NEWSLETTER OF THE COOPERATIVE RESEARCH CENTRE FOR CATCHMENT HYDROLOGY

CATCHWORD

NO 132 OCTOBER 2004

A NOTE FROM THE DIRECTOR

Rodger Grayson

Inside...

COOPERATIVE RESEARCH CENTRE FOR CATCHMENT HYDROLOGY

THE CATCHMENT MODELLING TOOLKIT - FROM CONCEPT TO REALITY, NOW WHERE?

Eighteen months ago, the Catchment Modelling Toolkit was a concept. Twelve months ago saw the first release of a "Product" with the hope that we would have a few hundred users by the end of the CRC. In an amazingly short period we have now have over 2200 users, 10 models and data products with several close to release and more expected before June 2005. We have recently launched the first product not developed through CRC Parties, where a developer with a high-quality piece of software chose the Toolkit site as a delivery platform. So based on the numbers, the Toolkit "has arrived" While it is still too early to fully assess its impact, early indications from sources such as the Communications Review and feedback on training indicates are that we're on track to have a significant impact on the land and water industry. With strong progress to date, I thought it opportune to reflect on the notion of the Toolkit, look at where we are heading in the coming months, and gaze ahead a little further into the future.

The Toolkit was developed to "improve the efficiency and standard of catchment modelling" by providing a platform for the development, delivery and support of catchment modelling tools. The assistance to developers comes from the infrastructure provided by TIME (The Invisible Modelling Environment) which enables developers to contribute to and access an ever growing library of model components to build their models in an efficient way. Initially this capability was used by a relatively small group within the core CRC modelling teams, but with TIME training now having been provided to 55 individuals, the number of developers is rapidly expanding both amongst our Parties and beyond. This augers well for the rapid expansion of capability as the benefits of a consistent modelling platform encouraging interchangeability and re-use of other's work become more widely recognised.

For users, the Toolkit offers convenient access to state of the art models, documentation and support through e-groups and access to the expertise of model developers. Carefully considered design standards and independent review provide confidence in the fundamental quality of the models hosted. The website is designed to encourage an active "Toolkit community" with announcements of training, new releases and other news of interest to members. As we have seen with the e-groups for MUSIC and EMSS (as used in the Development Projects), some of the best interaction comes from users sharing their experiences and helping each other solve problems. This encouragement of an active, informed modelling community is an important component of increasing the standard of modelling in Australia. This sort of infrastructure is also what attracts others to deliver their products via the Toolkit.

We are also encouraging undergraduate educators to use Toolkit models, support material and general information on modelling within their curricula. This is already occurring at the Universities of Melbourne, Monash and RMIT. It is a fantastic development that has the potential for probably the largest impact over the long-term and is an area that could be developed further via the eWater CRC.

To date, our focus has been on getting our research integrated into products and getting these products available through the website. This of course will continue, but new opportunities are opening up as well. The strong user community that is now accessible via the Toolkit website provides an ideal opportunity for disseminating more than just models and user manuals. In the August issue of *Catchword* I talked about our intention to develop a range of communications material around the issue of assisting users to choose the right model for the job and ask the critical questions of models and modelling needed for robust input into decision making. The Toolkit will be an important vehicle for providing this style of information, along with training activities and seminars. This provision of information about the wider role of modelling in planning and policy development is an area where our CRC and the Toolkit can play an important role.

A question I am often asked is "what happens to the Toolkit when the CRC ends?" The Toolkit notion is central to the delivery of the eWater CRC vision, so if eWater is successful, we will hand over the Toolkit to the new CRC. If eWater is not successful however, CSIRO Land and Water will take on the Toolkit and ensure its continuation after June 2006. The use of TIME and the delivery of products through the Toolkit is built into many non-CRC CSIRO activities so this is a logical home where on-going support and development can be assured.

CRC PUBLICATIONS LIST

For a complete list of all available CRC publications please visit www.catchment.crc.org.au/catchword

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So where might the Toolkit be in a few years time? To me the really exciting gains will come in two areas - one associated with increasing capability and the other improving efficiency of use.

Increased capability will come from the rapid expansion of developers using TIME and the wider recognition of the benefits of "Toolkit -style" delivery. We are already seeing those who fund and oversee modelling activity encourage model developers to use TIME and think about packaging tools as 'products'. Increased efficiency will come from the seamless integration of databases with modelling capability. As all of us who use models will attest, data collation, quality control and formatting for a particular model takes far too much time at present. It can be a source of enormous frustration and takes time away from the interpretation and communication of output. There are enormous gains to be made in this area and I hope the Toolkit can act as a catalyst for some of that activity in the future.

The leap from Toolkit concept to reality seems to have happened in the "blink of an eye", but this is really a reflection of the enormous work behind the scenes by a growing group of visionary individuals, dedicated to the Toolkit concept. As I seem to end up concluding in many of these notes from the Director, the quality and determination of our teams is an outstanding feature of this CRC and fills me with confidence that we can continue to fulfil the Toolkit vision.

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PROGRAM 1

PREDICTING CATCHMENT BEHAVIOUR

Program Leader
GEOFF PODGER

Report by Jake MacMullin

Applying 'New' Technologies to Data Management

Every so often, a technology comes along that is truly 'disruptive'. It changes things in such a dramatic way that earlier technologies or industries are displaced. An example of this is the advent of CD-ROM technology. Before the CD-ROM, there was a thriving industry (complete with an army of door-to-door sales-people) built around publishing and selling bound sets of encyclopaedias. The technology that allowed for an entire set of encyclopaedias to fit on a small shiny disc changed this industry almost over night. Within a few months of the first widely distributed CD-ROM encyclopaedia, a large number of 'traditional' encyclopaedia publishers went out of business. The new technology changed the way people accessed information so dramatically that the 'old' model was displaced.

In the past few years a number of technologies have emerged that have had a similarly profound effect on other industries. In this article, I want to look at a couple of these 'new' technologies, the effect they've had on the way people do things and how we might be able to apply those technologies to an issue in our domain: data management.

Peer-to-Peer Networking

The term 'peer-to-peer' is often used to describe a range of different styles of computer network, but broadly speaking it can be defined as a network in which computers can interact directly with one another without the need to go through a centralised server. This is not a new technology, there have been a number of network technologies that support this type of communication, including AppleTalk and Windows Workgroups. However, this style of communication has recently found new applications, most notably in peer-to-peer file sharing.

Peer-to-Peer file sharing clients such as Limewire, Gnutella, eMule and Kazaa allow people to easily exchange files without the need to use a centralised server. This technology (combined with mp3 audio compression and faster networks) is starting to change the way people think about music. Using peer-to-peer file sharing software, I could search through millions of

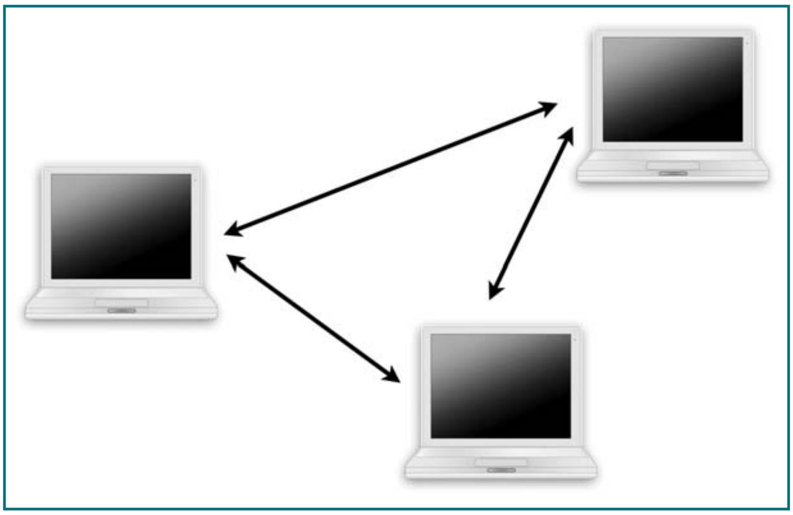

Figure 1.1. A peer-to-peer network

files on millions of computers around the world and in a matter of minutes download a copy of a song that I had just heard on the radio (theoretically of course, since that would be in breach of copyright law and I'm married to a lawyer).

The ease with which people can share (pirated) music in this way is changing the way both consumers and record companies think about music. Record companies have started to respond by launching a number of on-line music stores, where for around $1 US you can download a (legal) copy of that same song you just heard on the radio.

Ad-Hoc Networks

Another related 'new' technology that is changing the way people do things is 'Ad-Hoc' networking. Ad-Hoc networks are networks that are formed on a temporary basis. Whilst the idea of temporary networks is not new, technology is evolving that makes the process of establishing these networks easy to use and transparent to users. These type of networks are often established by people in physical proximity (in the same building, conference venue or coffee shop). They share many similarities with peer-to-peer networks in that they do not require a central server, but have the added advantage of the 'automatic discovery' of services.

For example, three people could be sitting in a coffee shop, using their laptop computers. Each computer could detect the presence of the other computers, and advertise the services that they offer. Two of the computers might advertise a 'music' service, letting the people sitting across from each other at the coffee shop listen to one another's tunes. This is all possible using today's technology and doesn't require a central server to provide a directory of which computers provide which service.

As these types of ad-hoc networks become more commonplace, and when they evolve to support the ad-hoc networking of mobile phones or mp3 players, this technology has even more potential to disrupt the status-quo. In addition to existing Local Area Networks (LANs) and Wide Area Networks (WANs), we might soon have Bus Area Networks (BANs).

"On the bus, your iPod will be a personal, short range radio station... Tune in to everyone else's iPod. Like what you hear? Then record it!" (Andrew Orlowski - The Register)

Applying 'New' Technologies to Data Management

So, how can we apply these 'new' technologies to the domain of environmental modelling?

The current crop of tools in the Catchment Modelling Toolkit do not provide any specific tools for managing the data that you need in order to run the models. If you

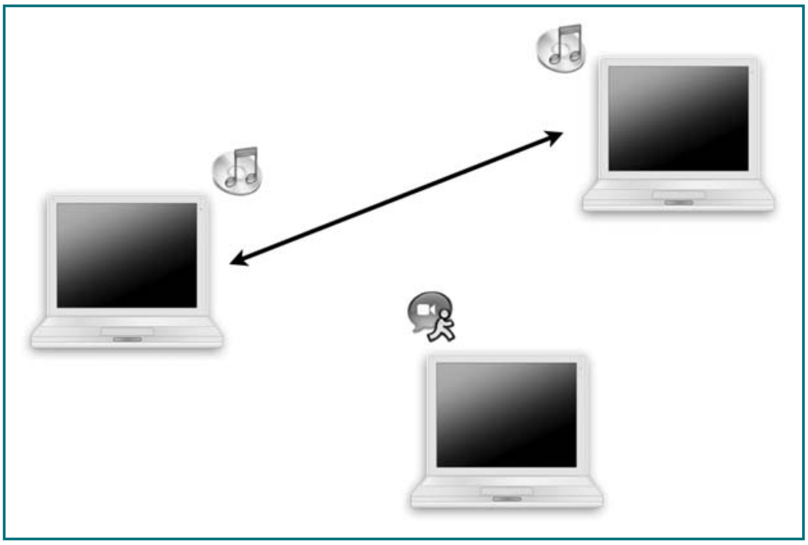

Figure 1.2. Automatic Service Discovery

NEW SOFTWARE VERSION

Rainfall Runoff Library (RRL)

Version 1.0 of the Rainfall Runoff Library software is now available from the Catchment Modelling Toolkit web site at www.toolkit.net.au

The user manual and software has been updated in response to feedback from users since the Catchment Modelling School in February 2004. This version replaces the earlier beta versions available through the Toolkit web site.

