Farming and land stewardship. Case study – Australia's innovations in sustainable irrigation

Colin Creighton[1], Wayne Meyer[1] and Shahbaz Khan[2]

[1] CSIRO and [2] Charles Sturt University

Abstract

Progress towards sustainability in irrigation for Australia is substantial. The prognosis for further improvement is extremely good, given the close link between science and practice and the widespread commitment to continuous improvement of public policy. This builds on the industry track record of rapid response through innovative science-based farm practices. This paper summarises the Australian irrigation industry, outlines how sustainability extends well beyond the farm and farmer control and concludes with some speculation on Australian irrigation futures as the irrigation industry meets the dual challenges of sustainability and productivity.

Irrigation in Australia

The National Land & Water Resources Audit has detailed the characteristics of the Australian irrigation industry. In summary:

- **Profitability –** Irrigation provides about 26% ($7Billion dollars per annum) of the gross value of agricultural production with flow-on benefits of about five times this value to the Australian community.
- **Area –** 2.4 million hectares of irrigated crops and pastures (0.5% of the total area of land in agricultural holdings and 12% of the total area of crops and pastures).
- **Locations**
- South-eastern Australia - the large inland river systems in the Murray-Darling Basin - rice, horticulture, cotton, wine, and dairy
- Queensland coastal catchments such as the Burdekin River floodplain and the black soils of the upper Fitzroy - sugar cane, cotton, grains and horticulture
- Western Australia: the Ord River and selected coastal floodplains in the north – horticulyure and sugar cane; and the Swan Coastal plain and other floodplains around Perth - horticulture and dairy
- **Water use by commodities –** dairying, with substantial areas of irrigated pastures and fodder crops, uses about 40% of the water; cotton (16%), rice (11%) and sugar cane (8%).
- **Increasing intensification–** In a response to climate variability and through the application of improved technology in the 15 years since 1985 the area irrigated has increased by 30% and the water diverted by 75%.
- **Major water user** - Irrigation uses about 72% of all water used in Australia (18,000 GL).

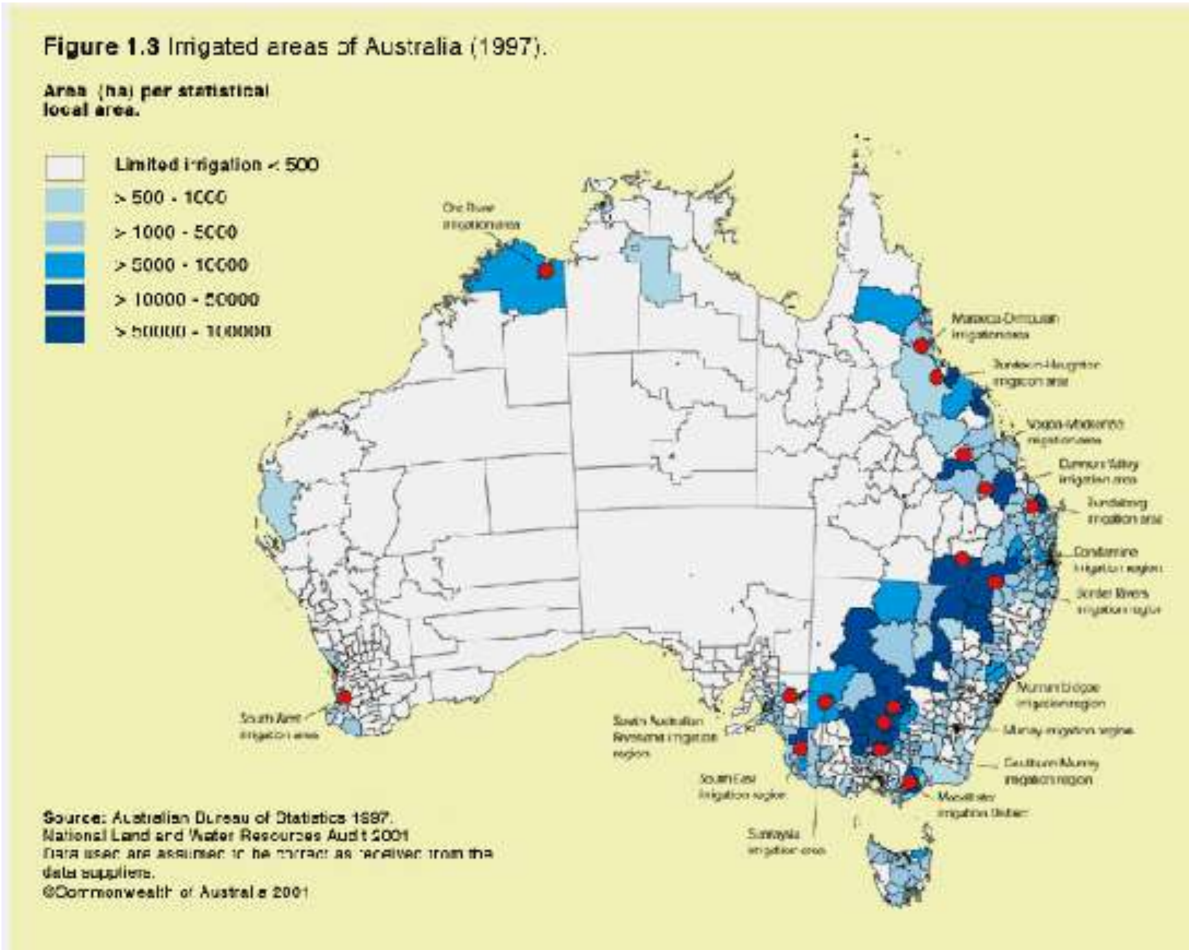


Figure 1: Irrigation Areas in Australia (1997)

