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ECONOMIC ASSESSMENT OF SELECTED INVESTMENTS OF THE NATIONAL PROGRAM FOR SUSTAINABLE IRRIGATION (PHASE 1)

Agtrans Research

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ECONOMIC ASSESSMENT OF SELECTED INVESTMENTS OF THE NATIONAL PROGRAM FOR SUSTAINABLE IRRIGATION (PHASE 1)

Final Report

To
NATIONAL PROGRAM FOR SUSTAINABLE IRRIGATION

17 December 2008

(amended 30 July 2009)

by

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Executive summary

The National Program for Sustainable Irrigation (NPSI) required cost-benefit analyses to be undertaken on a number of its research investments from phase 1 of the program, which ran from July 2002 to June 2007.

Eleven investments from phase 1 were identified by NPSI as having potential for analysis, and these were scanned by Agtrans using six criteria to further determine their suitability for analysis. As a result, four investments (projects) were selected for cost-benefit analysis.

Information from the original project proposals, milestone reports (where appropriate), final reports and other relevant reports were assembled with assistance from the program management. Discussions were held with principal investigators for each project as well as users of the research outputs as appropriate.

Each of the four analyses provides a description of the project background, objectives, activities, costs, outputs, actual and expected outcomes, and potential benefits. Table 1 identifies the benefits from each of the four case studies. Each benefit is categorised as economic, environmental or social. Not all of the case studies demonstrated benefits from each category.

Table 1: Summary of benefits for four NPSI phase 1 investments

Project	Benefits
Horticulture salinity	<u>Productivity and profitability</u> • Water savings due to more strategic application of water as part of precision irrigation • Reduced likelihood of a negative productivity impact on crops due to high soil salinity <u>Environmental</u> • Some potential for lowered salinity returns to the Murray River from irrigated land, leading to improved water quality <u>Social</u> • Recreational and aesthetic benefits from potential contribution to improved water quality
Harvey Water	<u>Productivity and profitability</u> • Lowered water costs to dairy and beef farmers • Higher net incomes from improved pasture production, pasture quality and milk and beef production • Water available for other uses <u>Environmental</u> • Marginally improved water quality in nearby estuaries. <u>Social</u>

	• More sustainable local community • Marginally improved recreational opportunities in estuaries
Irrigation futures	<u>Productivity and profitability</u> • Increase in efficiency of resource allocation regarding investment • Higher level of flexibility enabling the regional economy to adapt to changing circumstances more readily and at lower cost <u>Environmental</u> • More effective management of natural resources and the environment <u>Social</u> • Reduced impact of social adjustment required in future
NAIF	<u>Productivity and profitability</u> • Knowledge and tools to help ensure that any irrigation scheme developed in northern Australia achieves sustainable and maximum levels of productivity and profitability given other constraints • Potential efficiencies in planning and negotiations regarding development of new schemes through improved relationships and communication <u>Environmental</u> • Knowledge and tools to help ensure that any irrigation scheme developed in northern Australia meets the goals of ecological sustainable development and minimises any negative environmental impacts from the development <u>Social</u> • Knowledge and tools to help ensure that any irrigation scheme developed in northern Australia meets the social goals associated with community employment and sustainability

Some of the potential benefits were valued in monetary terms. The present value of benefits (PVB) and present value of costs (PVC) were used to estimate investment criteria of net present value (NPV), benefit-cost ratio (B/C ratio) and internal rate of return (IRR) at a discount rate of six per cent. The PVB and PVC are the sums of the discounted streams of benefits and costs. The discounting is used to allow for the time value of money.

Analyses were undertaken for total benefits that included future expected benefits. A degree of conservatism was used when finalising assumptions.

Sensitivity analyses were undertaken in most cases for those variables where there was greatest uncertainty or for those that were thought to be key drivers of the investment criteria.

Some identified benefits were not quantified due to:

- a suspected, weak or uncertain scientific relationship between the research investment and the actual R&D outcomes and associated benefits
- the magnitude of the value of the benefit was thought to be only minor
- some uncertainty in the assumptions concerning the counterfactual or the 'without' scenario

The analyses undertaken are consistent with other LWA analyses using the 'return on investment' approach.

Table 2 presents the investment criteria for each of the four investments analysed at a six per cent discount rate and expressed in 2007–08 dollar terms. Cash flows were discounted to the 2007–08 year. The costs in the table below refer to those for NPSI and the benefits refer to the proportion of all benefits valued attributed to NPSI on the basis of the program's cost contribution.

Table 2: Investment criteria for four NPSI phase 1 investments
(discount rate = 6%)

Investment	**PVB ($m)**	**PVC ($m)**	**NPV ($m)**	**B/C ratio**	**IRR (%)**
Horticulture Salinity	1.77	0.22	1.55	8.10	25.4
Harvey Water	4.26	0.32	3.94	13.34	30.8
Irrigation Futures	10.67	0.75	9.92	14.23	28.5
North Australian Irrigation Futures	6.83	0.66	6.17	10.34	21.1

Given the assumptions made for each evaluation, all investments appear to have realised or have prospects of realising potential benefits.

1. Introduction

The National Program for Sustainable Irrigation (NPSI) required cost-benefit analyses to be undertaken on a number of its phase 1 research investments to assist in identifying the outcomes and benefits that have emerged or are likely to emerge from the investments. Valuation of these benefits, along with identification of investment expenditure, was required in order to demonstrate their contribution to Australia's rural industry productivity and sustainability.

This analysis evaluates the benefits to be delivered from outcomes from four research projects from the first phase of the program, which ran from July 2002 to June 2007. The program is currently in its second phase.

Assessing the impact of investment in research is important as it can demonstrate to stakeholders that the research has made, or is likely to make, a difference and is providing benefits to Australia's rural industry productivity and sustainability.

One method identified for improving the ability to report on the effectiveness of the research investment is to undertake some formalised investment analyses (cost-benefit analyses) in order to estimate the returns to investment. Such analyses take into account the time differences between when the investment occurs and when benefits accrue.

Section 2 of the report provides a brief summary of the methods used in the analyses. Section 3 reports a summary of the benefits and of the investment criteria estimated for the four investments. A brief conclusion is provided in Section 4. The four investment analyses are presented in Appendices 1 to 4.

2. Methods

2.1 Project selection

Together with the consultants, the NPSI manager and program staff considered the full list of projects funded in phase 1 of the program and selected 11 projects or project groups that were thought to potentially be suitable for analysis. It was determined initially that four or five cost-benefit analyses could be undertaken with the time and resources available for the consultancy. Agtrans scanned the long list of 11 investments to help decide which investments to analyse.

For each of 11 investment areas, a short summary of its suitability for economic evaluation in 2008 is provided. The 11 investments were:

1. Knowledge model (CRD1)
2. LongStop (CLW81)
3. Irrigation Futures (VPI3, including Irrigation Insights)
4. North Australia Irrigation Futures (NAIF) (CDS23)
5. Horticulture Salinity (DEP15)
6. Dam Evaporation (UWA45 and including FSA1 and USQ11)
7. Effluent Water (VPI4)
8. ERA Ord (WRC12)
9. Harvey Water (DAW45)
10. Deep Drainage (CRD2)
11. Open Hydroponics (DAN22)

When collecting basic information on each of the investments the following six criteria were considered:

1. Whether the project/s has/have been completed and outputs have been produced and adopted
2. The likely availability of information regarding actual or likely adoption of any outputs and information providing links between outputs, outcomes and benefits
3. The suitability of the benefits to valuation
4. Whether a boundary can be easily placed around the investment in terms of all inputs over time and across funding organisations
5. The magnitude of NPSI investment in the innovation (both absolute and proportion)
6. The likely magnitude of the potential benefits.

Information scanned included final reports and proposals for projects developed from the original investments. Principal investigators and others reasonably well informed of the impact and implications of the investment were contacted where appropriate.

Each of the investment areas was given a high, medium or low rating against each of the above six criteria. If each of these ratings is assigned a numerical score (high = 3, medium = 2, low = 1), then a total score for each investment area could be calculated, with 18 being a perfect score (Table 2.1).

Table 2.1: Summary scores for the 11 investments

Criteria	**1**	**2**	**3**	**4**	**5**	**6**	**Total**
1.Knowledge Model	2	1	2	2	1	1	9
2. LongStop	2	2	2	1	1	2	10
3. Irrigation Futures	2	2	2	3	2	2	13
4. NAIF	2	1	2	3	2	3	13
5.Horticulture Salinity	2	3	3	3	1	3	15
6. Dam Evaporation	2	1	2	1	2	1	9
7. Effluent Water Use	2	1	1	2	3	1	10
8. ERA Ord	2	2	1	1	2	1	9
9. Harvey Water	3	2	3	2	1	3	14
10. Deep Drainage	2	1	1	1	1	2	8
11. Open Hydroponics	2	2	2	1	2	1	10

The investments with the highest scores were:

1. Horticulture Salinity (15)
2. Harvey Water (14)
3. Irrigation Futures (13)
4. NAIF (13)

These four investments were selected for further analysis.

Together, the investment in these four projects represents 16.4 per cent of NPSI's total phase 1 investment (in nominal terms).

2.2 Individual analyses

Each investment was evaluated through the following steps:

1. Information from the original project schedules, and any progress reports, final reports or other relevant reports and material was assembled with assistance from NPSI personnel, principal investigators and others.
2. An initial description of the project background, objectives, activities, costs, outputs, and expected outcomes and benefits was drafted. Additional information needs were identified.
3. Telephone contact was made with principal investigators and/or users of the research outputs and the draft sent to those persons for perusal and comment, together with specific information requests.

4. Further information was assembled where appropriate and the quantitative analysis undertaken.
5. Final drafts were passed by principal investigators for comment.

The actual and potential benefits from each investment were identified and described in a triple-bottom-line context. Some of these benefits were then valued.

The factors that drive the investment criteria for R&D include:

C	The cost of the R&D
K	The magnitude of the net benefit per unit of production affected; this net benefit per unit also takes into account the costs of implementation
Q	The quantity of production affected by the R&D, in turn a function of the size of the target audience or area, and the level of initial and maximum adoption ultimately expected, and level of adoption in the intervening years
D	The discount rate
T_1	The time elapsed between the R&D investment and commencement of the accrual of benefits
T_2	The time taken from first adoption to maximum adoption
A	An attribution factor can apply when the specific project or investment being considered is only one of several pieces of research or activity that have contributed to the outcome being valued
P	Probability of an R&D output, commercialisation etc. occurring. Can be applied when the research is not complete or when some further investment is required before the outputs of the research are translated into adoptable outcomes and extended to the industry.

Defining the ‘without R&D’ scenario to assist with defining and quantifying benefits is often one of the more difficult assumptions to make in investment analyses. The ‘without’ scenario (referred to here as counterfactual) usually lies somewhere between the status quo or business as usual case and the more extreme position that the research would have happened anyway but at a later time; or the benefit would have been delivered anyway through another mechanism. The important issue is that the definition of the counterfactual scenario is as consistent as possible between analyses.

The present value of benefits (PVB) and present value of costs (PVC) were used to estimate investment criteria of net present value (NPV), benefit-cost ratio (B/C ratio) and internal rate of return (IRR) at a discount rate of six per cent. The PVB and PVC are the sums of the discounted streams of benefits and costs. The discounting is used to allow for the time value of money. All dollar costs and benefits were expressed in 2007–08 dollar terms and discounted to the year 2007–08. A 40-year time frame was used in all analyses, with the first year being the initial year of investment in the R&D project. Total costs for the R&D project included the cash contributions of NPSI, as well as any other resources contributed by third parties (e.g. researchers or industry).

Analyses were undertaken for total benefits that included future expected benefits. A degree of conservatism was used when finalising assumptions.

Sensitivity analyses were undertaken in most cases for those variables where there was greatest uncertainty or for those that were thought to be key drivers of the investment criteria.

Some identified benefits were not quantified, due to:

- a suspected, weak or uncertain scientific relationship between the research investment and the actual R&D outcomes and associated benefits
- the magnitude of the value of the benefit was thought to be only minor.
- some uncertainty in the assumptions concerning the counterfactual or the ‘without’ scenario.

3. Summary of results

3.1 Qualitative results

Table 3.1 identifies the benefits from each of the four case studies. Each benefit is categorised as economic, environmental or social. Not all of the case studies demonstrated benefits in each category.

Table 3.1: Summary of benefits for four NPSI phase 1 investments

Project	Benefits
Horticulture Salinity	<u>Productivity and profitability</u> • Water savings due to more strategic application of water as part of precision irrigation • Reduced likelihood of a negative productivity impact on crops due to high soil salinity <u>Environmental</u> • Some potential for lowered salinity returns to the Murray River from irrigated land, leading to improved water quality <u>Social</u> • Recreational and aesthetic benefits from potential contribution to improved water quality
Harvey Water	<u>Productivity and profitability</u> • Lowered water costs to dairy and beef farmers • Higher net incomes from improved pasture production, pasture quality and milk and beef production • Water available for other uses <u>Environmental</u> • Marginally improved water quality in nearby estuaries <u>Social</u> • More sustainable local community • Marginally improved recreational opportunities in estuaries
Irrigation Futures	<u>Productivity and profitability</u> • Increase in efficiency of resource allocation regarding investment • Higher level of flexibility enabling the regional economy to adapt to changing circumstances more readily and at lower cost <u>Environmental</u> • More effective management of natural resources and the environment <u>Social</u> • Reduced impact of social adjustment required in future

NAIF	<u>Productivity and profitability</u> • Knowledge and tools to help ensure that any irrigation scheme developed in northern Australia achieves sustainable and maximum levels of productivity and profitability given other constraints • Potential efficiencies in planning and negotiations regarding development of new schemes through improved relationships and communication <u>Environmental</u> • Knowledge and tools to help ensure that any irrigation scheme developed in northern Australia meets the goals of ecological sustainable development, and minimises any negative environmental impacts from the development <u>Social</u> • Knowledge and tools to help ensure that any irrigation scheme developed in northern Australia meets the social goals associated with community employment and sustainability

3.2 Quantitative results

The investment criteria calculated for each investment were the NPV, the B/C ratio and the IRR. The NPV is the difference between the PVB and the PVC. Present values are the sum of discounted streams of benefits and/or costs. The B/C ratio is the ratio of the PVB to the PVC. The IRR is the discount rate that would equate the PVB and the PVC, thus making the NPV zero and the B/C ratio 1:1.

Table 3.2 presents the investment criteria for each of the four investments analysed at a six per cent discount rate. The costs in the table below refer to those for NPSI and the benefits refer to the proportion of all benefits valued attributed to NPSI on the basis of the program's cost contribution.

Table 3.2: Investment criteria for four NPSI phase 1 investments
(discount rate = 6%)

Investment	**PVB ($m)**	**PVC ($m)**	**NPV ($m)**	**B/C Ratio**	**IRR (%)**
Horticulture Salinity	1.77	0.22	1.55	8.10	25.4
Harvey Water	4.26	0.32	3.94	13.34	30.8
Irrigation Futures	10.67	0.75	9.92	14.23	28.5
NAIF	6.83	0.66	6.17	10.34	21.1

Further details on each of these investments and the associated results are provided in the individual analysis reports. It is evident from the results there is a wide range in the investment criteria across the four projects.

The benefits and costs from the four investments can be aggregated to provide aggregate investment criteria for the four projects. Table 3.3 shows that, together, these four analyses have a B/C ratio of 8.9 to 1.

Table 3.3: Investment criteria for NPSI phase 1 (using benefits and costs from four NPSI investments analysed)

PVB (four investments)	$17.23 m
PVC (NPSI phase 1)	$1.95 m
NPV	$15.29 m
B/C Ratio	8.85 to 1
IRR	24.3%

The benefits from the four investments analysed can be placed against the costs of the entire program to demonstrate a minimum return on investment for NPSI phase 1 as a whole. Table 3.4 shows that even if the benefits from these four investments alone are considered, then the program has yielded a positive benefit–cost ratio of 1.4 to 1.

Table 3.4: Investment criteria for NPSI phase 1 (using benefits from four NPSI investments analysed and total costs of NPSI program)

PVB (four investments)	$17.23 m
PVC (NPSI phase 1)	$12.12 m
NPV	$5.12 m
B/C ratio	1.42 to 1
IRR	8.2%

Confidence in analyses

The results produced are highly dependent on the assumptions made in each analysis, many of which are uncertain. Two factors warrant recognition, the first being the coverage of benefits. Where there are multiple types of benefits it is often not possible to quantify all the benefits that may be linked to the investment. The second factor involves uncertainty regarding the assumptions made, including the link between the research and the assumed outcomes, that is, the difference the research has made or is likely to make. Some of the necessary assumptions can be contentious and many made in the analyses are a matter of judgement. To account for the uncertain assumptions, a series of sensitivity analyses has been conducted, where the investment criteria are recalculated with variations of some of the uncertain assumptions.

In addition, a rating has been given to the confidence in the results of the investment analyses. The confidence is made up of the two factors described above. The rating categories used are high, medium and low, where:

High: denotes a good coverage of benefits or reasonable confidence in the assumptions made

Medium: denotes only a reasonable coverage of benefits or some significant uncertainties in assumptions made

Low: denotes a poor coverage of benefits or many uncertainties in assumptions made

Table 3.5 presents an estimate of the confidence in analyses for each of the investments, expressed via the factors defined above.

Table 3.5: Confidence in analysis

Investment	Coverage of benefits	Confidence in assumptions
Horticulture Salinity	high	medium
Harvey Water	high	high
Irrigation Futures	medium	medium
NAIF	medium	low

4. Conclusion

The four investment analyses all yielded positive results at a six per cent discount rate, with B/C ratios ranging from 8:1 to 14:1. Care should be taken in any comparisons across investments due to the different frameworks used for each analysis and the uncertainties involved in each set of assumptions.

Appendix 1: An economic analysis of investment in reducing salinity impact on Lower Murray horticulture (DEP15)

SUMMARY

Date of evaluation: November 2008

Duration: NPSI supported the development of this innovation over the period 2003–04 to 2005–06.

Nature of innovation

The principal output of the project was a set of draft best management practices (BMPs) for root zone salinity. The intention of the BMP document is to guide irrigators in starting to implement improved irrigation practices, resulting in more efficient water use. The BMPs are relevant at both the on-farm level (to be adopted by irrigators) and at the regional level (to be adopted by water managers and policy-makers).

The study also resulted in the development of a soil water extractor (SWE). While this device was not a planned output of the study, it was developed for use in the field studies. The SWE is a tool for irrigators and can be used for on-farm measurement of soil water salinity and nutrient content. The SWE is a simple and inexpensive device for in-situ monitoring offering real-time information.

Who was involved

The principal research was undertaken by the South Australian Research and Development Institute (SARDI). Partners in the research project included NPSI, the SA Department of Water Land and Biodiversity Conservation, SARDI, SA Centre for Natural Resource Management, Murray Darling Basin Commission, the Victorian Department of Primary Industries, CSIRO Plant Industry, CSIRO Land & Water, the NSW Department of Primary Industries (then NSW Agriculture) and horticultural industries.

Adoption and impact

A grower friendly ‘Root Zone Salinity WATCH Toolkit’, including the SWE was supplied to NSW, Victorian, SA and WA growers (including corporate wineries). At the time of the final report (January 2007) there were about 500 SARDI SWE extractors installed in irrigated horticulture. The SWE has been quickly taken up by irrigators and irrigation advisers in the Riverland, as well as some in south-east South Australia, NSW and WA. The technology is predominantly used by growers of high-value crops (mainly horticulture) that are salinity sensitive, and are irrigated with low to medium salinity water.

It is recognised that adoption of the SWE and BMPs is likely to occur in other districts, in other industries, and for purposes other than avoiding salinity build-up in the soil from saline irrigation water. Examples of such uses include for fertiliser management. The

potential benefits to these other adopters are not valued as part of this analysis due to the lack of adoption information.

Evaluation
A benefit–cost analysis for the investment in the project was carried out with key benefit assumptions being:

- increased water use efficiency
- decreased likelihood of productivity reductions from salinity in the root zone

Investment criteria
The period of analysis was for 40 years after the first year of investment. The results are expressed in 2007–08 dollar terms and all benefits and costs are discounted to 2007–08 using a discount rate of six per cent. Investment criteria were estimated for both total investment and for NPSI and LWA investment alone. Benefits for NPSI investment criteria were estimated as 10.1 per cent of the total benefits, 10.1 per cent representing the proportion of total costs contributed by NPSI. LWA contributed 15 per cent of NPSI phase 1 funding. The investment criteria are shown in Table 1.

Table 1: Investment criteria for the project

Criterion	LWA only	NPSI only	Total
Present value of benefits ($m)	0.27	1.77	17.57
Present value of costs ($m)	0.03	0.22	2.17
Net present value ($m)	0.25	1.55	15.40
Benefit:cost ratio	8.10	8.10	8.09
Internal rate of return (%)	25.5	25.4	25.4

Current contact: Tapas Biswas, Senior Irrigation Scientist, SARDI, telephone 08 8303 9730.

FULL CASE STUDY

Background

Water use efficiency (WUE) has been improving in many irrigated areas of Australia over the past two decades, including for irrigated horticulture in the Lower Murray Region (Riverland–Sunraysia). However, a negative consequence of improved WUE is the risk of salinity building up in the root zone. This risk occurs because the leaching fraction is either inadequately applied or not applied at all. (The leaching fraction is the additional water needed to flush residual salts from the root zone and is additional to the crop's evapotranspiration, i.e. plant transpiration and soil evaporation.)

The risk of such build up was also thought to be higher under the 'Living Murray' initiative, which would result in the seasonal distribution of salinity in the Lower Murray changing with subsequent increased salinity levels in irrigation water during the vegetative growth stage of most horticultural crops. There was some concern, therefore, that under conditions of higher salinity, the benefits from increases in irrigation efficiency may be limited by leaching efficiency (LE) in the Lower Murray irrigation districts. Leaching efficiency is defined as the efficiency at which drainage water mixes with the soil solution. It is often assumed as 100 per cent when every millimetre of water passing below the root zone carries completely mixed soil water.

At the time the study started, the Sunraysia and Riverland regions supplied about 50 per cent of the national citrus and vine production. The sole sources of irrigation water for these regions are the Murray and Darling rivers. Concerns about the possible impact of higher soil salinity in the root zone on the productivity of horticulture in the region led to the funding of this project to improve understanding of the interactions and risks, and to develop management practices to alleviate such risk.