There is no cost to obtain the RRL software but you must be a registered member of the Catchment Modelling Toolkit.

For further information about the RRL update please visit www.toolkit.net.au/rrl

NEW TECHNICAL REPORT

Estimating Extractable Soil Moisture Content for Australian Soils

By
Tony Ladson
James Lander
Andrew Western
Rodger Grayson

Technical Report 04/3

This report uses an unconventional approach to estimating plant available water content for Australian soils. Instead of using laboratory measurements of soil properties, the authors have collected actual measurements of soil moisture from a wide range of field studies around Australia.

In total, extractable soil water capacity is presented for 180 locations that include the six States and two Territories. The report also compares estimates of extractable soil moisture from field measurements with those from the Atlas of Australian Soils.

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

This report is also available as an Adobe Acrobat file from www.catchment.crc.org.au/ publications

have spent some time setting up an EMSS or SedNet configuration for your catchment, you'll no doubt have come up with some system for keeping your data organised. You might have a special set-up on your hard disk where you keep your data stored in folders that are organised by catchment, or by data type. You may also have some sort of centralised data repository - a database, file server or web site where you can get data for your models. But wouldn't it be great if finding data was as easy as finding an mp3 of that song you just heard on the radio? Wouldn't it be nice if sharing your data with your colleagues was as easy as sharing your playlists?

Peer-to-Peer Data Manager

It is interesting to explore how the technologies of peer-to-peer and ad-hoc networking might be able to benefit the field of environmental modelling. One possible way that we could harness these technologies is in the form of a peer-to-peer data manager.

Such an application would allow me to organise all of my spatial and temporal data. I'd be able to import my data and describe it with some additional meta-data. Perhaps I could sort it in to a number of different categories and look at it in a number of different ways. I could view all the data for a certain catchment, or look at all the data that I've got the came from a particular source, or look at all the rainfall data that I have.

In addition to being able to browse and search my own data, such an application could make use of peer-to-peer and ad-hoc networking to allow me to search through all the data of anyone else on the same network.

Finally, if such an application did exist, it'd be great if all my environmental models could 'hook' in to it, so that when I'm running the Rainfall Runoff Library or SedNet I could access my data (and my colleagues' data) from within the application.

Conclusion

The technologies of peer-to-peer and ad-hoc networking aren't going to change the world of data management in the dramatic way that the CD-ROMs displaced bound sets of encyclopaedias. There are also a number of issues to overcome if we were to embrace these technologies (not least of which is the issue of data 'ownership'). However, exciting new technologies are constantly being developed and every so often it is worth considering how some of these technologies might be applied within the domain of environmental modelling.

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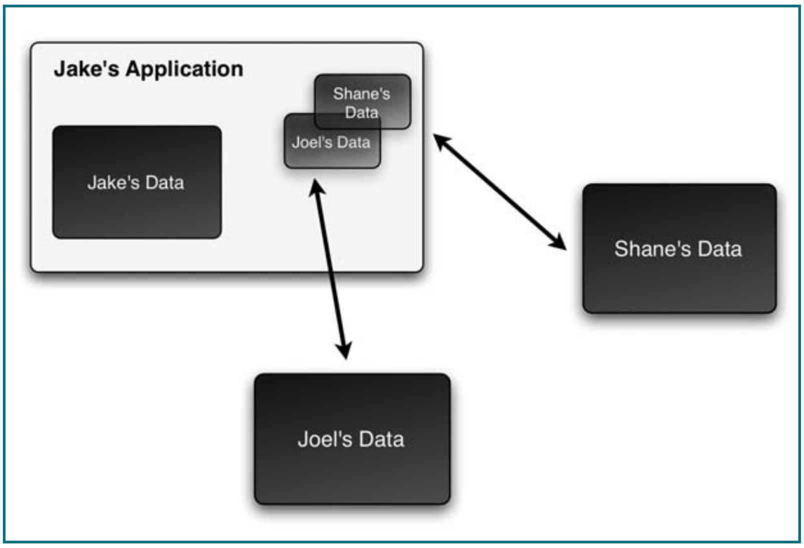

Figure 1.3. An environmental model could make use of data from anywhere on the network

PROGRAM 2

LAND-USE IMPACTS ON RIVERS

Program Leader
PETER WALLBRINK

Report by Mark Littleboy

Project 2.21 (2C): Predicting Salt Movement from Catchments

An overview and evaluation of State Agency recharge modelling

Model framework

The 2C Model links a number of previous modelling activities into a single framework. These include:

- Daily time step unsaturated zone modelling in Queensland, NSW, and Victoria using a suite of pasture growth, crop growth and tree growth models.
- 3 Stores groundwater model which evolved from the CSIRO Biophysical Capacity to Change (BC2C) model
- Groundwater flow systems concepts that evolved from the National Land and Water Resources Audit and the CSIRO led Catchment Classification Project
- Spatial apportionment of end-of-catchment stream flow and stream EC as developed in the NSW CATSALT model and Land Use Options Simulator
- Spatial connectivity of surface hydrology as applied in the Victorian CAT model
- Terrain analysis developed by CSIRO to define alluvial areas and extent of saturation in a catchment (MrVBF model).

Salt movement model

A key feature of the salt movement model being developed in Project 2C is its capability to utilise the extensive unsaturated zone modelling undertaken by Queensland, New South Wales and Victorian State Agencies over the past decade. These agencies are increasingly using unsaturated zone modelling in their decision frameworks to support salinity management. As part of this process, confidence in model predictions has been gained through extensive experience and model validation. However, this modelling has generally not been linked to groundwater or stream models. In Project 2C, we have built a modelling framework that links this extensive unsaturated zone modelling to both groundwater and stream models.

Hydrology component

The hydrology component of the 2C model is driven by the existing unsaturated zone modelling across eastern Australia. These models provide the time series of surface runoff, lateral flow, evapotranspiration and recharge as inputs into 2C. As part of the 2C project, a comparison between the recharge modelling by the Queensland Department of Natural Resources and Mines, New South Wales Department of Infrastructure Planning and Natural Resources, and the Department of Primary Industries, Victoria has been undertaken. The purpose of this evaluation, which is summarised here, was to provide details in the level of consistency in existing recharge modelling across CRC for Catchment Hydrology Industry Parties. A number of criteria were used to assess the consistency in modelling approaches: sources of input data, modelling methodology, land use scenarios simulated, data format and availability.

Input data for recharge modelling

A summary of the input data used is provided in Table 2.1 and reveals substantial consistency in the derivation of input data for recharge modelling across eastern Australia. Spatial climate surfaces were used by all States to develop rainfall zones based on average annual rainfall. Some States used additional climatic variables. For example, NSW added a seasonality index to account for different rainfall mechanisms across NSW; summer dominant rain in the north, uniform rainfall distribution in central NSW to winter dominant rain in the south.

Climate data

Daily climate data were all obtained from the Queensland Department of Natural Resources and Mines SILO database. NSW used the interpolated daily data from data drill in SILO. These data have been interpolated to a 5km grid. Both Queensland and Victoria used the patched point dataset in SILO which uses reconstructed and patched data sets for Bureau of Meteorology measurement stations.

Soils data

Each State used a composite of the best available soils mapping with the dominant soil type selected for each mapped soil-landscape unit. For each soil type, each State used measured data wherever possible. McKenzie *et al* (2000) was extensively used to obtain soil hydraulic properties for soils with no measured data.

Recharge maps

In producing recharge maps, each Agency has coupled ArcInfo GIS to a range of different unsaturated zone models. Hydrological Response Units (HRU) were defined by overlaying the soils, climate and land-use

NEW TECHNICAL REPORT

Water Farms: A Review of the Physical Aspects of Water Harvesting and Runoff Enhancement in Rural Landscapes

By
Laura Richardson
Peter Hairsine
Timothy Ellis

Technical Report 04/6

Water farming is an approach to the problem of managing the quantity of water input to our streams, and is an idea that has been around for thousands of years. In this concept, land managers are able to generate more runoff for a given amount of rain than would happen in normal circumstances. Historically, most examples focused on providing extra water from a farm for use on the same farm. However, there are considerable prospects for 'water farms' enterprises that use water harvesting techniques to provide additional water into the river system and new water markets. It is these prospects that have prompted this review.

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

This report is also available as an Adobe Acrobat file from www.catchment.crc.org.au/publications

CRC WEB SITE UPDATE

The CRC web site at www.catchment.crc.org.au has recently been redesigned and updated. The new site contains additional information about our research outcomes from 1999-2002 as well as the current round of CRC projects.

The new site includes past copies of *Catchword*, all CRC publications since 1999, a contact directory for CRC staff, news and events pages and a Google powered search engine that includes Adobe Acrobat files.

Further information and project reports will also be added over the coming months.

For further information contact Virginia Verrelli on 03 9905 2704 or email crcch@eng.monash.edu.au

Table 2.1. Derivation of input data layers

Data layer	New South Wales	Queensland	Victoria
Climate zones	Zones defined by average annual rainfall and rainfall seasonality (percentage of annual rainfall in winter months)	Zones defined by average annual rainfall	Zones defined by average annual rainfall and average annual temperature
Daily climate	QDNRM SILO datadrill data (5km grid of interpolated daily climate data) extracted for the centroid of each climate zone	QDNRM SILO patch point data set for key climate locations	QDNRM Silo Patched Point data used and spatially weighted by the mean average annual rainfall surface
Soil Mapping	Composite of best available soil mapping. Each polygon identified by either a Northcote or great soil group. Dominant soil type assigned to each polygon	Composite of best available soil mapping. Each polygon identified by a Northcote classification. Dominant soil type assigned to each polygon.	Composite of best available soil mapping. Each polygon identified by a Northcote classification
Soil hydraulic properties	Soil parameter files derived for each Northcote or Great Soil Group. Parameters for Northcote soils obtained from McKenzie *et al* (2000). Parameters for Great Soil Groups based on generic lookup tables containing measured soil properties and pedotransfer functions.	Sites with measured soil physical properties used for dominant soils. Modelling was done for 17 dominant soils for a range of depths.	Soil parameter files derived for for each Northcote soil. Parameters obtained from McKenzie *et al* (2000). Supplemented by measured data wherever possible. (minimum of 10m) for the Rassam
DEM	25m DEM used to derive slope for the Rassam and Littleboy (2003) lateral flow partitioning	A DEM has not been used yet.	DEM at various resolutions and Littleboy (2003) lateral flow partitioning

layers. This HRU concept has also been adopted in the 2C model. The only major difference in the definition of HRUs is that Queensland does not include topography. Presently, Queensland did not apply a lateral flow partitioning model (e.g. Rassam and Littleboy 2003). This functionality has now been added to the analysis as part of Project 2C.

Cropping land-use models

The PERFECT cropping systems model was used by all States for cropping land uses, with cropping systems relevant for each State being simulated. For pasture, different growth models were used. However, the water balance component within each model is conceptually similar. The selection of which pasture model to use was driven by other needs. In particular, each State used a pasture growth model where available expertise for each model. Similarly, different models were used to simulate trees, but again the water balance components of the models are conceptually similar.