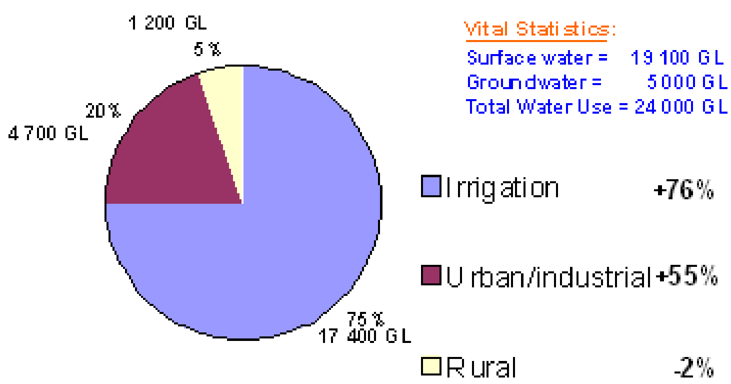


Figure 2: Annual Water Use in Australia

Science needs, national water initiative and sustainability challenges

The National Land & Water Resources Audit provided assessment of the sustainability of Australia's water resources. Many of Australia's key surface and groundwater resources were assessed by water resource managers as being at or used beyond the levels of sustainability. {Figures 3 and 4]. With irrigation responsible for about 72% of Australia's use, clearly goals of sustainability for Australia's water resources will involve the irrigation industry.

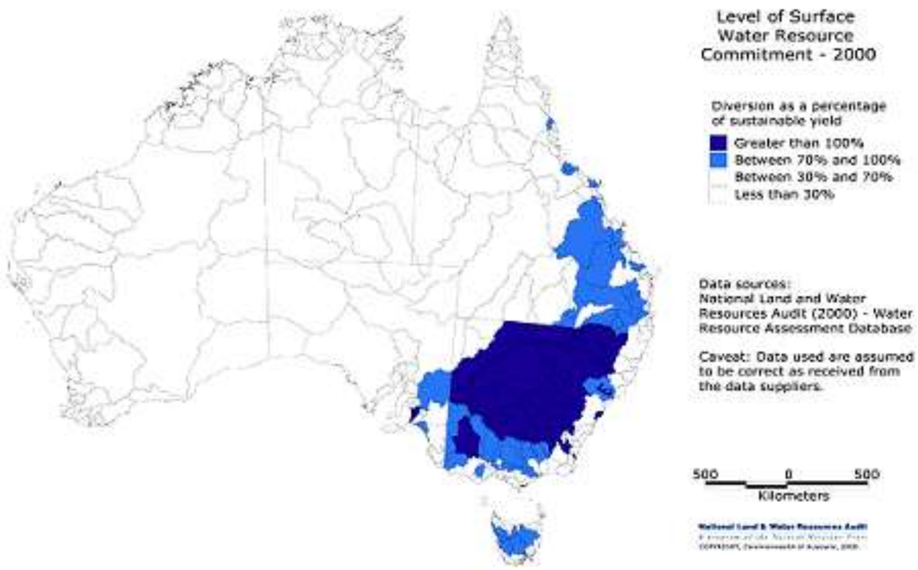


Figure 3: Level of Surface Water Commitment, 2000

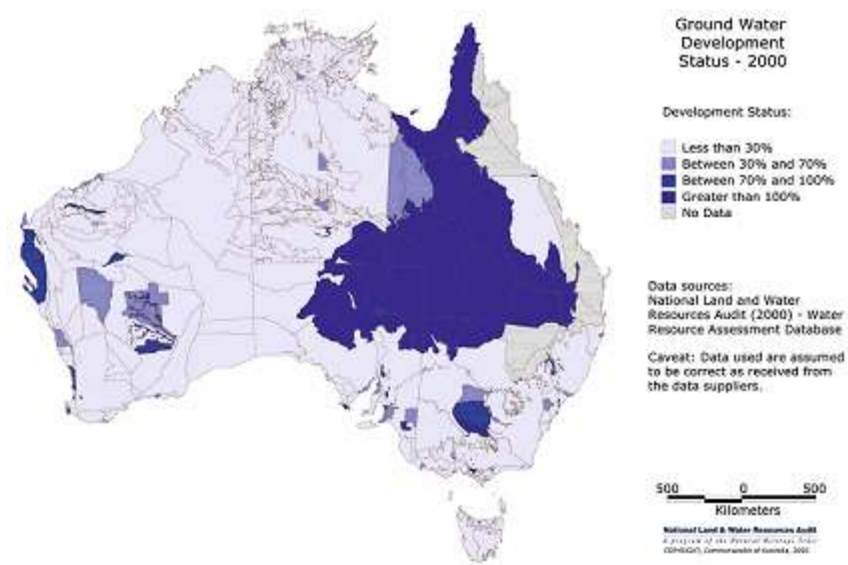


Figure 4: Ground Water Development Status, 2000

Companion Audit work detailed the health of Australia's catchments, rivers and estuaries. Irrigation and its impacts are part of the contributing factors to the health of the ecosystems that comprise our catchments, rivers and estuaries. Equally clearly, what happens on farm and is within farmer control is just part of the equation and part of the response as Australia seeks to implement sustainability.

