National Program for Irrigation R&D:

Optimising On- and Off-Farm Water Supply Systems Management

Report on the Findings and Proceedings of the Workshop held at The University of New England, 10–11 December, 1996

Land & Water Resources
Research &
Development
Corporation

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Introduction

Background

The Land and Water Resources Research and Development Corporation (LWRRDC) has collaborated with water authorities in NSW, Victoria and Queensland to fund a National Program for Irrigation Research and Development (NPIRD).

The original program was established in 1993 and ran until 1996 and priorities for funding projects were based on those developed for the National Irrigation Research Fund. In 1996 a program was prepared for the period 1996–1999 based on extensive consultation with industry, government and the community.

As a result of the planning process this workshop was organised in December 1996 in Armidale, to address issues of improved demand delivery of irrigation water by optimising on- and off-farm water delivery systems and their management.

This report contains the findings and proceedings of the Workshop.

Objectives

The workshop aimed to address a priority project area of the NPIRD Project Plan:

> *'Improved delivery of irrigation water by optimising farm and supply management systems on a scheme or catchment basis'.**

This involved the following objectives:

- To improve current scheme optimising systems for water delivery by integrating farm water efficiency systems and irrigation supply systems;
- To develop demand management based delivery systems;
- To develop network flow models on a scheme/catchment basis which maximises delivery efficiency whilst ensuing adequate supply of water of acceptable quality—using surface and groundwater supplies, storage options, water trading, drainage reuse and other strategies; and
- Develop economic assessment techniques and policies to encourage optimisation of on- and off-farm systems.

Attendees

Attendees came, by invitation, from NSW, Victoria, Queensland and South Australia covering:

- a range of disciplines and Universities
- representatives of irrigation industry
- representatives from key water agencies and government departments
- consultants

Appendix A contains a list of those who attended.

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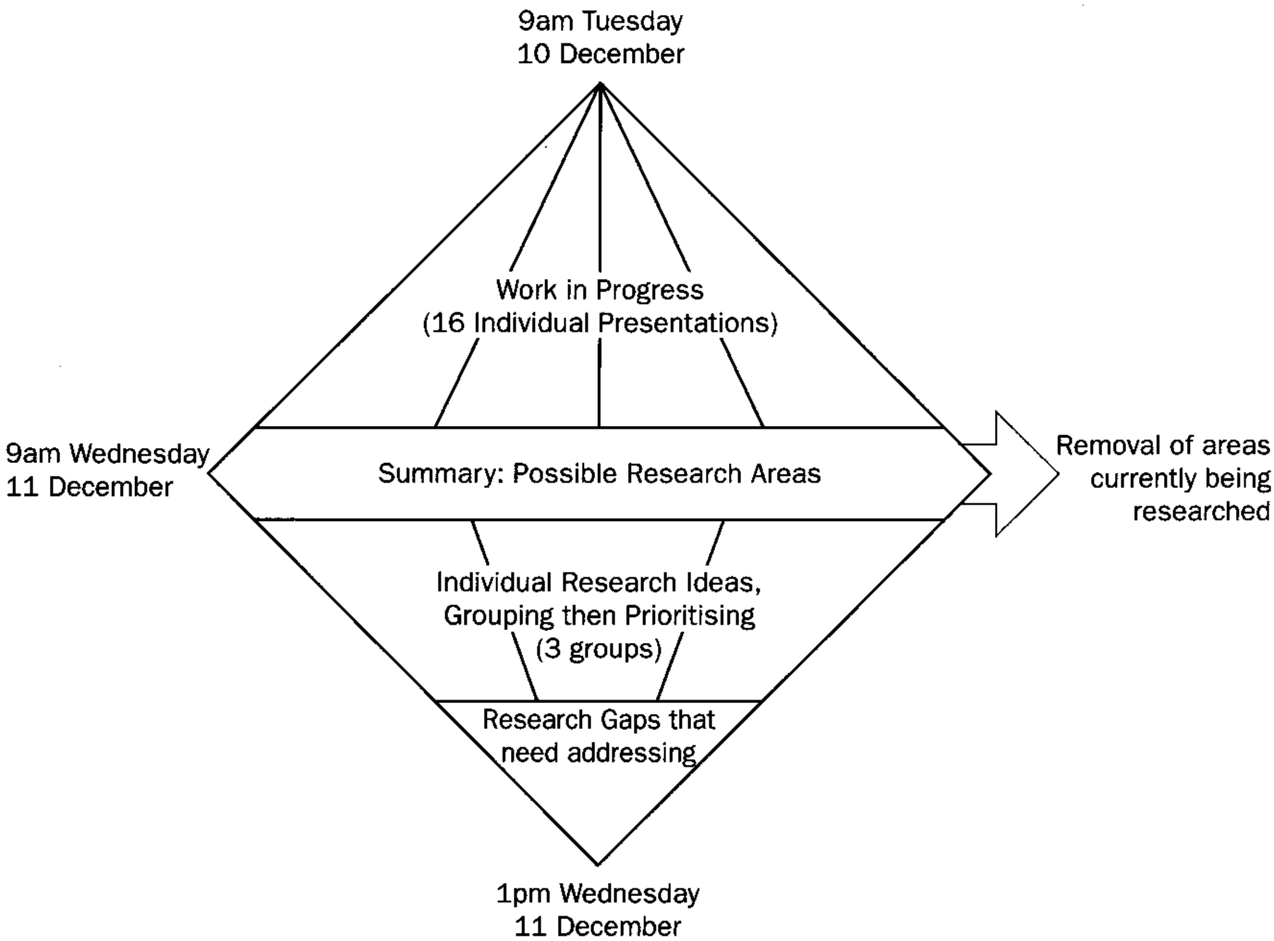
* When the term scheme/catchment is used it relates mainly to an area where planning and cooperation occurs to achieve benefits for the participants. Any planning at this level, however, must consider the impacts both within and outside that area. The area could be based on a distributed system, a natural flow system or a mixture of both.



Workshop Structure

This one and a half day workshop was structured as shown below in the diagram with Tuesday 10 December being taken up by 16 individual presentations (Appendix B) of work-in-progress and research issues (Appendix C). Participants used a report sheet to note:

1. Questions of Clarification to the Presenter.
2. Issues and Research Gaps identified.

At the end of each session a summary of the Issues and Research Gaps was made. Four summaries were completed throughout the day (based on the timed sessions indicated in Appendix B) and these were distributed at the end of they day to all participants. The issues raised in each section are listed in Appendix D .

On Wednesday, 11 December, the morning session was divided into two main activities. The first involved the forming of three groups by the NPIRD Program Coordinator (Noel Dawson) that had a wide range of disciplines and backgrounds. Each group generated their own individual research ideas, responding to the question;

'What are the major research (and development) issues you see that need to be addressed?'

Responses were grouped under themes and in some cases, groups prioritised the themes. Each group then presented their findings for discussion to all delegates.

The final session involved overall discussion of key research issues and gaps and where appropriate, who should be involved.

Research Ideas

As part of the process of generating research ideas, the 20 attendees were allocated to three groups. Groups were carefully chosen to provide maximum diversity of ideas, backgrounds and organisations. Each individual generated three research ideas based on their background and those generated throughout the previous day. All ideas were shared and then grouped under themes and the themes ranked on perceived importance. Groups came up with between two and four themes and these were shared with all participants and formed the basis for decisions as to which 'gaps' in research needed to be addressed. This took place in the next and final session. The overlap between groups is evident but diversity is also present and these themes provide a rich source of research and development needs. The themes are presented in decreasing importance within each group.

Group 1

Facilitating Better use of Models and MIS

- Use of remote sensing and satellite imagery to improve management of irrigation systems and demands;
- An audit and comparison of asset replacement, maintenance, and cost recovery (water pricing) strategies of water supply entities;
- Develop data collection and management systems for implementation of:
  - environmental sustainability, and
  - management/policies;
- How authorities can use various models effectively to incorporate these into day to day operations, including collection of data; and
- Quantifying model predictive uncertainty.