Land-use scenarios

A summary of land-use scenarios simulated in each State is provided in Table 2.2. A range of cropping, pasture and tree scenarios have been simulated. These scenarios provide the basis for determining the impacts of land-use change on hydrology as part of the 2C model. Additional scenarios can be simulated to enhance the list of intervention strategies that can be analysed in the 2C model.

Spatial coverage

The spatial extent of available data covers large areas of eastern Australia. In NSW, the entire NSW Murray-Darling Basin and coastal catchments are covered. In Queensland, the entire Qld Murray-Darling Basin is available. In Victoria, the Goulburn-Broken, Wimmera, Central, and Mallee have been modelled at a regional scale. Numerous priority subcatchments have been modelled at finer scales

Linking datasets

The various datasets are linked to the 2C model by importing monthly time series of rainfall, evapotranspiration, surface runoff, lateral flow and recharge for every Hydrological Response Unit. In that way, the hydrology within the 2C model is driven by this recharge modelling. Water and salt are then moved through a hillslope and an alluvial aquifer with appropriate time delays and mixing processes. The 2C

Table 2.2. Land use scenarios that are currently available

New South Wales	Queensland	Victoria
Cropping (PERFECT model) • Winter wheat • Winter rotation (Wheat/Canola) • Summer Winter rotation (Wheat/sorghum) • Wheat/Lucerne rotation • Opportunity (response) cropping	Cropping (PERFECT Model) • Winter wheat • Summer sorghum • Opportunity cropping (wheat/sorghum) • Irrigated Cropping	Cropping (PERFECT model) * Winter wheat * Winter rotation (Wheat/Canola) * Wheat/Lucerne rotation * Wheat/Canola/Lucerne rotation * Opportunity (response) cropping
Pasture (PERFECT crop factor model) • Annual winter pasture • Perennial pasture (high cover, low grazing) • Perennial pasture (low cover, high grazing) • Continuous lucerne	Pasture (GRASP Model) • native pastures • improved pastures	Pasture (PERFECT crop factor model) * Annual pasture * Perennial pasture * Continuous Lucerne * Different levels of management (e.g. stocking rate) considered
Trees (PERFECT crop factor model) • Different canopy cover to reflect forest type and tree species • 20% canopy cover • 40% canopy cover • 60% canopy cover • 80% canopy cover	Trees (GRASP Model) • Forest	Trees (3PG) * Blue Gum * Red Gum * Generic Native Vegetation * Different levels of management (e.g. thinning) considered
Bare Soil (PERFECT model) • gives an indication of "potential" recharge		

model has been specifically designed to utilise the results from State Agency Recharge modelling as part of a whole-of-catchment salinity modelling capability.

References

McKenzie, N.J., D.W. Jacquier, L.J. Ashton and H.P. Cresswell (2000). Estimation of Soil Properties Using the Atlas of Australian Soils, CSIRO Technical Report 11/00.

Rassam, D. and M. Littleboy, (2003). Identifying Vertical and Lateral Components of Drainage Flux in Hill Slopes. MODSIM 2003 Proceedings, 2003, pp 183-188.

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NEW TOOLKIT DATA PRODUCT

Soil Hydrological Properties for Australia

The first Catchment Modelling Toolkit data set has been released on the Catchment Modelling Toolkit website.

Soil Hydrological Properties for Australia (SHPA) provides continental coverage of soil properties relevant to catchment Modelling. This data set can be downloaded from www.toolkit.net.au/shpa

The data set provides estimates of twelve properties in total along with information on the uncertainty of the property estimates.

Further details of the data set development and its limitations are available in the data set documentation at www.toolkit.net.au/shpa

PROGRAM 3

SUSTAINABLE WATER ALLOCATION

Program Leader
JOHN TISDELL

Report by Daniel Clowes

Controlling Nonpoint Source Pollution

The purpose of this article is to introduce some of the characteristics of nonpoint source pollution and to explain how these characteristics give rise to problems for policy designers interested in its control. This article is the first in a series of three *Catchword* articles which will examine the nonpoint source pollution problem and review research work currently being undertaken by the CRC and its stakeholders. This first article reports on nonpoint source pollution and its current state in Australia, nonpoint source pollution characteristics, information problems, and issues in the design of policies for pollution control. Subsequent articles will examine the role of market-based incentives, particularly the design of tradable permit schemes, for controlling pollution from nonpoint sources in Australia.

State of Surface Water Pollution in Australia

Pollution from nonpoint or diffuse sources[1] has been identified as the leading cause of contamination in many of Australia's catchments and coastal ecosystems (see for example the National Land and Water Resources Audit 2001, Australia's State of the Environment 2001). Australia's National Pollutant Inventory (NPI) Summary Report of Third Year Data 2000-2001 suggests that, of the 23 water catchments assessed, nonpoint sources account for 65%-95% of nutrient emissions to inland waters, particularly in catchments dominated by non-urban land uses (NPI 2002, p.25). In 2003, the Australian Productivity Commission released a report identifying nonpoint pollution as the major contributor of sediment and nutrients to the Great Barrier Reef lagoon (PC 2003). Nutrients, primarily nitrogen and phosphorous, salinity (a measure of salt concentration) and turbidity (as a proxy for sediment concentration) have been identified as the major pollutants of concern (NLWRA 2001).

Characteristics of Nonpoint Source Pollution

Nonpoint source pollution, sometimes referred to as diffuse pollution, results from land runoff, precipitation, atmospheric deposition, drainage, or seepage. Nonpoint sources refer to broad, diffuse sources of activity that generate contaminants that are applied, spilled, leaked, leached, eroded, or dumped onto or into land or water (Dosi and Zeitouni 2000). Nonpoint source pollution is characterised by stochastic events, occurs over a range of scales (temporal and spatial) and because discharge is diffuse and driven by stochastic processes, cannot be easily quantified or measured.

Catchment or regional scale pollution problems will often involve numerous, small and spatially heterogeneous polluting agents including urban and agricultural sources. At such scales, it is considered difficult and/or costly to systematically monitor the individual production practices or production inputs of each agent that give rise to pollutants. Even if we could monitor each potential source, pollution events are typically driven by stochastic environmental processes such as climate. Similarly, it is difficult to infer the contributions of individual polluters by measuring ambient downstream water quality at a single point downstream since this too is affected by stochastic environmental processes and our knowledge about these processes (i.e. pollutant generation, transport and fate) is imperfect. Thus, not only are contributions from individual sources difficult to measure or observe, they cannot be accurately inferred from ambient monitoring of water quality either.

Interdependency exists between upstream sources and downstream concentrations and pollutants in these systems are not uniformly mixed. This occurs because water flow, and therefore contamination of surface waters in a catchment, typically occurs along a topographic gradient and pollutants are usually transported from upstream areas to downstream areas where impacts and damages occur. Unlike air pollution where pollutants may diffuse and uniformly mix with the receiving environment, nonpoint source pollution of surface waters is usually characterised by increasing pollutant concentrations at the bottom end of the catchment. Added to this are the time lags between when contaminants are produced and when environmental damages occur; this means that the damages associated with an individual agent are also difficult to establish.

Nonpoint Information Problems

The inherent characteristics of nonpoint source pollution give rise to information problems for policy designers. Braden and Segerson (1993) classified these nonpoint information problems as:

[1] *Nonpoint source pollution, of diffuse pollution, refers to broad, diffuse sources of activity that generate contaminants that are applied, spilled, leaked, leached, eroded, or dumped onto or into land or water (Dosi and Zeitouni 2000). Nonpoint sources are characterized by stochastic events, occur over a range of scales (temporal and spatial) and because discharge is diffuse, cannot be directly or easily quantified.*

1) Problems of natural variation
   a) Temporal variability
   b) Spatial variability
2) Problems of monitoring and measurement
3) Inability to observe individual emissions
4) Inability to observe individual inputs/practices
5) Inability to infer individual emissions from ambient concentrations

Spatial variation includes differences due to climate and landscape heterogeneity and includes variability associated with rainfall, evapotranspiration, runoff, soils, land use, physical location of management practices and the fate of contaminants in the environment. Temporal variability includes uncertainty due to rainfall frequency, abatement technology, hydrological variability, production factors (e.g. timing of management practices) and the assimilative capacity of the environment.

Inability to observe individual emissions implies moral hazard characterised by hidden actions (Braden and Segerson 1993). Since water quality can be considered a public good, moral hazard gives rise to another issue for policy design termed the 'free rider effect'[2]. The free rider problem, characteristic of public goods, occurs when one polluter derives benefits from the increased abatement undertaken by other polluting firms without actually reducing pollution itself. Since contributions are unobservable and subject to stochastic processes, the public good nature of water means that benefits are nonexclusive (i.e. nonexcludability applies) and indivisible; the free rider has no incentive to reduce their level of pollution (Tietenberg 2000). This moral hazard problem ultimately gives rise to increased discharges and higher environmental damages.

Just as it is not practical to observe individual emissions, it is also difficult to monitor and target agents based on production inputs, and technologies used by multiple polluting agents are also unobservable. Production and abatement technologies (eg. land management practices) define a firm's 'type' (Tomasi *et al.* 1994). For example, in an agricultural catchment, different soil types, hydrological characteristics and topographic factors give rise to differences in the kinds of crops that could be grown and therefore also differences in farming practices and technologies ('types'). As the number of polluting firms increases, so also does the problem for the policy designer in obtaining information about each firm's specific 'type' or for firms to know about the 'types' of other firms (Tomasi *et al.* 1994). This unobservability of firm's type is a form of information asymmetry characterised by hidden information and is termed adverse selection (Taylor *et al.* 2001; Tomasi *et al.* 1994).

Inability to infer individual emissions from ambient concentrations refers to the fact that it is not possible to attribute ambient pollution to any one firm since environmental damages are not separable across firms (Braden and Segerson 1993; Shortle and Abler 1997). Thus, the contribution of one firm is not only inseparable from that of another firm, but depending on their location within the catchment, the total contribution of that firm to ambient pollution levels could actually depend on the contributions of other firms as well as stochastic environmental processes. The inability to infer individual emissions from ambient pollution levels is also an example of moral hazard characterised by both hidden actions and natural variation (Segerson 1988; Xepapadeas 1991).

Policy Design Issues

Nonpoint pollution's characteristics and its associated information problems give rise to some important considerations for policy design. Horan and Shortle (2001) categorised these considerations as policy targeting problems, namely:

1. Who to target?
2. What to target?
3. How to target?

Who to target?

The answer to this policy targeting question may at first seem obvious, however nonpoint information problems give rise to uncertainty about who to target. For example, it may appear that an obvious choice is to target the individual firms responsible for creating the nonpoint externality and thereby managing externality contributions through a 'polluter pays' system (Shortle and Horan 2001). However the unobservability of emissions, the inability to infer individual contributions from ambient water quality concentrations, and a large number of small, diffuse, and heterogeneous contributors gives rise to moral hazard about which firms are responsible for nonpoint pollution and the degree of individual responsibility (Shortle and Horan 2001).