In mid 2003, a Land & Water Australia forum facilitated by the senior author identified nine key priorities for water resources science:

- improving entitlements and access rights to water;

- improving efficiency and productivity for all water uses;
- ensuring high quality surface water and groundwater through improved catchment management;
- integrating management of surface runoff, river water, groundwater, tidal and marine water;
- protecting key natural assets and repairing ecosystems, especially wetlands and riparian lands;
- building a decision-making framework for all uses that recognises climate variability and exploits climate predictions;
- fostering and improving irrigation scheme development and management in both rural and urban Australia;
- building improved institutional and governance frameworks for water resource management; and
- tracking progress and fine-tuning improvements in water resource management.

The National Water Initiative of late 2003 builds on these challenges and the Council of Australian Governments' *communiqu?* lists six key areas for improvement of Australia's water resources:

- nationally compatible entitlements – dealing with over-allocation [see figures 3 and 4], perpetual access, partitioning risks and change, water sharing plans and best practice specifications;
- nationally functioning water markets – dealing with market players and opportunities, market controls and market operations;
- best practice water pricing – determining full costs and who pays them, roles of downstream and upstream communities in setting prices, and using this information to assist development of institutional models;
- integrated management of environmental water – setting up water accounts, determining predictability of change and likely returns from change in water regime and conjunctive use of surface and groundwater;
- measuring, monitoring and information – determining how to cost-effectively move to volumetric allocations and metering protocols, the role of remote sensing systems, and how best to regularly report progress; and
- urban water reform – dealing with water re-se and recycling, maximising productivity, building systems understanding and fostering changes in community attitudes.

For the sustainability of Australian irrigation this leads to a series of key challenges –

- **Integrated catchment management –** all Australian governments recognise the interactions between landscape management, land use, on farm practice and river health, which in turn affects the quality and availability of water for water extractors and for the estuary and nearshore marine areas downstream. The irrigation industry recognises this inter-relatedness of natural resources with many industries [eg cotton, dairy, rice] leading the development of industry codes of practice. Underpinning integrated catchment management is -
- **Water Accounts and Benefits –** understanding where the water, both quality and quantity, is within a catchment, how it changes with climate variability and changes in land use and practice is essential if our catchments are to yield quality and quantity water. From this water accounts base, the next key set of information needs is what the benefits that we derive from water use are. With an understanding of the benefits, scenarios for changes in catchment management can be tested. Objectives are usually to maximise yield and quality of surface waters and ensure water balance in soils to mininise salt transport to groundwater. Understanding water accounts and benefits allows managers at basin, regional and catchment scales to set -
- **Sustainable allocations –** limits are set on the volume of surface and groundwater that can be diverted for consumptive uses or stored in farm dams. This does not constrain new irrigation nor urban and industrial developments but leads to these developments being based on -
- **Water Use Efficiency -** making water available for expansion in irrigation and increased productivity through a range of on-farm and regional efficiency measures in delivery and on-farm plant use measures. These include paddock scale water use efficiency, changed varieties, varied crops, changed technology and practice on-farm, improved delivery at irrigation scheme and channel management levels and making more effective use of water available through -
- **Rapid response to climate variability –** using climate predictions regional water managers are finetuning delivery and annual allocations. Climate predictions before the growing season interpreted through decision support tools allow individual irrigators to optimise inputs, vary the

area under cultivation and crop, and modify delivery practices and scheduling on farm. Capturing all the water available calls for -

- **Water Reuse and Recycling –** including tailwater recycling on farm through to urban water treatment and reuse for high value commodities near urban centres such as horticulture. All water used on farm, recycled or otherwise needs to be carefully managed to ensure -
- **Soil Health insitu –** so that the soil's physical structure, chemical status and biota provide for sustainable cropping and no adverse off-farm impact, be it through excessive leakage of nutrients, recharge to groundwater, build up of salts or soil erosion. Irrigators, as land and water users within a catchment contribute to and are part of -
- **integrated catchment management** - where this brief discussion of aspects essential for irrigation sustainability started.

Irrigation sustainability is part of catchment sustainability and a systems approach is essential if we are to identify which are the key areas for further investment as irrigation and catchments strive for sustainability.

Systems – the key to sustainability

All the challenges listed deliver maximum returns if evaluated and applied collectively. This systems approach and its implementation provide the key opportunity for Australia to improve the sustainability and productivity of its irrigation industry.