Integrated Design/Optimisation of Flexible On- and Off-Farm Irrigation Supply Systems

- Integration of Infrastructure design/refurbishment optimisation studies and development of a process for scoping the scale from the big picture in catchments down to detailed design;
- Design/optimisation of *flexible* supply systems to meet changing demand over time;
- Incorporation of stochastic inputs and scheduling into the engineering design process and the design of irrigation systems;
- Optimisation of flexible irrigation systems by integration of off-farm and on-farm delivery systems—considering environmental, economic, agronomic, operational and engineering design constraints for new systems and refurbishment of old systems;
- Evaluation of demand prediction technologies having regard to:
  - scale,
  - stochastic,
  - real time, and
  - historical predicted;

- Integration of water quality and quantity (on- and off-farm) in optimisation models;
- Worth of or need for recharge minimisation in North Australia;
- Total water management models that incorporate aggregation to the catchment level and account for future sustainability constraints; and
- Integration of water quality and quantity including:
  - conjunctive use,
  - groundwater pollution through nitrates etc., and
  - salt water intrusion.

Customer Service Level Agreements—Impact of infrastructure refurbishment and fluctuating supply levels

- Infrastructure refurbishment/retrofitting: a better understanding of open channel dynamics;
- Definition, implementation and measurement of customer service level agreements;
- Fluctuating supply level: impact on service to customer; and
- Level of service: infrastructure required (need to understand what customer first wants/needs).

Group 2

Catchment Modelling for Management

- Catchment modelling—to manage and optimise use of all water sources, including groundwater, tailwater and water storages;
- Optimisation of parameters in models;
- Develop 'systems' model for catchments/schemes (total water management at catchment level);
- Catchment scale climate prediction;
- Optimisation of supply scheduling including:
  - fluctuating supply,
  - hierarchy of objectives,
  - environment/economic tradeoffs,
  - water quantity and quality,
  - flexibility of supply, and
  - economic sustainability;
- Integrating management of on-farm /off-farm water demand/delivery systems;
- Remote sensing and decision support with SOI effects: developing prediction/feedback tools;
- Demand forecasting: Integration of farm information and meteorological forecasts;
- Capacity sharing:
  - to integrate supply and demand.
  - refine, develop and apply the concept, and
  - integrate on farm storage; and

- Predicting demand at catchment level:
  - current pressures to re-partition available water supplies between traditional users and the environment have resulted in a need to quantify the impact on affected industries.
  - simulation models being developed to measure this impact whilst effective and reliable at the farm level need to be developed to reflect happenings at the catchment and industry level.
  - investigations of new demand patterns emerging in river basins is required.

Constraints

- Environmental sustainability of models (Environmental economics);
- Flexibility:
  - understanding change forces,
  - customer needs from supply systems and infrastructure;
- Operational constraints:
  - understanding customer needs,
  - social determinants, and
  - demand pattern options;
- Flexibility of supply systems; and
- Cost benefit analysis of the increased level of service to irrigators through automated/remotely controlled supply and drainage systems.

Data Standards

- Water budget:
  - measure leakage, and
  - recharge estimation (especially on-farm storages);
- Develop standards for data collection for use in future modelling, analysis, etc.; and
- Cost-effective water measurement
  - supply channel,
  - supply to farms,
  - drainage channels, and
  - farm drainage.

Group 3

Infrastructure Requirements and Levels of Service System Operation

- Flexibility of supply systems (design conditions for refurbishment): on-farm off-farm optimisation;
- Differing infrastructure requirements for differing levels of service: Flexibility of supply systems to cope;
- Techniques for decision support for system planning and operation:
  - predicting demand at catchment level, and
  - remote sensing;

- Regional on-farm optimising models:
  - optimising models to aid integrated management and planning of on-farm-storages, reservoirs and associated distribution systems to foster integrated supply and demand decisions, and
  - including SOI effects and remote sensing to (help) predict demand;
- Research on level of service required by farmers and all of required infrastructure for level of service provision:
  - new infrastructure,
  - existing infrastructure, and
  - understanding customers' needs; and
- Understanding and predicting customer needs and characteristics to provide input into optimising models.

Integration of Quality and Quantity in Optimisation Models (IQQOM)—Surface, Groundwater, drainage

- Integration of water quality and quantity in optimisation models:
  - environmental sustainability,
  - saltwater intrusion, and
  - catchment scale demand prediction;
- Prediction models for biophysical futures and sustainability for scheme/areas based on water management options;
- Integration of water quality and quantity optimising systems; and
- Salt water intrusion integration of water quality–quantity.

Development of Environmental and Economic Sustainability Models

- Total water management at catchment/regional level: Developing an optimisation model;
- Incorporate economic evaluation into management
  - use of water (water pricing), and
  - environmental/economic trade offs;
- Model predictability (uncertainty):
  - risk analysis,
  - environmental sustainability, and
  - recharge estimation;
- Examination of tradeoffs between long-term economic and environmental sustainability and short-term profits—ie. what does sustainability cost and what are costs if not sustainable;
- Systems (of models) for quantifying and negotiating environmental and economic tradeoffs; and
- Ideally, cost-benefit framework, or more likely initially, cost-effectiveness framework.

Identified Research Gaps

The following represents the distillation of a number of summary documents and discussions. It represents the perceived needs of those present. However, there were concerns that managers from Northern Australia needed to be included in these identified areas and in projects on 'Capacity Sharing'. Also there was a recognition that 'non-water people' were needed in the research teams to enhance the possibilities that the various environmental issues identified during the course of the projects were addressed. It would then be more likely that the research findings would be accepted by Government, environmental groups, authorities, managers and users and implemented. The 'gaps' identified were;

Propose Data Audit

To be linked to Benchmarking Projects

- Collection of information on models and technical data relevant to
  - hydrology/water use efficiency,
  - agronomy/productivity,
  - environment,
  - financial,
  - remote sensing and imaging; and
- The audit should identify:
  - who is doing what and where,
  - the format for collection and interrogation of data,
  - the accuracy of data,
  - sampling integrity, and
  - education of various bodies on use of data and development of effective dissemination methods.

Key Players: LWRRDC/Water Authorities

Asset Management and Pricing

Audit and *compare* asset replacement, maintenance and cost recovery strategies for authorities

Key Players: Water Authorities/LWRRDC

Models

With the growth in number and variety of models, there is need to establish:

- guidelines (Codes of Practice),
- fitting and verification,
- uncertainty quantification, and
- end user involvement.

Key Players: Modellers/Societies

Customer Service Gaps to be addressed

Existing Issues

- Define supply constraints;
- Define customer needs (and wishes);
- Service supply/cost function;
- Business objectives of authorities;
- Flexibility of supply systems;
- Monitoring customer service delivery; and
- Natural resource management in relation to customer service.

New Issues

- Infrastructure maintenance/replacement interactions (information exchange strategies);
- Hydraulic infrastructure options in relation to customer demand;
- Integration of demand and design requirements—refurbishment requirements;
- Research community needs; and
- Prediction of future service needs—hydraulic modelling.

Key Players:

— all water users,

— environmental groups/agencies,

— supply authority,

— downstream communities, and

— key cities/towns.

Supply Optimisation with On-Farm Water Quantity and Quality Constraints

Where: CIA, MIA, Vic.

Key Players: UTS/CSIRO/UAD/Irrigation Agencies

Capacity Sharing—Trialing Implementation

Where: Northern NSW

Key Players: UNE/NCEA

Optimum design methodology for new, extended, refurbished systems including sustainability constraints

- Accounting for agronomic, on-farm, operational, off-farm engineering design, environmental and economic aspects; and
- The cost-effectiveness of pipes or open systems and required subsidies.

Where: to be decided

Key Players: UTS, UAD, UNE, Irrigation Agencies

Optimisation of Supply Scheduling

Where: Border Rivers, Gwydir River

Key Players: DLWC, DNR, NCEA, UAD, UTS, UNE

Projects Identified for Further Action

NOEL DAWSON

This is a further summary based on ideas/needs generated at the workshop. It is planned to develop these further with key players once these proceedings has been released and considered by the Management Committee who will clarify and prioritise these in terms of the overall objectives of the program.