The project

Project objectives

The project objectives were:

- determine the salinity relationships for irrigated horticulture along the Lower Murray: Riverland, Sunraysia and western NSW
- determine the variability of electrical conductivity (EC) (soil water) and leaching efficiency in the field under known soil conditions and irrigation management
- simulate the performance of vines under different scenarios of River Murray salinity at Morgan
- provide input to the implementation of the salinity strategy and integrated catchment management plan of the Murray-Darling Basin

Investment costs

The project was funded by the National Program for Sustainable Irrigation and a range of other organisations. Table 2 presents the investment costs of the project for all investors.

Table 2: Resources invested (nominal dollars) by year by LWA, NPSI partners and researchers

Year	NPSI[1]	Researcher and industry contributions[2]	Total
2003–04	66,000	547,000	613,000
2004-05	41,250	497,000	538,250
2005-06	57,750	427,000	484,750
Total	165,000	1,471,000	1,636,000

[1] Land and Water Australia (LWA) comprises 15% of NPSI Phase 1 funding

[2] Includes contributions from DWLBC, SARDI, SA Centre for Natural Resource Management, MDBC, Vic DPI, CSIRO Plant Industry, CSIRO Land & Water, NSW DPI, horticultural industries

Investment description

Stage 1 of the project involved a desktop review of crop salinity tolerance and a soil salinity survey of 14 properties in Sunraysia and the Riverland. An initial survey was conducted of salinity and leaching efficiency on three properties in the 2002–03 irrigation season and at another 11 properties during the 2003–04 season.

The instruments for measurement were located in areas of the paddock where variability due to salinity in the rooting depth was at a minimum. Such locations were identified using electromagnetic resonance imaging. Leaching efficiency was calculated using a water extraction model.

Regular soil coring and plant sampling were used, as were the following instruments for water and solute data collection below the active rooting depth:

- Wetting front detector (WFD) (FullStop): a buried funnel-shaped device used to indicate wetting front and passively collect soil water samples (<2 kPa suction) at about 300 mm depth for salinity and nutrient assessment
- LongStop: collects wetting front below 4 kPa at a greater depth (about 600 mm) in the soil profile
- Loggable tensiometer (UMS-T8): measures soil water suction at 90 and 120 cm depths and logs the data at given intervals
- TriScan (Sentek): integrated salinity and moisture sensing device using capacitance sensors
- Enviroscan (Sentek): similar to above without salinity sensors
- GBLites and Heavies: gypsum blocks, measuring soil water content (GBLite is specially designed for sandy soil conditions)

The method of surveying during the initial survey was found to result in a large coefficient of variation, as well as being laborious, expensive and requiring specialised skills and equipment, so the project developed a soil water extractor (SWE). The SWE together with an existing technology (WFD) were used following each irrigation and rainfall event to measure salt concentrations under drip and sprinkler irrigated vineyards. Data was collected over two years at sites in NSW, Victoria and South Australia.

During stage 2 of the project, four representative sites across NSW, Victoria and South Australia were chosen to more thoroughly study water and salt movement in the root zone. The sites were selected due to being fully instrumented and having data available on weather and management, as well as having long-term and reliable irrigation. The sites all had water tables deeper than three metres and represented typical vineyard and citrus orchard management in the Riverland and Sunraysia regions.

The data was analysed and conclusions drawn. These are presented in the following section (principal outputs). The data was analysed by using three methods to determine the amount of water draining from the soil zone. The quantity and distribution of salt within the root zone was then modelled using a two-dimensional solute transport model.

Results from another SARDI project were compared with the data from this project (DEP15). The other project collected data in a range of Sunraysia vineyards on the chloride and sodium content of petioles and leaves at flowering, veraison and harvest, and berries at harvest.

Historic river salinity data for different sections of the Lower Murray for the last 25 years was collected from the MDBC database for four river sections from Mildura to Lake Alexandrina. For a range of industries and crops, the area of production, related to the three major soil types in the four regions, was tabled. From these figures, the percentage and value of lost production was calculated under different salinity scenarios.

Draft best management practices were developed based on the findings of the study, and were presented at a workshop seeking to refine the identified best management practices.

A communication strategy for the project was developed. This identified key stakeholders, key messages and range of communication processes that would be utilised during the project. The strategy was updated over the life of the project as required. Communication activities included presentations at conferences and workshops, wide circulation of milestone reports, addresses to local irrigator groups and water agencies, and media interviews.

Principal outputs

The expected outputs as defined in the proposal were:

- An irrigator-friendly document on current 'state of knowledge' of the salinity relationships for the main horticultural crops grown along the Lower Murray
- Improved knowledge of leaching efficiency (LE) and potential variance of soil salinity under field conditions
- Desk-top identified bottlenecks and challenges for managing on-farm salinity under different soil conditions
- Information on variance of leaching efficiency measured under field conditions and possibly related to soil conditions and irrigation management
- Assessment of whether horticultural crops will be able to cope with changes in river salinities under future river flow management regimes and water use efficiency targets
- Attributes of land that will be difficult to manage under increased river salinity
- Strategies for reducing soil salinity and, hence, improved crop performance through improved irrigation (and leaching) techniques
- Improved analyses of the benefits and costs for improved irrigation and crop management practices and downstream benefits of salinity control works

- Improved knowledge of the trade-offs stemming from on-farm salinity management measures
- Crucial quantification of volume and salinity of irrigation leachate into triple-bottom-line models for regional drainage disposal, environmental flow planning and setting 'end of valley' targets.

The major findings of the report were:

- The average leaching efficiency of the surface 30 cm soil in drip-irrigated fields has been found to be 65 per cent compared to 90 per cent for sprinkler irrigation. This implies that for drip-irrigated fields, at least one-third of leachate in non-mixed irrigation water passes through the soil profile without removing salt from soil.
- Current irrigation management produces negligible leaching under drip irrigation (1–12 per cent) compared to the uniform sprinkler irrigation (14–21 per cent) regardless of the crops grown.
- There is a general concern that in the Lower Murray regions if winter rainfall does not provide effective leaching there is a major risk of accumulation of residual salt in the root zone.
- Simulations showed that if river salinity increases to 0.8 dS/m, 2000 kg/ha of salt would accumulate in a one-metre root zone during a single irrigation season.
- A drought year with high river salinity (~1 dS/m) will increase topsoil salinity (ECe) to 5 dS/m. The threshold ECe for grapes is 1.5 dS/m while for citrus the value is 1.7 dS/m.
- A survey undertaken during the project showed that there was no immediate risk of yield loss at that time due to soil salinity except at one site where a saline water table contributed salt to the roots.
- During summer there was a distinct trend of salt build up at around 60 cm and half way between dripper emitters which, during winter, was displaced from the profile by rain.
- Winter seems to be the best time when a supplementary leaching irrigation will be likely to maximise salt displacement from the root zone and result in minimum drainage.
- The leaching efficiency of intermittent irrigation was greater (seven per cent increase) than continuous application.
- Plant salt concentrations for both citrus and grapes were found to be low, with no immediate salinity risk, given the salinity of the irrigation water at the time of the analysis.
- If Morgan benchmark salinity were to reach 1,000 EC (1 dS/m), the estimated value of production loss from all irrigated crops including pasture along the River Murray from Nyah in Victoria to the Lower Lakes in South Australia was $117 million at 70 per cent LE. The impact would be greater in the more saline lake districts than the lower salinity river water areas from Sunraysia to Riverland.

The principal output of the project was a set of draft best management practices (BMPs) for root zone salinity. The draft BMPs were presented at the Root-Zone and Solute

Management workshop in October 2006. Key irrigators provided comments on the paper presented at the workshop, and the document was then modified.

The draft BMPs have not been field validated, however they were drawn from the field investigations at the project sites. The intention of the BMP document is to guide irrigators in starting to implement improved irrigation practices, resulting in more efficient water use. The BMPs are relevant at both the on-farm level (to be adopted by irrigators) and at the regional level (to be adopted by water managers and policy-makers).

The study also resulted in the development of a soil water extractor (SWE). While this device was not a planned output, it was developed for use in the field studies. The SWE is a tool for irrigators and can be used for on-farm measurement of soil water salinity and nutrient content. The SWE is a simple and inexpensive device for in-situ monitoring, offering real-time information. It is a modified porous ceramic cup device that samples soil water under a suction of 60–70 kPa created by a 60mL plastic syringe. This device is seen as an improvement on other similar devices as it is less expensive and does not require specialised skills. It can be permanently installed and then enables growers to track salinity within the rooting depth throughout the year by sampling at any time.

Principal outcomes

The expected outcomes from the funding of the project included:

- a broader understanding of the importance of the leaching efficiency and its possible impact on the current management of irrigated crop production systems in the Lower Murray region
- the provision of a valuable source of information on salinity relationships for irrigation management of horticultural crops.

A communication strategy was developed for the project to help extend the results to other scientists and key stakeholders in the irrigation industry. The target audiences identified in the proposal were:

- growers in the Lower Murray region (Riverland and Sunraysia)
- irrigation scientists and technologists
- water and land use policy makers
- NRM policy and decision makers

A workshop organised by the project team to present the findings of the project was attended by 74 scientists, consultants, growers and others. The evaluation survey for the workshop indicated the project was meeting a real need and that there was a growing interest in root-zone water and solute management. It was indicated that in the future, growers should be more actively involved in the development of tools and BMPs in relation to root-zone salinity.

Recommendations from the project (and the workshop) included:

- There should be an adult education approach for training of irrigators, regional planners and policy makers on risk management. Such training modules should be developed to sit alongside existing irrigation training.
- A network of trial sites should be developed in major irrigation areas to increase irrigator awareness for root-zone salinity management.
- The salt tolerance for grapes should be reviewed in light of current growing practices, whereby an optimum yield is no longer a criterion.
- A model is required for three-dimension visualisation of root zone salinity due to precision water application involving non-uniform wetting
- The deep drainage estimates need field validation against more robust techniques
- The current theory for crop yield/sustainability relationships is not applicable in years of substantial winter rainfall and also when the winter rainfall carry-over plus in-season rainfall is a substantial component of the crop water balance
- Salinity impact varies with the EC during the season, and depends on the crop physiological stages at which the salinity impact occurs
- Given the above two points, the methodology for estimating the value of crop production loss due to irrigation salinity across the Murray-Darling Basin needs further refinement before it can be used for policy decisions

A grower friendly 'Root Zone Salinity WATCH Toolkit', including the SWE was supplied to NSW, Victorian, SA and WA growers (including corporate wineries). At the time of the final report (January 2007), there were about 500 SARDI SWE extractors installed in irrigated horticulture. The technology has been licensed to SENTEK Sensor Technologies Pty Ltd (an Australian firm) for manufacture and national and international marketing. An instruction manual for the SWE has also been published. The SWE has been quickly taken up by irrigators and irrigation advisers in the Riverland, as well as some in south-east SA, NSW and WA.

The technology is predominantly used by growers of high-value crops (mainly horticulture) that are salinity sensitive, and are irrigated with low to medium salinity water. The device is also used by agronomists for researching non-irrigated crops grown in wetter climatic regions.

The device also offers tracing of fertilisers in the root zone for the purpose of fertiliser use efficiency (value for fertiliser input). The device can be used for measuring the salt, nutrient and trace element content in leachate from agricultural land and urban landfill in sensitive environments.

Following the completion of DEP15 the research team received further funding for the validation of the draft BMPs with grower involvement in the Lower Murray region from NPSI, the Grape & Wine Research and Development Corporation and catchment management authorities. The recommendation from this further validation was that growers should install at least one (but preferably two) SWEs in the profile at two sites, representative of the soil types for their high-value crops.

Sentek is now marketing the SWE in 33 countries as a part of its suite of instruments for measuring soil water, salinity and nutrient content/movement in irrigated soils. In early 2007 the device was launched at international trade exhibitions in Europe and USA. The sales figures from Sentek are not available for commercial reasons.

The SARDI team is collaborating on solute transport with extension specialists of University of California following the International Wine Industry Technical Conference held in Adelaide in July 2007.

Benefits associated with the investment

The benefits from the project are identified below in a triple-bottom-line format.

Economic
The major intended benefit from the project was a reduced likelihood of productivity reductions in horticultural crops, due to the management of irrigation water to avoid salinity build up in the soil. The results of the project have shown that there is a build up of residual salt in the soil under certain conditions where precision irrigation (right amount at the right time) is practised or in soils with a reduced leaching efficiency, even where the irrigation water being used is slightly saline. However, in the years the DEP15 study was undertaken, the data suggest that the irrigation water salinity levels were not high enough to have a major impact on crop productivity.

However, in subsequent years (when the SARDI team was undertaking a field validation of the draft BMPs) of a long drought in southern Australia all high security water allocations were severely reduced (e.g. to 30 per cent in South Australia for two subsequent years). The salinity of the Lower Murray started to rise rapidly because of stagnation of the river flow, ultimately rising to levels that are too excessive for permanent horticulture.

Despite the tight business conditions, there was rapid adoption of SWE because the device also offered reliable data for determining whether the soils needed to be leached in the subsequent winter (when highest leaching efficiencies can be achieved) or that any remaining water could be saved for use in the following water year under the policies of the state water agencies in the Lower Murray region.

There remains a risk of high salinity levels in irrigation water from the River Murray and the research has been successful in identifying the circumstances under which this risk increases. It has also developed a series of best management practices that should be implemented to ensure that the risk is reduced for salinity build-up in the root-zone.

The rate of root zone salinity build up depends on a host of factors, including irrigation water salinity, soil type characteristics, field application uniformity, seasonal crop water requirements and farm water use efficiency. The level of adoption of the recommended BMPs is difficult to quantify. As well as the 500 toolkits distributed, the BMPs have been incorporated into the drought survival strategies offered and promoted by state agencies.

Adoption of the BMPs to date has occurred largely on-farm in the form of crop management adjustments.

As well as the BMPs, the SWE enables growers to practise precision irrigation, resulting in increased water use efficiency. A spin-off and unexpected benefit from the research has been the potential for water savings if best management practices are followed. Previously, those who were concerned about salt build-up in the soil profile tended to apply extra irrigation water in summer to flush out the salts. However, the study has shown that this is not effective, and the additional water applied does not increase the leaching efficiency, and drains through the soil profile with no additional salt.

In fact, most of the leaching of salts through the profile occurs most effectively during winter and additional irrigation for this purpose is only required during winters with lower than average rainfall. The benefit therefore is saved irrigation water through avoiding unnecessary irrigations in summer for leaching purposes. Some additional water would be applied in winter, however this would be applied more strategically and would not be applied every year.

It is reasonable to assume that precision irrigation practitioners should be able to save at least 10 per cent of their normal water budget. It is estimated that the average leaching requirement of the Lower Murray crops is about 10 per cent of the annual evapotranspiration. In years of below-average irrigation water salinity (two out of five years) this percentage could be 2–3 per cent while in high-salinity years it would be about 15 per cent.

It is difficult to assess the likelihood of a high salinity year (>1000 EC) because of the future changes to the regimes in river flow and hence irrigation salinity in the Murray Darling Basin under the proposed developments of restoring natural flow regimes, water for the environment, large scale adoption of precision irrigation by corporate growers and managed investment scheme funded plantings. As well, there will be changes in river flows resulting from projected climate change/shift.

The cost of purchasing and installing an SWE is approximately $150 for each device (Gerrit Schrale, pers comm). However this cost may be reduced in future if the devices are mass produced overseas under contract.

Other tools are available that provide similar data, however the SWE is quicker and easier to use, and does not require expert knowledge. It also has the advantage of being marketed with an interpretation package, which relates the reading to international benchmarks derived from a worldwide literature review on crop salinity tolerance.

Environmental
There is potential for some influence on lowering salinity impacts on downstream users of the Murray River. This is due to the potential for a reduction in the volume of irrigation-induced saline returns to the Murray River due to hydro-geological conditions in the lower Murray region.

Social
The social impacts from the investment are limited and potentially include improved water quality, resulting in improved recreational access and enjoyment of aesthetics.

Summary of types of benefits
A summary of the principal types of benefits associated with the investment is shown in Table 3.

Table 3: Categories of benefits from the investment

Benefits
Productivity and profitability • Water savings due to more strategic application of water as part of precision irrigation • Reduced likelihood of a negative productivity impact on crops due to high soil salinity
Environmental • Some potential for lowered salinity returns to the Murray River from irrigated land, leading to improved water quality
Social • Recreational and aesthetic benefits from potential contribution to improved water quality

Public versus private benefits
Most of the benefits are private in nature and will accrue to irrigators in the Lower Murray. There is limited potential for some public benefits in the form of improved water quality for downstream water users (including for recreation and aesthetic reasons).

Benefits to primary industries
A range of horticultural crop producers should benefit from the investment

Distribution of benefits along the supply chain
While most benefits will be captured by irrigators, there is the potential for some benefits to move up the supply chain to processors and consumers of the relevant horticultural crop products.

Match with national priorities
The Australian Government's national and rural R&D priorities are shown in Table 4. This research has addressed national research priority 1, as well as rural research priorities 1 and 3. The priorities have also been supported (innovation skills and technology) through the development of the SWE.

Table 4: National and rural R&D research priorities 2007–08

Australian Government	
National research priorities	**Rural research priorities**
1. An environmentally sustainable Australia 2. Promoting and maintaining good health 3. Frontier technologies for building and transforming Australian industries 4. Safeguarding Australia	1. Productivity and adding value 2. Supply chain and markets 3. Natural resource management 4. Climate variability and climate change 5. Biosecurity *Supporting the priorities:* 1. Innovation skills 2. Technology

Quantification of benefits

Adoption
In 2006 there were approximately 800 properties growing oranges, and 1700 properties growing grapes in the Wentworth (NSW) and Mildura (Vic) statistical local areas (SLAs) as well as in the Murray Lands (SA) statistical division (ABS 2008). It is assumed that all of these properties are irrigated, and some may be growing both oranges and grapes, so the total number of properties may be less than 2500. It is not known how many irrigators in the Lower Murray district have taken up the BMPs and are using the SARDI/Sentek SWE. However, it is known that 500 toolkits, including the SWEs, were distributed towards the completion of the research project. Some of these have been used for research purposes and it is not known for certain how many were actually installed on properties in the Lower Murray region.

For the purposes of this analysis it is assumed that the BMPs and SWEs were adopted on 25 citrus and/or grape properties in the first year after the research was completed (2006–07) and that an additional 25 citrus and/or grape properties adopt the changes each year until the maximum number of adopters of 250 properties is reached in 2015–16. It is assumed that the only significant costs of adopting the BMPS are the purchase and installation of the SWEs, which is estimated at $150 per unit. It is assumed that 10 units are required per farm to take account of different soil types and crop types. Therefore the total cost of adoption per property is assumed to be $1500.

It is recognised that adoption of the SWE and BMPs is likely to occur in other districts, in other industries, and for purposes other than avoiding salinity build-up in the soil from saline irrigation water. Examples of such uses include for fertiliser management. The potential benefits to these other adopters are not valued as part of this analysis due to the lack of adoption information. Also, there will be a benefit to Australia from the sale of the Australian designed and manufactured SWE to overseas irrigators. This benefit is not included because sales data is not available due to confidentiality. However, an example of the likely magnitude of the potential benefit can be demonstrated by assuming that, if 500 units were exported per annum for the next ten years with a profit of $50 per unit, the benefit to Australia would be $25,000 per annum.

There are two benefits quantified in this analysis

1. Increased water use efficiency
2. Decreased likelihood of productivity reductions from salinity in the root zone

The potential environmental and social benefits from improved water quality are not quantified due to uncertainties regarding the level of adoption required in order to have any significant impact.

Water use efficiency

An ABARE survey of citrus and grape farms in the Mildura–Wentworth area (Mues and Rodriguez 2007) found that the average area under production (bearing and non-bearing area) is approximately 25 hectares. The same survey found that the average irrigation application rate on these farms was 8 ML/ha. The value of irrigation water supplied by Lower Murray Water is assumed to average $100/ML (Essential Services Commission 2008). It is assumed this value continues into the future. Therefore, the average value of irrigation water per annum per farm is $20,000. The analysis assumes that the adoption of the BMPs and the use of the SWE for precision irrigation to avoid a build-up of salt in the soil can result in the use of 10 per cent less irrigation water per year. This represents a saving of $2000 per property per annum.

Decreased likelihood of productivity reductions from salinity in the root zone

The average value of production per farm in the district is assumed to be $10,000 per hectare. This is based on the average value of oranges and grapes grown in the Wentworth (NSW), Mildura (Vic) and Murray Lands (SA) statistical divisions as reported by ABS (2008). It is assumed that without the adoption of BMPs and SWEs the likelihood of the salinity levels in irrigation water resulting in soil salinity increasing to the point of being detrimental to productivity is 20 per cent per annum (equivalent to an occurrence of one in five years). It is assumed that, with the research, the risk can be managed to a greater degree, and the probability of a reduction in productivity from this cause is decreased to 10 per cent (equivalent to an occurrence one in 10 years). It is assumed that the average decrease in productivity in the year of high risk is 15 per cent. This loss could be a productivity loss, as well as a tree/vine loss. It is recognised that years of high potential salinity impact are likely to coincide with years of reduced water availability and, therefore, the productivity loss in such a year could be much higher. However, the 15 per cent loss of productivity assumed here refers only to that loss due to saline soil in the root zone.

Summary of assumptions

Table 5 contains a summary of all assumptions made.

Table 5: Assumptions for the valuation of benefits from investment

Variable	Value	Source
Adoption		
First year of adoption	2006–07	Agtrans estimate
Year of maximum adoption	2015–16	Agtrans estimate
Adoption per annum	25 properties	Agtrans estimate, after discussions with Gerrit Schrale
Maximum adoption	250 properties	Agtrans estimate
Average size of irrigated area	25 hectares	Mues and Rodriguez 2007
Number of SWE units per property	10	Agtrans estimate, after discussions with Gerrit Schrale
Cost of each SWE unit	$150	Gerrit Schrale, pers comm
Water Use Efficiency		
Average irrigation application rate	8 ML/ha	Mues and Rodriguez 2007
Value of irrigation water	$100/ML	Essential Services Commission 2008
Savings in irrigation water due to research	10% per annum	Gerrit Schrale, pers comm.
Decreased likelihood of productivity reductions from salinity in the rootzone		
Average value of production per hectare	$10,000/ha/annum (average for grapes and oranges)	Estimated from ABS 2008
Likelihood of loss of productivity due to saline soil without research	20%	Agtrans estimate
Likelihood of loss of productivity due to saline soil with research	10%	Agtrans estimate
Decline in productivity in year of impact	15%	Agtrans estimate

Results

All past costs and benefits were expressed in 2007–08 dollar terms using the CPI. All benefits after 2007–08 were expressed in 2007–08 dollar terms. All costs and benefits were discounted to 2007–08 using a discount rate of six per cent. The base run used the best estimates of each variable, not withstanding a high level of uncertainty for many of the estimates. The base analyses ran for 40 years from the first year of investment (2003–04) to the final year of benefits assumed (2042–43).