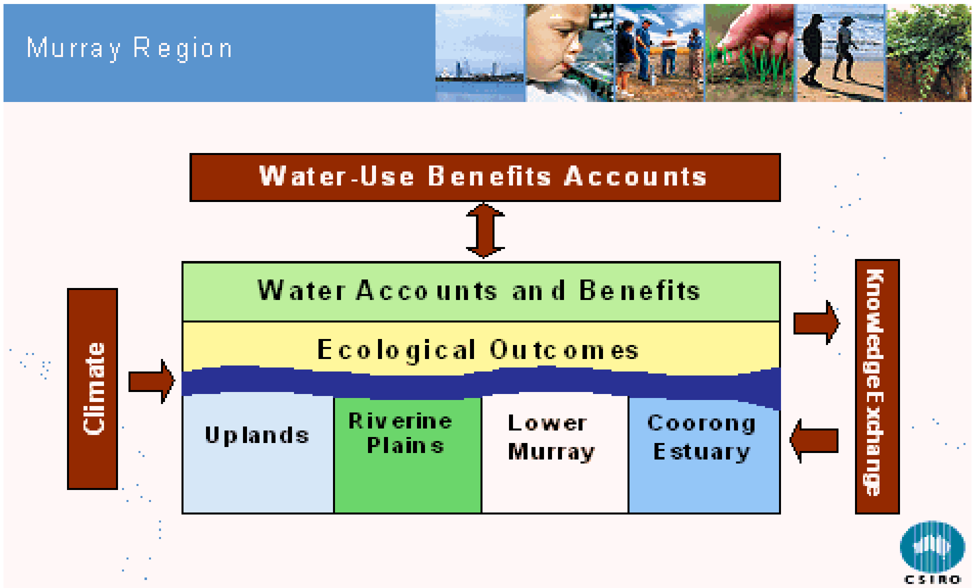
3.1 Key components of the Systems Approach

The systems approach requires:

- innovative and enabling policy frameworks – setting the context and enabling action by regional groups and individual irrigators
- clear articulation of targets – so that goals are agreed, achievable and well understood
- a mix of public and private activities – and resourcing these activities through a kitbag of measures, including incentives, extension, levies and regulations
- decision support tools – that predict key points of intervention and the returns that will accrue from investment and
- continued investment in research – seeking the next tier of major gains that can accrue from focussed R&D.

This systems approach is best illustrated using the Murray component of the National Research Flagship, *Water for a Healthy Country*.

Flowchart 1 outlines the projects in the River Murray region.



Detail on each of the component projects is provided in the National Research Flagship's *Strategic Overview 2004 – 2007*.

3.2 Uplands – Sustainability in Irrigation a price taker

To continue with the concepts of integrated catchment management and water accounts, Figure 5 illustrates upland water quantity yields for the Murrumbidgee. Sustainability involves multiple objectives. Other layers of information towards multi-objective sustainable management of uplands, a necessary condition for the sustainability of irrigation downstream include:

- water quality in surface water – salts, nutrients and sediments
- recharge to groundwater and hence salt export in groundwater
- land use pattern and on-farm practice, key determinants of water quality, quantity and biodiversity
- riparian and wetland habitat, linkages and condition

Irrigation and its sustainability is very much a "price taker" at this level of inputs. Linking upland land use and practice to downstream water quality and quantity needs will be a continuing challenge as Australia seeks to promote the concepts of "land fit for practice".

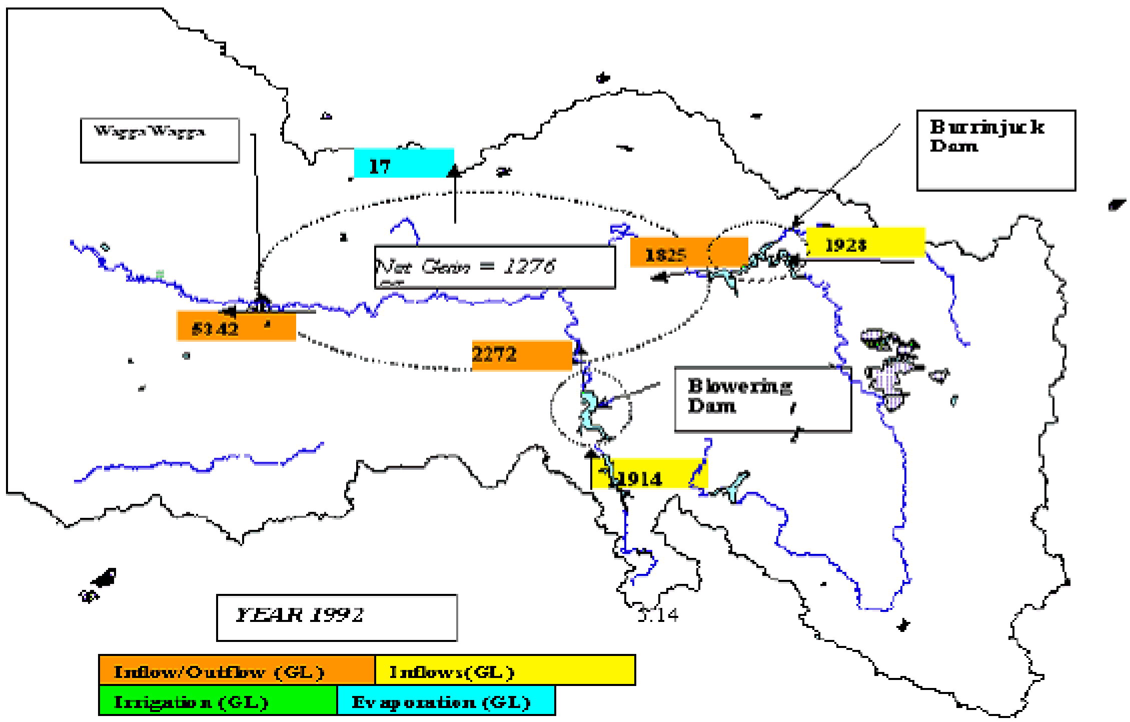


Figure 5: Upland Yields, Murrumbidgee Catchment (1992 data)

