and Quality Model (IQQM). Much to my surprise they wanted it written in Fortran. Time to dust of my old skills, but apply some of the things I learnt in commercial programming. Well, after 12 months they seemed to like what I did and decided to put me on as a permanent employee. They still seem to still like what I do and after nearly ten years I am still working for them, although they are now called the Department of Land and Water Conservation.

I now look forward to my new position at the CRC for Catchment Hydrology as Program Leader for Program 1: 'Predicting Catchment Behaviour'. This is really quite challenging but very exciting. Now I hope to get a lot of computer nerds and geeks to turn some great research into a really useful tool that will be used by a lot of Hydrologists around Australia and hopefully further abroad.

Geoff Podger
Tel: (02) 9895 7480
Email: gpodger@dlwc.nsw.gov.au

WHERE ARE THEY NOW?

Report by Nick Marsh

I'M STILL HERE!!! I never actually left. I'm stuck inside the CRC for Catchment Hydrology like it is The Hotel California.

I joined the CRC for Catchment Hydrology as a Research Assistant at Monash University in 1997 to work on 'A Rehabilitation Manual for Australian Streams'. I would encourage anyone with some serious hard disk space to download all 600pp of the rehabilitation manual from the Land and Water website. You can not only get the book but also the interactive CD of the book and perhaps in the future Channel 7 will make a TV drama series of the book. There are certainly enough characters for a TV drama with 30+ contributors (there is certainly enough material). Working on the manual was perfect preparation for my PhD because I got to understand the range of issues associated with stream rehabilitation (most of them social).

From Monash University I moved to the University of Melbourne to work on my PhD 'Large Woody Debris Loading, Distribution and Scour Hole Formation in Lowland Streams' (still within the CRC for Catchment Hydrology's River Restoration program). My PhD entailed measuring a lot of snags in rivers, brushing up on my fluid mechanics and constructing and running a mobile bed flume experiment in the University of Melbourne's Michell Hydraulic Laboratory. Mid PhD I opted for a change in climate and headed back to my home state of Queensland and to Griffith University in Brisbane. I finally submitted my PhD in December 2001 after several small breaks for other exciting (paying) projects. My thesis is still not back from the examiners so I am currently stuck in that intermediate ground of no longer being a PhD student, and not yet a Doctor. An exciting outcome from my PhD is the likely use of large woody debris (snags) in a stream rehabilitation trial on the Snowy River. It is somehow very gratifying that the focus of my PhD - predicting the creation of habitat due to scour hole formation around snags - may actually get to see the light of day.

Since December 2000 I have been working on CRC Project 6.4 : 'Evaluation of Riparian Revegetation in a South East Queensland Catchment'. Since submitting my PhD I have increased my input into this project. The main focus of Project 6.4 is the quantification of the effect of riparian vegetation on sediment delivery and water temperatures of a small stream. Turbidity and water temperature is continuously monitored using automatic data loggers in the focus stream (Echidna Creek), which has been fully revegetated as well as nearby streams that are either in poor condition and have not been revegetated or are in near natural condition. The project has required some serious background data collection time whilst the vegetation becomes established (and I finish my PhD). We are now about to enter the third growing season of the replanted vegetation and the business end of the data collection and comparison between catchments. The local rainforest species grow like weeds in this part of the world, we are already seeing full canopy cover over the stream in some places. To date all the electronic equipment that was duly purchased from the cheapest supplier have fared well and all our expectations of failed data loggers and vandalised field installations have been without base.

Anyone even vaguely associated with the CRC for Catchment Hydrology will have been involved in the recent process of developing projects for the next round of funding. I have been intimately involved in this process in the hope that I may continue to be involved with the CRC for the next three years in a project to develop flow-biota models for inclusion in the Toolkit. The project is to be jointly run with the CRC for Freshwater Ecology and looks like being a very tidy collaborative project and a real chance to combine computational hydrologic modelling and ecology. The project is looking positive at this stage so I may yet get a fourth life within the CRC.

Overall, I have had a very exciting range of work with the CRC for Catchment Hydrology over the last five years, working on very different projects, completing a PhD (almost) and moving from State to State.

Nick Marsh
Tel: (07) 3875 7101
Email: nick.marsh@mailbox.gu.edu.au

WORKING DOCUMENT

APPLICATION OF HIDDEN STATE MARKOV MODEL TO AUSTRALIAN ANNUAL RAINFALL DATA

by
Ratnasingham Srikanthan
Mark Thyer
George Kuczera
Tom McMahon

Working Document 02/4

In the past, the stochastic generation of annual data was performed generally with a first order autoregressive model which does not explicitly model the observed long periods of wet and dry periods in the annual data. Though geographers and geomorphologists have observed long cycles or changes in the mean level of rainfall and streamflow, it was not explicitly included in annual stochastic data models until the recent work of Thyer and Kuczera (1999, 2000). The model used is referred to as the hidden state Markov (HSM) model.