Data Auditing

Objectives

- Analyse the extent, accuracy and methods of recording data in relation to hydrological, agronomic, environmental and financial attributes in irrigation schemes;
- Identify the opportunity to develop more efficient systems based on remote sensing;
- Develop standards for data collection to enable better development of models; and
- Develop improved approaches to disseminating information and involve and educate users in the use of data.

Considerations

- Many of the issues are already being considered as part of the benchmarking review;
- A current study by SKP will identify some of the hydrological data measurement gaps and make recommendations to address these; and
- The opportunity to improve remote sensing and collection of data is an obvious area needing further work.

Asset Management and Pricing/Customer Service

Objective

- Develop systems to audit and compare cost of asset replacement, maintenance and cost recovery for irrigation systems;
- Account for the cost of meeting sustainability and environmental requirements;
- Define supply constraints and customer needs and monitor customer service delivery;
- Identify the flexibility of different systems (both existing and refurbished) to provide differing supply service; and
- Develop modeling systems to enable prediction of future service needs.

Considerations

- Again much of this information should be covered in the benchmarking studies;
- The current approach to benchmarking does not consider customer requirements as this has been seen to be a role of suppliers. However there should be clear linkages between inputs and the outputs of any benchmarking process and client satisfaction (output or outcome) must be able to be related to cost efficiency etc.; and
- Needs the development of interactive approaches specifically to encourage participation.

Model Development

Objectives

- Identify and publicise the range of models currently available to water managers;
- Establish the accuracy and sensitivity of these models under different operational conditions;
- Develop guidelines (codes of practice) for the development and verification of models; and
- Involve water managers in the development of models and train them in the use of models.

Considerations

- Some standards are already available; and
- There is a need for a compendium of models or the identification of people who can assist in providing information on particular areas of modeling.

Supply Optimisation with On- and Off-Farm Water Quality Constraints

Objectives

- To develop a process for scoping the integration of infrastructure design/refurbishment (the big picture down to detailed design);
- Develop procedures to design flexible optimisation systems to meet changing demand;
- Consider environmental, economic, agronomic, operational and engineering design constraints;
- Evaluation of demand prediction technologies having regard to scale, stochastic, real time and historical constraints;
- Consider total water management objectives that incorporate catchment level goals and account for future sustainability; and
- Integrate water quality and quantity into water management systems.

Considerations

- This area needs to be considered more fully to develop a proposal or proposals; and
- Consider studies in the SMDBC or Northern Areas.

Capacity Sharing

Objectives

- To integrate supply and demand;
- Refine, develop and apply the concept; and
- Integrate on farm storage into the approach.

Considerations

- Consider need to implement procedure in Northern NSW and Queensland as a trial.

Appendix A
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Appendix B

Workshop on Optimising On- and Off-Farm Water Supply Systems Management

Program

Tuesday 10 December 1996

8:45–9:15 am	**Introduction to aims of workshop: Nick Schofield and Noel Dawson**

Session 1

9:15–10:30 am	**Sunraysia Rural Water Authority** CHRIS STOLTZ AND BRENT GODKIN
	Goulburn–Murray Rural Water Authority (GMW) Perspective KEVIN PREECE
	Murray Irrigation—Channel Efficiencies DAVID WATTS
10:30–11:00 am	MORNING TEA

Session 2

11:00–12:30 pm	**Coleambally Irrigation Perspective** MARK BRAMSTON
	Improved Delivery of Irrigation Water by Optimising Farm and Supply Management Systems on a Scheme/Catchment Basis JEROME ARUNAKUMAREN
	A Decision Support System for Water Use Efficiency in the Northern Murray–Darling Basin 12 YAHYA ABAWI
	Agronomic and Socio-economic Aspects of Water Use Efficiency in the Australian Cotton Industry BRIAN HEARN
	Catchment level modelling NORM DUDLEY
12:30–1:30 pm	LUNCH

Session 3

1:30–3:00 pm	**MIS** TONY OAKES
	Real-Time Monitoring and Control of On-Farm Surface Irrigation System HECTOR MALANO
	Cost-Effectiveness of Managing Recharge JOHN DOHERTY
	Modelling GAMS Impacts on Watertables, Recharge NOEL MERRICK
3:00–3:30 pm	AFTERNOON TEA

Session 4

3:30–5:00 pm	**Modelling Chemical agronomic and Economic Impacts of water availability** JOHN TUITE
	Evaluation of the Applicability of Genetic Algorithm Technology to Flow Management of Open Channel Gravity Systems GRAEME DANDY
	Optimising Irrigation Pipeline Delivery Systems ANGUS SIMPSON
	Viability of Infrastructure Refurbishment and Implications for Private Ownership MIKE BRYANT
5:00–5:30 pm	**Develop plan of attack for Day 2**

Appendix C
Presenter's Reports

These reports are presented in order of the program and are divided into the various sessions.

Session 1

Sunraysia Rural Water Authority

CHRIS STOLTZ AND BRENT GODKIN

Establishment of the Authority

Sunraysia Rural Water Authority was constituted on 1 July 1994 by an order signed by the Minister for Natural Resources in accordance with the powers conferred by Division 2 of Part 6 of the Water Act 1989.

The Authority is a separate autonomous business entity which became responsible for the rights, liabilities, obligation, powers and functions of the predecessor Corporation. It is located in the northwest of Victoria.

It has a Board and is responsible for the following services:

- Water Supply
- Drainage
- Natural Resources
- Agent for MDBC

The Authority has approximately 3,500 customers

Customers	Number
Pumped Irrigation Districts	1,540
Stock and Domestic Supplies	517
Private Diverters	1,024

Role of Operations Manager

The role of Manager Operations in the Authority is to overview the day to day activities of the Operations group who receive water orders and ensure water deliveries to customers. In addition the Maintenance activities and Engineering support role of the Authority come under my area of responsibility.

Range of Services and Service Standards Provided

Sunraysia Rural Water Authority serves its customers through activity to

1. Supply water to meet the plant and crop demands

   The Authority strives to deliver water when requested by growers so that the timely supply of water ensures the plants are not stressed. In order to assist the customers determine the times to water, the Authority plays a key role in the education courses provided in the region.

2. Provide a drainage system to protect the plant root zone

The Authority maintains a drainage system which aims to control the perched water table within the plant root zone. In order to assist the customers manage the use of their drains, the Authority plays a key role in the education courses provided in the region.

3. Provide irrigation quality water for house, garden and stock use

   The Authority assists in providing an enhanced rural lifestyle and ensuring stock survival through the provision of river quality water throughout a vast area of the region.

4. Manage the environmental impacts of irrigation activities

   The Authority controls salinity and nutrient levels to agreed standards by effectively managing drainage and salinity regulation works and implementing salinity, nutrient, land management and water quality strategies.

5. Implement Salinity and Landcare Management Plans

   The Authority strives to ensure the plan objectives are met. It does this by providing administrative, technical and professional support to the respective community groups.

Research and Development

The Authority has a unit engaged on extension activities mostly centred on on-farm advice to improve water/plant relationships and effectiveness of water application.

In addition it undertakes work on water quality issues, trials, water supply system improvements.

It contracts its services and acts as agent for water related products such as:

- Aquater
- Polyacrylamide
- Sodium/Potassium—Nitrate testing of fruit and sap
- Tissue and soil testing
- Water quality tests

Goulburn–Murray Rural Water Authority (GMW) Perspective

KEVIN PREECE

What are you doing now towards achievement of the workshop objectives?

GMW's open channel supply systems are demand based delivery systems. Planning is undertaken from orders received and until demand exceeds capacity substantial flow fluctuations can occur. GMW has been examining the distribution efficiency of a small open channel supply system with a view to the optimisation of on- and off-farm systems and the introduction of new water services to help even out demand fluctuations. Services being considered include: off peak services, short notice/standby deliveries. Demand modelling has been undertaken to determine the likely impacts on service of increased demand or new services. The channel and drainage system is currently being monitored to determine components of the distribution and farm system efficiency and how efficiency changes with fluctuating demand.