An alternative approach to targeting the producers of pollution is to target the beneficiaries of pollution

[2] *"When goods exhibit both consumptive indivisibility and nonexcludability properties, some consumers may enjoy the of the goods purchased by others without paying anything themselves." (Tietenberg 2000, p.71)*

NEW TOOLKIT SOFTWARE

CatchmentSIM

CatchmentSIM is a freely available stand-alone 3D-GIS application specifically tailored to hydrology based applications. It can be thought of as a collection of topographic and hydrologic analysis algorithms that have been purpose built for the process of hydrologic analysis and included in a Windows based user-friendly GIS environment.

CatchmentSIM is designed for use by anyone interested in automated catchment delineation and parameterisation from GIS data. However, the software is primarily focused on automated setup of run-files for flood and stormwater hydrograph models.

For further information visit www.toolkit.net.au/catchmentsim

control. This approach too is complicated by nonpoint information problems including unknown and spatially variable damages, time lags between contamination and damages, and the inability to identify all potential beneficiaries.

Alternatively, policies may target polluters indirectly. For example, if fertiliser was identified as a major polluting input it is possible (and potentially feasible) for the policy to target a few larger fertiliser manufacturers rather than multiple, unobservable and heterogeneous farm sources. However the targeting of a potentially law-abiding manufacturer also raises equity and political considerations

What to target?

The question of what to target is concerned with what aspect of nonpoint pollution production should be regulated, that is, which base to target. The term 'base' describes the target that is to be regulated or leveraged by the policy instrument to create an incentive for the firm to undertake abatement. It has been suggested that preferred bases should be more or less correlated with environmental conditions, easily enforceable at minimal cost, and targetable in time and space (Braden and Segerson 1993).

The question of which base to target arises because nonpoint characteristics and information problems prevent the use of traditional bases such as actual discharges, production inputs or practices, and ambient concentrations. The existing literature contains policy designs which have targeted:

- production inputs which give rise to pollution e.g. irrigation water use, fertilisers,
- production (land management) practices (types) e.g. crop management and tillage practices,
- emissions proxies - a measure of the performance of a management practice in reducing contaminant production
- modelled or estimated discharges - an estimate of actual emissions, and,
- ambient water quality concentrations

While the potential of these bases has been demonstrated in the literature, nonpoint information problems impose obstacles to their efficient and practical application. Such obstacles include establishing liability, enforcement and transferability of property rights, monitoring at reasonable cost, and that the information requirements associated with implementing an efficient or cost-effective policy design are often significant and onerous.

How to target?

Considering who to target and what base to target, regulators need also consider the question of policy instrument choice. Policy instruments for pollution control can be categorised into two major groups (Russell and Powell 1999):

- Regulatory instruments or 'command and control', and,
- Incentive instruments or economic or market-based incentives (MBIs).

Regulatory instruments

Regulatory instruments, sometimes referred to as command-and-control instruments, refer to instruments that specify a standard or metric to which polluters must comply and include such mechanisms as product prohibitions, technology-based discharge standards, quotas on emissions and disclosure of private information about polluting activities (Russell and Powell 1999). Regulatory instruments typically prescribe either a performance-based standard such as an emissions level, which firms must achieve, or a technology-based standard by which all firms must operate. Technology-based standards include restrictions on the use of certain types of inputs which give rise to pollution or by mandating the use of certain pollution-reducing (abatement) technologies (Baumol and Oates 1988). Performance standards set a uniform control target which all polluting firms must meet, however there is some flexibility as to how this goal is met (Stavins 2003).

Incentive instruments

Incentives include a range of instruments such as tradable permits, pollution charges or taxes, liability provisions, subsidies and schemes based on education and suasion (Russell and Powell 1999). Market-based instruments (MBIs) differ from command and control approaches in that they offer the polluter a financial incentive to undertake abatement. This incentive may come in the form of a direct price incentive as in the form of a tax or subsidy, or indirectly through liability law provisions. Incentives may not necessarily be driven by price. Other incentive policies include approaches such as education, extension and moral suasion. However, evidence suggests that these latter methods have only limited success when used in isolation from other approaches such as MBIs or regulation (Horan and Shortle 2001).

Unlike regulatory approaches which encourage behaviour through explicit directives regarding pollution control levels or methods, market-based instruments provide inducements, usually in the form of price incentives and market signals, for firms to reduce pollution discharges (Stavins 2003). Examples of MBIs include taxes or subsidies, tradable emissions permits, deposit-refund systems, liability provisions and information programs such a public revelation about pollution of information disclosure (Russell and Powell 1999; Shortle and Horan 2001; Stavins 2003).

Regulation or incentives?

While MBIs can be at least as cost-effective as a regulatory instruments, the conditions for this are shown to be highly restrictive (Baumol and Oates 1988; Griffin and Bromley 1982). A range of different incentive instruments which take advantage of the differences in the production characteristics of firms, particularly marginal costs of abatement, have been shown to be more cost effective than a uniform regulatory approach which treats all polluting firms the same way (Baumol and Oates 1988; Cropper and Oates 1992). Baumol and Oates (1988) demonstrated that in the presence of imperfect information about firms, including lack of information about individual emissions and their control costs, MBIs will generally achieve environmental targets at a lower cost than command-and-control approaches. It has been shown that where the costs of abatement differ widely among polluting sources or firms, incentive instruments are likely to deliver greater benefits, relative to regulatory instruments. As such, market-based instruments or incentives are expected to be more cost effective than regulatory approaches when information problems and heterogeneity amongst sources exist. Since these are characteristics of pollution from nonpoint sources, it is possible that market-based instruments offered important advantages as policy instruments in nonpoint pollution control.

Conclusion

This article has provided an overview of the characteristics of nonpoint source pollution and explained the reasons why these characteristics give rise to difficulties for pollution control policy designers. These characteristics and associated nonpoint information problems may help to explain public policy's lack of progress in systematically addressing nonpoint pollution problems and why nonpoint pollution of surface and groundwater remains a pervasive environmental problem in Australia.

The CRC's Catchment Modelling Toolkit aims to provide a range of data and modelling tools which will allow users to predict and analyse many of the catchment biophysical processes which are important in the generation, transport and fate of nonpoint contaminants. Projects such as the "Toolkit" are fundamental in to improving our understanding of, and ability to predict nonpoint pollution dynamics. With such information and prediction tools at their disposal, policy designers will be better equipped to design policies which are able to successfully target and control nonpoint source pollution.

Regulatory instruments and incentives based on moral suasion and education are the most common policy approaches to nonpoint pollution control in Australia, with market-based instruments having received very little attention until recently. The next article in this series on policies for controlling nonpoint source pollution will examine the role of MBIs and their use in Australia, with an emphasis on the role of tradable emissions permit schemes (markets).

References

Baumol, W. J. and W. E. Oates (1988). The Theory of Environmental Policy. Cambridge, UK, Cambridge University Press.

Braden, J. B. and K. Segerson (1993). Information Problems in the Design of Nonpoint Source Pollution Policy. Theory, Modelling and Experience in the Management of Nonpoint-Source Pollution. C. Russell and J. F. Shogren. Dordrecht, The Netherlands, Kluwer Academic Publsihers: 34p.

Cropper, M. L. and W. E. Oates (1992). Environmental Economics: A Survey. Journal of Economic Literature 30: 675-740.

Dosi, C. and N. Zeitouni (2000). Controlling Groundwater Pollution from Agricultural Nonpoint Sources: An Overview of Policy Instruments. Fondazione Eni Enrico Mattei, Milan, Italy.

Griffin, R. C. and D. W. Bromley (1982). Agricultural Runoff as a Nonpoint Externality: A Theoretical Development. American Journal of Agricultural Economics 70: 37-49.

Horan, R. D. and J. S. Shortle (2001). Environmental Instruments for Agriculture. Environmental Policies for Agricultural Pollution Control. J. S. Shortle and D. G. Abler, CAB International.

NLWRA (2001). Australian Water Resources Assessment 2000. Surface water and groundwater - availability and quality. Land & Water Australia on behalf of the Commonwealth of Australia, Turner, ACT, Australia.

NPI (2002). Summary Report of Third Year Data 2000-2001. Australian Government Department of the Environment and Heritage, Canberra, ACT, Australia.

PC (2003). Industries, Land Use and Water Quality in the Great Barrier Reef Catchment. Research Report. Productivity Commission, Canberra, ACT, Australia.

Russell, C. and P. T. Powell (1999). Practical considerations and comparison of instruments of environmental policy. Handbook of Environmental and Resource Economics. J. C. J. M. van den Bergh. Cheltenham, UK, Edward Elgar Publishing Limited.

Segerson, K. (1988). Uncertainty and Incentives for Nonpoint Pollution Control. Journal of Environmental Economics and Management 15: 87-98.

Shortle, J. S. and D. G. Abler (1997). Nonpoint Pollution. International Yearbook of Environmental and Resource Economics 1997/1998. H. Folmer and T. Tietenberg. Cheltenham, UK, Edward Elgar Publishing Ltd.

Shortle, J. S. and R. D. Horan (2001). The Economics of Nonpoint Pollution Control. Journal of Economic Surveys 15(3): 255-289.

Stavins, R. N. (2003). Experience with Market-based Environmental Policy Instruments. The Handbook of Environmental Economics. K.-G. Maler and J. Vincent. Amsterdam, Elsevier Science.

Taylor, M. A., A. Randall and B. Sohngen (2001). Point-Nonpoint Source Pollution TRading Using Collective Performance Incentives. Annual Meeting of the American Agricultural Economics Association, Chicago, Illinois.

Tietenberg, T. (2000). Environmental and Natural Resource Economics. Reading, Massachusetts, Addison Wesley Longman Inc.

Tomasi, T., K. Segerson and J. B. Braden (1994). Issues in the Design of Incentives Schemes for Nonpoint Source Pollution Control. Nonpoint Source Pollution Regulation: Issues and Analysis. C. Dosi and T. Tomasi. Dordrecht, Netherlands, Kluwer Academic Publishers.

Xepapadeas, A. P. (1991). Environmental Policy Under Imperfect Information: Incentives and Moral Hazard. Journal of Environmental Economics and Management 20: 113-126.

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PROGRAM 4

URBAN STORMWATER QUALITY

Program Leader
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Report by Tony Wong and Tim Fletcher

Some brief notes on the application of MUSIC

Rainwater/stormwater harvesting

Since its first release in 2002, MUSIC is now widely adopted in Australian practice for developing stormwater management strategies. Stormwater quality management has been the primary focus of the majority of these applications. However, there have been some applications where harvesting of stormwater at the building and precinct scales have been investigated as an integrated strategy, since the "diversion" of stormwater for use as an alternative source of water implicitly reduces the pollutant loads that are discharged to receiving waters. Using the pond module is the most common approach to modelling rainwater or stormwater harvesting with the volume of the permanent pool being set equal to the storage capacity of the tank and the extended storage being set to reflect the provision of on-site detention volume for flood control. If the model is used exclusively to determine stormwater harvesting performance, the choice of time step is only marginally relevant and it is common to adopt a daily time step (especially if the "catchment area" is 100% impervious) as most water demand can only be represented as mean daily demand.