Investment criteria were estimated for both total investment and for NPSI and LWA investment alone. Benefits for NPSI investment criteria were estimated as 10.1 per cent of the total benefits (10.1% representing the proportion of total costs contributed by NPSI). LWA contributed 15 per cent of NPSI phase 1 funding. The investment criteria are reported in Table 6.

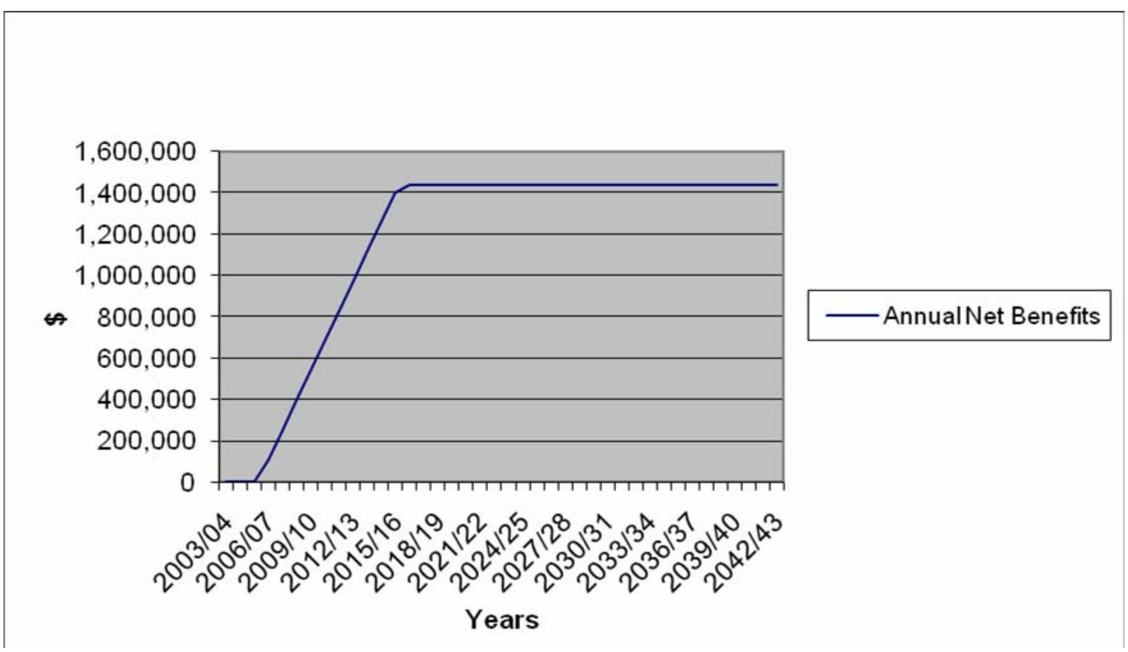
Table 6: Investment criteria for costs and benefits (discount rate 6%)

Criterion	LWA only	NPSI only	Total
Present value of benefits ($m)	0.27	1.77	17.57
Present value of costs ($m)	0.03	0.22	2.17
Net present value ($m)	0.25	1.55	15.40
Benefit:cost ratio	8.10	8.10	8.09
Internal rate of return (%)	25.5	25.4	25.4

Given the assumptions made, the proportion of total benefits estimated from the water use efficiency benefit is 34 per cent, while the avoided productivity loss contributed 66 per cent.

Figure 1 demonstrates the rate at which net benefits accrue.

Figure 1: Annual net benefit flow for total investment



Sensitivity analysis

Analyses have been carried out to demonstrate the sensitivity of the investment criteria to a number of the key assumptions. Results are presented in Tables 6 to 8. The analyses were carried out using a discount rate of six per cent, and use the NPSI costs and benefits as the base scenario.

Table 7 demonstrates the sensitivity of the investment criteria to the maximum number of farms adopting. The analysis shows that if the adoption is only half of that currently assumed, then the investment criteria are still significantly positive, with a B/C ratio of 4 to 1.

Table 7: Sensitivity of investment criteria to number of farms adopting (NPSI costs and benefits)

Criterion	Discount rate 6%		
	Maximum adoption of 125 farms	**Maximum adoption of 250 farms (base scenario)**	**Maximum adoption of 500 farms**
Present value of benefits ($m)	0.88	1.77	3.54
Present value of costs ($m)	0.22	0.22	0.22
Net present value ($m)	0.67	1.55	3.32
Benefit:cost ratio	4.05	8.10	16.21
Internal rate of return (%)	17.2	25.4	36.5

Table 8 demonstrates the sensitivity of the investment criteria to the assumed savings in irrigation water. It shows that the analysis is not highly sensitive to the water savings.

Table 8: Sensitivity of investment criteria to savings in irrigation water (NPSI costs and benefits)

Criterion	Discount rate 6%		
	5%	**Base value (10%)**	**15%**
Present value of benefits ($m)	1.46	1.77	2.08
Present value of costs ($m)	0.22	0.22	0.22
Net present value ($m)	1.24	1.55	1.866
Benefit:cost ratio	6.67	8.10	9.54
Internal rate of return (%)	22.8	25.4	27.9

Table 9 demonstrates the sensitivity of the investment criteria to the assumed likelihood of loss of productivity due to saline soil with the research. It shows that even if this likelihood is only reduced from 20 per cent without the research to 15 per cent with the research, that the investment criteria are still significantly positive, with a B/C ratio of 5.4 to 1.

Table 9: Sensitivity of investment criteria to likelihood of loss of productivity due to saline soil with the research (NPSI costs and benefits)

Criterion	**Discount rate 6%**		
	5%	**Base value (10%)**	**15%**
Present value of benefits ($m)	2.36	1.77	1.18
Present value of costs ($m)	0.22	0.22	0.22
Net present value ($m)	2.14	1.55	0.96
Benefit:cost ratio	10.79	8.10	5.41
Internal rate of return (%)	29.8	25.4	20.2

Conclusions

The research has improved the understanding of the risks contributing to the potential for salt building up in the root zone of horticultural crops in the Lower Murray regions. It has also developed a series of best management practices as well as an on-farm piece of equipment for irrigation management that can be used to minimise such risks, and therefore reduce the likelihood of a loss of productivity in horticultural crops due to increased salinity in the root zone. The best management practices and the SWE also have the spin-off benefit of improving water use efficiency, and in some cases fertiliser use efficiency.

The analysis has shown that the investment has the potential to deliver significant benefits, with a B/C ratio of 8 to 1 and an IRR of 25 per cent.

Acknowledgments

Tapas Biswas, SARDI
Gerrit Schrale, SARDI

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Mues C. and Boero Rodriguez B. (2007) Mildura–Wentworth – A Case Study of Horticultural Farm Performance. ABARE Research Report 07.6, prepared for the Australian Government Department of Agriculture, Fisheries and Forestry, Canberra, March 2007.

Addendum 1.1: An economic analysis of investment in reducing salinity impact on Lower Murray horticulture (DEP15): results for CRRDCC process

All past costs and benefits were expressed in 2007–08 dollar terms using the CPI. All benefits after 2007–08 were expressed in 2007–08 dollar terms. All costs and benefits were discounted to the year of analysis (2007–08) using a discount rate of five per cent. These results are shown in Tables A.1 and A.2 and are reported for different periods of benefits with year 0 being the last year of investment. All analyses ran for a maximum period of 30 years from year 0. Investment criteria were estimated for both total investment and for the program investment alone.

Table A.1: Investment criteria for total investment and total benefits

(discount rate 5%)

	0 years	5 years	10 years	15 years	20 years	25 years
Present value of benefits ($ m)	0	1.81	5.92	10.13	13.43	16.02
Present value of costs ($ m)	2.11	2.11	2.11	2.11	2.11	2.11
Net present value ($ m)	-2.11	-0.30	3.81	8.03	11.33	13.91
Benefit-cost ratio	-	0.86 to 1	2.81 to 1	4.81 to 1	6.37 to 1	7.60 to 1
Internal rate of return (%)	-	1.8	20.5	24.2	25.1	25.3

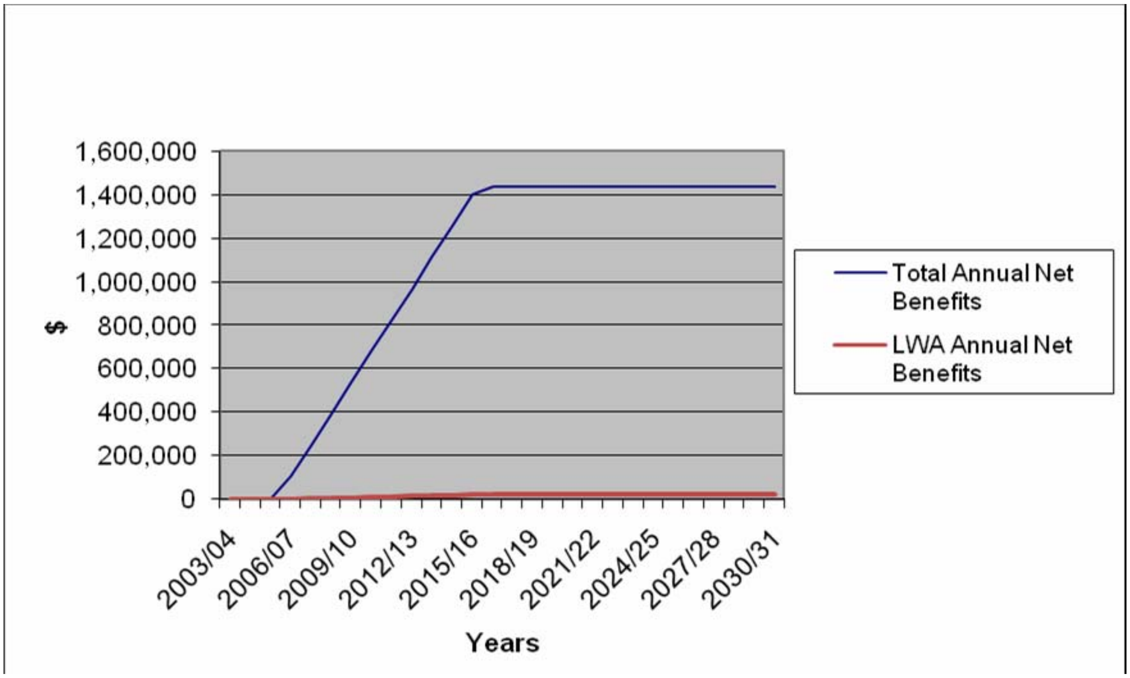
Table A.2: Investment criteria for LWA investment and LWA benefits

(discount rate 5%)

	0 years	5 years	10 years	15 years	20 years	25 years
Present value of benefits ($ m)	0	0.03	0.09	0.15	0.20	0.24
Present value of costs ($ m)	0.03	0.03	0.03	0.03	0.03	0.03
Net present value ($ m)	-0.03	0.00	0.06	0.12	0.17	0.21
Benefit-cost ratio	-	0.86 to 1	2.81 to 1	4.81 to 1	6.38 to 1	7.61 to 1
Internal rate of return (%)	-	1.8	20.5	24.2	25.1	25.4

The flow of annual benefits is shown in Figure A.1 for both the total investment and for the LWA investment.

Figure A.1: Annual benefits



Appendix 2: Economic analysis of changing irrigation systems and management of the Harvey Water Irrigation Area (DAW45)

SUMMARY

Date of evaluation: November 2008

Duration: NPSI supported this project over the period 2002–03 to 2004–05.

Nature of innovation
The project (DAW45) concerned best practice irrigation methods on the dairy farm of Dale Hanks in the Harvey Water Irrigation Area (HWIA) in Western Australia. The project took a whole farm approach and focused on the replacement of flood irrigation with centre pivot irrigation technology. The project adopted a demonstration and learning-by-doing approach.

Who was involved
Land and Water Australia invested in this project via the National Program for Sustainable Irrigation. Harvey Water was strongly involved. The host organisation was the WA Department of Agriculture. Third parties included Rob Kuzich & Co, Dairy Australia, Western Dairy, Chemistry Centre of Western Australia, and the dairy farmer Dale Hanks.

Adoption and impact
About 10 dairy farmers have purchased centre pivot systems since the project commenced and up to June 2008. Five beef producers have also installed centre pivots. Other dairy and beef farmers are considering changes to their pasture irrigation systems, which would result in overall water savings and increased production and profitability. Environmental benefits include reduced groundwater recharge, reduced water runoff, and reduced export of nutrients compared to surface irrigation. Secondary impacts include a more viable local community from irrigators realising and demonstrating higher water use efficiency and reducing nutrient runoff into estuaries.

Evaluation
A benefit–cost analysis for the total investment in changing irrigation systems in the HWIA was carried out with the following key benefit assumptions:

- water savings
- productivity and profitability gains to both dairy and beef farmers
- actual extent of adoption of the changed practices as well as projections of future adoption.

Investment criteria
The period of analysis was for 40 years after the first year of investment. The results are expressed in 2007–08 dollar terms and all benefits and costs are discounted to 2007–08

using a discount rate of six per cent. Investment criteria were estimated for total investment, NPSI investment, and for the LWA investment alone. Benefits for NPSI investment criteria were estimated as 15 per cent of the total benefits (15 per cent representing the proportion of total costs contributed by NPSI). LWA contributed 15 per cent of NPSI phase 1 funding. The investment criteria are reported in Table 1.

Table 1: Investment criteria for the project

Criterion	LWA only	NPSI only	Total
Present value of benefits ($m)	0.64	4.26	29.29
Present value of costs ($m)	0.05	0.32	2.26
Net present value ($m)	0.59	3.94	27.04
Benefit-cost ratio	13.34	13.34	12.99
Internal rate of return (%)	30.8	30.8	29.1

Contact: Guy Roth, program coordinator, Land & Water Australia, ph 0417 223 179

FULL CASE STUDY

Background

The Harvey Water Irrigation Area (HWIA) of Western Australia contains up to 10,000 hectares of land under permanent irrigation, including pastures and horticulture. Water is gravity fed to the coastal plains areas from seven dams located on the edge of the Darling Scarp. The total available irrigable area (land with access to the irrigation system) in the HWIA is 34,000 ha. The trading name was changed from the South West Irrigation Area to the Harvey Water Irrigation Area in 2002.

Western Australia's prime irrigated dairying region, which supplies more than 40 per cent of the milk supply to Perth and south-west WA, is located in the HWIA. In past years, 65 per cent of the water used for irrigation in the HWIA was used for irrigating pastures for dairying, with other pasture irrigated for beef and the rest used for horticultural production.

All pastures were flood or surface water irrigated. The coastal lands are generally poorly drained and some soils are waterlogged or moderately saline, with salt build-up being usually flushed out by winter rainfall. Surface and subsurface drainage has increased productivity.

Pressures on the HWIA had been growing to improve water use efficiency (WUE) and sustainable disposal of irrigation waste water. State Government water strategies and conservation plans were driving the need for greater WUE. Also, salinity had been estimated to affect one-third of irrigated land and waste water was discharged into environmentally sensitive estuaries.

As well, in 2002 the dairy industry was under pressure from deregulation, low product prices and rising costs. The number of dairy farmers in Western Australia fell from 479 to 344 from 1995 to 2002 (Dairy Australia 2007). However, the number of dairy cows in the state remained fairly constant at about 70,000 over the same period, signifying increases in herd sizes. Currently, Western Australia has 175 dairy farms, including 60 in the HWIA.

Further, in the face of competing demands for water, the HWIA needed to protect its water allocation by demonstrating that its use of water was productive and sustainable.

In response, the region developed the INTERACT project, a plan for agricultural development in the region identifying the economic, biophysical and social conditions necessary for future change and development. Western Dairy was one of the dairy industry's regional development programs and was responsible for dairy research and development and extension programs in the Western Australian region including dairy farms in the HWIA.

At about the same time, an irrigation technology supplier (Rob Kuzich & Co) identified both productivity and WUE issues in the HWIA associated with surface irrigation of pasture for dairy cattle. This, together with the interest of Dale Hanks, a local dairy farmer, led to the idea of trialling and comparing different irrigation methods.

The project (DAW45) concerned best practice irrigation methods on the dairy farm of Dale Hanks in the HWIA. The project took a whole farm approach and focused on the replacement of flood irrigation with centre pivot irrigation technology. As of 2001 there was no centre pivot technology being used by Harvey Water farms for pasture irrigation.

In 2001, Harvey Water began local trials, installing piping systems to improve the water delivery service to irrigators. The extension of this gravity fed system to the Dale Hanks farm made the option of installing a centre pivot possible. Since then Harvey Water has piped all of the Waroona and Harvey Irrigation districts installing over 400 km of pipe to service all irrigators in those districts.

The investment in such a change of technology was considerable for an individual irrigator and limited information was available on performance and management of the centre pivot technology and the costs and benefits of changing. As there was growing interest in this technology for irrigation of pasture, the project was aimed at producing information that was the best available in making comparisons and demonstrating best on-farm irrigation practices.

The project

Project objectives

The original objectives of the project were:

- To bring innovation to irrigation systems and agronomy on-farm in the Harvey Water Irrigation Area that would increase water use efficiency and farm productivity, and reduce ecological impacts through factors such as nutrient run-off and soil structural problems.
- To demonstrate and document a model of integrated R&D and knowledge management through a strategic alliance that is capable of achieving sustainable irrigation on-farm and extended across the broader farming community and irrigation area with lessons.
- To develop a learning and information exchange strategy with the Goulburn Broken catchment project to provide opportunities for stakeholders to learn from other irrigation areas and regions.

The final report for the project implies that two more objectives were added during the project. These were:

- To demonstrate the energy efficiencies and overall energy balance of a gravity pressure-fed piped system of irrigation water delivery.
- To understand the issues surrounding the operation/ordering procedures for the water authority (managing a pressurised water supply system) and irrigator if there was widespread adoption of centre pivot sprinkler technology.

Investment costs

Details of the funding of the project are provided in Table 2.

Table 2: Resources invested by year by NPSI, Harvey Water, the host organisation and third parties (nominal dollars)

Year	NPSI	Harvey Water	Host organisation and third parties (a)	Total
2002–03	0	40,000	366,226	406,226
2003–04	115,800	68,000	493,526	677,326
2004–05	115,800	44,000	332,526	492,326
Total	231,600	152,000	1,192,278	1,575,878

(a) The host organisation was WA Department of Agriculture; third parties included Rob Kuzich & Co, Dairy Australia, Western Dairy, Chemistry Centre of Western Australia, and Dale Hanks.

In nominal terms, the proportion of funding of the total investment derived from the National Program for Sustainable Irrigation (NPSI) was 15 per cent. The proportion of

NPSI funding contributed by Land and Water Australia was also 15 per cent (Sarah Leonardi pers comm.).

Investment description

The irrigation technology project focused on demonstration and learning by doing rather than a strictly scientific and controlled comparison of irrigation systems.

Stage 1

Stage 1 was a desk review of changing to, and experience with, centre pivots and ensuring engagement with irrigators. It included a review of literature, including grey literature (e.g. from the Goulburn Broken catchment).

Stage 1 was also charged with:

- surveying Harvey Water irrigators about their perceptions of benefits and constraints of moving to centre pivot technology, and their interest in changing
- developing a framework for incorporating irrigation into whole farm planning
- locating the centre pivot and surface irrigation sites on Dale Hanks's property.

The stage 1 irrigator survey needed to show potential for adoption of centre pivot irrigation for pasture production being manifest in irrigator interest and commitment.

Stage 2

Stage 2 involved on-farm trials and comparisons between surface irrigation and centre pivot technologies. This involved measuring the economic and environmental costs and benefits of both systems, and then the potential for changing to centre pivot technology within the context of a whole farm plan. These measurements and comparisons took place in the irrigation seasons commencing October 2003 and October 2004.

Measurement systems were established for water quality, WUE, and pasture production and quality. WUE was defined as kilograms of dry matter produced per megalitre of water applied. Data for pastures were collected through the two summer and two winter periods to demonstrate differences in pasture composition and quality for both perennial and annual species. Also measured were milk production and quality.

Measurements to assess the optimal performance of centre pivots were also made, including infiltration rates, water use, ease of use, costs and benefits, and drainage water quantity and quality.

Dairy farmers in the HWIA and other stakeholders were involved throughout the project through field days, seminars, and other communication methods. This allowed some assessment of irrigators' capacity to change and highlighted the interaction with, and implications for, irrigation technology change to other farm characteristics (soil types and pasture systems), as well as farm management decision making and the need to plan on a whole farm basis.

The project DAW45 was highly integrated with other R&D supported by Dairy Australia, Western Dairy, the Department of Agriculture and Harvey Water. In particular, the project was integrated with DairyCatch, a program designed to work with farmers in developing and implementing best practice natural resource management strategies. DairyCatch WA approved a total grant of $375,000 to be implemented in close association with DAW45 with the objective of developing environmental best practices for the WA dairy industry. The DairyCatch project focused on establishing eight DairyCatch monitor farms that compared a range of current and best practices including stock exclusion buffers in irrigation bays, fertiliser timing and placement, irrigation scheduling and automation and practice concerned with effluent management. The Hanks farm on which DAW45 was centred was also the monitor farm for DairyCatch in the HWIA, with monitoring of effluent runoff, effluent management etc.

Some of the staff involved in the project were heavily involved in the development of regional water conservation plans so there was direct input from the project into the environmental and practice standards to be included in the broader plans and hence affected practice and management targets to be set at the local, regional and state levels.

Principal outputs

Irrigation technology comparisons

The main output from the project was the comparison of the centre pivot technology (CPT) with surface irrigation technology. CPT used 29 per cent and 31 per cent less water than surface irrigation in each of the two years respectively. Pasture growth rates were considerably higher for the CPT (54 per cent and 100 per cent). The CPT provided higher crude protein and energy levels in pasture with lower fibre, due to:

- fewer weeds
- the higher stress on ryegrass due to waterlogging followed by drying out with surface technology
- reduced take up of nutrients due to waterlogging under surface irrigation
- better mineralisation under CPT (more restricted soil microbial action due to waterlogging and drying under surface irrigation).