3.3 Riverine Plains, their characteristics and water budgets – a key underpinning for sustainability

Figure 6 provides water budget and balance information for Murrumbidgee's irrigation areas. Surface water from the river and extensive groundwater resources is used to irrigate extensive areas of rice, grains, vines, citrus and other horticulture. Much of the responsibility for sustainability here rests jointly with water management agencies such as Murrumbidgee and Coleambally Water and with the farmers and their practices.

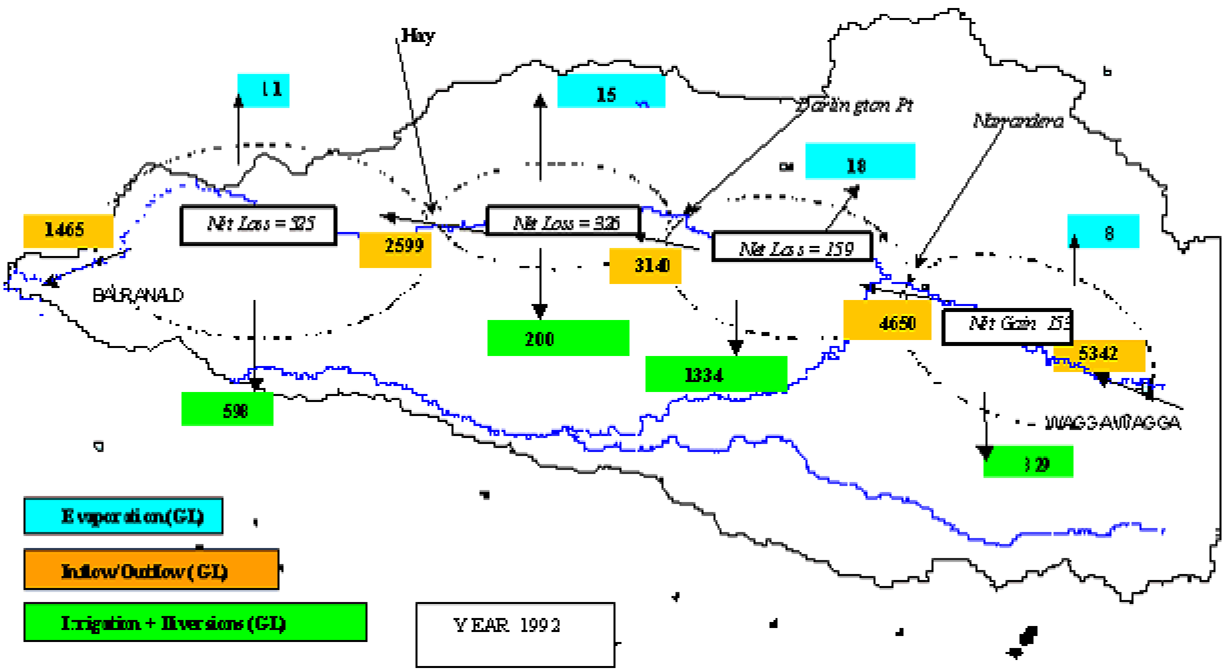


Figure 6: Water Use and Budget, Murrumbidgee Irrigation Areas (1992 data)

Local issues in the Murrumbidgee Riverine Plains include:

- rising watertable levels in both Murrumbidgee and Coleambally irrigation areas,
- a growing extent of salt-affected sites,
- greater restrictions on water availability with the need to share water across all users, and
- increased environmental requirements for both the supply river and the irrigated areas.
- The building blocks of the solutions developed via collaboration between irrigators, Government agencies and CSIRO include:
- establishing and maintaining the regional weather record
- precise measurement of crop water use and water balances
- quantifying watertable influences and salinity changes
- understanding losses and opportunities for improvement at both delivery and farm scales
- developing the *SWAGMAN*[7] series of models to educate, propose and assess options and make the links between climate, irrigation, crops, salinity, groundwater and economics
- education and training programs for the ongoing management of Coleambally Irrigation and Murray Irrigation regions

A key part of the solution involves the actual location of the Griffith Research Station. Because scientists are members of the local community there is excellent cross flow of ideas and solutions between irrigators, water authorities and the scientists.

A second part of the solution lies in continued effort towards long term goals. The senior author and Kay Dalton first prepared the formats and conceptualised the role for Land and Water Management Plans in the early 1990's, an early output of the then NSW Government promotion of the concept of Total Catchment Management. Land and Water Management Plans for the regions have been progressively implemented using farmer, regional, State and Commonwealth resources since that time. Land and Water Management planning has provided structure, focus and certainty to the actions and investments from farmer to regional scales.