A trial is being undertaken which will provide the opportunity for landholders to take excess outfall/relief water to on farm storage.

More flexible work arrangements are being implemented to enable more 'out of hours' operation of distribution systems to improve service delivery and system efficiency.

SCADA systems are being implemented to improve remote regulation and system efficiency.

GMW is collaborating in several projects in related areas.

- Real time monitoring and control of on-farm surface irrigation systems. (UME12)
- Scheduling flow management of open channel gravity systems. (UAD14)
- Performance testing of automatic irrigation equipment for flood irrigation. (AIT 1)
- Review of irrigation flow control and measurement to farms. (SKP 1)

What are the gaps in R&D in this area?

It is unknown how far improved systems planning and the implementation of remote operations and monitoring will improve distribution efficiency. Currently SCADA systems are being implemented on large systems. It is unknown if the benefits can be achieved economically on the micro scale and integrated effectively with smart farm systems.

Transferable Water Entitlements are changing historic demand patterns on distribution systems. It is difficult to allocate capacity based on Water Entitlements when demand patterns are changing. The relationship between fixed entitlements, seasonal entitlements and demand varies from system to system due to the differing levels of security adopted by various farm enterprises.

What should be done?

The entire system efficiency, including distribution and farm systems should be benchmarked to enable improvements due to improved planning, new services and technology to be measured effectively.

Planning systems should include improved methods of forecasting demand based on culture requirements and farmer demand to enable better matching of the perceived and actual demand to provide optimum farm water efficiency.

Improved methods are required to track water movement, changes in culture and impacts on distribution systems and service delivery as a result of water transfers.

Murray Irrigation Limited

DAVID WATTS

- Murray Irrigation Limited is the largest private irrigation company in Australia.
- The shareholders in the company (2,400) are the owners, and the customers.
- The Bulk Supply license (1,445,999 Mls) includes a component for system losses.
- Savings in system losses means more water for shareholders in the rapidly declining access to resource.
- Shareholders pay full cost of water delivery infrastructure enhancement etc.
- MIL is the implementing authority for the Land and Water Management Plans.

Murray Irrigation is implementing strategies to improve delivery efficiency in channel systems by:

1. Development of a Central Water Ordering (CWO) system 'in house' at minimal cost. The system allows:
   - shareholders to place orders 24 hours a day directly to the program.
   - recording of water ordered/metered on a weekly basis.
   - recording of water usage by crop.
   - access to water usage and general information 24 hours a day.

- Planners to utilise water as efficiently as is possible.
- shareholders to alter their wheel by placing an order up to 6.30 a.m. each day.

2. Development of models to assess where water is actually lost, ie. through escapes, evaporation, seepage, inaccurate measurement etc. To assist modelling MIL have:
   - installed continuous recorders on some escapes
   - installed various soil moisture meters to determine channel seepage
   - determining surface area of channels for evaporation calculations.
3. Establishment of a Geographical Information System for use in irrigation intensities, crop measurement, etc.
4. Investigation of 'on line' storages for major channel systems, secondary channel systems and on farm to ascertain the benefits to channel operation and irrigator supply.

One impediment to establishing accurate models of supply systems is the lack of accurate, cost-effective flow measuring devices for large, and small, earthen channel systems in very flat terrain.

We believe there should be major research and development undertaken in the area of cost-effective and accurate measurement of flow in all facets of irrigation water delivery both on- and off-farm, as well as analysis of the cost/benefit of on-line storages.

Session 2

Coleambally Irrigation Perspective

MARK BRAMSTON

What are you doing now towards achievement of the workshop objectives?

Focus in on replacement of older technologies with modern materials and systems, where possible based on computerised data collection. Primary goal—Maintain existing service levels and meet management and reporting objectives with existing manpower.

For example we are:

- Participating with CSIRO Griffith (Dr Liz Humphries) in developing on farm water measurement methods. Focused on improving measurement within the farm.
- Developing models to improve Recharge management both regionally and On Farm as part of LWMP implementation. Models are part of a 'Net Recharge Management' suite (ON Farm Options, Regional Options, Leaky Pad, Groundwater Model). Three year joint venture with CSIRO—$1 million project 30% funded by Coleambally Irrigation. Nearing completion of year 2. Field testing of models about to commence.
- To complement this model computerised water ordering is about to be commissioned with the first users operational in January 1997. Rubicon Pty Ltd developed the system, which will collect water use data for input to the NRM models.
- Working with Charles Stuart University, Wagga Wagga on the introduction of an accredited Irrigation course which will meet the needs of local agriculture.
- Commenced the installation of SCADA technology. Plans to have the Main Canal fully monitored by SCADA by mid 1997. An integrated water quality monitoring system is also being installed.
- Started replacing existing Dethridge Wheels with Water Specialities Open Flow Pipe Meters in 1996. Plan to have 653 Dethridge Wheels removed from service by 1999.

- Annual program of testing supply channels using an Idaho Meter to measure seepage. This work is used to plan channel relining and refurbishment work. Approximately 10% of the supply system has been tested to date. Development work is underway to use this method to test the drainage network.
- Remodelling supply system escape outfalls using modern materials (eg. Urethane and Epoxy claddings). Modern tilting door structures replacing drop board regulators.

Where are the gaps in R&D in this area?

Recently a RRA (rapid rural appraisal) was conducted in the CIA to measure community response and understanding of water related issues. The RRA provided interesting information but also highlighted difference in perception within the community. this work suggested more effort needs to be focused on alternatives to dry economic assessment. For examples SIA (Social Impact Assessment) and Environmental Economic Theory.

What should be done?

- What impact will unrestricted water trading have on river flow objectives?
- Does permanent trading need SIA criteria for approval (see Owens Valley History—California)?
- Do infrastructure fixed costs move with traded water? Does this include Irrigation Areas and Districts?
- What level of cost socialisation fits within the definition of efficiency?

Improved Delivery Of Irrigation Water By Optimising Farm And Supply Management Systems On A Scheme/Catchment Basis

JEROME ARUNAKUMAREN

Background

Many of Australia's major irrigation areas are mature and have developed interacting complexities of issues such as movement of saline water, over-development, rising water tables and increasing demand for water. Agencies responsible for water resource management have seldom adopted the most efficient methods for determining management strategies. Most of the time these methods involve a trial and error approach which does not consider the full range of complex interacting issues operating on a system and usually focus on short-term remedies. They may overlook opportunities for improving overall scheme water use efficiency and often do not incorporate any consideration of environment, social and user costs.

Often four major elements may be identified in an irrigation scheme: groundwater system, surface water system, landuse and society. Irrigation scheme managers' major task is to identify limits of scheme development to ensure our institutions, communities and societies may continue in a healthy balanced way in the long term. The tasks also include systematic methods for allocating water, identifying an optimal combination of water sources, identifying supply shortfalls and identifying opportunities for additional sources of water which would otherwise be wasted or cause environmental problems.

Current achievement

Our current LWRRDC project QPI27, which identified the need for a holistic approach in which models simulate the processes involved, needs to take into consideration the interdependence of the various elements in the irrigation scheme. In working towards this goal, we have developed a suite of software 'Groundwater Data Utilities' that greatly reduce model set-up and calibration, and a set of 'Graphical Groundwater Utilities' that allow a user to inspect, query and plot irrigation scheme hydrological data within a Geographical Information System framework. One of the main reasons for developing these utilities is to overcome difficulties in transferring large amounts of data into and out of models, and between models, databases and visualisation software. These utilities also provide an interface between data as presently stored in databases and as used in cell-centred finite-difference models, cush as MODFLOW, SHARP and MT3D. Further, it provides interfaces to quadrilateral finite element models, such as SUTRA which is a USGS flow and solute-transport model.