A common approach to defining the degree to which potable (mains) water is substituted by harvested rainwater is by simply comparing the volume of inflows and outflows from the catchment (roof area) with the difference being the amount that has been reused. Users need to be cautious when adopting this approach for the following reasons:-

(i) Users quite often need to "factor up" (by a factor of 10 or 100) the catchment area (roof area) and the corresponding demand when examining stormwater harvesting and reuse owing to the units used in accounting for catchment runoff volume (ML/yr to two decimal places). MUSIC Version 3 will increase this to four decimal places so that water harvesting at individual allotment scale can be simulated without the need to adjust catchment areas and demand;

(ii) Evaporative losses in the storage could account for a significant percentage of the difference in inflow and outflow of the system - this generally only applies to storage systems exposed to evaporation potential, while in most cases, the user should ensure that the evaporation factor is set to zero to disable evaporation losses. If evaporation losses are "real", the user will have to examine the flux file output to determine the actual volume of water substitution;

(iii) An incomplete rainfall record (eg. a gap in rainfall record for severally months) can lead to an under-estimation of the percentage of potable water substitution owing to "no rainfall" being assumed for the period of incomplete rainfall record while the water demand remained effective.

Groundwater Inflow

The interaction of surface and groundwater flows can be modelled using MUSIC by simply creating one or more "source" nodes that represent the groundwater catchment (which may be different in area to the surface area catchment). A node may be calibrated to observed groundwater flow by adjusting the pervious area storage parameters, including the catchment area.

An example of the simulation of groundwater and surface water interaction is some recent work in Perth. In this study, options were examined for a regional approach to reducing nutrient loads to a sensitive receiving waterbody. The loads were from a combination of surface stormwater and subterranean pathways of nutrient from shallow groundwater flow.

Perth is underlain by a sand layer (Bassendean Sand geology) over a more impervious clay layer (Guildford Clay Formation). The availability of a shallow sand aquifer has defined stormwater discharge practices in the city for over 100 years. Stormwater runoff from impervious surfaces is discharged mainly through infiltration into the Bassendean Sand layer with groundwater levels rising in the wet autumn-winter months to surface levels in some cases. Groundwater baseflow discharges into natural and excavated watercourses that intersect the groundwater table for most of the spring-summer months. The Bassendean Sand has very poor nutrient adsorption capacity and groundwater quality has high concentrations of nutrient, with a high proportion in bio-available form. An extended period of nutrient-rich baseflow over the dry summer months is regarded as one of the principal causes of regular toxic algal blooms in the Swan-Canning Estuary.

In applying the model, MUSIC was first calibrated to represent the hydrology of the receiving water by modelling both surface and groundwater inputs. Water quality data for surface water inputs were stochastically generated using established pollutant concentration log-normal distributions while groundwater quality was modelled with constant average concentrations. A range of water quality treatment measures were then modelled to assess their effectiveness in reducing nutrient discharge into the Swan-Canning Estuary. Figure 4.1 shows a schematic of the model layout with descriptions of the surface and sub-surface components and simulated flow time series. The model was calibrated to observed flow data and subsequently used to simulate management options for reduction of nutrients and other contaminants.

Calibration of the groundwater flow component involves adjustments to the following key parameters:-

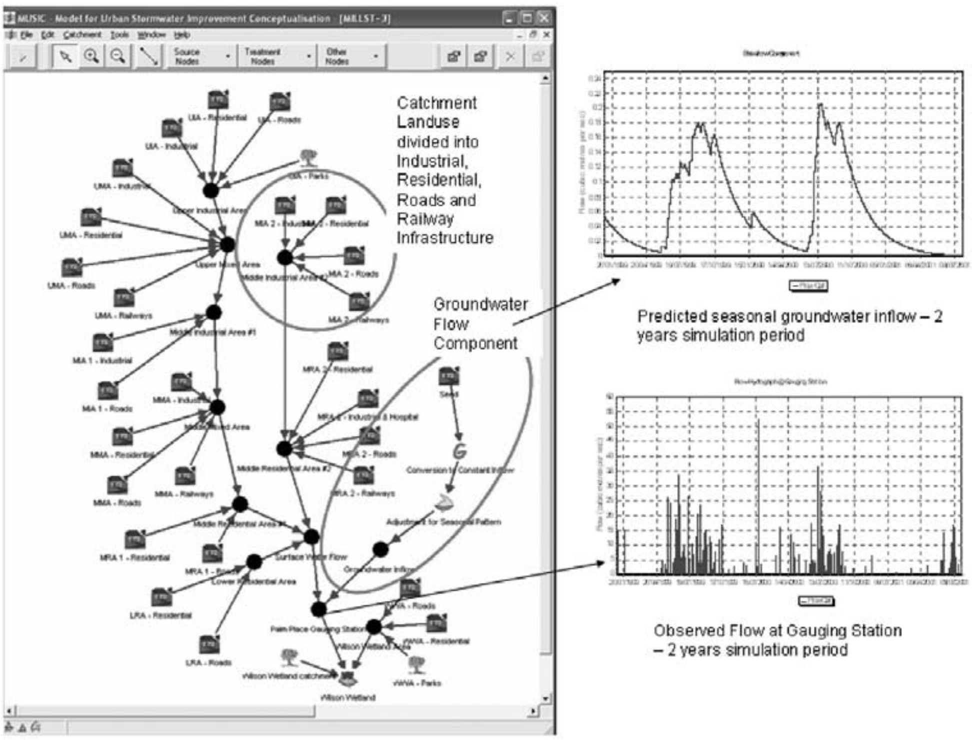

Figure 4.1. Illustration of Model Layout and Simulated Flow time series

MUSIC TRAINING COURSES - REGISTRATIONS CLOSING

This two day MUSIC (Model for Urban Stormwater Improvement Conceptualisation) training workshop is aimed at professionals in local government, consultancies and waterway and catchment management agencies.

Sydney
8-9 December 2004
9am - 5pm University of Technology, Sydney

Registrations close 26 November 2004 and there is a concession for staff from CRC Parties and Associates.

For further information visit www.toolkit.net.au/training

URBAN STORMWATER SOFTWARE

Model for Urban Stormwater Improvement Conceptualisation (MUSIC) Version 2.0.1

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 Version 2.0.1 is available as a free evaluation Version download from the Catchment Modelling Toolkit web site at www.toolkit.net.au/music

The MUSIC evaluation version allows you to trial the MUSIC software for 6 weeks. During that period you are able to purchase the MUSIC software for $330. Discounts apply if you are a current MUSIC Version 1 user.

For further information visit the MUSIC web site at www.toolkit.net.au/music

Please note: You must be a registered Catchment Modelling Toolkit member to download the MUSIC evaluation version.

Catchment area

- this needs to be adjusted to match the predicted and observed mean annual volume of groundwater discharge

Daily Baseflow Rate (%)

- this defines the rate at which groundwater baseflow is discharged and as shown in Figure 4.2, the rate controls how quickly rainfall that has infiltrated into the ground returns to the adjoining waterway. At a rate of 0.5%, groundwater discharge extends throughout the year, peaking at the end of the winter months and receding to the commencement of the following winter months. With higher baseflow rate, groundwater flow is more "responsive" to rainfall and ceases to flow during the dry summer periods.

Modelling with MUSIC was used to investigate the relative contribution of nutrients from the surface and groundwater flow components and to examine options in which water quality treatment measures could be used to reduce these discharges. Options examined included the following:-

- reuse of groundwater for summer irrigation to reduce groundwater level and thus groundwater discharge to the estuary
- bioretention systems along major drainage watercourses to intercept and treat groundwater for nutrient reduction prior to their discharge into the estuary
- distributed bioretention systems for treatment of impervious surface runoff prior to their discharge into the watercourse or infiltrate into groundwater

Future Development of MUSIC

There are a number of ongoing improvements in MUSIC to better refine the application of the model. Current research is focused on four areas:

1. Pollutant generation: MUSIC's stochastic pollutant generation algorithm uses a dry and wet weather mean concentration for each subcatchment being modelled, with the defaults based on a worldwide review by Duncan (1999). Whilst this model can simulate the long-term pollutant loads within a catchment, the intra-event behaviour does not reflect any of the processes of buildup, washoff, or climate often considered important (e.g. Ball *et al.*, 1998; Charbeneau & Barrett, 1998; Deletic *et al.*, 1997; Huber & Dickinson, 1988; Vaze & Chiew, 2003b). Current research is aimed at addressing this, using a relatively simple model (see Francey *et al.*, this volume).
2. Treatment processes: The treatment model (USTM) has been developed primarily using data from storm events. However, current research suggests that the inter-event processes may be very important in determining the overall treatment effectiveness (Fletcher *et al.*, 2004). We are also examining the influence of particle size on pollutant behaviour in both open water and vegetated systems.
3. Ecological response: Predicting ecological responses to alternative stormwater management strategies has proven to be very difficult, despite strong evidence of urbanisation impacts on receiving waters (Booth & Jackson, 1997; Walsh *et al.*, 2000). Recent research (Walsh, 2004; Walsh *et al.*, in review) has demonstrated a clear link between effective impervious area and ecological condition, and we are hoping to incorporate the predictive models from this research into MUSIC (where different treatment strategies would result in different effective impervious areas, which would then predict ecosystem response).
4. Lifecycle cost analysis: Using data from an extensive national survey, capital and operating costs can be estimated for a range of stormwater management devices, over their expected lifespan. Subsequent versions of MUSIC will thus predict lifecycle costs for alternative strategies.

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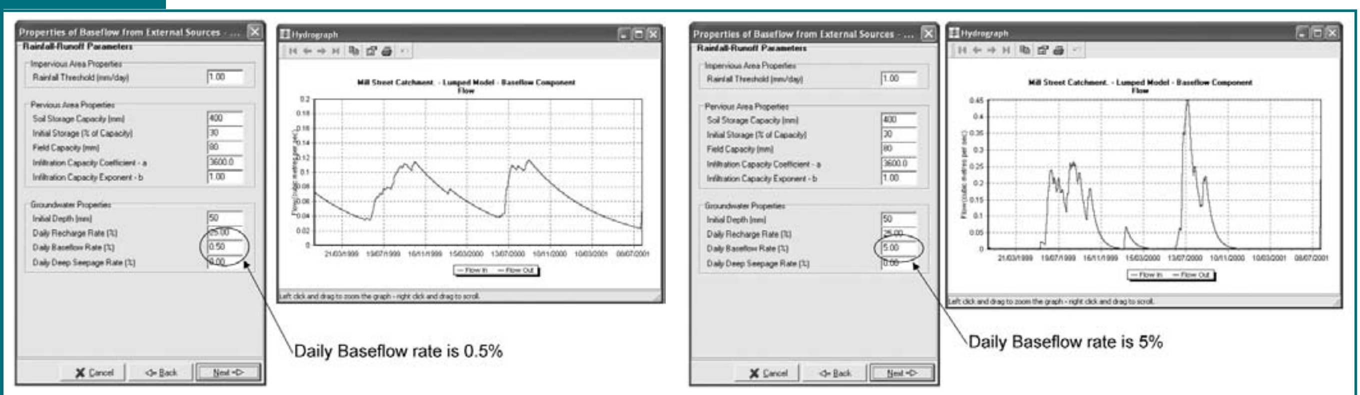

Figure 4.2. Using MUSIC to model groundwater - surface water interactions

PROGRAM 5

CLIMATE VARIABILITY

Program Leader
FRANCIS CHIEW

Report by Sri Srikanthan

A preliminary assessment of the effect of climate change on extreme rainfall in Australia

As a result of global warming, the frequency of occurrence of floods and droughts is also expected to change. Activity 3 in Project 5.05 (5B): "Stochastic rainfall data generation models" attempts to incorporate the effects of climate change into stochastic models. The potential climate change impact on runoff (and other hydrological variables) is commonly estimated by comparing the runoff simulated by a hydrological model using present climate data, and then using future climate change scenarios produced by general circulation models (GCMs) of the climate system.