The purpose of this study is to apply the HSM model to annual rainfall data from a number of rainfall sites across Australia and identify the the sites where a two-state persistence structure was likely to exist.

Copies are available through the Centre Office for $22.00.

DOWNLOAD CRC REPORTS

All of the current CRC's reports (1999-present) are able to be downloaded from our website www.catchment.crc.org.au/ publications

You can use our search engine to find the exact report you are seeking or list all reports that can be downloaded.

CURRENT CRC FOR CATCHMENT HYDROLOGY PUBLICATIONS 1999 - PRESENT

PREDICTING CATCHMENT BEHAVIOUR PROGRAM

02/4 The Status of Catchment Modelling in Australia
by Frances Marston, Robert Argent, Rob Vertessy, Susan Cuddy, Joel Rahman
Technical Report (Price $27.50* per copy)

02/3 Optical Properties of Leaves in the Visible and Near- Infrared Under Beam and Diffuse Radiance
by Iain Hume, Tim McVicar, Michael Roderick
Technical Report (Price $27.50* per copy)

02/2 Estimation of Pollutant Concentrations for EMSS Modelling of the South-East Queensland Region
by Francis Chiew, Philip Scanlon
Technical Report (Price $27.50* per copy)

02/1 Catchment Scale Modelling of Runoff, Sediment and Nutrient Loads for the South-East Queensland EMSS
by Francis Chiew, Philip Scanlon, Rob Vertessy, Fred Watson
Technical Report (Price $27.50* per copy)

00/14 Predicting the Water Yield Impacts of Forest Disturbance in the Maroondah and Thomson Catchments using The Macaque Model
by Murray Peel, Fred Watson, Rob Vertessy, Alex Lau, Ian Watson, Mike Sutton, Bruce Rhodes
Technical Report (Price $27.50* per copy)

99/12 Predicting the Effect of Vegetation Changes on Catchment Average Water Balance
by Lu Zhang, Warrick Dawes and Glen Walker
Technical Report (Price $27.50* per copy)

LAND-USE IMPACTS ON RIVERS PROGRAM

01/8 Implementation of a Mean Annual Water Balance Model within A GIS Framework and Application to the Murray-Darling Basin
by Andrew Bradford, Lu Zhang and Peter Hairsine
Technical Report (Price $27.50*per copy)

99/11 Managing Sediment Sources and Movement in Forests: The Forest Industry and Water Quality
by Jacky Croke, Peter Wallbrink, Peter Fogarty, Peter Hairsine, Simon Mockler, Bob McCormack and Jim Brophy
Industry Report (Price $27.50*per copy)

SUSTAINABLE WATER ALLOCATION PROGRAM

02/9 Water Trading in the Goulburn-Murray Irrigation Scheme
by Wijedasa Hewa Alankarage, Hector Malano, Tom McMahon, Hugh Turral and Garry Smith
Technical Report (Price $27.50*per copy) - available mid September 2002

02/5 The Development of Water Reform in Australia
by John Tisdell, John Ward, Tony Grudzinski
Technical Report (Price $33.00*per copy)

01/5 Irrigator and Community Attitudes to Water Allocation and Trading: A Comparative Study of the Goulburn Broken and Fitzroy Catchments
by John Tisdell, John Ward, Tony Grudzinski
Technical Report (Price $27.50*per copy)

01/3 Irrigator and Community Attitudes to Water Allocation and Trading in the Goulburn Broken Catchment *by John Tisdell, John Ward, Tony Grudzinski, Geoff Earl*
Technical Report (Price $27.50* per copy)

01/2 Irrigator and Community Attitudes to Water Allocation and Trading in the Fitzroy Catchment
by John Tisdell, John Ward, Tony Grudzinski
Technical Report (Price $27.50* per copy)

01/1 Irrigator and Community Attitudes to Water Allocation and Trading in the Murrumbidgee Catchment
by John Tisdell, John Ward, Tony Grudzinski
Technical Report (Price $27.50*per copy)

URBAN STORMWATER QUALITY PROGRAM

01/7 Water Sensitive Urban Design in the Australian Context – Conference Synthesis
by Sara Lloyd
Technical Report (Price $27.50*per copy)

00/1 Water Sensitive Road Design - Design Options for Improving Stormwater Quality of Road Runoff
by Tony Wong, Peter Breen and Sara Lloyd
Technical Report (Price $27.50*per copy)

99/14 The Reuse Potential of Urban Stormwater and Wastewater
by Grace Mitchell, Russell Mein and Tom McMahon
Industry Report (Price $27.50*per copy)

99/13 Blackburn Lake Discharge and Water Quality Monitoring Program: Data Summary and Interpretation
by Sharyn RossRakesh, Chris Gippel, Francis Chiew and Peter Breen
Technical Report (Price $27.50*per copy)

99/8 Effectiveness of Street Sweeping for Stormwater Pollution Control
by Tracey Walker and Tony Wong
Technical Report (Price $27.50*per copy)