Simulating irrigation demand is a tedious task faced by scheme managers as it is controlled by complex soil-water transferring processes governed by a number of soil parameters. SPLASH, is a regional scale soil process model, was developed as part of this project QPI27, because no existing model could handle moisture and salt movement in a complex manner on the regional scale required. Existing models (SWIM, PERFECT, etc.) were developed to simulate conditions on a small ['paddock'] scale using field measured data. SPLASH can be run in 'continuous' mode in order to allow calibration against historical regional water use and crop yield data. SPLASH also simulates regional recharge and can be coupled with models which require irrigation demand as an input (eg. MODFLOW, REALM etc.).

Seawater intrusion is one of the major threats to our coastal aquifers. Excessive pumping of groundwater has stressed these aquifers beyond their safe yielding capacity and in some coastal aquifers seawater intrusion has occurred. As part of this project QP127, SHARP (USGA cell-centred finite difference seawater intrusion model) was used unsuccessfully to develop a regional-scale seawater intrusion model. After it became obvious that SHARP would not meet this need, the market in seawater intrusion modelling software was surveyed and a number of codes were tested on sample and real problems. This simple, readily available and inexpensive codes have proven to be unsatisfactory for complicated deltaic aquifer systems. At present, a two-dimensional cross-sectional model is being developed to study the seawater intrusion processes for instructional purposes. For this the USGS model SUTRA is used.

REALM, developed by the Victorian Department of Conservation and Environment, is being used in the modelling of surface water distribution. The calibrated SPLASH model is used to simulate irrigation demand in irrigation sub-areas. REALM is used to optimise water movement from storages to demand distribution points in the surface water system.

Future Goals

The management of irrigation schemes raises complex scientific, social, economic and legal issues. Ultimate success in achieving a sustainable development depends on our ability to bring all these issues together within a management framework that is comprehensive and consistent. The application of computer modelling will help scheme managers in efficient resource development, but it will not allow the manager to examine the trade-offs required to optimise one or a variety of objectives (eg. resource sustainability and maximise scheme water production), subject to system constraints.

Sustainability can be introduced into the management framework by setting a constraint on the depletion and degradation of the stock of environmental capital. this constraint introduces another complex issue of valuing the environment. But there is a broader valuation structure in economics that needs to be recognised in the context of natural resource management. Efforts to integrate environmental values into the management framework should be greatly extended, both at the level of understanding environmental effects and at the level of valuing these effects.

Defining property rights and letting the market carry out the allocation of water represents an efficient approach. However this approach is likely to work best for well-defined problems such as sharing irrigation water between irrigators and capacity sharing for storages and sustainable yields, where conventional use-values, including public water supply, are involved. Where irrigation practices involve externalities such as saline water intrusion, rising watertable due to excessive irrigation application upstream, groundwater contamination and pollution in local water-bodies resulting from irrigation runoff, these cause inefficiencies in the market system. Most of these externalities are the consequences of farm inefficiencies in the use of water where the social optimum has not been reached. The future of sustainable irrigation development depends on defining appropriate property rights such that these externalities can be included in the market price mechanism.

Our next objective to develop a systematic general purpose simulation-optimisation approach for identifying management options for multiple water source irrigation areas by incorporating economic and environmental constraints in the management framework.

A Decision Support System for Water Use Efficiency in the Northern Murray–Darling Basin

YAHYA ABAWI

Funding for this project is provided by the Murray–Darling Basin Commission under the Investigation and Education Program. The project is due to commence in January 1997.

The main objectives of this research project are:

- to develop decision support systems that enable water users and managers to make better decisions on crop type, area of crop, irrigation strategy, irrigation schedule, announced water allocations and water harvesting procedures taking into account the climatic, hydrologic and economic risk and the reliability of various water resources. The system will be based on irrigated cotton in the northern Murray–Darling Basin with flexibility to apply to other irrigated crops and regions and deal with a diverse range of systems and conditions.
- to demonstrate the benefits of the system to irrigation users and managers in the pilot case study.
- to develop an extension program to improve the adoption of better risk management strategies leading to better benefits to growers, the environment and the local community.

What are the gaps in R&D in this area? What should be done?

A significant amount of information (data and simple models) exists which addresses various water use efficiency issues on-farm and off-farm. The focus of these models, however, are specific and are limited in their understanding of the processes of resource degradation, risk management and the future security of supplies. A key constraint to policy making is the lack of holistic models that can explore futures scenarios and assess the impact of any changes in a totally integrated system. Gaps in R&D include:

- A systems approach to modelling water use efficiency (integration of existing models)
- Development of practical farmer decision aids
- Strategic drought risk monitoring research
- Research describing the biophysical futures for irrigation districts

Agronomic Aspects Of Water Use Efficiency In The Australian Cotton Industry

BRIAN HEARN

Introduction

The project extends the economic assessment of the industry to its use of irrigation water. The aim was to find out how much water the industry uses, how efficiently it uses that water, and how that use compares with other irrigation industries. The efficiency of water use encompasses agronomic, engineering and economic components.

Strategy For The Study

The study was done at three levels—region, farm and field. Data was sought for each level. Efficiency indices were calculated at each level in order to evaluate irrigation practices.

Efficiency of Water Use

In order to evaluate how the cotton industry uses the water inputs it receives from the country's water resources, a number of efficiency indices have been calculated. These indices fall into two groups—water use efficiency (WUE) and irrigation efficiency (IE).

The term water use efficiency is used in different ways. Crop WUE (CWUE). Irrigation efficiency expresses how much of the water input is used in crop evapotranspiration.

CWUE = lint/ET

IE = ET/water_input

Results

The Bench mark crop WUE is a value of 300kg/Ml which is a reasonable average for fully irrigated crops.

The Bench mark irrigation efficiency was an average of 66% from the three farms with the estimated ranges from 25 to 92%.

There is clearly scope for improving the irrigation efficiency of the irrigation systems used in the Australian cotton industry.

Options For Action

WATER SUPPLY AUTHORITIES

The difficulty encountered in assembling the data for this study is disturbing and is of itself an important finding. Water resources used for irrigation are not being adequately measured, and the data are not readily accessible. At a recent CRDC workshop on irrigation water use efficiency, in introducing the application of Total Quality Management to irrigation, Richard Clarke said "If you can't measure it, you can't manage it". It is therefore arguable that the country's water resources are not being managed, because they are not being adequately measured.

If the country's water resources are to be responsibly managed, and if debate on the issue is to be informed, the information must be readily available in the public domain, as accessible as, or part of, ABS data. Only then will regulating authorities be able to make informed decisions on the competing claims of irrigation and the environment for water. It is doubtful if current decisions are informed.

RESEARCH

Irrigation Practices: The CRDC is considering a project to measure the components of the water balance of a whole farm. The Co-operative Research Centre for Sustainable Cotton Production has a project in Sub-Program 1.5 entitled *Measuring the hydrologic cycle in relation to cotton* in which Jennelle Douglas is measuring the components of the water balance of a single field.

In Queensland, Greg Claydon and Brian Venz are doing a project in the National Landcare Program entitled *Best Practice Irrigation Systems—Northern Murray–Darling Basin* which aims to identify specific best management practices to increase the efficiency and sustainability of on-farm irrigation systems.

Evaporation Losses: It is reported that floating plastic covered rings show great potential in reducing evaporation losses. The reduction amounted to 65% giving a payback period of three years. Further testing is being done.

Variety: It is often suggested that short season varieties should be grown to save water, particularly when irrigation water is in short supply, the implication being that yield would be maintained resulting in an increase in WUE. Under Australian conditions this suggestion does not stand up to analysis, nor is it supported by experience.

ON FARM OPTIONS

Water Accounting: At a farm level full use is not being made of the information collected. It is recommended that farms make more use of information currently collected in order to evaluate the efficiency of their practices. Several growers made unsolicited comments which indicate an increasing awareness of the need to do this.

It is recommended that growers standardise book-keeping and accounting for water inputs (including rainfall), estimation of storage losses and carryover of water in storage from one season to the next. It is recommended that farms use the neutron probe and associated software to estimate seasonal ET in order to calculate IE and CWUE.

Strategies with Limited Water: When irrigation supplies are restricted, growers can reduce the area of crop in proportion to the reduced allocation in order to have the same M1 per ha, or maintain the area of crop with less Ml per ha, or something in between. These strategies have been evaluated using long term weather data. For most regions the strategy which maximised gross margins per Ml was a water supply of 5 to 6 Ml per ha.