The value of milk production from CPT was higher than from surface application. These values were derived estimates from metabolisable energy estimates of each pasture, as cows had access to other pastures and other feeds.

The principal output was the demonstration that, with appropriate management practices, there were increases in WUE for CPT sprinkler systems, as well as a positive impact on pasture production and financial returns. It was also demonstrated that CPT could be integrated into pasture systems for dairying, but it was recognised that results may vary between farms due to soils, skills and management practices.

There was more control over irrigation with the centre pivot but critical factors were the management of fertiliser and grazing with CPT.

The demonstration concluded that a shift to CPT can be achieved economically and practically, incorporating changes to farm layouts that take into account regulatory and statutory planning requirements.

Centre pivot management
The comparisons of the technologies were made on a pivot covering eight hectares and surface irrigation over six hectares. Flow rates and waterings were based on evaporation estimates, crop factors, soil holding capacity, rooting profiles, and leaching and efficiency factors. Scheduling for the centre pivot was based on evaporation and rainfall data and continuous logging of soil moisture from Enviroscan sensors, as well as other information.

Differences between the two years of data showed that the first year involved considerable learning, with the centre pivot resulting in improved irrigation scheduling. This was seen as one of the reasons for the increased pasture production figures and the reduced amount of water applied with the centre pivot technology.

Surface irrigation management
The 15 per cent reduction in water use by surface irrigation from the first year of the trial to the second year demonstrated the potential for further improvement that may be possible for HWIA surface irrigators through further analysis and adjustment to present practices, if greater attention is given to performance evaluation of current systems.

Whole farm planning
Changing irrigation technology has ramifications for many other aspects of farm management such as percentage of farm irrigated, labour requirements, pasture productivity, number of cows, stocking rate etc. Hence, changes need to be made in a whole farm context. As this process was necessary for the farmer involved, there were some important learnings in this exercise.

Water quality
Groundwater
Neither irrigation technology resulted in any net groundwater accessions through the length of each year. Groundwater quality was not an issue for nitrogen or phosphorus.

Surface runoff
A large reduction in surface runoff occurred from the surface irrigation system between the first and second year (65 per cent to 20 per cent). The fall was due to improved management of the surface system. No water at all ran off from the CPT system in either year, hence there were few nutrients exported off the farm due to CPT irrigation activities.

Nutrients in runoff water
About 90 per cent of phosphorus (P) runoff from surface irrigation systems was identified as the soluble and more ecologically active form. P concentrations at the 'end of farm'

monitoring points approached background levels, but were still above recommended maxima for ecosystem protection.

For the surface irrigation, P concentrations in tail drains and large farm drains were similar to P concentrations in drains on non-irrigated properties.

Nitrogen concentrations in drain water were also scale related but increased with increases in scale of measurement, probably due to microbial nitrification processes.

It was concluded that monitoring of land management practices at any scales larger than which the practices are implemented is unlikely to yield meaningful information because of the diluting influence of those parts of farm or catchment which do not contribute nutrients. However, it could be concluded that in terms of irrigation management practices to control nutrient export, use of CPT was most desirable.

Wider irrigation area issues

Project objectives 4 and 5 were associated with the interaction of the project with the irrigation area's future system development. The HWIA has had for many years the objective of improving the distribution efficiency of the water supply to the area. A piped system was known to reduce seepage and evaporation losses but only 28 per cent of the Harvey system was piped.

The piping investment for the HWIA was designed before DAW45 commenced. The design was on the basis that 70 per cent of the then current volume would be needed because irrigators would convert to lower volume–higher efficiency irrigation technologies such as centre pivot types (Geoff Calder pers comm.).

The project produced data on the water delivery pressure requirement for dairy farmers to operate centre pivots of varying sizes. Baseline information was provided on system capacity, millimetres per day, megalitres per year and appropriate pivot sizes for clay based soils.

Demonstrating partnership research

The second objective of the project was to demonstrate partnership research integration. This was achieved through the interactions between commercial input from irrigators and consultants as well as input from the state agencies, irrigation water providers, and university-based scientists.

Learning and adoption

Objective 3 of the project was to develop a communication and learning strategy for the knowledge produced from the case study. In this regard the key outputs were:

- field days and field trips
- knowledge that irrigators prefer to receive information via field days and field walks, hard copy newsletters and hard copy project reports
- recognition of the importance of networks, both within and outside the HWIA

- the importance of irrigator involvement in research, measuring and learning by doing rather than being instructed by courses and manuals alone.

A summary of the principal outputs from the project is reported in Table 3.

Table 3: Summary of principal outputs

Principal outputs
• Summary of latest R&D on use of CPT and change to irrigation systems and practices
• Survey results regarding HWIA irrigators' knowledge and constraints to adopting CPT
• CPT required less water than surface irrigation and produced more and higher-quality pasture, and more milk per megalitre of water applied
• CPT produced lower environmental impacts than surface irrigation
• Monitoring of land management practices at any scales larger than which the practices are implemented is unlikely to yield meaningful information
• Demonstration that CPT can be implemented technically, economically and practically on existing surface irrigated dairy farms in the HWIA
• Demonstration that considerable learning took place in the trials for both surface and CPT from the first year to the second year
• A whole farm planning framework developed that addressed how centre pivot technology interacted with and could be integrated with other farm management operations and investments
• Extension and adoption activities with stakeholders and knowledge about irrigators' preferences for receiving information, the importance of producer networks, and the importance of irrigators being involved in learning by measuring and doing

Principal outcomes

Demonstration of feasibility and benefits
The successful demonstration of CPT with its large increases in WUE, pasture production and dollar returns for added milk produced has stimulated greater interest and confidence of both dairy and beef farmers considering changing to this irrigation technology.

While total labour involved was about the same for each system, CPT did not involve the irrigator having to remain on the farm all day as with the surface irrigation system.

Results from simulation of larger pivots suggested that large pivots with a higher application rate were preferable. Larger pivots also capture some economies of size; the marginal investment is only $1700 per ha for moving from a 40 to a 50 ha size; the average cost for a 40 ha pivot was $3875 per ha and the average for a 50 ha pivot was $3440 per ha.

The results of the project are assisting other farmers in assessing their irrigation systems and their future investment in improved systems and management for changed systems. The project also demonstrated the potential for improving surface irrigation technology.

Adoption

Dale Hanks purchased a 43 ha centre pivot in December 2007 (Dale Hanks pers comm.). By June 2008, about 10 dairy farmers had purchased CPT systems since the project commenced. Five beef producers had also installed centre pivots (Geoff Calder and Rob Kuzich pers comm.). Other dairy and beef farmers are considering changes to their pasture irrigation systems which would result in overall water savings and increased production and profitability.

The extension and training program design implications have been manifest since the project was completed. These were the preference for learning by doing, recognition of the confidence gained from involvement, and direct observation of changes made through measurement (instead of a strict adherence to guidelines or promoting detailed irrigation scheduling and water management training packages).

Surface irrigation improvements

The recognition of potential for significant improvements in existing surface irrigation performance from measurement, monitoring and associated management changes has led to an insignificant number of dairy farmers changing their surface irrigation management practices. This is probably because the scientific method of monitoring promoted was hard to adopt and needed consulting advice (Ken Moore pers comm.).

Environmental outcomes

Another important outcome was the capture of the positive environmental impacts of irrigation, particularly in addressing the wider area and regional issues (e.g. resource saving, reduced nutrient export). It is presumed that nutrient exports have not fallen measurably due to CPT as the impact of lowered runoff from the small number of farms installing centre pivot technology would not be highly significant in a whole of catchment context.

Wider area issues

The project has contributed to other programs in WA, namely the Water Wise on the Farm program, the Harvey Water strategic plan, the Western Dairy regional action plan and the strategies for the Peel sub-region. The project demonstrated for the first time in Western Australia the value of large-scale investment in CPT. Harvey Water believes that CPT and other technology will be the new standard for irrigation compared to flood irrigation. This has direct effects on the thinking involved in all the other programs (Geoff Calder pers comm.).

Project awards
The project was selected as one of 12 case studies from across Australia featured in the Australian Government Innovation in Irrigation Showcase in 2004. The project was also a finalist in the 2004 WA Premiers Water Foundation Water Conservation and Management Awards and received a special commendation in the SGIO 2004 Western Australian Environmental Awards. The project won the 2005 Western Australian Environmental Award for the category of Water Conservation and Management.

A summary of the principal outcomes from the project is reported in Table 4.

Table 4: Summary of principal outcomes

Principal outcomes
• Potential for changed practices and systems that optimise productivity and profitability and minimise ecological impacts
• Adoption of improved technology that is more profitable, uses less water and is more environmentally sustainable than current technology
• Improved decision making regarding centre pivot management, including choice of pivot size, fertiliser and grazing, and interactions of changed irrigation technology with other farm management decisions
• Demonstration that the HWIA can compete for water with other potential water uses in order to retain its water allocations
• Contribution to other water and dairy programs in WA
• More effective extension and training programs through enhanced recognition of importance of learning by doing with regard to irrigation technology changes and improvements

Benefits associated with the investment

Despite the capital costs associated with a change to CPT, there are significant benefits. The benefits associated with the project are described in a triple-bottom-line format below:

Economic
- Improved decision making regarding investment in CPT as opposed to surface irrigation
- Water savings compared to surface irrigation for those dairy and beef farmers changing to CPT
- Increased pasture production, pasture quality and milk and beef production for those farmers changing to CPT.

Environmental
- Reduced groundwater recharge, water runoff and export of nutrients.

Social

- More viable local community from irrigators realising and demonstrating higher WUE and reducing nutrient runoff into estuaries
- Some improvements in water quality in estuaries, potentially resulting in improved recreational opportunities.

Type of benefits
A summary of the principal types of benefits associated with the investment is shown in Table 5.

Table 5: Categories of benefits from the investment

Benefits
Productivity and profitability • Lowered water costs to dairy and beef farmers • Higher net incomes from improved pasture production, pasture quality and milk and beef production • Water available for other uses
Environmental • Marginally improved water quality in nearby estuaries
Social • More sustainable local community • Marginally improved recreational opportunities in estuaries

Public versus private benefits
The principal benefits are being captured by the private sector, namely the water saving and productivity improvements on-farm by irrigating dairy and beef farmers. However, some public benefits have been captured in the form of reduction in water export and nutrients off-farm and associated water quality benefits in nearby estuaries.

Distribution of benefits along the supply chain
A small part of the benefits received by dairy and beef farmers may be passed along the supply chain to processors and consumers.

Match with national priorities
The Australian Government's national and rural R&D priorities are shown in Table 6. In terms of national research priorities, the investment addresses national priority 1. For the rural research priorities, numbers 1 and 3 are supported by the investment.

Table 6: National and rural research priorities 2007–08

Australian Government	
National research priorities	**Rural research priorities**
1. An environmentally sustainable Australia 2. Promoting and maintaining good health 3. Frontier technologies for building and transforming Australian industries 4. Safeguarding Australia	1. Productivity and adding value 2. Supply chain and markets 3. Natural resource management 4. Climate variability and climate change 5. Biosecurity *Supporting the priorities:* 1. Innovation skills 2. Technology

Quantification of benefits

Counterfactual scenario
As there were some dairy farmers in the HWIA already considering centre pivot irrigation technology in 2002, it is likely that there would have been some change to sprinkler irrigation even without the NPSI investment. However, the form that this would have taken is uncertain. For example, the number of dairy and beef farmers making the change may have been fewer, the change may have been slower, or any changes made may have been less effective. As DairyCatch had been funded before the NPSI project, some nutrient export reduction impacts described earlier would need to be attributed to the DairyCatch investment.

As the decision to pipe the HWIA was made before the NPSI project, there would not be any attribution to the NPSI investment from the benefits emanating from the piping investment.

Scenario with the NPSI investment
Water savings from change to CPT
The first impact of the NPSI investment is the water savings from moving from surface irrigation to CPT. The savings are assumed to be 30 per cent per ha per annum. Based on an average surface irrigation use of 11 ML per ha, this is equivalent to a saving of about 3.3 ML per ha per annum.

Value of water saved
The value of water in 2006 included a fixed charge of $19.11 per ML plus a variable charge of $22.29 per ML (DAF 2006). In 2008, the unit cost of water is $26.01 per ML for fixed costs plus a delivery cost of $22.23 per ML (a total of $48.24 per ML, Geoff

Calder pers comm.). This would be the minimum value of water saved as the water could well be used for a higher-value use. Most irrigators are using water savings to increase reliability or to expand the irrigated area on their own farm (Geoff Calder pers comm.).

Increased production from use of CPT
Based on the difference in metabolisable energy and pasture quality of the respective pasture production for the two irrigation methods, an estimate of additional milk production was derived in the project report. This estimate was made for each of the two years of the trials. If the added milk production was valued at 30 cents per litre, the average gain per annum was estimated at $4554 for each irrigated hectare. Due to the nature of the trials and the method of estimation, for purposes of the current analysis, the gain has been assumed less than that estimated in the project. Important factors driving this reduction were:

- No allowance of additional cows to utilise the additional energy produced was made although it could be assumed that the additional energy produced on-farm could replace some purchased feedstuffs.
- The derived estimates assumed that more fertiliser would be required for CPT compared to surface irrigation. Since the derived estimates were made, the price of nitrogenous fertiliser has increased significantly, possibly trebling (Dario Nandapi pers comm.).
- Counterbalancing these factors is the fact that the price of milk has risen, possibly doubling.

Overall it is assumed conservatively that the average gain per annum would still be 50 per cent of the $4554 or $2277 per ha. It is assumed that the net value of the additional beef produced from beef producers irrigating pasture would be only half of that for dairy, namely $1138 per ha, because of the higher return per hectare for dairy systems.

Cost of CPT investment and other changes on farm
Experience from the project has shown that the capital cost of CPT is about $4000 per ha based on a pivot capacity of 40 ha. The capacity of the CPT units introduced to date has ranged from 15 to 70 ha. It is assumed no on-farm pumping equipment is required and that maintenance costs of the CPT are similar to those of the surface irrigation system. Similar labour costs are also assumed.

Number of farms
About 60 dairy farms are irrigating pasture in the HWIA. Over time this number may fall as farms become larger. However, such changes will probably make CPT technology more attractive than assumed in this analysis.

As well, there could be up to 300 farmers irrigating pastures for beef production in the HWIA, albeit most on a small scale. However, it is only the larger beef producers who are likely to invest in CPT. It is assumed conservatively that the maximum number of beef producers who are likely to adopt CPT is 15.

Adoption of CPT due to the project

The project has given considerable stimulus for increasing WUE and consideration of adoption of CPT by HWIA dairy and beef farms.

However, existing pressures in the HWIA may well have resulted in some adoption of WUE increases and some changes to irrigation systems even without the project. It is assumed that adoption has commenced sooner and the adoption rate has been and will be considerably greater with the NPSI investment than without it. It is also assumed that, given time, all dairy and beef producing farms in the HWIA would have the potential to convert their systems to CPT or other forms of sprinkler systems such as lateral moves (Geoff Calder pers comm.).

Table 7 shows the comparative increases assumed for adoption of CPT, with and without DAW45.

Table 7: Assumptions for adoption of CPT

Period	**Without DAW45**	**With DAW45**
First year of adoption	2008–09	2004–05
Adoption rate	3% of farms per annum	5% of farms per annum
Maximum adoption level of farms producing milk or beef	Maximum of 100% of farms, reached 33 years after year of first adoption	Maximum of 100% of farms, reached 20 years after year of first adoption

Benefits not valued
The possible environmental benefits were not valued in this analysis due to the weak linkages between the irrigation practice changes and their attribution changes in water quality downstream.

Summary of assumptions
A summary of all assumptions made is given in Table 8.

Table 8: Assumptions for the valuation of benefits from project DAW45

Variable	**Value**	**Source**
Water savings		
Water savings due to CPT	30% lower than the 11ML per ha used for surface irrigation	Based on an average of first and second year of the trials
Average irrigated area per dairy farm	40 ha	Agtrans Research
Value of water saved	$48.24 per ML	Geoff Calder, pers comm.
Increased production		

Net value of higher production of milk per irrigated ha with CPT	$2277 per ha; this is based on a conservative adjustment (50%) to the average increase across the two years of trials of $4554 per ha	Agtrans Research, based on Table 8 in Project Report, and after discussions with Rob Kuzich
Net value of higher production of beef per irrigated ha with CPT	50% of that assumed for dairy, i.e. $1138 per ha	Agtrans Research after discussions with Rob Kuzich
Additional costs for those adopting CPT		
Capacity of CPT systems installed	40 ha, based on minimum capacity of some systems installed to date	Agtrans Research after input from Geoff Calder and Rob Kuzich
Capital costs for a CPT system	$4000 per ha for a system of 40 ha capacity	Project documents
Additional operating costs for CPT over surface irrigation systems	Nil	Agtrans Research
Adoption of CPT without NPSI investment		
Number of dairy and beef farms in HWIA	75	Agtrans Research after input from Geoff Calder and Rob Kuzich
First year of adoption	2008–09	Agtrans Research
Proportion of dairy and beef farms	80% dairy and 20% beef	Agtrans Research based on inputs from Geoff Calder and Rob Kuzich
Adoption rate	3% of farms per annum	Agtrans Research
Maximum adoption level	100% of dairy and beef farms in 33 years	Agtrans Research
Lag between adoption and first year of benefits	1 year	Agtrans Research
Adoption of CPT with NPSI investment		
Number of dairy and beef farms in HWIA	75	Agtrans Research after input from Geoff Calder and Rob Kuzich
First year of adoption	2004–05	Agtrans Research
Proportion of dairy and beef farms	80% dairy and 20% beef	Agtrans Research based on inputs from Geoff Calder and Rob Kuzich
Adoption rate	5% of farms per annum	Agtrans Research after input from Geoff Calder and Rob Kuzich
Maximum adoption level	100% of dairy and beef farms in 20 years from year of first adoption	Agtrans Research after input from Geoff Calder and Rob Kuzich

Lag between adoption and first year of benefits	1 year	Agtrans Research

Results
All past costs and benefits were expressed in 2007–08 dollar terms using the CPI. All benefits after 2007–08 were expressed in 2007–08 dollar terms. All costs and benefits were discounted to 2007–08 using a discount rate of six per cent. The base run used the best estimates of each variable, not withstanding a high level of uncertainty for many of the estimates. The base analyses ran for the length of the investment period plus 40 years from the first year of investment to the final year of benefits assumed. Investment criteria were estimated for total investment, NPSI investment, and for the LWA investment alone. Benefits for NPSI investment criteria were estimated as 15 per cent of the total benefits, which represents the proportion of total costs contributed by NPSI. LWA contributed 15 per cent of NPSI phase 1 funding. The investment criteria are reported in Table 9.

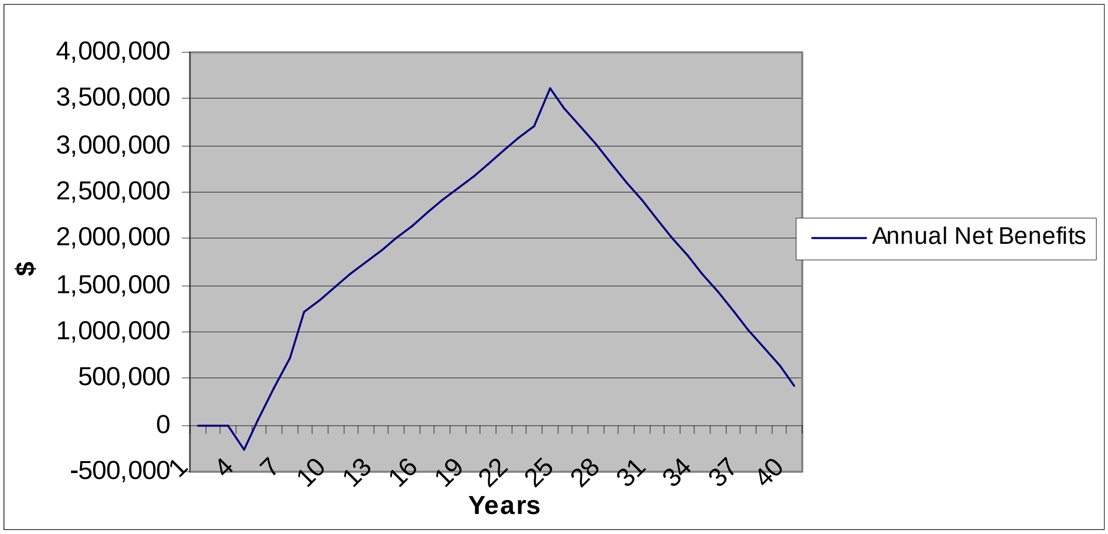
Table 9: Investment criteria for the investment (discount rate 6%)

Criterion	LWA only	NPSI only	Total
Present value of benefits ($m)	0.64	4.26	29.29
Present value of costs ($m)	0.05	0.32	2.26
Net present value ($m)	0.59	3.94	27.04
Benefit-cost ratio	13.34	13.34	12.99
Internal rate of return (%)	30.8	30.8	29.1

Given the assumptions made, the proportion of benefits estimated for each source (for the 40-year analysis) is 93 per cent for the productivity benefits and seven per cent for the water savings.

Figure 1 demonstrates the rate at which net benefits accrue for the total investment.

Figure 1: Annual net benefit flow



Sensitivity analysis

Sensitivity analyses were carried out on several variables and results are reported in Tables 9 to 11. All sensitivity analyses were performed on the NPSI investment criteria using a six per cent discount rate with benefits taken over 40 years from the first year of investment. All other parameters were held at their base values. Table 10 shows the sensitivity of the investment criteria to the level of maximum adoption of centre pivots in the HWIA.

Table 10: Sensitivity of investment criteria to maximum level of adoption (NPSI benefits and costs only)

Criterion	**Discount rate 6%**		
	50% of dairy and beef farms	**75% of dairy and beef farms**	**100% of dairy and beef farms (base)**
Present value of benefits ($m)	2.13	3.19	4.26
Present value of costs ($m)	0.32	0.32	0.32
Net present value ($m)	1.81	2.87	3.94
Benefit:cost ratio	6.67	10.01	13.34
Internal rate of return (%)	22.1	27.0	30.8

The maximum adoption where the investment breaks even is about eight per cent, i.e. only a maximum of about six farms need to convert to centre pivots for the project investment to break even, given the other assumptions made.

Table 11 shows the sensitivity of the investment criteria to the productivity gain assumed per ha (weighted average of dairy and beef farms) from a change to centre pivot technology.