The simplest method for reflecting the impact of climate change on rainfall is to multiply observed records of point (or catchment) rainfall by the average change in GCM grid square rainfall from current to future conditions, calculated on a monthly basis (Prudhomme *et al.* 2002). This commonly used method applies a constant factor for each month or season to scale all the daily rainfall in that month or season. A major advantage of this method is that it is easy to apply to a range of different GCMs and emissions scenarios, enabling a range of possible climate scenarios to be explored. However, this methodology is not sensitive to the changes in extreme rainfalls that are modelled by GCMs. The number of wet days may also change with global warming and applying this simple method with monthly data gives the same number of wet days as are present now.

This article describes a refinement of the scaling method (Harrold and Jones, 2003) to better estimate the impact of climate change on rainfall at the extremes. The pattern of change in the ranked GCM daily rainfalls is used to scale the ranked historical catchment daily rainfall. This method will be referred to as the "daily scaling" method to differentiate it from the commonly used "constant scaling" method. Climate change impacts on maximum daily rainfall and droughts of several durations are assessed for six catchments (Figure 5.1) located in eastern Victoria, central New South Wales, northern New South Wales, northeast New South Wales, southwest Western Australia and northwest Northern Territory using the daily scaling method.

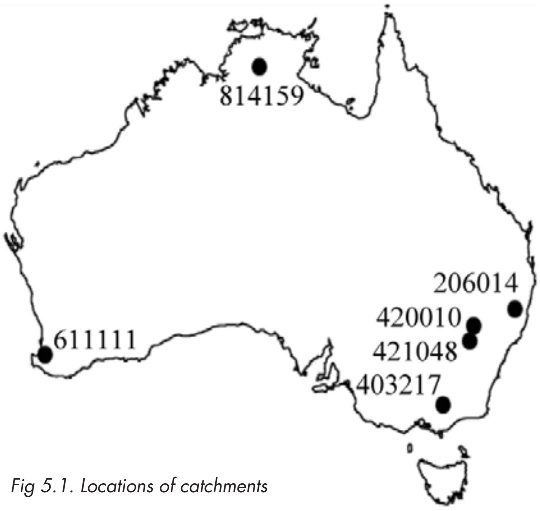

Fig 5.1. Locations of catchments

Climate change simulations from the CSIRO Mark 2 GCM for an ensemble of five transient runs (1871-2100) for the A2 greenhouse gas emission scenario are used (Watterson and Dix, 2003). The A2 scenario is a "high growth" scenario that reflects high greenhouse gas emission. The GCM outputs for 2021-2050 are compared with the outputs for 1961-1990 (present climate) to estimate changes to the 1901-1998 historical catchment data in a 2021-2050 climate.

Annual maximum daily rainfall

From the historical record and the GCM influenced catchment average daily rainfall data, annual maximum

Table 5.1. Percentage change in daily maximum rainfall.

Location	N-E NSW	Eastern Vic	North NSW	Central NSW	SW WA	NW NT
ARI (years)	206014	403217	420010	421048	611111	814159
200	8.1	2.3	12.2	8.1	15.3	18.1
100	5.3	2.3	11.1	6.7	14.9	17.3
50	2.8	2.4	9.9	5.2	14.4	16.5
20	-0.2	2.5	8.4	3.4	13.5	15.1
10	-2.2	2.5	7.1	2.1	12.5	13.8
5	-3.7	2.6	5.7	1.0	11.0	12.1
2	-4.6	2.7	3.6	0.3	7.6	8.7

NEW TECHNICAL REPORT

Stochastic Generation of Point Rainfall Data at Subdaily Timescales: A Comparison of DRIP and NSRP

By
Andrew Frost
Ratnasingham Srikanthan
Paul Cowpertwait

Technical Report 04/9

One of the goals of the Climate Variability Program in the Cooperative Research Centre (CRC) for Catchment Hydrology is to develop and test computer programs for generating stochastic climate data at timescales from less than one hour to one year and for point sites to large catchments. The appropriate models will be part of SCL (Stochastic Climate Library - a suite of stochastic climate data generation models), a product in the CRC's Modelling Toolkit (see www.toolkit.net.au/scl).

This report describes the evaluation of two point subdaily stochastic rainfall models - the Newman-Scott Rectangular Pulse (NSRP) and the Disaggregated Rectangular Intensity Pulse (DRIP). The models are evaluated using relatively long pluviograph data from ten major Australian cities and regional centres.

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

This report is also available as an Adobe Acrobat file from www.catchment.crc.org.au/publications

daily rainfalls were extracted. A Log Pearson Type III distribution was fitted to the annual maximum daily rainfall series and the magnitudes of rainfall at average recurrence intervals (ARI) 2, 5, 10, 20, 50, 100 and 200 years were calculated. The percentage changes in the magnitudes of extreme daily rainfalls are presented in Table 5.1. It can be seen that the extreme rainfall for all the catchments except 206014 increases under the climate change scenario up to a maximum of about 18%, with the largest increase observed in the Northern Territory and southwest Western Australia.

Low rainfall

Rainfall totals over 3, 6 and 9 months were examined to determine the effect of climate change on rainfall deficiency. The percentage change in the low rainfall sums are presented in Table 5.2. The zeroes in the table indicate that the rainfall sums are zero for both the present and future climate scenarios. The larger percentage values are usually associated with the 3-month rainfall sum and they correspond to differences between small rainfall totals. As shown by the negative values in Table 5.2, in most cases, the rainfall sums are smaller for the future climate than the present one.

In addition, rank one low rainfall sums over 2, 3, 5, 7 and 10 years were calculated for the present and future climate scenarios. The percentage change relative to the current climate in the rank one low rainfall sums are presented in Table 5.3. Except for catchment 814159, the results in Table 3 show that the rank one low rainfall sums are more severe in this future climate scenario than in the present. This implies that, for a given recurrence interval, droughts may be more severe and that drought conditions may occur more frequently.

Conclusions

The "daily scaling" method used to estimate the impact of climate change on rainfall takes into account both the decrease in mean annual rainfall and the increase in extreme daily rainfall estimated by the GCM. However, the daily scaling method assumes that the change in the catchment rainfall is the same as the change in the much larger GCM grid rainfall. Given this limitation and the uncertainties associated with the GCM outputs, the analysis carried out indicates that, for this climate scenario, there will be an increase in maximum daily rainfall up to about 18% for all the six catchments and a decrease in low rainfall sums for all the catchments except the one located in Northern Territory (814159).

It should be noted that this analysis is based on a single GCM and a single emissions scenario - analysis of the uncertainty associated with these results has not been undertaken. Such an analysis would be required before any definite conclusions about the impacts of climate change on extreme rainfall events can be reached.

In addition, the results reported are obtained by empirical methods and may include some sampling variability. Work is in progress to simulate long sequences to minimise the effects of sampling variability.

Table 5.2. Percentage change in 3, 6 and 9 months rainfall sums.

ARI(years)	Months	206014	403217	420010	421048	611111	814159
100	3	-5.0	-16.9	-56.6	-32.3	-24.6	0.0
	6	-3.0	-9.1	-17.0	-12.7	-11.3	0.0
	9	-4.0	-6.8	-13.4	-7.4	-9.3	4.1
50	3	2.3	-15.8	-38.6	-30.6	-19.6	0.0
	6	-1.4	-9.8	-15.8	-8.3	-11.0	0.0
	9	-2.2	-6.2	-13.3	-3.9	-9.5	1.1
10	3	-0.5	-13.1	-15.6	10.8	-34.4	0.0
	6	-2.0	-3.7	-13.7	-22.4	-10.3	7.3
	9	-1.8	-3.1	-10.8	-5.7	-9.2	-6.4
5	3	-1.4	-11.9	-15.8	-9.2	-22.4	0.0
	6	-0.5	0.1	-13.8	-16.7	-8.8	-10.3
	9	-2.6	-2.6	-9.2	-5.2	-6.2	-7.3
2	3	0.7	-9.4	-10.9	-6.7	-15.1	0.0
	6	-1.4	-1.4	-10.0	-12.0	-7.4	18.2
	9	-3.7	-2.3	-6.7	-4.1	-6.8	-3.5

Table 5.3. The percentage change in the rank one low rainfall sums

	2 years	3 years	5 years	7 years	10 years
206014	-2.8	-2.9	-2.9	-2.7	-3.1
403217	-4.7	-5.0	-4.1	-3.5	-3.4
420010	-5.1	-6.6	-8.5	-7.5	-7.6
421048	-5.7	-5.5	-5.9	-4.9	-5.1
611111	-9.9	-9.6	-10.7	-9.4	-9.0
814159	-0.6	1.6	1.6	2.0	1.5

References

1. Harrold, T.I., and Jones. R.N. (2003) Generation of rainfall scenarios using daily patterns of change from GCMs. In: Franks S., G. Bloschl, M. Kumagai, K. Musiake, and D. Rosbjerg (eds). Water Resources Systems- Water Availability and Global Change (Proceedings of symposium HS2a held during IUGG2003 at Sapporo, July 2003). IAHS Publ. no. 280, IAHS Press, Wallingford UK.

2. Prudhomme, C., Reynard, N. and Crooks, S. (2002) Downscaling of global climate models for flood frequency analysis: where are we now? Hydrological Processes, 16, 1137-1150, 2002.

3. Watterson, I.G. and Dix, M.R. (2003) Simulated changes due to global warming in daily precipitation means and extremes and their interpretation using the gamma distribution, Journal of Geophysical Research, Vol. 108, No D13, 4379, doi 0.1029/2002JD002928.

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NEW TOOLKIT SOFTWARE

Stochastic Climate Library (SCL)

The Stochastic Climate Library (SCL version 1.0.3b) and its associated user guide can now be downloaded from www.toolkit.net.au/scl

For details of changes made to this version of SCL please look under 'Version History' on this page.

Stochastic climate data can be used as inputs into hydrological and ecological models to quantify uncertainty in environmental systems associated with climate variability.

SCL is a library of stochastic models for generating climate data. Version 1.0.3b of SCL has stochastic models for generating rainfall and climate data at a site at annual, monthly and daily time steps. Other stochastic models will be added to future versions of SCL, after model development and testing.

For further information about SCL and its application visit www.toolkit.net.au/scl

NEW TECHNICAL REPORT

Evaluating the Effectiveness of Habitat Reconstruction in Rivers

By
Michael Stewardson
Peter Cottingham
Ian Rutherfurd
Sabine Schreiber

Technical Report 04/11

River restoration is a new science and many projects are necessarily experimental. Our understanding of processes of degradation is improving but our ability to prescribe efficient restoration treatments which might include environmental flows, reintroduction of large wood debris and riparian restoration is still limited.

This report reviews approaches to river restoration. Those considering an evaluation will benefit from reading the limitations and advantages of the various approaches. River engineers, aquatic ecologists and fluvial geomorphologists now work in multi-disciplinary teams to plan river restoration work including monitoring and evaluation. In recognition of this, two chapters of this report are devoted to discussing conceptual aspects of restoration planning and evaluation as common ground across the disciplines.