This evaluation was done using the OZCOT computer model with general assumptions for growing costs and cotton price. It would be preferable for growers to be able to do the analyses themselves using their own assumptions. It is therefore recommended that the OZCOT model for the CERCOT model be put in a user-friendly form for this purpose.

Water application technology: Drip irrigation increased CWUE in only one case out the three, and was the result of increased yield, not reduced ET.

Australian research showed no saving in water nor increase in yield. This finding has been confirmed in a number of commercial attempts in Australia to use drip irrigation which were not sustainable. Meanwhile large scale commercial trial are continuing.

Catchment Level Modelling

NORM DUDLEY

Current work toward achievement of objectives:

- My research addresses the integrated, efficient and sustainable use of water and other resources within catchments located where summer rainfall is important and highly variable and unpredictable, and where high-capacity natural water ways are the main supply channels.
- This line of research into water resources management began with combining different operations research computer methods to help integrate supply-side and demand-side decision making in highly unpredictable climatic environments.
- The work developed models and methods to help make integrated decisions about short-run (ie. within season), intermediate-run (ie. start of season) and long run (ie. sizes of: reservoir, distribution system capacity, and area developed serviced decisions) aspects of system management under uncertainty of future weather-based events, and argued that the short and intermediate run decisions should be optimised in planning as well as management decision aiding modelling.
- This was ground-breaking work, with current water-use decision-making taking account of the probabilities of the value of any water saved for the future, but the achievements were for systems controlled by one decision maker integrating all supply-side and demand-side management decisions, as with a large dam on a large farm.
- Capacity sharing was developed as a means of providing both the incentives and mechanisms for individual water users to integrate supply-side and demand-side management.
- Integrated management was then expanded to confront decision makers with the current and future value if water to other users by modelling water market activities.
- Current modelling extensions focus on integrating the management of irrigation and environmental (instream flows and wetlands) water demands with supply, with daily time-step simulation/optimisation decision aiding models nested within monthly time-step ones.

Suggested R&D gaps and ways to fill them:

1. This work and current industry trends suggest the need to refine the modelling to assist in the integrated management of on-farm storages with on-farm water harvesting, minimising chemical-laden return flows to the river, and supplies from regulated and unregulated streamflows. Integrating environmental instream-flow concerns with other catchment resource use may well result in expanded use of on-farm storages which will reduce on-farm efficiency of water use. This suggests the need for environmental/socio-economic tradeoffs to be quantified and minimised to aid decision making about efficient and sustainable water allocation and management. Expansion of the above types of models would be one way to help such decision making.

2. Both current work and discussions with irrigators suggests the need for information and decision-aiding tools to help irrigators make better crop rotation decisions which are efficient, sustainable and profitable in areas where cotton is the main short-term profit earner. This requires both better agronomic information and decision-aiding tools where both long-term production effects and shorter-term outlooks for water supply and demand, insect populations and disease potential are important. Better agronomic information is required for better decisions, but perhaps it is not too soon to begin developing models to aid decisions under these uncertainties. The latter may help derive the most cost-effective agronomic data by indicating information gaps which might be missed otherwise.

3. Integrating the management of surface and ground water is important. Property right structures and models similar to the above would be one way to help in this case also.

Session 3

Management Information Systems

TONY OAKES

Rubicon Systems Australia delivers a range of technologies to support the operation and management of major irrigation systems. At the core of these technologies is a database management system that manages the water network definition, customer and stake holder relationships, customer order and meter reading transactions and quantitative and qualitative measurements of water system status. This database management system is the vehicle for integrating functional modules to monitor and control field based equipment, receive customer water orders using Interactive Voice Response (IVR) technology and predict and schedule demands.

Rubicon is working in the following areas to achieve the workshop objectives

- The Rubicon technology enables water authorities to define the areas and crops being grown on each farm, input estimates of water consumption for each crop type and compare actual customer orders with expected consumption. Capture of these data in a timely and structured manner enables water authorities to monitor on farm efficiencies and predict demands in advance of water orders. These tools when integrated with schematic based facilities for network representation and visualisation, high speed computation tools and real time system status data enable the behaviour of these systems to be simulated under different management scenarios.
- To support the better scheduling and operation of these systems Rubicon is currently working with Goulburn–Murray Water and the University of Adelaide on a LWRRDC funded project to assess the applicability of the genetic algorithm optimisation technique to the scheduling of customer water orders.

What are the R&D gaps in the areas of the workshop objectives?

- Is the optimisation objective function well understood? Are the water authorities trying to minimise operational costs or maximise system efficiencies, are customers trying to maximise daylight based watering hours or is everyone trying to maximise the net economic worth? What is this anyway?
- What drives customers ordering patterns and how is this influenced by environmental factors like crop type, climate etc., versus social factors such as time of day, weekends, on-farm capacities and system capacities.
- How does the environment fit into the optimisation picture and how can this be integrated with the commercial operations of the authorities and customers.

What should be done?

- better understanding of 'whole system' dynamics
- stimulation of investment for both on- and off-farm works and technologies

Real-Time Monitoring and Control of On-Farm Surface Irrigation Systems (UME12)

H.M. MALANO

Current Work Towards Achievement of Workshop Objectives:

This project was initiated in 1992 with the aim of (a) testing and selecting a soil moisture sensing device that is appropriate for soil moisture monitoring in irrigated pasture, and (b) developing a DSS (Decision Support System) to aid in irrigation timing decisions by integrating soil moisture status and other farm variables.

The Aquaflex moisture sensor developed by Lincoln University (now Lincoln Ventures Pty Ltd) was selected after two years of laboratory and field testing in which cost and performance variables such as accuracy and reliability were evaluated. The field testing was carried out at the facilities of Dookie College, Victoria. At the same time, a DSS (IRRIGATE) software package designed to assist irrigators in timing their water orders was developed. The DSS integrates real-time soil moisture content and 4-day weather forecasts provided by the FARMWEATHER service of the Bureau of Meteorology. The hardware and software package were first tested on five farms during the 1994–95 irrigation season. Testing continues during the current season.

R&D Gaps

FARM IRRIGATION

Both irrigation scheduling and field water application play an equally critical role in improving farm irrigation efficiency. The first phase of research project UME12 has focused primarily on the irrigation scheduling problem. A two-year extension of the project will address the problem of improved application efficiency. The aim of this phase of the project is to develop appropriate tools to enable irrigators to evaluate their irrigation performance and correct performance shortcomings both in real-time and seasonally.

MAIN SYSTEM OPERATION

The increasing adoption of farm irrigation scheduling based on continuous sensing of soil moisture by irrigators can provide distributed soil moisture information across an irrigation scheme. This information can be used in conjunction with short term weather forecasts to aid in scheduling the operation of the water supply system on a scheme/catchment basis. Moreover, emerging remote sensing techniques have also shown potential to capture spatial variation in soil moisture on a scheme/catchment basis.

Research Needs

- Research into the potential of remote sensing techniques to capture spatial variation of soil moisture within an irrigation scheme/catchment.
- Development of DSS that integrates geographically distributed soil moisture information and weather forecasts to predict water demand within an irrigation scheme/catchment.

Cost-Effectiveness of Managing Recharge

JOHN DOHERTY

Perceptions of irrigation research needed:

The first is the concept of 'irrigation efficiency'. For a water manager this means using as little water as possible to achieve a certain result. However this may not lead to groundwater recharge minimisation as it may involve re-using tailwater after letting it lie for a while in a depression used for this purpose; this, of course, promotes recharge. However then the question must be asked (applicable to the whole of North Australia, eg. the Burdekin and the Ord) as to whether recharge efficiency (ie. minimising irrigation-sourced aquifer recharge) is really worth the trouble. A lot of faith is being put in this to keep water levels from getting too high. But if the contribution of irrigation-sources recharge is 30% of total recharge (the remainder coming from the yearly monsoon season, or even a 5-yearly cyclone) is it worth the effort promoting, for example, a 5% diminution in recharge for only 30% of the total recharge?