Table 11: Sensitivity of investment criteria to productivity gain
(NPSI benefits and costs only)

Criterion	Discount rate 6%		
	\$512 per irrigated ha (one-quarter base)	**\$2049 per irrigated ha (base)**	**\$4098 per irrigated ha (twice base)**
Present value of benefits (\$m)	0.95	4.26	8.66
Present value of costs (\$m)	0.32	0.32	0.32
Net present value (\$m)	0.64	3.94	8.34
Benefit:cost ratio	2.99	13.34	27.14
Internal rate of return (%)	10.9	30.8	50.9

The productivity gain where the investment breaks even is \$217 per ha. Without a productivity gain, the water savings would not pay for the investment.

Table 12 shows the low sensitivity of the investment criteria to the assumed value of water saved from the change to centre pivot technology.

Table 12: Sensitivity of investment criteria to value of water saved from CPT
(NPSI benefits and costs only)

Criterion	Discount rate 6%		
	\$24 per ML	**\$48 per ML (base)**	**\$96 per ML**
Present value of benefits (\$m)	4.09	4.26	4.60
Present value of costs (\$m)	0.32	0.32	0.32
Net present value (\$m)	3.77	3.94	4.28
Benefit:cost ratio	12.80	13.34	14.40
Internal rate of return (%)	29.9	30.8	32.5

The value of the water saved would need to rise to \$114 per ML for the investment to break even, if there were no productivity gain.

Conclusions

The NPSI investment in the trialling of changes to the traditional surface irrigation systems used for pasture on dairy farms in the Harvey Water Irrigation Area has shown a positive return. The net present value for the total investment has been estimated at $27 m, the benefit cost ratio at 13 to 1, and an internal rate of return of 29%. The change has not only saved scarce water for the region but also has given a significant productivity lift to dairy and beef producers who adopt centre pivot technology. In addition, the reduced surface water runoff from centre pivots compared to surface irrigation is most likely limiting the export of sediment and nutrients from those farms who have adopted.

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Dario Nandapi, Smart Cow Consulting
Esther Price, Western Dairy
Mark Rivers, Department of Agriculture, Western Australia
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Addendum 2.1: Economic analysis of changing irrigation systems and management of the Harvey Water Irrigation Area (DAW45): results for CRRDCC process

All past costs and benefits were expressed in 2007–08 dollar terms using the CPI. All benefits after 2007–08 were expressed in 2007–08 dollar terms. All costs and benefits were discounted to the year of analysis (2007–08) using a discount rate of five per cent. These results are shown in Tables A.1 and A.2 and are reported for different periods of benefits with year 0 being the last year of investment. All analyses ran for a maximum period of 30 years from year 0. Investment criteria were estimated for both total investment and for the program investment alone.

Table A.1: Investment criteria for total investment and total benefits

(discount rate 5%)

	0 years	5 years	10 years	15 years	20 years	25 years
Present value of benefits ($m)	0	1.96	8.25	15.22	22.28	28.37
Present value of costs ($m)	2.17	2.17	2.17	2.17	2.17	2.17
Net present value ($m)	-2.17	0.21	6.08	13.05	20.10	26.20
Benefit–cost ratio	–	0.90:1	3.80:1	7.01:1	10.26:1	13.06:1
Internal rate of return (%)	–	3.1	23.9	27.7	28.7	29.0

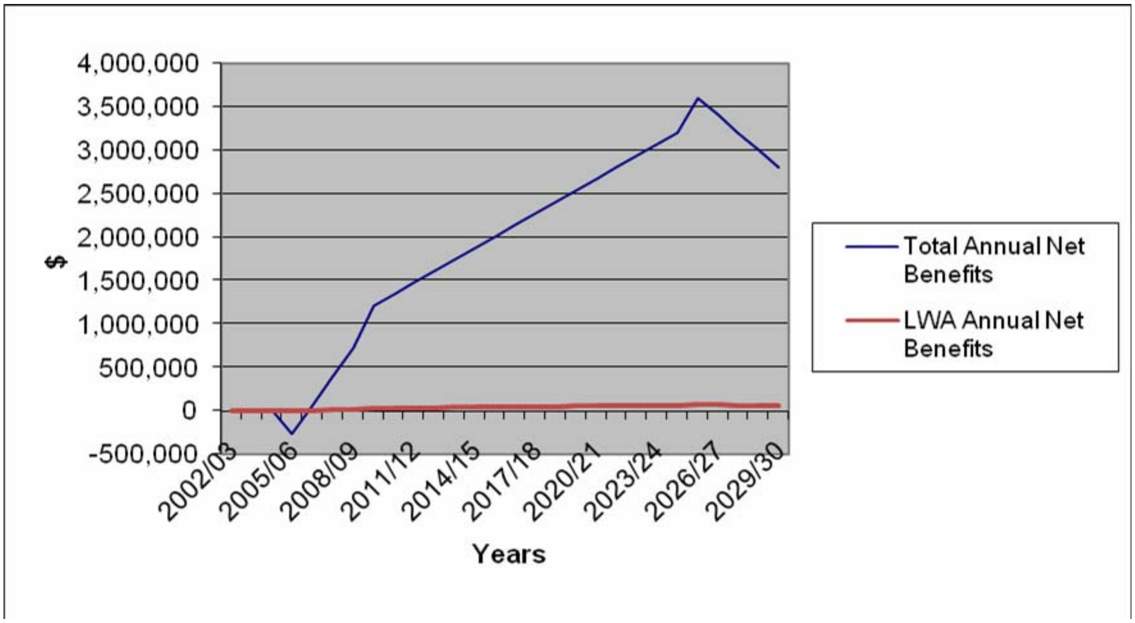
Table A.2: Investment criteria for LWA investment and LWA benefits

(discount rate 5%)

	0 years	5 years	10 years	15 years	20 years	25 years
Present value of benefits ($m)	0	0.04	0.18	0.33	0.49	0.62
Present value of costs ($m)	0.05	0.05	0.05	0.05	0.05	0.05
Net present value ($m)	-0.05	0	0.13	0.29	0.44	0.57
Benefit–cost ratio	–	0.92:1	3.88:1	7.17:1	10.49:1	13.36:1
Internal rate of return (%)	–	3.4	25.7	29.5	30.5	30.8

The flow of annual benefits is shown in Figure A.1 for both the total investment and for the LWA investment.

Figure A.1: Annual benefits



Appendix 3: An economic analysis of investment in irrigation futures of the Goulburn Broken catchment (VP13)

SUMMARY

Date of evaluation: November 2008

Duration: NPSI supported this project over the period 2003–04 to 2006–07.

Nature of innovation

The project included the development of a shared vision for the future of irrigation in the Goulburn Broken catchment. It was characterised by wide stakeholder engagement, scenario planning, development of robust strategies and tools and processes for future planning of irrigation water supply infrastructure, businesses and industries, catchment management and individuals.

Who was involved

Land and Water Australia invested in this project via the National Program for Sustainable Irrigation (NPSI). Other funding partners included the Victorian Department of Sustainability and Environment, the Victorian Department of Primary Industries, the Goulburn Broken Catchment Management Authority and Goulburn-Murray Water.

Adoption and impact

The process itself has had some impacts on the capacity of those involved and hence the broadening of horizons implicit in the process is likely to be embedded in many future decisions to be made by regional institutions and others in the community. These decisions are likely to produce economic, environmental and social benefits. The recognition of uncertainty is likely to be reflected in more robust or more flexible strategies that result in a more efficient allocation of resources. Also, improved preparedness for some of the common features of the scenarios is likely to improve adaptation processes at lower costs as they are developed in the regional community.

Most of the economic benefits from this investment will probably be captured by changes within the modified strategies of local government, the Goulburn Broken Catchment Management Authority and Goulburn-Murray Water. Modified strategies include those associated with investment allocations, farm planning and land use planning at local government level. Environmental and social benefits are likely to be associated with these changes.

Evaluation

A benefit–cost analysis for the total investment in the project was carried out with key benefit assumptions and attribution parameters referring to economic impacts on:

- Goulburn-Murray Water
- Goulburn Broken Catchment Management Authority
- Greater Shepparton City Council and the shires of Moira and Campaspe

Investment criteria
The period of analysis was for 40 years after the first year of investment. The results are expressed in 2007–08 dollar terms and all benefits and costs are discounted to 2007–08 using a discount rate of six per cent. Investment criteria were estimated for total investment, NPSI investment and for the LWA investment alone. Benefits for NPSI investment criteria were estimated as 20 per cent of the total benefits, which represents the proportion of total costs contributed by NPSI. LWA contributed 15 per cent of NPSI phase 1 funding. The investment criteria are shown in Table 1.

Table 1: Investment criteria for the project

Criterion	LWA only	NPSI only	Total
Present value of benefits ($m)	1.60	10.67	52.54
Present value of costs ($m)	0.11	0.75	3.68
Net present value ($m)	1.49	9.92	48.85
Benefit-cost ratio	14.23	14.23	14.26
Internal rate of return (%)	28.5	28.5	28.4

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FULL CASE STUDY

Background
Irrigation has been the mainstay of the economy in the Goulburn Valley for many years. However, in 2002 it was facing significant challenges including:

- ageing irrigation infrastructure
- risk of reduced supply of water due to climate change, transfer of water to other irrigation regions from tradeable water entitlements, and loss to other uses including environmental flow requirements
- requirement of natural resources management (NRM) including water quality and accessions to groundwater

Stakeholders included primary producers, including dairy farmers and fruitgrowers, processors of dairying and horticultural products, NRM agencies and local, regional, state and Commonwealth government agencies and their programs.

In order to meet the future challenges that irrigation would face, stakeholders considered that a shared vision was basic to effective preparation and response. Involvement of the community and reliance on the best available information about the present and the future in a systems context were also considered essential. In particular, constraints and opportunities (including water availability, property rights, climate change, environmental policy, technological changes and market performance) needed scoping in order to build a community consensus on the most effective responses. Community engagement through scenario planning was adopted as the preferred method of approaching these issues and formulating strategies and actions.

The project included the development of a shared vision for the future of irrigation in the Goulburn Broken catchment. It was characterised by wide stakeholder engagement, scenario planning, development of robust strategies and tools and processes for future planning of irrigation water supply infrastructure, businesses and industries, catchment management and individuals.

The project

Project objectives

The key objectives of the investment were:

- To facilitate key stakeholders to develop a shared vision on the future of irrigation in the Goulburn Broken catchment, and to identify scenarios of major constraints and opportunities and of regional response options.
- To understand the social, economic and environmental consequences of various scenarios through impact assessment based on an integration of the best available knowledge.
- To facilitate key stakeholders to build consensus on preferred regional options for future irrigation, and recommend regional follow-up actions.
- To develop a methodology that can be applied elsewhere in Australia for sustainable irrigation planning at a catchment scale.

Investment costs

Table 2 shows the investment by year and by different investors.

Table 2: Resources invested by year by NPSI and others
(cash plus in-kind, nominal dollars)

Year	NPSI including LWA (a)	Victorian Department of Sustainability and Environment (a)	Victorian Department of Primary Industries (a)	Goulburn Broken Catchment Management Authority (b)	Goulburn -Murray Water (c)	Total
2003–04	105,772	105,772	105,772	216,851	20,000	554,167
2004–05	163,522	163,522	163,522	280,648	20,000	791,214
2005–06	171,358	171,358	171,358	289,304	20,000	823,378
2006–07	159,348	159,348	159,348	276,036	20,000	774,080
Total	600,000	600,000	600,000	1,062,839	80,000	2,942,839

(a) Cash; includes contribution from CRC for Irrigation Futures
(b) $100,000 per year in-kind contribution; balance in cash
(c) All in-kind contributions

In nominal terms the proportion of NPSI funding for the total investment was just over 20 per cent. The proportion of NPSI funding contributed by Land and Water Australia (LWA) was assumed to be 15% (Sarah Leonardi, pers comm.).

Investment description

The project applied a scenario approach to plan for the future of irrigated agriculture in the Goulburn Broken catchment for the next 30 years. The scenario planning was characterised by stakeholder participation, systems analysis and integration with the strategic planning cycles of key stakeholder groups.

Four stages occurred over the four years of the project. Stage 1 (project planning) included plans for stakeholder participation, evaluation and communication.

Stage 2 was a community engagement phase where 120 invitees participated in four workshops (irrigation futures forums) held at six locations throughout the region. A diversity of participants was sought so traditionally under-represented groups (e.g. women and young people) were particularly targeted. This stage explored the visions of stakeholders for the future and focused on the identification of strengths of the region and factors (challenges/opportunities) affecting the future.

Stage 3 consisted of a technical working group taking the outputs from stage 2 and constructing four future scenarios of external drivers, regional responses and consequences. The purpose was to further develop the material generated by the irrigation futures forums. The scenarios contained a range of uncertainties about the future drivers and responses. The various futures were characterised by such factors as irrigation water availability, contraction or expansion of irrigation, farm terms of trade, trade agreements, climate change, rural lifestyle residential development, farm size changes, water trading and water reform, technology advancement, landholder conflict, development of new agricultural industries, changes in salinity risk, and trade in environmental credits. General strategies to address the various futures were developed.

The scenarios were then assessed with regard to the relationship of various land uses, catchments and regional systems and with regard to multiple outcomes including water, salt, nutrients, soils, greenhouse emissions, agricultural production, economics and social and ecological factors. Estimated for each scenario were the likely changes in irrigated area, volume of irrigation water used, and farm-gate income. A consensus was then built on the future options and directions for irrigation in the region.

Stage 4 included building the learning from the project into the business and strategic plans of regional groups, as well as the development of a number of tools and processes to support change. The regional strategies were underpinned by the need to build adaptive capacity, requiring organisations to be flexible and adaptable.

The four stages encompassed six themes including hindsight, insight, foresight, both broad and specific implications, and project communication and evaluation. Adoption was addressed by widespread stakeholder participation in all stages, the integration with strategic planning of key stakeholder groups, widespread communication and the development of processes and tools.

Principal outputs

Stakeholder ownership
An important characteristic of the project was the involvement of regional stakeholders throughout the different stages. These stakeholders showed and maintained a high degree of interest and involvement and came from many parts of the community. This resulted in a high degree of stakeholder ownership of the outputs and findings from the investment. Agencies that strongly committed to the project included the Goulburn Broken Catchment Management Authority, Goulburn-Murray Water and the three local governments of Greater Shepparton City Council, Moira Shire and Campaspe Shire. In terms of irrigators, the dairy sector strongly contributed followed by a small number of horticultural producers.

Identification of stakeholder aspirations
The process developed a set of agreed stakeholder aspirations describing how the community would like to see itself in the future, including the future of irrigation in the region. This was important in directing both generic community responses and responses from specific stakeholder groups.

Identification of strengths of the region
In developing the aspirations, it was necessary to identify the features of the region that contributed to its competencies. These included access to irrigation water; land, including a diversity of soil types; agribusiness, including agricultural product processing; community, including population growth and a cultural diversity; institutional support; and environmental assets.

Future scenarios
A major part of the project was the development of four very different future scenarios for irrigation in the region. These scenarios were built upon key driving variables, challenges and opportunities, likely responses and the impact on the wellbeing of the region. Each of the scenarios had quite different economic, social and environmental consequences for the region.

The four scenarios were:
1. Moving on – a general decrease in area irrigated followed by moderate recoveries of 10–50 per cent. The focus was on increasing opportunities via trade agreements and productivity gains coupled with increasing competition.

2. New frontiers – agricultural production in the region declines over time by about 70 per cent overall. The focus is on a shift from an agricultural economy to lifestyle and development of synthetic food.
3. Pendulum – large shifts in water policy reduce production by 60 per cent followed by 100–300 per cent recovery.
4. Drying up – global economic recession and natural disasters decrease production up to 95 per cent followed by two to 20-fold recoveries.

Graphical and quantitative depictions of the consequences of the scenarios were particularly useful in assisting people to understand some of the underlying themes.

Regional strategies
A number of regional strategies were produced that could be applied to protect and strengthen areas of regional competency in the future. A few such strategies that were defined, for example, would need to take into account:

- the need to build flexibility into irrigation infrastructure due to uncertainty in the size and location of the irrigated area
- retention of competitiveness will depend on generating differentiated products
- high-value industries and lifestyle properties will require a greater level of service in water supply than currently
- changing farming systems may require whole farm planning to move from a focus on irrigation layout to a more flexible use of water services, products and environmental management systems
- as land and water management changes there may be a need to change surface and subsurface drainage systems, such as mothballing existing subsurface drainage works
- in order to provide support to individuals and businesses to recognise and adapt to change, regional initiatives such as providing regular information on international markets and climate trends and assisting people to interpret such information would be helpful

A number of specific agency strategies were developed in the project. Specific agency strategies to address the future were developed by the project team in conjunction with Goulburn Murray Water, Goulburn Broken Catchment Management Authority and local government.

Tools and processes
Practical tools to support the development and adoption of specific agency strategies were developed. These included:

- a handbook of flexible technologies for irrigation infrastructure.
- a framework for R&D to support adaptive management in the Goulburn Broken catchments
- a process for assisting individuals and businesses to assess the scenario implications for their own enterprise
- a process for assessing the feasibility of new enterprises
- curriculum material for secondary school students titled ‘Water and Food: Futures Thinking’.

- material made available to the teaching program of the Dookie campus of the University of Melbourne.

As well, the project developed and tested a regional scenario planning process (described with a significant amount of documentation) and a guide for other organisations wishing to undertake scenario planning at a catchment scale (Regional scenario planning in practice). A summary of the principal outputs from the project is shown in Table 3.

Table 3: Summary of principal outputs

Principal outputs
• Agreed vision by the community of the future for irrigated agriculture in the region
• Identification of regional strengths and competitive advantage, challenges and opportunities
• Construction of different scenarios for the future and consideration of regional strategies that are robust across the different scenarios
• Tools to incorporate generic strategies into specific strategies for different agencies
• A tool or process to assist individuals and businesses to assess the scenario implications for their enterprise
• A process for assessing new enterprise feasibility
• Description of the regional scenario planning process so that it can be used by other regional planning processes

Principal outcomes

The outputs from the investment have been produced from the knowledge, values and aspirations of the participant stakeholders so that the attitude to adoption of the strategies developed is likely to be positive. The key outcomes from the project were the stronger recognition of uncertainty, the need for robust strategies, and the need to plan for flexibility, more confident leadership due to the agreed vision, and more informed debate among the stakeholders of the region.

Evidence of changes in strategic plans

Some of the strategies, directions and priorities developed by the project have been incorporated (both directly and indirectly) into the strategies and business plans of a number of agencies in the region. Many of the regional strategies are now embedded in the strategic and operational plans of the collaborating organisations, suggesting that follow-up actions will be implemented over time.

Johnston (2007) reports that the scenarios and their implications have been, or are being, used in three major exercises of strategy formulation. Changes in strategies of these key stakeholder groups in the region are illustrated in the following paragraphs.

Goulburn-Murray Water

Goulburn-Murray Water (GMW) is the entity responsible for delivery of bulk water to irrigators and other water users within the Goulburn Broken region. As mentioned earlier, much of the irrigation infrastructure is nearing the end of its design life and replacement of assets in some areas is pending. In addition, water trading is increasing infrastructure costs in some areas as water is traded away. Hence, an infrastructure reconfiguration issue has to be addressed. As part of this strategy GMW was preparing a strategic view of assets and service needs. This meant that planning needed to be flexible, which is why the handbook of flexible technologies for irrigation supply infrastructure was prepared. Examples of flexible technologies include:

- in-channel and off-channel storages
- groundwater injection or aquifer recharge where cost effective
- channel lining
- staged development of supply systems
- waterway enlargement
- oversizing pipeline systems
- channel system reconfiguration
- mothballing of channels

On this issue Johnston (2007) reports:

> "GMW is planning for reconfiguration of the irrigation distribution system using a detailed water atlas of the region with working groups systematically examining scenario implications. Reviews that are part of the GMW reconfiguration planning have documented how much they have used the findings of the irrigation futures project.
>
> However, the process and what it is achieving is not apparently highly transparent to all. Thus the GMW reconfiguration of the irrigation distribution system is apparently being carried out by 'secret planning committees'; we are not sure if they are building on the scenario findings or not.
>
> GMW is also involved in the continued development of the handbook of flexible technologies for irrigation infrastructure developed as an output of the irrigation futures project to achieve greater flexibility in future delivery systems. This is based on acceptance of the need to move from a standard one-size-fits all model of irrigation infrastructure, which has prevailed for many years (e.g. irrigation channels with a 100-year lifetime), to flexible infrastructure, allowing for shorter-term solutions to water delivery, e.g. with regard to frequency (daily for greenhouse products, monthly for dairy) or lifetime requirements."

Despite the above concerns, infrastructure investment by GMW has been affected by the study through the following pathways:

- considering mechanisms to provide different levels of service to irrigators as a part of their irrigation reconfiguration planning processes
- recognition that different parts of the supply system have different life expectancies
- building of flexibility into the selection of technological and design processes.

Goulburn Broken Catchment Management Authority (GBCMA)
Within the GBCMA the Shepparton Irrigation Region Implementation Committee is primarily responsible for implementation of the catchment management strategy and activities concerning irrigation in the region (Sampson et al. 2007). The strategy has five main programs one for each of the following: farm, environment, waterways, surface water management and sub-surface drainage. This strategy was undergoing a five-year review and the irrigation futures project ran a planning process involving workshops and other support activities.

As a result of exploring the scenarios, the thinking of members of the implementation committee about some of these five programs has changed. One outcome was a recognition of the merit of delaying the construction of high-value assets such as evaporation basins for as long as possible, due to the uncertainty of changes in irrigation practices and irrigation areas. It was also recognised that, given the uncertainty of land and water management changes, there was a need to investigate technologies and management practices for increasing flexibility in surface and subsurface drainage systems so that the systems are adapted to future conditions.

As a result of the irrigation futures project, it is likely that regional drainage infrastructure priorities may change and drainage may be managed differently in future. For example, the level of future investment in drainage may change, as well as the balance of surface and subsurface drainage (Ken Sampson pers comm.).

The scenario analysis also highlighted the uncertainty in future farming enterprises and systems. This was seen to require a greater emphasis on whole farm planning, which may shift from its current focus on farm and irrigation layout to dealing with more strategic issues such as enterprise and system flexibility, and use of new water products and services and environmental management systems at both the farm and regional level.

Because of the significant changes in land use contained in some scenarios and between agricultural, lifestyle and environmental uses, it was recognised that there is a need for change in land use planning to manage new interfaces and potential conflicts. Land use planning issues considered included accommodation for lifestyle residents and flexible amalgamation and subdivision of land parcels.