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

This report is also available as an Adobe Acrobat file from www.catchment.crc.org.au/publications

PROGRAM 6
RIVER RESTORATION

Program Leader
MIKE STEWARDSON

Report by Dan Borg and Ian Rutherfurd

The Granite Creeks, the Snowy River and stochastic scour

Wood in streams is considered important for fish habitat. It is a major driver of instream physical diversity, particularly in sand-bed streams. The streambed scours pools around the wood, and this physical bed-diversity is considered to be an important fish habitat. Instream wooden structures are therefore becoming a common component of rehabilitation projects in sand-bed streams.

The CRC for Catchment Hydrology's River Restoration group has been involved in a major multidisciplinary trial investigating the physical and biological response of adding timber in a stream rehabilitation experiment in the Granite Creeks of NE Victoria. Lowland reaches of streams in the Granite Creeks system have historically filled with sediment - in the form of sand slugs - burying debris and filling pools. This sediment has resulted in a relatively homogeneous physically environment devoid of habitat. Working with the CRC for Freshwater Ecology and the Goulburn Broken Catchment Management Authority, we added wooden structures in two streams of the system with the intention of forming scour pools in the sand below the structures.

We used Nick Marsh's PhD work to guide the design of structures and formation of hypotheses about the amount and extent of pool scour. Structures were based on a naturally occurring orientation of wood, constructed using red gum sleepers and installed in 100m reaches either individually or as a series of four structures, spaced eight metres apart. Physical and ecological responses were compared to changes at a number of un-manipulated reaches.

Granite Creeks Results

We found that geomorphic diversity could be restored with instream wood and this can have positive effects on fish abundances (see *Catchword* Article, November 2003). However, scour around the structures was much more variable than we anticipated. For the same, relatively simple design of habitat structure, resultant pool scour varied from site-to-site, within sites and also over time. This variation was driven by site scale differences, local geomorphic features and the build-up of woody debris around the structure. Flow regime was also an important driver, with pools forming with floods, then infilling as flows recede and the hydraulic effect of the structures diminishes.

Results have led to a major shift in the way we consider flow and scour around instream structures, and their permanence for habitat applications in these unstable sand bed environments. Traditional engineering approaches, where we predict the maximum scour depth around a structure and scour-to failure, proved not too useful for habitat applications. Rather, we need to know the full range of scour and fill over the entire flow regime. We argue that the relationship between flow and pool

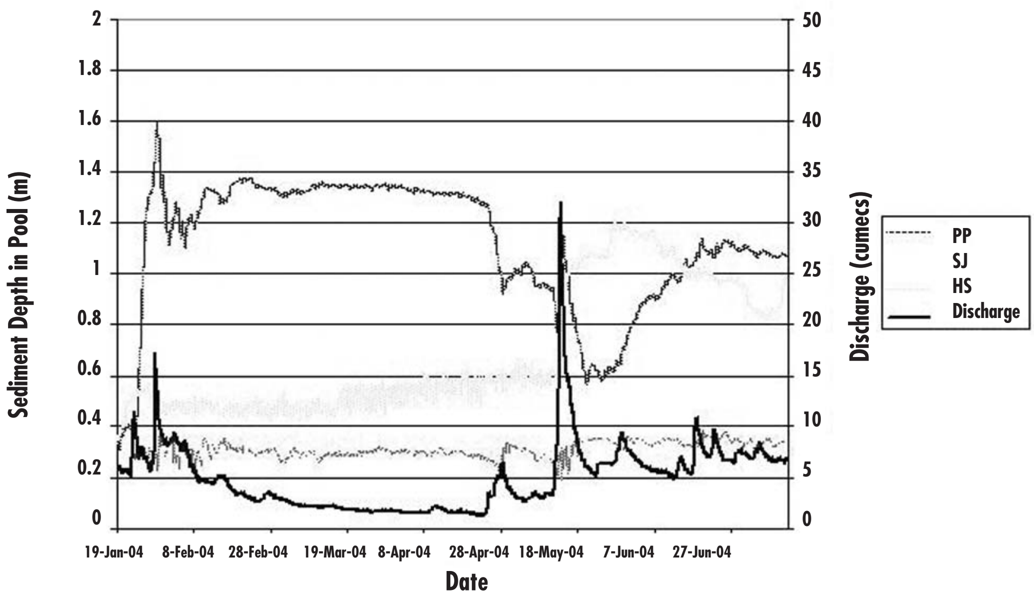

Figure 6.1. Pool formation and persistence is different for different orientations of wood. This figure presents sediment depth changes in three woody debris-induced scour pools in the Lower Snowy River. HS, PP and SJ refer to different scour mechanisms (the horseshoe vortex, plunge pool and submerged jet scour mechanisms, respectively). Discharge is presented on the secondary y-axis.

scour is stochastic. This stochastic relationship is further complicated by local variation that can be of a magnitude much greater than initially anticipated.

We are now using a recently developed real-time monitoring method to better understand aspects of pool permanence and further elucidate the dynamics of scour and fill with flow regime. The method is pressure based, and uses geotechnical instrumentation to monitor the changes in pressure of sediment in real-time (independent of the changes in water pressure associated with flow events). This change in pressure is linearly related to changes in sediment depth. The method overcomes many of the limitations of traditional real-time streambed elevation monitoring techniques, and for the first time allows us to continuously measure changes in pool size during floods.

Monitoring in the Lower Snowy River

With support from the Victorian Government's Department of Sustainability and Environment, our attention has turned to the Lower Snowy River. In the Snowy River we are using the new monitoring technique to investigate the persistence of scour pools around different orientations of woody debris.

Pool permanence associated with three orientations of natural wood has been monitored for over six months now. We find that the pool permanence and response to flow differs between different orientations of wood (refer to Figure 6.1). Different pool formation mechanisms can scour, fill or experience no change for the same flow event. Such information will be used to inform design of the rehabilitation trial.

Implications for Management

Introducing wood to sand-bed streams can increase instream physical diversity in the form of scour pools; however the permanence of these pools remains uncertain. Simply adding wood does not ensure that habitat is available at key times for biota. Formation and permanence of pools varies between different orientations of wood, and even for the same uniform orientation of wood in space and over time.

Any rehabilitation trial using woody debris in unstable sand-bed streams needs to consider these drivers of variability and acknowledge the uncertainties in pool habitat permanence in these dynamic environments.

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EDUCATION AND TRAINING PROGRAM

Program Leader
DAVID PERRY

The Flow on Effect - October 2004

At a glance - a summary of this article

A workshop/event registration section in the Catchment Modelling Toolkit website has recently been launched to assist Toolkit members and others interested in learning about and registering for CRC for Catchment Hydrology training. Visitors to the site at www.toolkit.net.au/training can register for advertised workshops, express interest in a repeat of earlier CRC training or request assistance in sourcing training that better meets their organisation's needs.

CRC Training

Over the last few years the CRC has been steadily increasing its commitment to training industry professionals in many aspects of catchment hydrology. With the success of the Catchment Modelling Toolkit (see the Directors Note in this edition of *Catchword*) CRC project teams have taken responsibility to provide training to support the understanding and application of the Toolkit software. In the twelve months to June this year, the CRC delivered over 40 workshops and short courses to over 700 people. A little under half of these participants attended the two weeks of the Catchment Modelling School in February 2004.

Many of the Catchment Modelling Toolkit products build on an intuitive approach by users in learning about the products and applying them. As is the case with almost any tool however, its effective use comes with a deeper understanding of the tool, its development, how it works and when it is best applied.

Planning training

All Toolkit software products are supported by an eGroup which is a web-based mailing list designed to create a community of users and developers who can provide support to each other. However this is not a substitute for training. As regular *Catchword* readers would know, the CRC offers regular training workshops in Catchment Modelling Toolkit products. Matching the delivery of training with demand can sometimes be a challenging task. Knowing when and where to offer particular training requires some informal market research and a lot of gut feeling to get ensure that the resources we commit are most effective in meeting the needs of model users. Over the last few weeks Susan

SPECIAL PUBLICATION AVAILABLE ON-LINE

Spatial Patterns in Catchment Hydrology

Edited By
Rodger Grayson
Günter Blöschl

This publication (404pp) brings together a number of recent field exercises in research catchments, that illustrate how the understanding and modelling capability of spatial processes can be improved by the use of observed patterns of hydrological response. In addition the introductory chapters review the nature of the hydrological variability, and introduce basic concepts related to measuring and modelling spatial hydrologic processes.

Written in an intuitive and coherent manner, the book is ideal for researchers, graduate students and advanced undergraduates in hydrology, and a range of water related disciplines such as physical geography, earth sciences, and environmental and civil engineering as related to water resources and hydrology.

This publication can be downloaded at no cost from the CRC web site. Follow the 'Special Publication' link from www.catchment.crc.org.au

Daly and Jake MacMullin have been working towards improving this situation.

www.toolkit.net.au/training

By the time this *Catchword* is printed and distributed, a new area will be available to visitors to the Toolkit website. The Toolkit training site has three main sections. Visitors to the site will be able to:

- Register for an advertised CRC workshop
- Express interest in a repeat of a workshop, and
- Request assistance in sourcing training that better meets their organisation's needs.

Registering for CRC courses on-line

All of the formal training workshops scheduled by the CRC will be listed on the Toolkit training site. By visiting the training 'home page' at www.toolkit.net.au/training, visitors will be able to see exactly what courses are scheduled; their duration, location and cost and importantly when registrations close. By selecting the title of a workshop or course of interest, additional information is revealed including the course location, presenters, objectives, recommended prerequisites for participants and how many places are currently available. Registration for all CRC scheduled courses can now be done through the website. Toolkit members will be pleased to learn that by entering their username and password, their details will be automatically inserted. The last step for registration is to fax the automatically generated registration form to the CRC Centre Office. From our side, things are also very easy. When the registration form is received at the Centre Office, the course participants list is updated and a confirmation email automatically sent to the registrant. The count of places left in that course will then adjusted in the database. Until the site is connected to a financial institution gateway, we will be unable to accept on-line payment. An on-line payment facility however, is expected to be in place for the Catchment Modelling School during 2005.

CRC courses that are not scheduled

From the training home page, visitors will also be able to express interest in courses that the CRC has offered previously but are not currently scheduled. These expressions of interest will allow us to better judge when there is sufficient interest in a particular course and where it could be delivered. People who use this facility will receive an initial email inviting them to register before it is more widely advertised.

Seeking assistance with training

In some cases an organisation or individual may have particular requirements for training that the CRC may be able to assist with. In the past, for example, the CRC in conjunction with Monash University staff has held Flood Management workshops. These workshops were in response to requests from organisations that had a large number of staff requiring training in that particular area. We aim to assist with such requests, and at the very least, we may be able to direct inquiries to another organisation who can provide the required training services.

Upcoming MUSIC course trial of the site

During early December 2004, the CRC will be offering MUSIC Version 2 training in Sydney. This will be the first opportunity to gauge our new website's usefulness and to receive feedback about its operation. If the website system is successful we will apply the same principles in managing registrations for the Catchment Modelling School - scheduled for mid next year in Brisbane and Sydney.