I just plucked these figures out of my head but there is an urgent need for some modelling here. The repercussions are large because an awful lot of groundwater modelling is coming up in the Ord and North Queensland. Modelling at the Ord will be done by consultants (will it be done well?) and issues like this have to be flagged and explored because 'irrigation efficiency' is often the first solution that comes to mind when people suddenly perceive that they are under threat from rising water levels (which is the case in the Ord). While it may work in the south of Australia, its efficacy is unexplored in North Australia I think. Yet people in North Queensland are being asked to minimise groundwater recharge through careful irrigation management, but no-one has yet demonstrated that this is a worthwhile enterprise. And, as I mentioned above, it may conflict with the requirements of minimising overall water use.

The second issue is groundwater modelling in irrigation areas. I'm thinking of hooking SWIM (a CSIRO-built Richard's equation unsaturated zone model) to MODFLOW (a groundwater model used by everyone). This has CSIRO's support but money is needed, firstly to see if it can be done. This would enable better modelling of these areas than is presently being done.

The third issue is model predictive ability where data is scarce as it often is, especially in areas like the Ord for which the proper groundwater measurement regimen has simply not been instituted yet for which some big decisions are coming up based on model results. The whole question of how to calibrate a model where data is scarce and to quantify just what the predictive power of such a model is must be looked at further in irrigation areas where 'high precision modelling' is needed due to the fact that a small error in predicted water levels can mean hundreds of hectares wrongly declared as safe or under threat (because the land and water tables are both flat and therefore intercept at a very shallow angle).

What am I doing now?

I am presently involved in groundwater modelling in many settings, including irrigation management. though all cases are different, there are also many similarities. these include the need to incorporate data from many different sources into a model, calibration using scarce or conflicting data, the need for quantification of model predictive uncertainty, and the use of visualisation methods to convey model results to consumers and stakeholders.

I recently did a modelling job in a potentially salinity-affected area in North Queensland. the catchment was complex and the modelling was difficult. However we managed to develop a methodology whereby we could obtain useful model results, thereby allowing the government to make some important decisions, and stakeholders to feel happy about those decisions. Even though water levels were rising, we carried out a 'pseudo-steady state' calibration whereby we corrected salt-balance-determined recharge estimates for catchment water-level rises. then through a process of 'rapid-fire recalibration' for a variety of different assumptions concerning things we did not know, we were able to develop a suite of models for the catchment, instead of just one, and made predictions using all of them. This went a long way toward quantifying model predictive uncertainty in that catchment.

The gaps in R&D in this area

Predictive uncertainty is something that everyone talks about but hardly anyone does anything about. In most cases is involves finding a whole suite of parameter sets that all calibrate the model, and making predictions on the basis of each of these. The sheer dimensionality of the problems is staggering, because a means has to be developed of 'wandering around' in parameter space looking for points that are deemed to calibrate the model. The frightening thing is that in many cases this 'calibration sub-domain' is very large indeed.

Another significant gap is whether, in North Australia, recharge minimisation through proper irrigation practices is worth the trouble, especially if it conflicts with water use minimisation (which it can sometimes do, eg. if tailwater is stored and recycled). A lot of store is being put into the development and promulgation of efficient irrigation practices as a means of keeping water tables low. But what percentage of overall recharge is caused by irrigation inefficiencies in tropical areas where the long-term average recharge may be dominated by the yearly monsoon season or even a five-yearly cyclone? A lot may depend on whether the ground is 'charged' or not prior to one or two big events. It would not take a very difficult modelling exercise to throw light on this problem.

Another gap is the lack of recharge modelling capabilities for use in conjunction with groundwater models. While there are some in-house packages, and some up-market alternatives such as SHE, it is something that I see people continually struggling with.

Saltwater intrusion is a big problem in Queensland and all over the world. However it is extremely difficult to model. Few, if any, government or academic people can do it at a reasonable price; I would be surprised if even one Australian consulting company would know where to begin.

What should be done?

I have mentioned only a few 'gaps' above; there are more. Problems will be exacerbated where consultants are doing the modelling in irrigation areas (as will happen more and more) because time will be limited and the trying out of new ideas will be frowned upon. However 'high-precision modelling' is required in potentially saline areas because a small error in computed water levels can result in large errors in salinity-affected area predictions. The development of software and methodologies to overcome these problems and the facilitation of its distribution through LWRRDC-sponsored courses may be an option. Such courses would be not just 'another modelling course', but one in which concepts, software and methodologies had been battle tested in irrigation areas.

Another idea may be for LWRRDC to fund someone to develop saltwater intrusion capabilities. This would involve purchase of the correct model, development of any interface software required between it and data repositories and graphing/display software, testing of the software, documentation of a case history, etc. So that the investment would not be wasted, that person or organisation should then be accessible by other organisations for training and/or consulting purposes where salt water intrusion is a problem anywhere in Australia.

Modelling GAMS Impacts Watertables and Recharge

NOEL MERRICK

Current Work:

- No current LWRRDC funding
- Member of Net Recharge Management project team, Coleambally Irrigation Area
- Instructor in GAMS programming and applications
- Optimisation applications to groundwater supply, dewatering, urban conjunctive use, thermal and hydroelectric power, aquaculture, network rationalisation
- Supervisor of students researching use of genetic algorithms and/or GAMS for optimising irrigation network supply and contaminated site remediation
- Developer of Namoi and botany regional groundwater models
- Contributor to Lower Murrumbidgee and Lower Macquarie regional groundwater models

R&D Gaps:

- Applicability of traditional nonlinear programming to supply scheduling
- Applicability of genetic algorithms and other global optimisation techniques
- Comparison of optimisation methods
- Coupling with deterministic (or stochastic) hydraulic simulation models
- Coupling with economics
- Is real time optimisation possible?
- Recognition of physical, economic and social constraints
- Incorporation of groundwater augmentation and drainage water recycling
- Is water quality optimisation possible?

Future Work:

- Promote acceptance of rigorous mathematical optimisation as a valid methodology
- Develop nonlinear programming and genetic algorithm solutions to supply scheduling, to reduce escape flows
- Apply optimal schedules at a number of sites
- Integrate supply scheduling with on-farm scheduling, to reduce groundwater accessions

Session 4

Modelling Chemical Agronomic and Economic Impacts of Water Availability

JOHN TUITE

Government actions in partitioning available river water supplies between the environment and traditional users has had major impacts on the irrigation industry in NSW.

Engineering works constructed on-farm and operational strategies practised are being reviewed by irrigators in an attempt to maintain historic income levels given the lower levels of irrigation supplies available. In addition Government authorities responsible for the delivery of water supplies are being challenged to develop innovative ways to react to the different demand patterns emerging.

A computer simulation model is under continuing development as part of the LWRRDC Pesticides Program. This model is capable of addressing the hydrological, chemical, agronomic and financial response of a farm to changes in water availability.

It is also capable of examining the financial impact of constructed on-farm engineering works such as storages, pumps, channels etc. as well as being able to examine various farm operational strategies such as varying areas planted to maximise returns under conditions of limited water availability.

The simulation model operates on a continuous basis, is generic in nature and can be used to simulate a farm's response for extended periods. Each component has been designed in modular form for exceptional flexibility and is configured to run under MS DOS using high performance micro-computers.

The deterministic nature of the hydrologic module and the use of simple computational algorithms in the chemical and agronomic modules has proved practical when obtaining calibration data and is also efficient in the computational sense.

Whilst the model can be used to reliably optimise management systems at the farm level, additional work is required to develop an understanding of the behaviour in terms of water demand of groups of farms at the catchment level.

Questions as to how the behaviour of farmers acting as individuals, influence the spatial diversity and subsequent water demand patterns within catchments needs to be resolved if efficient demand based management systems and cost-effective delivery works are to be developed.

Data is currently being gathered by some water authorities in relation to water orders placed by irrigators as well as the subsequent use of the water supplies. However not much work has been carried out linking the simulated use of irrigated supplies at the farm level to the water use of a number of farms at the catchment level.