The various programs of the GBCMA then completed their strategies and built them into their work plans for the next five years. Also, to support implementation of the strategies developed it was recognised that there was a need to develop a framework for research and development to support adaptive management

Johnston (2007) reports that that the GBCMA has set aside a budget for further meetings addressing follow-up to the irrigation futures project. GBCMA is also planning to link with the irrigations futures project for its ten-year celebrations.

Greater Shepparton City Council and Shires of Campaspe and Moira
At the time of the project, local governments were developing a rural strategy associated with land use zoning for the irrigation areas in the Goulburn Broken region. The scenarios were used to assist development of this rural strategy and for regional economic development. It is uncertain how this initiative shaped the resulting zoning and other strategies for the region. It is possible that land use planning changes are evident in local government strategies. For example, amalgamation or subdivision of land may change to be more flexible in future to encourage farming systems to remain competitive and reduce land use conflicts with new rural housing to provide certainty of investment in agriculture. Land use planning and zoning for a flexible environment will need to consider, for example, the application of zones, lot size and lot size adjustments, the environment/residential mix, and transport and service provisions (Colin Kalms pers comm.).

Capitalising on emerging opportunities such as biofuel production and workforce development (a regional development policy) were two policy areas that have been mentioned.

Johnston (2007) comments that the extent of the impact of the project on local government is difficult to evaluate, as active engagement with the irrigation futures scenarios and findings has only recently begun. It was planned to be underway earlier, but a number of factors intervened. These included other higher-priority issues, such as dealing with limited water allocation in 2006, a new Victorian regional planning process, and achieving agreement between the shires on the joint rural strategy development.

However, the initiative enabled local government to interact with the other agencies, industry representatives and farmers who were involved in the project.

Capacity building
Johnston (2007) reports that other strategic impacts, which are more difficult to conclusively demonstrate, are claims of the type that:

> "there is evidence of a much greater resilience in the producer community, that is the community has a greater capacity to identify and respond to the need to change, and to formulate and take urgent action where it is considered necessary. This constitutes an addition to the intellectual and social capital of the region."

Evaluation of the positive experiences gained by the forum participants and the members of the technical working group has been reported by Kelly (2006a and 2006b). The workshops resulted in a positive and quantifiable change in the participants' understanding of the complexity involved in sustainable development and a greater willingness to share this understanding, as well as a positive change in social networks. Technical working group members experienced profound personal changes in the way they view and respond to irrigation issues in the region.

At the time of the project, and shortly thereafter, a series of network expansion and integration moves among stakeholders was evident. The project was the driving force for this network building and integration of effort; some project champions emerged. However, it is uncertain whether the regional capacity built during the project has been maintained now that the project has been completed. No post-project activity in the form of monitoring or evaluation has been undertaken to date.

Process

At this stage there are no plans to repeat or update the process in the Goulburn Broken region (Leon Soste pers comm.). A scenario planning process using and refining the Goulburn–Broken irrigation futures framework is being used in the Sunraysia region to plan for climate change and drought. The first part of this new initiative has been completed (Henderson and Treeby 2008) and approval given for the next stage. Some voluntary support for the Mallee CMA is ongoing between the Goulburn Broken, Sunraysia and Mallee regions.

A summary of the principal outcomes from the project is provided in Table 4.

Table 4: Summary of principal outcomes

Principal outcomes
• Improved and cohesive regional leadership with greater confidence that leaders are representing their regional stakeholders
• Catchment, industry and regional planning that demonstrate a shared vision and informed by the best available knowledge and arguments
• Better informed debates on environmental policy regarding triple bottom line impacts
• Strengthened linkages and understanding of other views from different sectors of the regional economy
• Impact on strategies and plans associated with principal stakeholders in the region including local government planning, irrigation infrastructure and catchment management issues
• Capacity building among participants, stakeholders, clients, facilitators and members of the project team
• A scenario planning process that has been used in other regions

Benefits associated with the investment

Due to the wide representation of stakeholders involved, any benefits to be derived from the investment are likely to be widespread and diverse.

Participants, stakeholders, clients, facilitators and the project team have reported extensive learning benefits (Johnston 2007). Areas of change reported included:

- a broadening of thinking about future possibilities for the region
- a more realistic understanding of the potential for growth of industries in the region, based on an understanding of regional, national and international competition
- a willingness to speak up at public forums.

On this basis it can be concluded that there has been some capacity building for those involved. The challenges, as indicated by Johnston (2007), are to identify the flow-on consequences to the rest of the community.

Hence, the broadening of horizons implicit in the process is likely to be embedded in many future decisions to be made by regional institutions and others in the community. These more informed decisions are likely to produce economic, environmental and social benefits into the future.

Economic
The recognition of uncertainty is likely to be reflected in more robust or more flexible strategies that result in a more efficient allocation of resources. Also, being better prepared for some of the common features in the scenarios is likely to improve adaptation processes at lower costs as they are developed in the regional community.

Environmental
Most of the environmental benefits from this investment will probably be captured by changes within the modified strategies of local government, the Goulburn Broken Catchment Management Authority and Goulburn-Murray Water. Specific benefits are difficult to identify but, in general, they will probably fall into the area of biodiversity improvement through native vegetation restoration and reducing the impact of irrigation on water quality.

Social
Successful preparedness strategies, including the emphasis on flexibility, should minimise the future social impacts of change and adjustment in household incomes, training, employment, welfare, community tolerance and social empowerment.

A summary of the principal types of benefits associated with the investment is shown in Table 5.

Table 5: Categories of benefits from the investment

Benefits
Economic • Increase in efficiency of resource allocation regarding investment • Higher level of flexibility enabling the regional economy to adapt to changing circumstances more readily and at lower cost
Environmental • More effective management of natural resources and the environment
Social • Reduced impact of social adjustment required in future

Public versus Private Benefits
Both public and private benefits will accrue to the region. However, since the focus of the study was on irrigation, it is likely that a higher proportion of benefits will be captured by the private sector. Any specific distribution of benefits will probably only be known for the specific future scenario that unfolds for the region.

Match with National Priorities
The Australian Government's national and rural R&D priorities are reproduced in Table 5.

Table 5: National and Rural R&D Research Priorities 2007-08

Australian Government	
National Research Priorities	**Rural Research Priorities**
5. An environmentally sustainable Australia 6. Promoting and maintaining good health 7. Frontier technologies for building and transforming Australian industries 8. Safeguarding Australia	6. Productivity and adding value 7. Supply chain and markets 8. Natural resource management 9. Climate variability and climate change 10. Biosecurity *Supporting the priorities:* 3. Innovation skills 4. Technology

Each of the five rural research priorities was addressed with this investment with some bias towards productivity and adding value. In terms of the National Research Priorities, the principal priorities addressed were the first and second priority.

Quantification of benefits

Counterfactual

In the absence of the Irrigation Futures project, the actions taken by those in the region would have been in response to the specific events that develop in the future. Activities would have been attuned to one predicted future and probably delayed until there was a high level of certainty that the specified future was going to develop. It should be noted that the actual future that unfolds may be completely different to the four scenarios postulated.

Benefits with the project

The benefits valued in this analysis and attributed to the Irrigation Futures project include:

1. Benefits from the strategies of GM Water
2. Benefits from the strategies of the GBCMA
3. Benefits from changes to the strategies of local government

Goulburn–Murray Water

A significant part of the benefits that may accrue to Goulburn-Murray Water and hence irrigators and the community will accrue from the strategies and flexible technologies that have been integrated into the organisation's planning for the future. In particular, the benefit from the Futures project is likely to be associated with its effect on expenditure within the Food Bowl Modernisation Project, now called the Northern Victorian Infrastructure Renewal Project (NVIRP). The first stage of the NVIRP is being funded to the extent of $1 billion from the Victorian Government, Melbourne Water and Goulburn Murray Water, with an additional $1 billion made available by the Australian Government. The objective of NVIRP is to save 800 billion litres of water lost every year through leaks, system inefficiencies and evaporation, with the water savings to be shared equally between irrigators, the environment and Melbourne (Sampson et al, 2007).

It is highly likely that the resource allocation of the $2 billion NVIRP has been influenced significantly by the Irrigation Futures project. For the purposes of the current analysis, it is assumed that 5% of the investment by NVIRP is influenced positively. It is assumed that the internal rate of return for that part of the investment (the 5%) influenced would have been 10% per annum but with the influence of the Irrigation Futures project, the return increases to 12% per annum. It is assumed that the NVIRP investment is made over 5 years with the first year as the 2007-08 financial year and the final year 2011-12. It is assumed that benefits commence in the year after the last year of investment.

Goulburn Broken Catchment Management Authority (GBCMA)

<u>On-farm program/ Whole farm planning</u>

The whole farm planning component of the GBCMA on-farm program has invested an average of $853,000 per annum in the five years to 2005-06 in 2005-06 $ terms (Montecillo, 2007). Montecillo also reports this investment has produced an estimated internal rate of return of 10.5% over a 30 year period. If the same annual investment in whole farm planning is made in the future, it might be assumed that the Irrigation Futures thinking may increase this return from 10.5% to 12.5% per annum.

Surface and Subsurface Drainage

Due to a reducing CMA budget, activities are being scrutinised as to where cost savings can be made. One of the areas identified in the Irrigation Futures project was a potential change in the subsurface and surface drainage programs. The CMA decision to reduce the budget for the surface drainage program by $1 m per annum and the subsurface program by 0.5$ m per annum was in part driven by the Futures project. If it is assumed that the resources saved in these programs would have had a low rate of return in future, then at least part of these savings could be considered absolute (say 50%) and these savings could be attributed partly to the Irrigation Futures project (say 50%).

Greater Shepparton City Council and Shires of Campaspe and Moira

It is assumed that the Irrigation Futures project will have some influence on land use planning changes in the three local government areas affecting irrigated agriculture. It is understood that the two shires of Moira and Campaspe have adopted the regional rural land use strategy recently developed and the Greater Shepparton City Council is considering its adoption.

It is likely that zoning changes will protect a growth zone for large scale irrigated development through allowing minimal subdivision, a consolidation zone to allow existing enterprises to expand, with niche areas providing a variety of existing small lots to be utilised for small farming operations. The zoning changes also affect the ability of new houses to be constructed thus minimising a potential source of conflict. The Futures Project provided a basis for the proposition that any zone changes needed to ensure flexibility to respond to ever changing nature of agriculture. This is expected to maintain a slice of the production base and allow economies of scale to be exploited in the future in the Goulburn Murray region, providing certainty and security for investment and the price of land to reflect its agricultural value rather than an inflated rural residential price.

Benefits not valued

All of the benefits valued are in the economic category. While it is likely that social and environmental benefits will be captured in future, specific linkages between the likely changes in strategies identified and environmental and social benefits were not identified.

Summary of assumptions

A summary of all assumptions made is given in Table 6.

Table 6: Assumptions for the valuation of benefits from Irrigation Futures Project
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Variable	Value	Source
Goulburn Murray Water		
Reconfiguration investment	$2 billion over 5 years	Various sources
Year commencing	2007-08	Various sources
Proportion of investment benefiting from Irrigation Futures	5%	Agtrans Research
IRR without Futures project	10%	Agtrans Research
IRR with Futures project	12%	Agtrans Research
Annual Benefit	$2.83 m per annum for 30 years commencing 2012-13	Derived from discounted cash flow analysis
Goulburn Broken Catchment Management Authority		
Whole Farm Planning		
Investment in whole farm planning	$853,000 per annum in five year to 2005-06 in 2005-06 $ terms	Montecillo, 2007
Investment return from investment in five year period to 2005-06	10.5% per annum	Montecillo, 2007
Assumed investment return in future, with increase due to due to Irrigation Futures	12.5% per annum	Agtrans Research
Annual Benefit	$132,000 per annum for 30 years commencing 2012-13	Agtrans Research
Drainage		
Surface drainage program reduction	$1 m per annum	Agtrans Research after discussions with Ken Sampson
Subsurface drainage program reduction	$0.5 m per annum	Agtrans Research after discussions with Ken Sampson
Percentage of savings that could be considered absolute	50%	Agtrans Research
Attribution of savings to Irrigation Futures	50%	Agtrans Research
Year of first benefit	2007-08	Agtrans Research
Greater Shepparton City Council		
Value of total irrigated production in region	$1.2 billion per annum	Various sources
Year changes are made to plans including zoning	2008-09	Agtrans Research
Proportion of total	10% ($120m per annum)	Agtrans Research

production value affected by land use planning changes		
Decline in net production value without Futures project	1% per annum for the production affected commencing in 2013-14	Agtrans Research
Attribution of benefit to the Irrigation Futures project	10%	Agtrans Research

Results
All past costs and benefits were expressed in 2007-08 dollar terms using the CPI. All benefits after 2007-08 were expressed in 2007-08 dollar terms. All costs and benefits were discounted to the 2007-08 year using a discount rate of 6%. The base run used the best estimates of each variable, not withstanding a high level of uncertainty for many of the estimates. The base analyses ran for the length of the investment period plus 40 years from the first year of investment to the final year of benefits assumed.

Investment criteria were estimated for total investment, NPSI investment, and for the LWA investment alone. Benefits for NPSI investment criteria were estimated as 20% of the total benefits, 20% representing the proportion of total costs contributed by NPSI. LWA contributed 15% of NPSI Phase 1 funding. The investment criteria are reported in Table 9.

Table 9: Investment criteria for total costs and benefits (discount rate 6%)

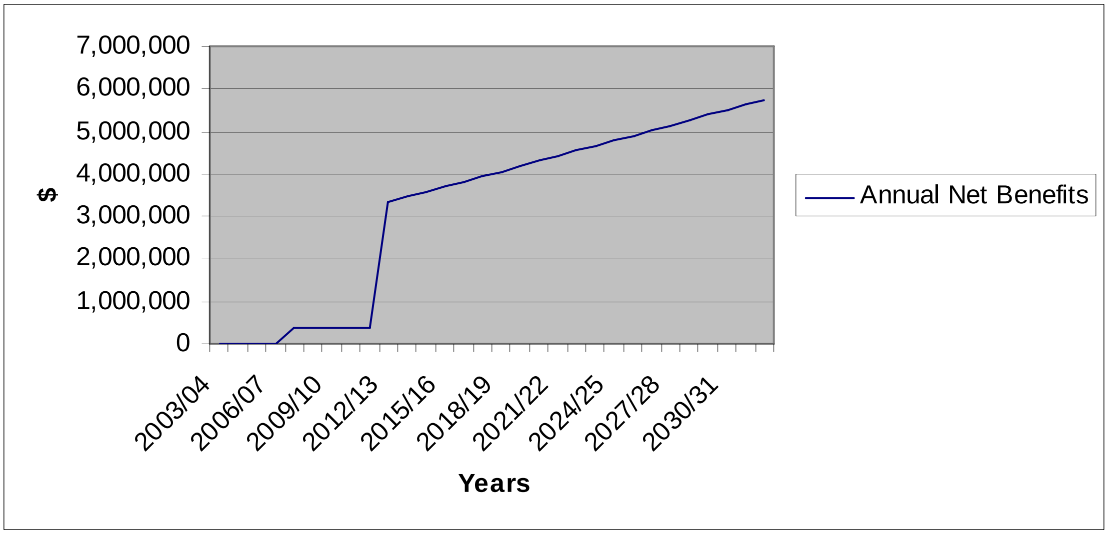
Criterion	LWA only	NPSI only	Total
Present value of benefits ($m)	1.60	10.67	52.54
Present value of costs ($m)	0.11	0.75	3.68
Net present value ($m)	1.49	9.92	48.85
Benefit-cost ratio	14.23	14.23	14.26
Internal rate of return (%)	28.5	28.5	28.4

Given the assumptions made, the proportions of benefits estimated for each source (for the 40 year analysis) is

- Irrigation infrastructure investment Efficiencies 54%
- CMA Farm Program Efficiencies 3%
- CMA Drainage Cost Savings 8%
- Local government planning efficiencies 35%

Figure 1 demonstrates the rate at which net benefits accrue for the total investment.

Figure 1: Annual Net Benefit Flow (undiscounted)



Sensitivity analysis

Table 10 shows the sensitivity of the investment criteria if only one of the organisations accrues benefits. The table shows that while the investment criteria differ depending on which organisational benefits are omitted, they are all still positive if two of the three benefits assumed do not materialise.

Table 10: Sensitivity of investment criteria to only one benefit being delivered (NPSI benefits and costs only)

Criterion	**Discount rate = 6%**			
	Goulburn Murray Water benefits only	**CMA benefits only**	**Local government benefits only**	**All three organisations benefiting (Base)**
Present value of benefits ($m)	6.35	1.48	2.84	10.67
Present value of costs ($m)	0.75	0.75	0.75	0.75
Net present value ($m)	5.60	0.73	2.09	9.92
Benefit:cost ratio	8.47	1.97	3.79	14.23
Internal rate of return (%)	23.0	11.7	12.4	28.5

Table 11 shows the sensitivity of the investment criteria to the proportion of the Goulburn Murray Water infrastructure that has benefited from the Futures project.

Table 11: Sensitivity of investment criteria to proportion of Goulburn Murray Water infrastructure benefiting (NPSI benefits and costs only)

Criterion	Discount rate 6%		
	2.5%	**5% (Base value)**	**10%**
Present value of benefits ($m)	7.49	10.67	17.01
Present value of costs ($m)	0.75	0.75	0.75
Net present value ($m)	6.74	9.92	16.26
Benefit:cost ratio	9.99	14.23	22.69
Internal rate of return (%)	24.1	28.5	34.6

Table 12 shows the sensitivity of the investment criteria to the discount rate. The criteria are particularly sensitive to the discount rate used as many of the benefits lie in the future years.

Table 12: Sensitivity of investment criteria to discount rate (NPSI benefits and costs only)

Criterion	Discount rate		
	3%	**6% (Base value)**	**12%**
Present value of benefits ($m)	17.90	10.67	4.72
Present value of costs ($m)	0.70	0.75	0.86
Net present value ($m)	17.20	9.92	3.86
Benefit:cost ratio	25.61	14.23	5.49

Conclusions

It is concluded that the Irrigation Futures investment by NPSI and others is likely to contribute to significant changes in planning in the Goulburn Broken region. One of the reasons supporting the observed impact and the high probability of future impact is that the strategic planning process of the three major organisations related to irrigation in the region were revising their plans and the futures thinking was encompassed in these planning documents. That is, the project was timely.

However, there was considerable uncertainty in deciding on the level of influence that can be attributed to the Irrigation Futures Project compared to other factors that have influenced change and what would have happened anyway if the Futures Project had not been funded.

Conservative assumptions have been made regarding improvements, level of impact, and attribution. Furthermore, there are likely to be environmental and social impacts but these have not been valued. Also, the investment criteria are probably underestimates as capacity building benefits within the region were identified but not valued.

It would be desirable for the project to be revisited and a workshop held to tease out the benefits more realistically than in the current analysis, as well as to update and refocus the futures thinking. This should occur within the next year to ensure corporate memories are still relevant.

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Addendum 1: An Economic Analysis of Investment in Irrigation Futures of the Goulburn Broken Catchment (VP13): Results for CRRDCC Process

All past costs and benefits were expressed in 2007/08 dollar terms using the CPI. All benefits after 2007/08 were expressed in 2007/08 dollar terms. All costs and benefits were discounted to the year of analysis (2007/08) using a discount rate of 5%. These results are shown in Tables A.1 and A.2 and are reported for different periods of benefits with year 0 being the last year of investment. All analyses ran for a maximum period of 30 years from year 0. Investment criteria were estimated for both total investment and for the Program investment alone.

Table A.1: Investment Criteria for Total Investment and Total Benefits

(discount rate 5%)

	0 years	5 years	10 years	15 years	20 years	25 years
Present value of benefits ($ m)	0	1.70	14.42	26.05	36.48	45.68
Present value of costs ($ m)	3.60	3.60	3.60	3.60	3.60	3.60
Net present value ($ m)	-3.60	-1.89	10.82	22.45	32.88	42.08
Benefit-cost ratio	-	0.47 to 1	4.01 to 1	7.24 to 1	10.14 to 1	12.69 to 1
Internal rate of return (%)	-	-	23.61	27.2	28.1	28.3

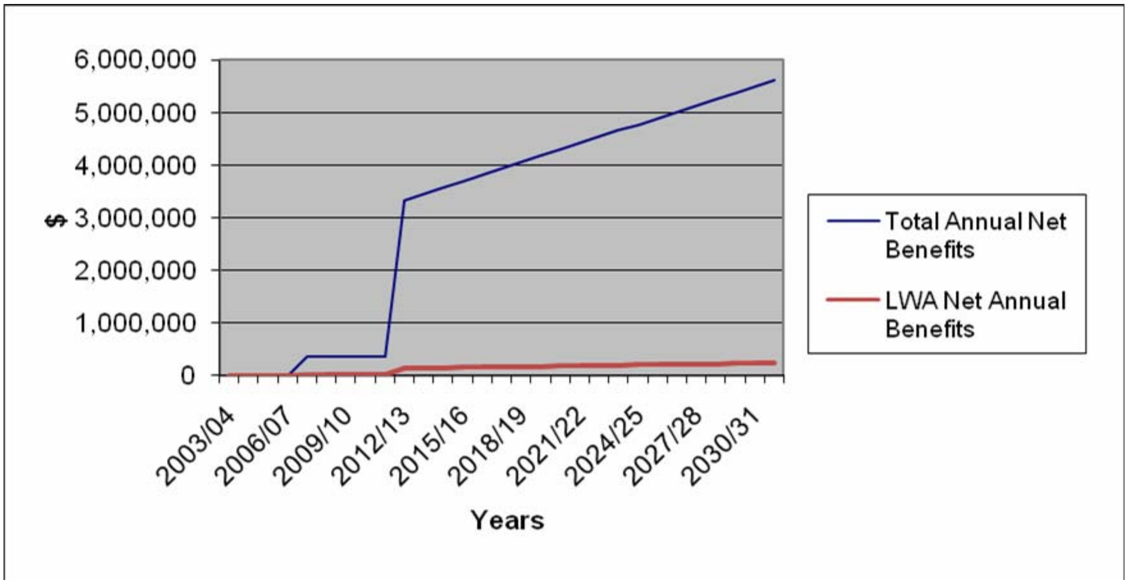
Table A.2: Investment Criteria for LWA Investment and LWA Benefits

(discount rate 5%)

	0 years	5 years	10 years	15 years	20 years	25 years
Present value of benefits ($ m)	0	0.07	0.59	1.07	1.49	1.87
Present value of costs ($ m)	0.11	0.11	0.11	0.11	0.11	0.11
Net present value ($ m)	-0.11	-0.04	0.48	0.96	1.38	1.76
Benefit-cost ratio	-	0.63 to 1	5.37 to 1	9.70 to 1	13.59 to 1	17.02 to 1
Internal rate of return (%)	-	-	28.3	31.5	32.2	32.3

The flow of annual benefits is shown in Figure A.1 for both the total investment and for the LWA investment.