3.4 Regional Delivery Improvements towards Sustainability

Minimising losses and maximising water use opportunities has both regional supply and on-farm components. Gains in water and the profitability of improved infrastructure and techniques varies with region, soil and crop type and the nature of the intervention. Finding the most sustainable and profitable mix of interventions on and off farm provides an excellent example of the systems approach.

Figure 7, detailing levels of channel leakage as indicated by electromagnetic survey demonstrates part of this systems approach as research assists in understanding the opportunities for improvement at the delivery scale. Across Australia, almost all the major irrigation water delivery companies and private diverters have upgraded their supply systems in the period 1990 to 2000 with further upgrades underway continuously. Coleambally Irrigation Company Limited, Goulburn Murray Water and Murray Irrigation, have all invested in identifying excessively leaky supply channels, minimising leaks through lining or piping and in identifying improved delivery needs and then installing automatic control structures with remote monitoring and control.

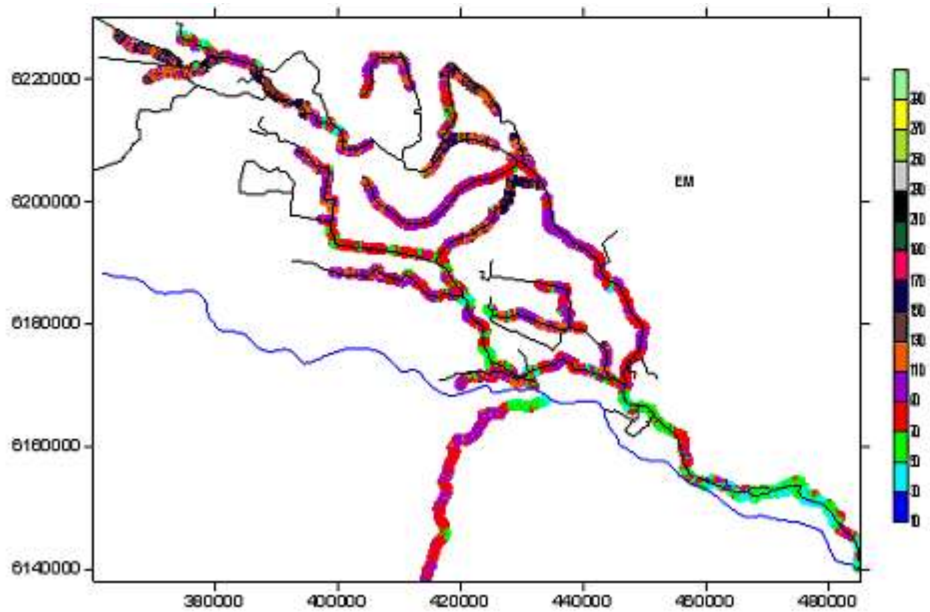


Figure 7: Electromagnetic Survey to determine channel leakage, Murrumbidgee Irrigation Area

Coleambally has also worked extensively with Rubicon Systems to upgrade the monitoring and control of channels in a program called Total Channel Control. This has involved the installation of remote monitoring and control stations based on radio telecommunications and a web-based ordering and distribution control system.

Likewise, ways of measuring water delivery at the farm gate are changing. Dethridge Wheels, with a delivery error of plus or minus 20% are being replaced in the Coleambally Irrigation Area by Rubicon's FlumeGate™, a device used to control and measure flow through a flume using differential pressure sensors.

Pratt Water is investigating ways of changing delivery systems to reduce losses. The company is working with CSIRO and Murrumbidgee Irrigation on options ranging from changing open channels to pipes to increased on-route and farm storages.

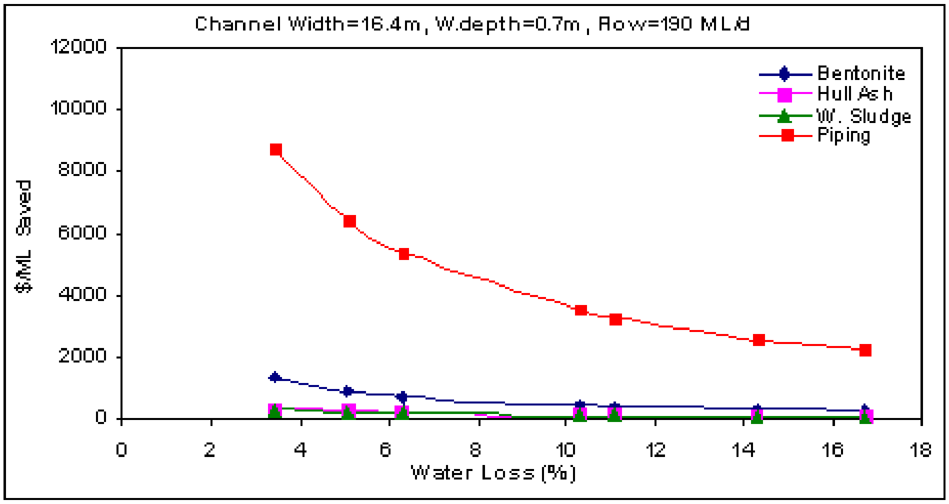


Figure 8: Capital Costs for reducing Seepage Losses

Similar systems approaches are underway in Victoria. Against a base of substantial on-farm commitment and improvement, Goulburn Murray Water has commissioned a multi-agency initiative to assess Irrigation Futures at the systems scale. Based on this assessment key points for further investment will be identified. Key opportunities are likely to include:

- stranded assets – where irrigation water delivery is to a small number of farms and use cannot be justified compared to water savings if the enterprises were able to be relocated onto areas of proximity to the main delivery channels
- irrigation losses through poor delivery system design, especially through evaporation and seepage – including the use of otherwise ephemeral lakes for delivery and their possible replacement by lined channels or pipes
- on-farm changes in delivery – though the profitability of many of the proposed irrigation technologies is limited without incentives

3.5 Working towards Sustainability On-Farm

On-farm the challenge of linking sustainability with productivity requires a multi-faceted approach involving finetuning irrigation water delivery, application and use, to climate variability, soil type and crop needs. There are multiple techniques, practices and decision support tools already being applied. To list a few:

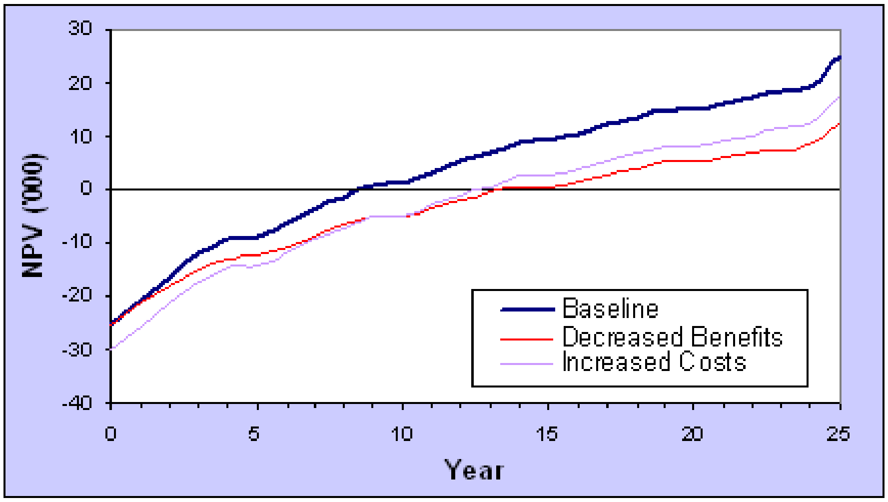
- **Laser levelling and layout design -** surface irrigation is still the main form of irrigation in Australia. For some soil types and well-designed irrigation layouts, well-managed surface irrigation can be practiced efficiently so that there is minimum loss of water into the deeper soil layers and effective plant growth. Australian operators have optimised layout design to minimise the volumes of soil that need to be shifted, and to deliver water efficiently around the farm. Good grades improve the evenness of distribution and speed of irrigating, and reduce labour costs to manage water.
- **Weather data and water use estimates -** Daily weather information is vital to better manage irrigation. Weather stations such as the *Campbell Scientific Weatherhawk* can be connected to a range of soil water measurement devices to provide data that informs irrigation decisions. The measured and derived values of daily evaporation rates collated through the Bureau of Meteorology also provide valuable data.
- **Climate Analysis and decision support packages –** including *Australian Rainman* - a software package containing monthly and daily rainfall for 3800 locations and streamflow records for 9500 locations and *FARMWEATHER*^{TM} - containing expert commentaries, synoptic charts, satellite

images and four day forecasts of temperature, rainfall and windspeed to help make better decisions about planting short-term irrigation, spraying and harvesting.

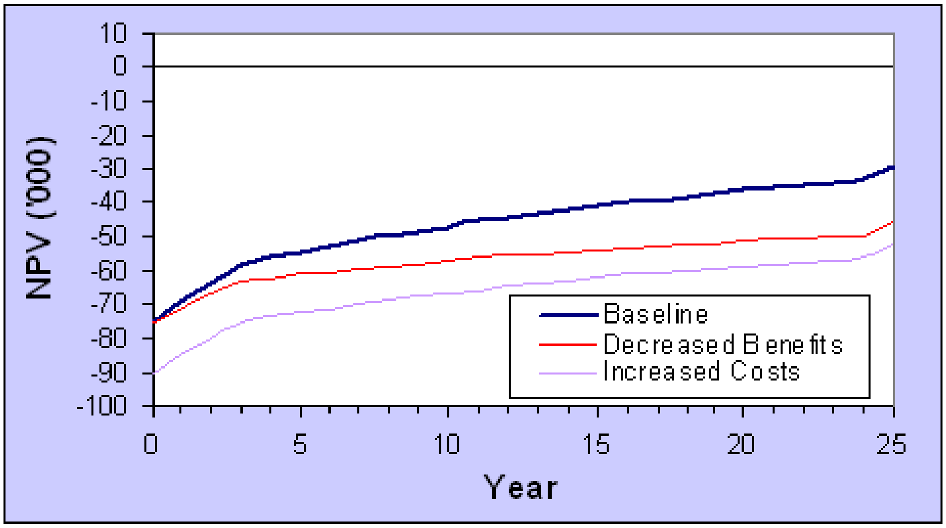
- **Soil water monitoring and linked systems –** for example, electrical capacitance sensors that operate on similar principles to neutron probes. Their advantages are reduced cost, no radiation hazard, and the ability to continuously monitor changes in water content through the soil profile eg *Sentek Technologies*™
- **FullStop™** - to measure when the soil has sufficient water for plant growth. This device enables the soil-wetting front to be measured through location of a pair of detectors, one halfway down and another near the bottom of the root zone. A visible signal at the surface helps farmers adjust irrigation to plant needs as they grow through the season.
- **Controlling plant water status -** Surface drip irrigation continues to be developed, adapted and better managed in a wider range of crops. Firms such as *Netafim*™ and *Philmac*™ have improved dripper design and application method to uniform distribution of water through the whole system. Regulated deficit irrigation and partial root zone drying are techniques that save water while improving production and grape quality.
- **Precision Farming** - Electromagnetic surveys are used in whole farm planning to provide information about where salts are stored in the soil. These surveys can identify the most optimum layout for drains, on-farm channels, storages, paddock irrigation design, cropping and pasture planting, as well as providing information on where to undertake remediation methods such as applying gypsum.