Evaluation of the Applicability of Genetic Algorithm Technology to Flow Management of Open Channel Gravity System

GRAEME DANDY

Objectives of the Project:

1. To evaluate the applicability of genetic algorithm optimisation to improving scheduling and delivery of irrigation flows via open channel gravity systems
2. To determine what objectives are important in delivering irrigation water by interviewing personnel in irrigation authorities
3. To apply the methodology to a case study open channel flow delivery system for the Tatura irrigation area of Goulburn–Murray Water in Victoria
4. To determine the cost savings arising from implementation of optimisation within computerised irrigation ordering techniques.

Principal Investigators: Assoc Prof Graeme Dandy and Dr. Angus Simpson

Collaborating Partners: Rubicon Systems Australia Pty Ltd, Goulburn–Murray Water

Time Scale: This is a 2.5 year study which commenced late in 1996

Gaps in Current R&D: The following research projects are needed:

1. A comprehensive modelling approach which enables all water resources in a catchment to be managed in an optimal fashion (including water reuse options)
2. A study into the integration of water ordering systems and the design and operation of off-farm delivery systems
3. A study into the optimum integrated design and operation of on-farm and off-farm delivery systems
4. Development of systems for optimum real-time control of channel delivery systems.

Optimising Irrigation Pipeline Delivery Systems

ANGUS SIMPSON

What is being done now?

Over the last six years a comprehensive methodology for the design of off-farm piped irrigation systems has been developed at the University of Adelaide. the methodology is based on genetic algorithm optimisation and allows a designer to determine a range of alternative low cost configurations. these include the least cost combination of pipe sizes, tanks (including the optimal normal operating level), pump sizes and operating schedules. The technique applies equally well to the design of new systems, the expansion of existing piped systems and the rehabilitation of existing systems (where a combination of new pipes, pipes in parallel to existing pipes and cleaning of pipes may be considered). The technique has been successfully applied to two irrigation rehabilitation projects in Australia. in the first, the Loveday/Cobdogla pipe network originally constructed in the 1910s was redesigned for the South Australian Water Corporation using the genetic algorithm optimisation technique. A design had originally been completed by SA Water by traditional design methods involving hydraulic simulation of the piped network using a commercial computer package. a trial and error improvement procedure based on previous engineering experience was used to determine sizes of the pipe diameters for the new replacement piped system. Application of the genetic algorithm optimisation technique reduced the pipe costs (purchase and installation) from $4.25 million to $3.79 million, a saving of approximately $500,000 or 11%. The second application was for the replacement of a channel system at Corbie/Merungle Hills near Leeton, NSW for Murrumbidgee Irrigation in conjunction with the Department of Land and Water Resources, NSW. Use of genetic algorithm optimisation resulted in $458.000 of savings (15.8%) for the Corbie Hill project.

Research into the use of improved hydraulic modelling and inclusion of genetic algorithm optimisation for the optimal allocation of irrigation water in piped off-farm delivery systems has been conducted over the last two years. Use of computer hydraulic simulation models has been shown to significantly improve the operation of the scheduling system (in particular advance notice water ordering systems).

Finally, research into the optimisation of on-farm piped delivery systems has also been carried out over the last four years.

What are the gaps?

1. For irrigation refurbishment and rehabilitation, the design of both the off-farm delivery system and upgrade of on-farm irrigation system to more efficient drip or spray systems should be considered simultaneously. The design demands for the system may be able to be reduced thereby reducing the sizes of the off-farm delivery system pipes.

2. The design process should more carefully consider the operation of the piped irrigation system. Currently, it is usual to consider a limited number of design demand loadings cases in the design process for off-farm delivery systems. A linking of actual on-farm demands, the anticipated operation of the system and the design criteria for the off-farm piped delivery system is needed.

What should be done?

Research projects should be developed and commenced in these two areas mentioned above. A combined University/Industry approach is probably best. The expertise of engineers, economists and agronomists is needed to be pooled to develop a comprehensive modelling and optimisation capability.

The findings of the research relating to the use of computer hydraulic simulation models need to be conveyed and implemented in the irrigation industry. Further research into the use of genetic algorithm technique for the optimal allocation of irrigation deliveries in piped off-farm delivery systems is needed.

Viability of Infrastructure Refurbishment and Implications for Private Ownership

MIKE BRYANT

Infrastructure Refurbishment—Viability of irrigation infrastructure refurbishment and implications for private ownership' (LWRRDC Project No., UNE23)

- Research collaborators: ABARE and CSIRO
- Research location: The Murrumbidgee Region is the case study area
- The Problem: Costs of refurbishing concrete lined channels that have deteriorated may exceed the ability to pay of irrigation farmers.

Questions:

1. How much would it cost to replace existing infrastructure?
2. How much can farmers afford to pay with existing farming systems?
3. What would the farming systems and irrigation system look like if we could optimise the design of both, to maximise economic viability?
4. Given answers to the above three questions, what are the implications for government in terms of possible subsidies or social welfare costs?

RESEARCH METHOD

Mathematical programming to simultaneously optimise on-farm enterprise mixers and irrigation demand, with the supply system capacity and costs.

EXPECTATIONS

A unique solution for each supply system and for each farm within it.

WORK TO DATE

Development of the on-farm model component to optimise enterprise mixes use of on-farm storages etc. with respect to cost and quantity of water supplies.

CASE STUDY SITE

Development of the supply system component will use a case study lateral in the MIA (Lateral 123 at Stanbridge has been selected due to diversity of farms and the poor state of repair of the channel system).

Appendix D
Issues and Research Gaps Identified from the Presentations (in Appendix C)

Session 1

- Measurement of leakage—if only 3%, is it part of a larger research issue?
- Fluctuating supply and services level.
- Benchmarking studies needed
- Time scheduling (use at night);
  - supply
  - cost/pricing issues
- Reducing tail water loss;
  - what are the competing objectives?
    - Quality
    - Quantity
    - Cost
    - Services
  - what is the best mix?—what tradeoffs and best optimisation
- Level of Service—infrastructure required and costs involved
- Use of satellite imagery needs consideration
- Hierarchy of objectives;
  - Government—Environment Issues
  - Scheme Managers—Customer Service and Viability
  - Farmers—profitability/viability
- Understanding of customer needs;
  - differing farms and needs of farmers
  - ability to change focus to meet farming changes
  - farm viability
  - systems to understand changes
  - physical and environmental changes

Session 2

- Salt water intrusion issues need attention
- Modelling on-farm storages, salt levels and instrusion is required
- Predicting biophysical futures for irrigation systems
- Regional/on-farm options models for optimisation—looking at interface factors between authorities and customers
- Catchment scale and climate predictions
- Use of data to form a national database (part of benchmarking)
- Effect of SOI on discussion making

- Systems for negotiating;
  - environmental/economic tradeoffs
  - Incorporate economic evaluation into management
- Evaporative losses from storages needs attention
- Defining what is meant by 'Efficiencies' and developing standards
- More effective measurement system to develop better databases.

Session 3

- Integration of Quality and Quantity in Optimisation models
- Model predictability uncertainty and what are the confidence intervals
- Training and education in using the models
- Working with consultants and developing a skills base
- Developing 'home tutoring' packages and approaches
- Issues of commercialisation of products and software;
  - developing a partnership between public and private funding
  - Intellectual property issues
- Remote sensing and decision support to predict demand
- How authorities can use various models effectively in day to day operation (in collection of data)
- Using publicly available data (eg. weather) in developing better models which are made available to a wider clientele
- Having funding for short term response to 'coalface' issues;
  - develop processes to put up case
  - the need to involve clients
- Estimating recharge and ground water for North Queensland
- Recharge efficiency in Northern Australia

Session 4

- Predicting demand at catchment level
- Total water management at catchment level
- Economic sustainability of GA models
- Environment sustainability of models
- Problem on handling the demand constraints;
  - stochastic
  - real time
  - projected
- Flexibility of supply system—refurbishment issues
- Best management procedures for cropping—how to integrate strategic and tactical decisions