Figure A.1: Annual Benefits



Appendix 4: An Economic Analysis of Investment in Northern Australian Irrigation Futures (Project No. CDS23)

SUMMARY

Date of evaluation: November 2008

Duration: NPSI supported the development of this project over the period 2003-04 to 2007-08.

Nature of innovation
As the biophysical functioning of northern Australia is vastly different from southern Australia, the North Australia Irrigation Futures (NAIF) project was developed as an opportunity to provide the tools and knowledge to address new developments in a proactive way by designing irrigation systems to fit specifically within the northern Australian environment and minimising the risk of problems now being experienced by irrigation schemes in other parts of the country.

Who was involved
The principal research was undertaken by CSIRO Land and Water in Townsville. Partners in the research project included NPSI, CRC for Irrigation Futures, Australian Government, Queensland Government, Northern Territory Government, Western Australian Government, and CSIRO Land & Water.

Adoption and impact
NAIF has produced a number of technical reports and reviews, and has identified an appropriate framework to aid with knowledge collection and decision making (ESD Component Trees). Together these tools have led to a number of stakeholders being more informed and with the potential to use the sustainability framework including key biophysical datasets and sustainability indicators when debating and making decisions regarding irrigation in northern Australia. Networks and relationships have also been developed and maintained. The ultimate intended impact is a sustainable irrigation industry in northern Australia that delivers a wide range of economic and social benefits whilst minimising environmental impacts.

Evaluation
A benefit–cost analysis for the investment in NAIF was carried out with the key benefit assumption being that NAIF will increase the probability of the successful approval of an irrigation development that meets society's expectations regarding economic and environmental impacts.

Investment criteria
The period of analysis was for 40 years after the first year of investment. The results are expressed in 2007-08 dollar terms and all benefits and costs are discounted to 2007-08 using a discount rate of 6%. Investment criteria were estimated for both total investment

and for NPSI and LWA investment alone. Benefits for NPSI investment criteria were estimated as 30.6% of the total benefits, 30.6% representing the proportion of total costs contributed by NPSI. LWA contributed 15% of NPSI Phase 1 funding. The results of the investment analysis were as follows.

Criterion	LWA only	NPSI only	Total
Present value of benefits ($m)	1.02	6.83	22.31
Present value of costs ($m)	0.10	0.66	2.10
Net present value ($m)	0.93	6.17	20.21
Benefit:cost ratio	10.34	10.34	20.61
Internal rate of return (%)	21.1	21.1	21.8

Current contact: Keith Bristow, Senior Principal Research Scientist, CSIRO Land and Water, Townsville, telephone 07 4753 8596.

FULL CASE STUDY

Background

Northern Australia is defined as north of Tropic of Capricorn and covers approximately 40% of Australia's land mass. Around 70% of Australia's freshwater lies in the rivers and groundwater systems of northern Australia. Existing irrigation schemes in the north include the Pioneer, Lower Burdekin, and Mareeba schemes in central and north Queensland, and the Ord River in Wester Australia.

It was considered a real possibility that further irrigation developments would occur in northern Australia. As the biophysical functioning of northern Australia is vastly different from southern Australia, an opportunity was identified to address new developments in a proactive way by designing irrigation systems to fit specifically within the northern Australian environment and minimising the risk of problems now being experienced by irrigation schemes in other parts of the country.

The Northern Australian Irrigation Futures (NAIF) project was funded in 2003 by the National Program for Sustainable Irrigation (NPSI) and other funders.

The Project

Project Objectives

The project objectives for NAIF were:

1. To delineate key landscape attributes (including soil and water resources, climate, vegetation, rivers, near shore marine environments, and where appropriate links to people, industries markets) relevant to ecologically sustainable irrigation across northern Australia.
2. To use key landscape attributes to develop sustainability indicators and associated management criteria covering a range of scales (field, farm, district, irrigation scheme, catchment) for northern Australia.
3. To develop an overall framework that, through their involvement, is embraced by policy makers, regulators, investors, and managers, to help ensure any irrigation is managed in a consistent, ecologically sustainable manner in northern Australia.
4. To use a number of linked case studies and stakeholder input to support and inform development and testing of the framework.
5. Through provision of a robust framework, contribute tools and knowledge to support considered debate, decision making and long-term strategic planning for northern Australia and Australia as a whole.

Investment costs

Table 1 reports the resources invested in NAIF by NPSI and others.

Table 1: Resources invested (nominal dollars) by year by NPSI and others

Year	NPSI[1]	Researcher and other contributions[2]	Total
2003-04	95,911	33,561	129,472
2004–05	60,000	50,000	110,000
2005–06	150,000	400,000	550,000
2006–07	130,000	450,000	580,000
2007-08	120,000	350,000	470,000
Total	555,911	1,283,561	1,839,472

[1] LWA makes up 15% of total NPSI Phase 1 funding

[2] Includes CRC for Irrigation Futures, Australian Government, Queensland Government, Northern Territory Government, Western Australian Government, CSIRO

Investment description

A Steering Committee (SC) was established to provide strategic guidance to the project team. The SC was both representative and skills based and comprised individuals from the Western Australian (WA), Northern Territory (NT), Queensland (Qld) and Australian Governments, NPSI, the Cooperative Research Centre for Irrigation Futures (CRC IF), SunWater and the North Burdekin Water Board. There was also a Stakeholder Reference Group (SRG) established which comprised ten members (three from each of WA, NT and

Qld and one from NSW). The purpose of the SRG was to provide a point of reference for the project team and the SC. The project team comprised contributions from a range of CSIRO and CRC IF researchers, and involved four CRC IF funded PhD students.

The research was divided into two stages.

Stage 1
The first stage of the project was focussed on engaging with clients to:

- Identify a broad range of stakeholders;
- Identify data required and data sources; and
- Determine the willingness of stakeholders to participate in project activities.

Three reports were produced from the first stage of the project that summarised the outcomes of the stakeholder engagement. A workshop of WA, NT, Qld and Australian government agency staff, as well as key project stakeholders was held in Darwin in May 2004. This workshop recommended that a Stage 2 work plan should be developed that recognises the important linkages of existing and prospective State and Commonwealth initiatives. The Stage 2 work plan was endorsed by the SC in December 2005.

Stage 2
The work plan for Stage 2 included four key research areas:

1. Understanding the context for irrigation in northern Australia
2. Understanding tropical water systems
3. Understanding the concept of irrigation mosaics
4. Developing an overall framework to support irrigation decision making, which became known as a 'sustainability framework'

Three case studies were established as part of the project in the Lower Burdekin, Ord and Katherine-Douglas-Daly areas. The purpose of the case studies was to help ground the research and enable direct feedback and testing of ideas and frameworks being developed. This was to help ensure their practicality, suitability and likelihood of adoption.

A Monitoring and Evaluation (M&E) Plan and a Stakeholder Engagement and Communication (SE&C) Strategy for the project were also developed and were finalised in March 2006.

The key activities under research area 1 were:

- Documenting the policy, legislation and institutional arrangements relevant to water and irrigation management in northern Australia.
- Reviewing past and present irrigation in northern Australia, focussing on key biophysical information and sustainability issues.
- Analysing the Lower Burdekin, Ord and Daly irrigation areas to identify the implications for future design and management of tropical irrigation systems.

The key activities under research area 2 were:

- Synthesising existing geological, geomorphological and hydrogeological studies of northern Australia.
- Assessing the practicality of developing a groundwater flow classification system for northern Australia.

The key activities under research area 3 were:

- A review of research into mosaics relating to ecology, forestry, meteorology and saline basins to aid understanding of the concept of irrigation mosaics and whether it may be an appropriate style of irrigation for northern Australia.
- A review and application of existing and new modelling and analysis tools to explore potential advantages and disadvantages of irrigation mosaics.

The key activities under research area 4 were:

- Examining the role and use of biophysical indicators of sustainability.
- Understanding irrigation decision making processes.
- Understanding social-ecological systems, sustainability and resilience concepts.
- Reviewing the use of 'ESD Component Trees' in fisheries, agriculture and irrigation.
- Understanding learning models and the potential role of new and emerging web-based technology in resolving complex problems.

Principal outputs

The principal outputs from each of the four research areas, including details of publications, are provided in the following sub-sections.

Research Area 1: Understanding the context for irrigation in northern Australia
The principal outputs from research area 1 were:

- Reports on the policy, legislation and institutional arrangements relevant to irrigation in northern Australia.
- A template to enable each northern jurisdiction to provide a report towards an overview of irrigation which was distributed to the northern governments.
- A report drawing lessons from existing irrigation for future design and management of irrigation in northern Australia.

Table 2 identifies the three reports produced for research area 1 and summarises their purpose and content.

Table 2: Reports produced for research area 1

Petheram et al (2007) "Analysis of the Lower Burdekin, Ord and Katherine-Douglas-Daly Irrigation Areas: Implications to future design and management of tropical irrigation". CSIRO Land and Water Science Report No. ??/07, CRC for Irrigation Futures Technical Report No. 04/07. This report found: • For the Burdekin and Ord Rivers, flow regulation and irrigation tail water drainage have resulted in morphological and ecological changes to downstream river reaches and riparian and aquatic ecosystems. • In the Burdekin Haughton Water Supply Scheme (BHWSS) and the Ord River Irrigation Area (ORIA) water tables are rising in several districts because of poor water efficiency and inadequate deep drainage management. Secondary salinity is also being observed in some areas. • The Lower Burdekin and ORIA highlight he need for site specific hydrogeological assessment that also takes into account the timing of water release and water quality. • Experience in the ORIA and Katherine-Daly-Douglas area suggests extrapolating data from other regions is often unreliable. Crops and farming systems should be evaluated at specific locations to assess true yield potential and risks, and determine appropriate management practices before they are applied on a large commercial scale.
Hegarty et al (2007a) "A guide to institutional, legislative and policy frameworks relevant to irrigation and water management in northern Australia". CSIRO Land and Water Science Report No. ??/07, CRC for Irrigation Futures Technical Report No. 05/07. The document provides a snapshot of the current institutional, legislative and policy frameworks affecting northern Australia's water resources management and development at the international, national and state and territory levels. The local level is recognised but not included. Key findings were that control structures are not static and change frequently, and differ widely between jurisdictions.
Hegarty et al (2007b) "A hotlink directory to northern Australia's irrigation and water management institutional, legislative and policy frameworks". CSIRO Land and Water Science Report No ??/07, CRC for Irrigation Futures Technical Report No. 06/07. The report contains a set of hotlinks allowing the user to navigate to websites of the institutions and mechanisms controlling or influencing irrigation and water management in northern Australia.

The principal findings from research area 1 were:

- A constraint to the scientific and practical understanding of northern systems is the limited research, monitoring and history of use in many areas. What data does exist has rarely been well analysed and synthesised.
- Even with current efforts, it will take a long time to build knowledge about the north, and the precautionary principle should be judiciously applied.

- The land and water resources of northern Australia are currently being used to maintain ecological systems, indigenous and other cultural values, and economic activity.
- There is limited focus on the development of water policy that is appropriate for northern systems as opposed to adapting southern approaches to the north.
- Northern Australia should be viewed, understood and managed through a 'northern lens' that takes account of the national and international context.

Research Area 2: Understanding tropical water systems
The key research outputs from research area 2 were:

- A report on current understanding of the hydrological constraints and opportunities for irrigation in northern Australia.
- A report to the SC on the practicality and benefits of developing a groundwater flow classification system for northern Australia.

Table 3 identifies the three reports produced for research area 2 and summarises their purpose and content.

Table 3: Reports produced for research area 2

Petheram, C and Bristow, K.L. (2007) "Towards an understanding of the hydrological factors, constraints and opportunities for irrigation in northern Australia: a review". CSIRO Land and Water Science Report No. ??/07, CRC for Irrigation Futures Technical Report No. 07/07. Presents an overview of the landscape of northern Australia with respect to soil and water resources, with special emphasis on attributes relevant to irrigation. The purpose of the report is to address community perceptions and misconceptions about northern Australia, and highlight key issues, constraints and opportunities for irrigation in the north. The report illustrates the differences between water systems in the north compared to the south of Australia. It examines the broad scale geological history and evolution of key landscape features, discusses the key climatic processes driving precipitation and evaporation, and examines terrestrial water balance and regional scale streamflow.
Bristow, K.L. and Petheram, C., (2007) "Assessment of the practicality and benefits of developing a groundwater flow classification system for irrigation in northern Australia". Report to the NAIF Steering Committee. Summarises the understanding of attitudes to and potential benefits of developing a groundwater classification system. The report found that most State based groundwater maps have more detail than is likely to be captured in a groundwater classification system, and most State/Territory hydrologists are more interested in increasing the level of detailed understanding of groundwater systems rather than developing classification systems unlikely to contain sufficient detail for highly managed irrigation systems. However, it was concluded that such classification systems might be a useful management and communication tool for those responsible for water, irrigation and catchment planning and management.
Petheram, C., Charlesworth, P.B., and Bristow, K.L., (2006) "Managing on-farm and

regional water and salt balances in Mona Park". CSIRO Land and Water Technical Report No. 23/06, July 2006. Reports the findings of a field and desktop study conducted to build understanding of the processes driving the trends of rapidly rising groundwater levels and rising salt concentrations in the Mona Park district of the Burdekin Haughton Water Supply Scheme (BHWSS). The study found that high levels of diffuse deep drainage and channel leakage appear to be the main factors leading to rising groundwater levels in Mona Park. However a well calibrated groundwater flow model is needed to further analyse the groundwater system and the likely response to future wet or dry periods and changes in management practice. A groundwater model was initiated as part of the study, but data was not available for it to be calibrated. A number of options for managing groundwater levels and reducing diffuse deep drainage in the region were identified.

The key findings from research area 2 were:

- The landscapes of the north are very old and relatively flat. This has implications for streamflow and options for water storage.
- The soils are complex, highly weathered and generally low in nutrients.
- Many regions across northern Australia are characterised by high inter-annual variability in rainfall, as well as high potential evaporation. The scarcity of rainfall and streamflow during the dry winter months necessitates either the extraction of groundwater of sufficient quantity and quality for irrigation or large above ground storages.
- Most externally draining rivers tend to be ephemeral; the few perennial rivers have strong connections to groundwater systems and are fed by them.
- The use of groundwater for irrigation presents substantial management challenges because of the uncertainties associated with recharge, discharge and lateral flow, and the time lags associated with these processes. Such detailed information exists in few areas of northern Australia.
- High flow events have important ecological implications for in-stream, estuarine, near-shore and marine environments.
- The relationships between surface and groundwater in terms of both water quality and quantity are not well understood.
- Irrigation must be preceded by catchment scale salt and nutrient management plans on long term sustainability objectives.

Research Area 3: Understanding the concept of irrigation mosaics

The principal outputs from research area 3 were:

- A report on the current understanding of irrigation mosaics drawing lessons from irrigation and other fields.
- A report on the biophysical advantages and disadvantages of irrigation mosaics.

Table 4 identifies the two reports produced for research area 3 and summarises their purpose and content.

Table 4: Reports produced for research area 3

Paydar, Z., Cook, F.J., Xevei, E. and Bristow, K.L. (2007) “Review of the current understanding of irrigation mosaics”. CSIRO Land and Water Science Report No. 40/07, CRC for Irrigation Futures Technical Report No. 08/07. Irrigation mosaics are defined as involving smaller patches of irrigated land dispersed across the landscape, as an alternative to traditional large-scale contiguous irrigation systems. The report provides an overview of the existing knowledge and current biophysical understanding of systems with natural spatial patterns in the landscape. A framework for further study on the environmental impacts was provided. The priority studies identified for the future included the effect of patch number, size and connectivity on evapotranspiration rate from irrigated land in a mosaic set up; fate of solutes; recharge to groundwater and the surrounding land; salinisation; groundwater quality; system losses and biodiversity. The report considered existing models that might be appropriate for adapting to assess the spacing of irrigation mosaics.
Cook, F.J., Xevi, E., Knight, J.H., Paudar, Z. And Bristow, K.L. (2007) “Analysis of biophysical processes with regard to advantages and disadvantages of irrigation mosaics. CSIRO Land and Water Science Report No. ??/07, CRC for Irrigation Futures Technical Report No. 09/07 This report investigates methods for analysing irrigation mosaics in terms of their biophysical effects and impacts compared with a large contiguous area of irrigation. A range of analytical and numerical solutions and programs were developed to quickly analyse the spatial and temporal issues associated with irrigation mosaics. A scaling method was developed which calculates the marginal impact of mosaics compared to one large contiguous area. It showed that only one parameter is required to determine whether irrigation mosaics will result in positive, neutral or negative effects on the environment for a particular property of the irrigation system, compared with one contiguous irrigation scheme of equal area. The key output of this subproject is seen to be the development of the analytical and numerical solutions and programs. The article also provides some key possible benefits/changes from a mosaics approach. It concluded that further research is required on the biophysical, ecological, social and economic advantages and disadvantages of irrigation.

The key findings from research area 3 were:

- Irrigation mosaics, involving smaller discrete patches of irrigated land dispersed across the landscape, may offer an alternative to traditional large-scale contiguous irrigation.
- Irrigation mosaics could have both negative (higher evapotranspiration, increased operational losses) and positive (reduced water-table height, reduced water-table spread, reduced solute spread, improved filtering of surplus nutrients, reduced erosion) effects on the environment.

- The actual benefit is likely to be positive, but will depend on a range of factors including the size of the individual patches, spacing between patches and assimilative capacity of surrounding areas.
- Further research is required on the biophysical, ecological, social and economic advantages and disadvantages of irrigation mosaics.

Research Area 4: Developing an overall framework to support irrigation decision making (sustainability framework)

The principal outputs from research area 4 were:

- An ESD Component Tree System for irrigation in northern Australia
- A prototype web-based Lower Burdekin Knowledge Platform (LBKP).
- Establishment of a Lower Burdekin Water Futures (LBWF) Group to promote integration of policy, science and stakeholder in irrigation and water resources management in the catchment.
- Reports summarising the journey of the research and development of frameworks to support irrigation decision making in northern Australia.
- A suite of other reports relating to irrigation decision making processes, including sustainability indicators, ecological risk assessment and Bayesian Belief Networks.

Table 5 identifies the three reports produced for research area 4 and summarises their purpose and content.

Table 5: Reports produced for research area 4

Kellett, B., Bristow, K.L. and Charlesworth P.B., (2005) "Indicator Frameworks for Assessing Irrigation Sustainability" CSIRO Land and Water Technical Report No. 01/05. The report identifies key criteria for assessing the usefulness of sustainability indicators for assessing the sustainability of an irrigation system. It then analysed nine natural resource sustainability indicator frameworks against these criteria. It was concluded that Bayesian Belief Networks satisfy seven of the eight assessment criteria established. A Bayesian Belief Network is a conceptual representation of a system that links indicators with arrows that represent the flow of cause and effect.
Kellet, B.M., Walshe, T. and Bristow, K.L. (2005) "Ecological Risk Assessment of the Wetlands of the Lower Burdekin" CSIRO Land and Water Technical Report No. 26/05. An Ecological Risk Assessment (ERA) was conducted for the wetlands of the Lower Burdekin at a workshop involving a broad range of stakeholders. However, stakeholders expressed distrust in the process as it appeared that ecological protection took priority over other social and economic matters. Therefore the major output from this study was four recommendations for conducting ERAs. Two of them were consistent with existing literature, however the following two could suggest a change to the process: • The elicitation and documentation of stakeholders' social and economic values should not be delayed until management alternatives are being

selected, but brought forward as a problem formulation task; and • A stakeholder engagement plan should be developed for each ERA to make transparent how and why stakeholders need to be engaged at different stages of the process.
Camkin, J.K., Kellett, B.M. and Bristow, K.L. (2007) "Northern Australia Irrigation Futures: Origin, evolution and future directions for the development of a sustainability framework." CSIRO Land and Water Science Report No. ??/07, CRC for Irrigation Futures Tech. Report No. 10/07. Initially, it was thought that a set or framework of biophysical indicators with guidelines on how they should be used would be a useful product to emanate from NAIF. However, during the project it was recognised that this would not be sufficient to address the complexity, subjectivity and site specific nature of irrigation decision-making. There was then a shift to incorporating the natural and human context for decisions into the sustainability frameworks considered. Six sustainability frameworks were reviewed.
Camkin, J.K. and Story, J. (2007) "An ESD component system to support irrigation decision making in northern Australia" CSIRO Land and Water Science Report No. ??/07, CRC for Irrigation Futures Technical Report No. 11/07. Of the six sustainability frameworks considered in the previous report, a decision was made to proceed with Ecological Sustainable Development (ESD) Component Trees, which was found to have been successfully used in fisheries, agriculture and irrigation. The ESD Component Tree was tested against previous irrigation and water resources decisions in northern Australia. A Toolkit was also prepared. The ESD Component Tree was first researched by the Fisheries R&D Corporation in early 2000. It is used to help break down the concept of ESD into understandable components. ESD Component Trees are a set of all issues, impacts or factors (positive and negative) which may be of interest when considering a particular activity (e.g. irrigation). Each issue is a separate component, is part of a hierarchical tree, and is connected to other components through that tree. They allow the user to navigate through the myriad of issues that may be relevant in a systematic way. The NAIF ESD Component Trees Toolkit includes: • Generic ESD Component Trees set for irrigation in northern Australia • Formatted Excel spreadsheet to assist in documenting components which are or are not identified as being an issue and why • Process guide description • PowerPoint presentation • Example of application: The Lower Burdekin • Example of use: Construction of the Lower Burdekin Knowledge Platform 2

The key findings of research area 4 were:

- Dealing with complexity, uncertainty and risk in irrigation decision making is a shared need and responsibility for catchment communities, proponents and governments.
- Maintaining resilience and achieving ecologically sustainable development will require more sophisticated approaches to irrigation and water resource planning, decision making and management than currently exist.
- Developing catchment knowledge platforms and ESD component tree systems with science, policy and stakeholders operating in an integrated way can help deliver more comprehensive, transparent and consistent decision making.