With multiple on-farm water management tools and opportunities care must be taken by irrigators to invest wisely in those innovations and technologies most appropriate to their enterprise. In many states the cost of water is a very minor component of farm input costs. On farm incentives for capital investment that leads to water use efficiency are more often linked to productivity improvements than to savings from reduced water use. Figure 9 provides 3 examples for the Murrumbidgee of the likely returns on investment – with up to 12 years to recoup capital. Without financial incentives for change in practice, flood irrigation will remain economically a preferred method for many commodities such as dairy pasture.

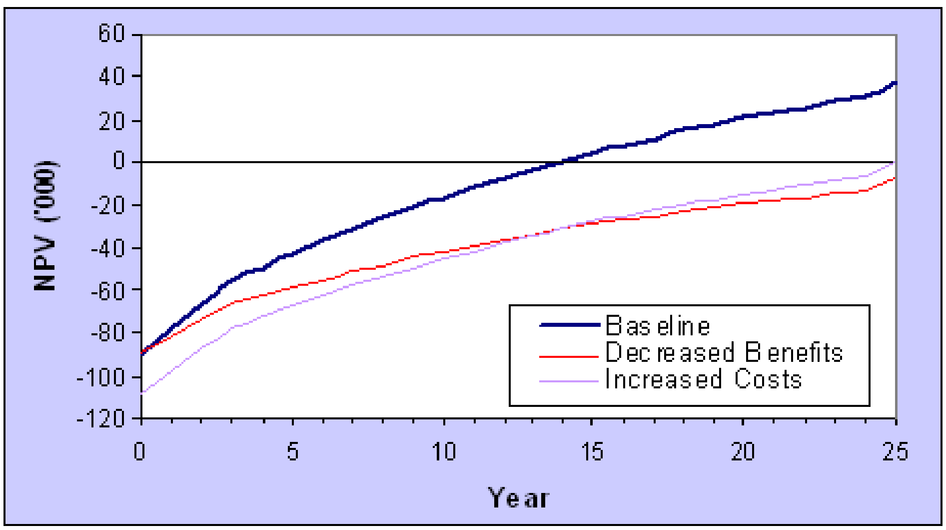
Moving back up scale to understanding possible water use efficiencies, Table 1 lists the likely savings for the Murrumbidgee Irrigation Area.. Clearly scheme improvements will yield similar water savings to optimising on-farm practices. Economic analysis at this systems scale is yet to be completed and with an assessment of adoption rates will provide a basis for investment in further water use efficiency.



(a) Cost benefit of conversion from contour bay to border check



(b) Cost benefit of conversion from contour bay to centre pivot (20 ha farm)



(c) Cost benefit of conversion from contour bay to centre pivot (3 circles)

Figure 9: Returns on Capital investment in on-farm infrastructure

Possible Water Savings in Murrumbidgee Irrigation Area	Gigalitres
On Farm Conversions by matching soils with irrigation and crops	80 – 100 GL
Piping On Farm Channels	20 – 40 GL
Improving Supply Channels	70 – 100 GL

Concluding Comments

Irrigation in Australia is embedded in a systems based policy and planning framework that includes a commitment to integrated catchment management and equitable water sharing principles. Australia is already acknowledged as a world leader in community participation in integrated catchment management and the development of Land and Water Management Plans at community level.

Improvements will continue to be made in the productivity and sustainability of irrigation as Australia continues to wring further benefits from its scarce and variable water resources. Many of these improvements will be underpinned by the cluster of research activities across Universities, Cooperative Research Centres and CSIRO now building around the National Research Flagship – *Water for a Healthy Country*.

Acknowledgements

This paper summarises multiple projects and activities from a range of institutions and individuals too numerous to list. Key amongst these are state agencies in Qld, NSW, Vic and SA; CSIRO across a number of its Divisions and groups, CRC's for Catchment Hydrology and Irrigation Futures and the National Program of Sustainable Irrigation. Where particular trademarks have been referred to care has been taken to denote registered trademarks as indicative of the substantial private industry support for developing the sustainability and productivity of the Australian irrigation industry.