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POSTGRADUATES AND THEIR PROJECTS

Dale Browne

My interest in water started at The University of Melbourne, where I studied environmental engineering and Indonesian. Little did I think as I finished my five year degree that I would soon be back at university embarking on yet another degree. Then again, I am still involved with the university clubs, rollerblading and doing Aikido so perhaps it was inevitable.

Seeking some real world experience, and cash to travel overseas, I landed vacation work at Sinclair Knight Merz and was introduced to the world of salinity and irrigation, heading up north to investigate salt interception schemes around Kerang to reduce salt loads into the Murray.

After graduating from university, I applied the other half of my degree, travelling to Indonesia for three months. I stayed in a small Javanese village on a cultural exchange program, living with a Muslim family, singing Aussie songs to school children and coordinating a project to provide village street lights. The community embraced our group enthusiastically and we joined noisy soccer expeditions, religious events and even weddings not to mention everyday village life. In light of recent events in Indonesia, such experiences remind us that we are all human regardless of our cultural differences and that we can, indeed must, work together to address the social and environmental challenges our world faces. Even in a tropical country, water issues are as pressing as they are in drought-stricken Australia. While the pollution problems seem insurmountable, it was heartening to meet fellow environmentalists and engineers who cared and were working to address them.

On returning to Australia, I joined Melbourne Water and shifted my focus to urban water issues, dealing with flooding and urban development. I soon moved into water quality, becoming one of the first to use a beta version of MUSIC to design treatment systems. Before long, I realised that stormwater treatment was a whole lot more complex than it seemed at first and started looking into bioretention and infiltration systems in detail. Before I knew it, I was presented with an opportunity I couldn't refuse - to research these systems at Monash University and really understand how they work.

The purpose of my research is to model the clogging of stormwater infiltration systems. In plain English, a stormwater infiltration system is a hole in the ground full of gravel that stores stormwater and lets it soak into the ground. They could be as simple as a soakaway behind your house, a grassed swale drain along your street with a gravel filled hole beneath it, or a larger basin. These systems help to restore the hydrology of urban areas back to something approaching natural conditions and reduce the impacts of higher flows and pollution on streams.

Not surprisingly, these systems which filter pollutants tend to clog up with sediment, preventing water from soaking into the surrounding soil. This process is not well understood and consequently many systems fail where clogging risks are not addressed.

The model developed within this study will address this by modelling flow through an infiltration system and the clogging process, enabling the consequences of clogging for a stormwater system to be predicted. Hopefully, this will help stormwater managers to build infiltration systems with confidence and accelerate the growing trend towards sustainable urban drainage systems.

Having spent some time delving into the depths of water flow through soil and groundwater modelling, I will now be focussing on model development. Hopefully there will still be time for a bit of rollerblading and travel overseas on the side.

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AUSTRALIAN CRC YOUNG WATER SCIENTIST WINNER ANNOUNCED

Congratulations to Sara Lloyd who recently won the Young Water Scientist of the Year Award. Sara is a postgraduate student with the CRC for Catchment Hydrology and investigated key aspects of water sensitive urban design: its effectiveness, life cycle costs and community acceptance.

The award, worth $2500 this year, is given annually by the CRC Water Forum, an alliance of the five water-focused Australian cooperative research centres.

Congratulations also to the other award participants from the other water-based CRCs.

For further information visit http://mooki.canberra.edu.au/waterforum

CRC PROFILE

Our CRC Profile for October is:

Jean-Michel Perraud

Well I thought I could try an anti-chronological format to give the recent events first, but somehow that just didn't work at all, so I'll stick to the good old chronological storyline.

France

I grew up in a small, fairly typical village in the South-East of France, which however avoids complete anonymity by having been the birthplace of Mandrin, a kind of Robin Hood of the 18th century. Unfortunately, the end of his story is realistic and violent, certainly different from the one of his British counterpart!

After high school I met the selection requirements to get into scientific preparatory classes, where students are known as taupes (slang, 'moles'), referring to the higher than average rate of short-sightedness, books being to blame. That was a tough period with little time for anything else (not much skiing anymore!), but with really good memories of comradeship. For about half of the taupes this usually meant three years of hardship to get through it, but fortunately I was in the other half and made it through the competitive entrance exams in the second year to an engineering school in Paris, Centrale.

The coursework there was purposely multi-disciplinary. It was sometimes demanding to juggle in a day between, say, thermodynamics, civil engineering and language courses, but I liked that. Somehow many of the fellow students I had around me at the time happened to be well versed in computer science. I became more interested, bought a PC and installed a Debian-Linux, and got quite hooked. I then decided to take Information Systems, Network and Telecommunications as a major, albeit after some hesitation since it was a major change, physics having been my main interest for a long, long time.

After graduating, I worked for one year in Paris in the Department of Information Systems at the headquarters of a water utility. My main professional interests at the time were cryptography, authentication systems, and network architecture.

Malaysia

I was, however, one of the last batch required to do a military service given my date of birth. Fortunately, it was a common thing for most tertiary graduates to undertake a more 'civil' form of service (don't get me wrong, it is not avoidance!). So instead of playing soldiers on the firing range, I worked as an expatriate in a subsidiary of this water utility in a foreign country. I opted for an opportunity in Malaysia and landed in Kuala Lumpur in 1999. Work there was pretty much a continuation of the project I was doing in Paris. Having had little opportunity to travel prior to that, being in the Malaysian blend of cultures for twenty months was really a good and valuable experience. Besides the cultural aspect, it was great to enjoy now and then the islands on the east and west coasts of Malaysia.

Australia

In Malaysia I fell for an Aussie girl, my partner since then. She decided to apply for a PhD in Sydney and I thought it could be a good experience to spend a few years down under. I actually first contacted CSIRO to enquire about a PhD as well, but could not apply with a temporary residency at the time. However this first contact with Rob Vertessy led instead to a work opportunity as a modeller and software engineer. I saw then the opportunity to work at the interface of software engineering and sciences, which suited me, so I moved to Canberra. For the anecdote, I made a faux-pas the first day of work and came not only with the ironed shirt, but also a neck-tie. Oops. Colleagues and manager were nice enough not to frown upon this shameful breach of the usual dress code!

CSIRO is a good place to work at, and allows for a variety of projects. The Rainfall-Runoff Library was a good opportunity to work on non-linear optimisation. It was also a trail blazer for the applications built on TIME, which had interesting but sometimes difficult aspects. The Stochastic Climate Library allowed for some interesting work with probability and statistics, and there was even a bit of macro-economics with a multi-attribute decision support system. I guess I also prefer dealing with TIME-related developments that have a marked scientific aspect whenever I can. These days the main CRC project I am working on is the rather daunting "whole-of-catchment" river system model, a.k.a. E2 before a better name is found. Apart from that I would like to find some time to investigate what is currently being done in sensitivity analysis.

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WHERE ARE THEY NOW?

Report by Antony Motha

My PhD thesis, submitted in December 2001, was passed in April 2002, much to the relief of my wife and me. Going back to study after four years working in the Northern Territory took some adjustment, however the PhD was a very satisfying experience. My PhD work dealt with the application of tracer methods in studying sediment delivery in multiple-source catchments. Components of this work have been published in journal articles, with my supervisors Peter Hairsine, Rodger Grayson and Peter Wallbrink. The implications of my research work range from the recognition of the strength of the tracer-based methodology for identifying suspended sediment sources within watersheds (e.g., Olsen, 2003), to the adoption of more specific conclusions relating to the role of roads and tracks as sediment sources in native forests (e.g., Polglase and Hairsine, 2004, Wallbrink *et al.*, 2003), and in agricultural catchments (e.g., Wallbrink and Hancock, 2003).

Since completing my PhD, I have worked in a variety of jobs and for the past year have been working with Bill Guy & Partners, a civil engineering consultancy in Canberra. Our projects are largely in the Canberra and Queanbeyan area, however we do get involved in projects in NSW and Victoria from time to time.

I am working in the Water Resources and Urban Infrastructure section and have worked on projects ranging from infrastructure design, to modelling the hydrology of catchments so that the results can be fed into the design work. Examples of the latter include rainfall-runoff modelling and flood estimation to facilitate the design of stormwater drainage and retarding basins, water quality simulation for catchments up to a few hundred hectares in order to design water quality control ponds, and water balance modelling to aid the design of stormwater re-use for lawn irrigation and toilet flushing for residential/ residential-retail developments up to 2 ha in area. Water quality control ponds are designed to reduce post-development pollutant export to existing levels, and stormwater re-use helps reduce the export of stormwater runoff and associated pollutants to receiving waters.

Stormwater re-use and pollutant export reduction are key objectives in Water Sensitive Urban Design (WSUD) and form part of the ACT's long-term water resources strategy "Think Water Act Water". I believe WSUD is an area that will keep us busy and challenged, and make huge contributions towards the sustainable development of Canberra. No doubt we will benefit from the work of the Urban Stormwater Quality program of the CRC for Catchment Hydrology, which leads the way in research related to WSUD, and the MUSIC model will be integral to our work in this area.

Although I have had little formal involvement in soil erosion and sediment delivery issues since my PhD, I constantly keep my eye out for that 'invaluable dirt'. For instance, there was a sediment deposit in one of our project sites within the Mugga Creek catchment. This sediment deposit, believed to be about 125 years old, had earlier been identified as potential research material by Peter Fogarty of Soil and Land Conservation Consulting. With encouragement from our client, the ACT Planning and Land Authority (ACTPLA) we contacted potentially interested parties. The CRC for Freshwater Ecology, through Fiona Dyer's and Martin Thoms' involvement, took some sediment cores from the deposit. We are hoping that these sediment cores will form the basis for a good student research project in the coming year.

In the meantime, I look forward to the challenges of civil engineering design particularly WSUD. Outside work, I am still searching for those winning Lotto numbers and continue to dream of that round-the-world trip.

I wish Rodger and the CRC for Catchment Hydrology team every success in their bid for the eWater CRC.

References

1. Olsen, L.D. (2003) Selected applications of hydrologic science and research in Maryland, Delaware and Washington, D.C. USGS Fact Sheet FS-126-03, U.S. Geological Survey, Maryland.
2. Polglase, P. and Hairsine, P. (2004) Maximising the benefits of new tree plantations in the Murray-Darling Basin. A joint statement by CSIRO Forestry and Forest Products and CSIRO Land and Water.
3. Wallbrink, P.J. and Hancock, G. (2003) Western Port sediment study: Background and literature review. Technical Report 12/03, CSIRO Land and Water, Canberra
4. Wallbrink, P.J., Olley, J.M. and Hancock, G. (2003) Tracer assessment of catchment sediment contributions to Western Port, Victoria. Technical Report 8/03, CSIRO Land and Water, Canberra

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OUR MISSION

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

OUR RESEARCH

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

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

CRC AUSTRALIA

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 Infrastructure, Planning and Natural Resources
Department of Sustainability and Environment, Vic
Goulburn-Murray Water
Grampians Wimmera Mallee Water Authority
Griffith University
Melbourne Water
Monash University
Murray-Darling Basin Commission
Natural Resources and Mines, Qld
Southern Rural Water
The University of Melbourne

Associates:
Water Corporation of Western Australia

Research Affiliates:
Australian National University
National Institute of Water and Atmospheric Research, New Zealand
Sustainable Water Resources Research Centre, Republic of Korea
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Industry Affiliates:
Earth Tech
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