CLIMATE VARIABILITY PROGRAM

02/8 Stochastic Generation of Monthly Rainfall Data
by Sri Srikanthan, Tom McMahon, Ashish Sharma
Technical Report (Price $27.50*per copy) - available late August 2002

02/7 On the Calibration of Australian Weather Radars
by Alan Seed, Lionel Siriwardena, Xudong Sun, Phillip Jordan, Jim Elliott
Technical Report (Price $27.50*per copy) - available late August 2002

02/6 Stochastic Generation of Annual Rainfall Data
by Ratnasingham Srikanthan, George Kuczera, Mark Thyer, Tom McMahon
Technical Report (Price $27.50*per copy)

01/4 Monte Carlo Simulation of Flood Frequency Curves from Rainfall
by Ataur Rahman, Erwin Weinmann, Tam Hoang, Eric Laurenson, Rory Nathan
Technical Report (Price $27.50*per copy)

00/16 Stochastic Generation of Climate Data: A Review
by Ratnasingham Srikanthan, Tom McMahon
Technical Report (Price $27.50*per copy)

RIVER RESTORATION PROGRAM

01/6 The Calculation of Streamflow from Measurements of Stage
by John Fenton, Robert Keller
Technical Report (Price $27.50*per copy)

99/10 Guidelines for Stabilising Streambanks with Riparian Vegetation
by Bruce Abernethy, Ian Rutherfurd
Technical Report (Price $27.50*per copy)

STREAM MANAGEMENT CONFERENCE PROCEEDINGS

- Third Australian Stream Management Conference Proceedings: The Value of Healthy Streams
27-29 August 2001 Brisbane, Queensland.
Edited by Ian Rutherfurd, Fran Sheldon, Gary Brierly and Chris Kenyon
The two volume set contains over 120 papers (700+pp) (Price $110.00* per set)
- Second Australian Stream Management Conference Proceedings: The Challenge of Rehabilitating Australia's Streams. 8-11 February 1999 Adelaide, South Australia
Edited by Ian Rutherfurd, Rebecca Bartley
The two volume set contains over 150 papers (750+pp) (Price $104.50*per set)

SOFTWARE AND MODELS

MUSIC VERSION 1.00

Model for Urban Stormwater Improvement Conceptualisation
CD-ROM includes installation software, manual and six-minute rainfall files for 'reference cities' throughout Australia.
CRC user agreement applies (visit www.catchment.crc.org.au/toolkit/music)
(Price $88.00* per package)

CRCFORGE-EXTRACT

Rare Design Rainfalls from the CRC-FORGE Database for Victoria
by Nanda Nandakumar, Lionel Siriwardena, Erwin Weinmann, Russell Mein, Rory Nathan
CD-ROM includes installation software and manual. CRC user agreement applies.
(Price $27.50*per package)

AQUACYCLE

A Daily Urban Water Balance Model Developed to Assess Urban Stormwater and Wastewater Reuse
by Grace Mitchell
CD-ROM includes installation software and manual. CRC user agreement applies.
(Price $27.50*per package)

TO ORDER A COPY ....

Copies of videos, reports and working documents are available from the Centre office at $22.00* per copy unless otherwise noted and can be ordered by contacting:

Virginia Verrelli at the Centre Office
CRC for Catchment Hydrology
Department of Civil Engineering
PO Box 60
Monash University
Vic 3800
fax: (03) 9905 5033
or by email: crcch@eng.monash.edu.au

(order details must be in writing)
enquiries: (03) 9905 2704

WHAT'S HAPPENING WHEN?

FIND OUT ABOUT CRC ACTIVITIES BY EMAIL

THE CRC WILL NOTIFY YOU OF AN UPCOMING CRC ACTIVITY IN YOUR AREA OF INTEREST

You can register to receive this information on line at www.catchment.crc.org.au/subscribe

or you can contact Virginia Verrelli at the Centre Office on 03 9905 2704.

COOPERATIVE RESEARCH CENTRE FOR

CATCHMENT HYDROLOGY

Print Post Approved
PP338685/00026

If undelivered return to:

Department of Civil Engineering
PO Box 60
Monash University
Vic 3800

Surface Mail

Postage Paid Australia

CENTRE OFFICE:
CRC for Catchment Hydrology
Department of Civil Engineering
PO Box 60 Monash University,
Vic 3800
Telephone: +61 3 9905 2704
Facsimile: +61 3 9905 5033

crcch@eng.monash.edu.au

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:

Brisbane City Council
Bureau of Meteorology
CSIRO Land and Water
Department of Land and Water Conservation, NSW
Department of Natural Resources and Environment, Vic
Goulburn-Murray Water
Griffith University
Melbourne Water
Monash University
Murray-Darling Basin Commission
Natural Resources and Mines, Qld
Southern Rural Water
The University of Melbourne
Wimmera Mallee Water