Case studies

Specific outputs from the three case studies included:

- Initial workshops were held in Brisbane, Darwin, Perth, Karratha, Broome and Kununurra in 2004.
- Information from the Lower Burdekin, Daly and Ord areas is included in a review of past and present irrigation in northern Australia, comparisons and lessons from the three irrigation systems and an overview of hydrology of the north.
- Stakeholder interviews capturing personal views on lessons from the three areas were completed and analysed. The results of this form part of a CRC IF funded NAIF directed PhD thesis.
- NAIF convened a meeting of key organisations in the Lower Burdekin in June 2006 which resulted in the establishment of an ongoing Lower Burdekin Water Futures Group.
- The NAIF framework of an ESD Component Tree System, catchment based knowledge platforms, and science, policy and stakeholders operating in an integrated way, was demonstrated through a Lower Burdekin prototype, which has received strong support in the Lower Burdekin through the SC and at the NAIF final workshops.
- A Bayesian network models stakeholder workshop was held for the Burdekin Group in June 2006.
- NAIF convened and chaired a Lower Burdekin Water Forum in 2006 with 80 stakeholders.
- NAIF chaired regular cross project meetings with Charles Darwin University (CDU), Environmental Research Institute of the Supervising Scientist (ERISS) and the Northern Territory Department of Natural Resources, Environment, The Arts and Sport (NRETS).
- Final NAIF NPSI workshops were held in Ayr, Brisbane, Darwin, Kununurra and Perth in September 2007.

Other outputs

The research process and the learnings from this project have also been a significant output in themself.

Altogether, NPSI has produced the following:

- 7 NPSI milestone reports
- Stage 2 work plan
- Stakeholder Engagement and Communication (SE&C) strategy
- Monitoring and Evaluation (M&E) Plan
- Project Status Reports and other papers for 23 SC meetings
- 6 editions of NAIFNEWS (distributed to a stakeholder network of 300 individuals and organisations),
- 5 NAIF media releases
- 26 media items
- 5 initial and 6 final NPSI workshops
- Over 160 major meetings, workshops, seminars and conferences featuring or coordinated by NAIF

Principal outcomes

Achievement of anticipated outcomes

The four anticipated outcomes from NAIF as defined in the M&E Plan were:

1. By 2007 leading stakeholders (Governments, communities, investors, land and water managers) will be more informed and able to use the sustainability framework including key biophysical datasets and sustainability indicators when debating and making decisions regarding irrigation in northern Australia.
2. By 2007 testing of existing northern irrigation management systems and practices against the sustainability framework and indicators will have commenced.
3. By 2010 relevant State and Australian policies will have adopted the framework and sustainability indicators.
4. By 2015 a sustainable irrigation industry in northern Australia will be functioning that delivers a wide range of economic and social benefits whilst minimising environmental impacts.

With regards to proposed outcome 1, NAIF has facilitated or featured in a significant number of conferences, workshops, seminars etc with the intention of providing opportunities to inform a wide range of stakeholders about NAIF and its products. Feedback from a series of invited workshops as part of the NPSI final reporting process was generally positive and supportive of the activities and outputs being generated.

With regards to proposed outcome 2, a prototypical framework was developed for the Lower Burdekin to demonstrate the concepts, but the framework has not yet been tested against other existing northern irrigation management systems.

With regards to adoption of the framework (proposed outcome 3), the ESD component Tree System, catchment based knowledge platforms and science, policy and stakeholders operating in an integrated way, have been demonstrated through the Lower Burdekin prototype. However it is not yet possible to determine if the Queensland, Northern

Territory, Western Australian, and Australian Governments will incorporate the framework into policy and decision making. However, a number of statements have been made which indicate interest in the possibility of its use.

With regards to proposed outcome 4, it is recognised by the project that such an outcome will be influenced by many factors, of which NAIF could be one component. It is hoped that beyond the framework, the project's emphasis on inter-jurisdictional cooperation will be one of the lasting outputs that will contribute to this outcome.

Impacts on Case Study Regions

In the Burdekin region, the project has facilitated better relationships between the Queensland Department of Natural Resources and Water and CSIRO and the Burdekin stakeholders. A Lower Burdekin Water Futures Group has been formed. The group is currently considering protocols and arrangements for the development of a Lower Burdekin Knowledge Platform, which will make data sets from a range of organisations available to all stakeholders to aid with information sharing for holistic and strategic decision making.

In Western Australia, the ongoing long–term engagement associated with the project has been valued by stakeholders as opposed to the fly-in fly-out style that often occurs.

Broader Impacts

A key outcome has been the trust built between the NAIF project team and other individuals and organisations, resulting in the opportunity to influence broader discussions, for example members of the NAIF project team were asked to brief the Australian Government's Northern Australia Land and Water Taskforce. The Taskforce has recently changed its focus and membership after a hiatus due to the most recent Commonwealth election. The NAIF outputs have been timely in being able to be used by the new Taskforce.

The project has had a significant positive impact on inter-jurisdictional cooperation between the three state and territory governments in the North but also with community and industry stakeholders and other research programs. For example, prior to this project there were no relationships between the three northern States in terms of irrigation management. The project, particularly the Steering Committee membership, promoted such relationships developing and they have been maintained. Queensland and the Northern Territory have been cooperating with policy development on the management of indigenous water in Cape York Peninsula through the Indigenous Water Policy Group, which is a subgroup of the North Australian Indigenous Land and Sea Management Association (NAILSMA) which is based in Darwin.

In the time since the NAIF project commenced there has been an increase in the level of focus on the role that irrigation may play in the future of northern Australia. Several initiatives relevant to irrigation in northern Australia that have commenced since 2003 include the National Plan for Water Security, the establishment of a Northern Australia Land and Water Taskforce, funding for Northern Australian Land and Water

Assessments and establishment of the Tropical Rivers and Coastal Knowledge (TRaCK) research hub.

TRaCK is a research initiative that aims to provide the science and knowledge that governments, communities and industries need for the sustainable use and management of Australia's tropical rivers and estuaries. NAIF is well connected with TRaCK and is in a good position to evolve and grow in synergy with TRaCK to harness different funding sources and tackle different but related issues.

The target audiences of the project were:

- Policy and regulatory agencies within each State and Territory involved in the environmental assessment and approval of proposed irrigation developments in northern Australia.
- Proponents of new irrigation developments
- Managers and farmers in existing irrigation schemes

It was intended that the project outputs would strongly influence a range of policy, regulation, management and institutional requirements across northern Australia. Examples of where it was likely to have influence include in meeting COAG water reform requirements and minimising the environmental footprint associated with irrigation developments. An aim was to provide consistent guidance to regulatory organisations within each State and territory for the assessment of proposed irrigation developments in northern Australia.

Influence on R&D priorities

NAIF has laid foundations for understanding the hydrology of northern Australia. There were a range of future research priorities, both for northern Australia and for NAIF in particular, that were identified from the project.

The WA, NT, Qld and Australian Governments have funded a CSIRO position for three years to October 2008 to focus on frameworks to support decision making in northern Australia and bridge the gap between science, policy and stakeholders. The CRC IF and Water for a Healthy Country Flagship funded a geochemist position for three years from December 2007 to develop improved understanding of the geochemistry of groundwater systems and their role as a key link between land and water management practices and downstream ecosystems.

Irrigation Mosaics

With respect to irrigation mosaics, a number of key issues were highlighted and areas for further research have been identified.

ESD Component Trees as a Framework

The potential applications for using ESD Component Trees in relation to irrigation in northern Australia include:

- Catchment and irrigation visioning and planning
- Developing irrigation proposals

- Assessing irrigation proposals
- Improvement of existing irrigation
- Triple-bottom-line or ESD reporting
- Identifying and managing knowledge gaps

Benefits associated with the investment

The potential benefits associated with the NAIF project include:

- Improved cooperation and understanding between governments and other stakeholders in the north, resulting in more efficient future decision-making, planning and negotiations.
- Improved overall outcomes in regards to ESD aspirations from potential future irrigation developments in the north (includes improved economic, social and environmental outcomes over what would have been achieved without NAIF).

Previous uses of ESD Component Trees have shown their benefits to be:

- Comprehensiveness: a common, comprehensive starting point reduces the chance of bias and of relevant factors not being considered.
- Transparency: documenting the reason why a component is not relevant allows all stakeholders to see how each issue has been addressed.
- Consistency: consideration of each activity starts from the same set of potential issues which are then either accepted or rejected.
- Dealing with complexity: all potential issues are processed in a structured way and are systematically prioritised.
- Understanding and managing risk: factors identified as relevant are prioritised so that the issues of high importance are addressed first.
- Capacity building: users are guided in a way that encourages them to consider all issues relating to an activity or proposal, not just familiar ones.

The ESD Component Trees system:

- enhances rather than replaces decision-making procedures
- ensures that all relevant factors have been identified
- helps reduce complexity
- helps build confidence in the community and decision makers

The experience with fisheries has been that ESD Component Trees have helped reduce regulation by identifying overlaps, redundancies and omissions for correction.

Examples of potential impacts from the use of irrigation mosaics include:

- Irrigation mosaics could be used to create or enhance ecotones (zones of transition between adjacent ecological systems) in the landscape for greater biodiversity, improving microclimate, preventing erosion and in absorption of surplus nutrients flowing from irrigated lands. However it is recognised this may have a negative impact on biodiversity due to fragmentation.

- Effects of advection on enhancing evapotranspiration and water use in irrigated mosaics seems to point to an approximately 10% increase (compared to larger irrigation schemes) due to heat coming from surrounding dry areas. However this may not be a desired feature in northern Australia.
- The size of irrigation units could have some implications for loss of water due to transport. There are engineering economies of scale and potentially lower unit costs for infrastructure etc with large irrigation schemes.
- Smaller schemes may provide improved opportunities for farmers to participate in planning and management of the system.
- Smaller schemes can be better adapted to supplying local markets and incur smaller risks of adverse environmental and social impacts such as displacement of settlements or disruption of wildlife habitats.
- Depending on the spacing, mosaics can result in less water table rises that are detrimental to the irrigated areas. Water table rise under an irrigation patch is also strongly dependent on the size (radius) of the patch.
- The radius that is impacted by solutes increases as the radius of the patch increases.

The specific potential benefits of NAIF are difficult to define. Overall, the tools, knowledge and networks developed by the project will be essential components of planning for any future irrigation development in northern Australia. The use of the project's outputs will help ensure that any subsequent irrigation developments follow the principles of ecologically sustainable development and meet the expectations of industry, the community and government. It will ensure the decisions are made with the best available knowledge, and with the best available input and cooperation from all relevant stakeholders.

Type of benefits
A summary of the principal types of benefits associated with the investment is shown in Table 6.

Table 6: Categories of Benefits from the Investment

Benefits
Productivity and Profitability • Knowledge and tools to help ensure that any irrigation scheme developed in northern Australia achieves sustainable and maximum levels of productivity and profitability given other constraints. • Potential efficiencies in planning and negotiations regarding development of new schemes through improved relationships and communication.
Environmental • Knowledge and tools to help ensure that any irrigation scheme developed in northern Australia meets the goals of ecological sustainable development, and minimises any negative environmental impacts from the development.
Social • Knowledge and tools to help ensure that any irrigation scheme developed in northern Australia meets the social goals associated with community employment and sustainability.

Public versus Private Benefits
The benefits that accrue will be both public and private in nature. There will be private benefits to a range of industry participants including landholders, input suppliers, processors etc. Through its encouragement of ecologically sustainable development approaches, the project also has the potential to provide public benefits in the form of minimised environmental impact from any irrigation development in the north.

Distribution of Benefits Along the Supply Chain
There is the potential for benefits to accrue to all sectors along the supply chain if NAIF contributes to the development or management of an ecologically sustainable irrigation development in northern Australia.

Match with National Priorities
The Australian Government's national and rural R&D priorities are reproduced in Table 7.

Table 7: National and Rural R&D Research Priorities 2007-08

Australian Government	
National Research Priorities	**Rural Research Priorities**
9. An environmentally sustainable Australia 10. Promoting and maintaining good health 11. Frontier technologies for building and transforming Australian industries 12. Safeguarding Australia	11. Productivity and adding value 12. Supply chain and markets 13. Natural resource management 14. Climate variability and climate change 15. Biosecurity *Supporting the priorities:* 3. Innovation skills 4. Technology

The research has contributed to National Research Priority 1, and Rural Research Priorities 1 and 3. There is also some potential contribution to Rural Research Priorities 4 and 5 through the development of the north as risk aversion strategies with respect to diversifying production areas in terms of climate and geographic location.

Quantification of benefits

The wide ranging possible future benefits from this research investment mean that a broad and prospective framework is necessary to quantify the value of the potential benefits.

It is assumed that both with and without the NAIF project there is a high probability of the development of one new irrigation development in the north in the next ten years. It is recognised that the development is unlikely to be in the form of a large centralised scheme with one or two large surface water storages such as in the Ord. Rather it will more likely take the form of a 'mosaics' development, possibly based on groundwater irrigation.

Regardless of the nature of the development, it is assumed the production from the development will be of the scale of that produced in the existing Ord River Irrigation Scheme. In 2004-05 the gross value of production from the Ord River Irrigation Area was estimated at $53.6 million. This was made up of crops such as melons, sugar, mangoes, hybrid seeds, pumpkins and bananas. For the purposes of this analysis, it is assumed that from the time the development is established, it takes five years for the full level of production of $53.6 million to be achieved.

It is assumed that the relationships, knowledge, tools and networks developed as part of the NAIF project will be instrumental in the planning and establishment of such a development. Examples of such knowledge and tools include the ESD Component Toolkit, the knowledge identified relating to irrigation mosaics, and the relationships developed through the workshops and committee meetings. These tools will provide a framework to assist with identifying and collecting appropriate knowledge and consulting with all relevant stakeholders. It is assumed that without the NAIF project, the probability of a development that meets the industry, public and governments ESD goals being successfully developed and implemented is only 70%. With the NAIF project, the probability of such a development being successfully developed and implemented has increased to 75%. This increase in probability is due to improved knowledge about the most important factors in the decision making, as well as an improved framework for identifying and considering that knowledge. The improved networks and relationships will also be key contributors to the improved probability of success.

Without the NAIF project, it is assumed that such a development would be up and running in the year 2014-15 (seven years after the completion of the NAIF project). It is uncertain what impact the NAIF project, and subsequent activities to improve the probability of a successful development, might have on the timing of the establishment of such a development. For example, the use of the ESD Component Tree System and the relationships and networks developed may actually increase the speed with which a development can be designed and approved due to more targeted knowledge collection and consultation. Alternatively, the tools developed as part of NAIF may in some circumstances lead to a delay due to increased knowledge and data collection requirements, or increased consultation requirements. Either of these alternatives is a possibility, and therefore this analysis assumes that for the 'with NAIF' scenario, the timing of the development is the same as for the 'without' scenario. However, a sensitivity analysis is undertaken on this assumption to demonstrate the impact of an improvement or delay in the speed of development.

Benefits not quantified

The benefits that are quantified focus on the economic benefits from a potential irrigation development, and potential environmental and social benefits are not explicitly quantified. However there is some implicit inclusion of these benefits in the analysis, in that it is assumed that the increase in probability of the development being successful partly relates there being more likelihood of the development meeting sustainability expectations. The environmental benefits have not been explicitly quantified, due to difficulties in making appropriate benefit transfer assumptions in northern Australia.

Summary of assumptions

A summary of all assumptions made is given in Table 8.

Table 8: Assumptions for the valuation of benefits

Variable	Value	Source
Annual gross value of production from future irrigation development	$53.6 million	Kimberley Development Commission
Number of years for full production to be reached	5 years	Agtrans assumption
Year of irrigation development commencement without NAIF	2014-15	Agtrans assumption
Year of irrigation development commencement with NAIF	2014-15	Agtrans assumption
Probability of development being implemented without NAIF	70%	Agtrans assumption
Probability of development being implemented with NAIF	75%	Agtrans assumption

Results

All past cost and benefits were expressed in 2007-08 dollar terms using the CPI. All benefits after 2007-08 were expressed in 2007-08 dollar terms. All costs and benefits were discounted to 2007-08 using a discount rate of 6%. The base run used the best estimates of each variable, not withstanding a high level of uncertainty for many of the estimates. The base analyses ran for 40 years from the first year of investment (2003-04) to the final year of benefits assumed (2042-43).

Investment criteria were estimated for both total investment and for NPSI and LWA investment alone. Benefits for NPSI investment criteria were estimated as 30.6% of the total benefits, 30.6% representing the proportion of total costs contributed by NPSI.

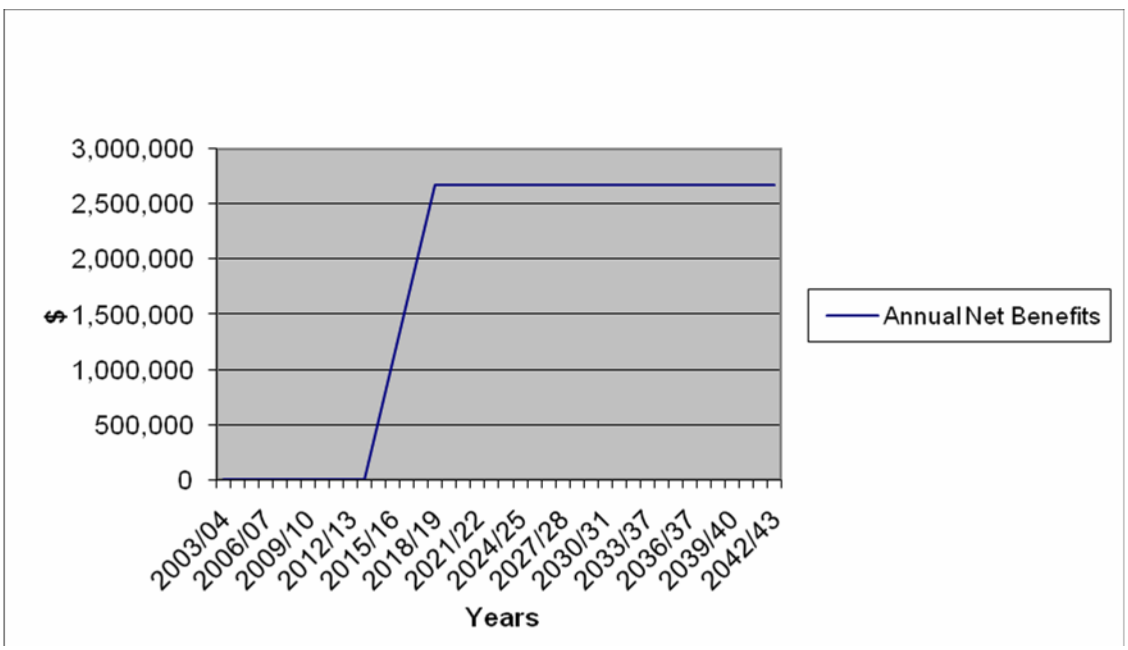
LWA contributed 15% of NPSI Phase 1 funding. The investment criteria are reported in Table 9.

Table 9: Investment criteria for costs and benefits (discount rate 6%)

Criterion	LWA only	NPSI only	Total
Present value of benefits ($m)	1.02	6.83	22.31
Present value of costs ($m)	0.10	0.66	2.10
Net present value ($m)	0.93	6.17	20.21
Benefit:cost ratio	10.34	10.34	20.61
Internal rate of return (%)	21.1	21.1	21.8

Figure 1 demonstrates the rate at which net benefits accrue.

Figure 1: Annual Net Benefit Flow
(undiscounted)



Sensitivity analysis

Analyses have been carried out to demonstrate the sensitivity of the investment criteria to a number of the key assumptions. Results are presented in Tables 10 to 12. The analyses were carried out using a discount rate of 6%, and use the NPSI costs and benefits as the base scenario.

Table 10 demonstrates the sensitivity of the investment criteria to the assumed annual gross value of production of the development. The analysis shows that if the gross value is only half of that currently assumed, then the investment criteria are still significantly positive, with a B/C Ratio of 5.2 to 1.

Table 10: Sensitivity of investment criteria to annual gross value of scheme (NPSI costs and benefits)

Criterion	**Discount rate 6%**		
	50% of base	**$53.6 million (base)**	**150% of base**
Present value of benefits ($m)	3.41	6.83	10.24
Present value of costs ($m)	0.66	0.66	0.66
Net present value ($m)	2.75	6.17	9.58
Benefit:cost ratio	5.17	10.34	15.50
Internal rate of return (%)	15.9	21.1	24.3

Table 11 demonstrates the sensitivity of the investment criteria to the assumed probability of success of the scheme going ahead with NAIF. It shows that the analysis is not highly sensitive to the difference in the probability of success assumed for the 'with NAIF' scenario, and the investment criteria are still positive when a 72.5% probability of success is assumed.

Table 11: Sensitivity of investment criteria to probability of success with NAIF (NPSI costs and benefits)

Criterion	**Discount rate 6%**		
	72.5%	**Base value (75%)**	**90%**
Present value of benefits ($m)	3.41	6.83	27.32
Present value of costs ($m)	0.66	0.66	0.66
Net present value ($m)	2.75	6.17	26.66
Benefit:cost ratio	5.17	10.34	41.34
Internal rate of return (%)	15.9	21.1	33.2

Table 12 demonstrates the sensitivity of the investment criteria to the assumed time difference of the establishment of the scheme between the 'with' and 'without' scenarios. It shows that if the information requirements associated with the NAIF tools require the development to be delayed up to two years, then the investment criteria are negative. This demonstrates that the increase in probability of success due to NAIF would have to be very high if there were still to be a benefit when such a delay is evident. On the other hand, if the NAIF initiative results in a development decision being made earlier, then the benefits increase greatly.

Table 12: Sensitivity of investment criteria to time difference between the 'with' and 'without NAIF' scenarios
(NPSI costs and benefits)

Criterion	**Discount rate 6%**		
	With NAIF occurs two years earlier	**With and without NAIF occur in the same year (base scenario)**	**With NAIF occurs 2 years later**
Present value of benefits ($m)	22.79	6.83	-7.37
Present value of costs ($m)	0.66	0.66	0.66
Net present value ($m)	22.13	6.17	-8.04
Benefit:cost ratio	34.49	10.34	-11.16
Internal rate of return (%)	50.2	21.1	negative

Conclusions

NAIF has been a wide ranging investment that has successfully developed knowledge, tools and relationships that will be important for the future development of agriculture based around irrigation schemes in northern Australia. Due to the wide and varied potential use of such tools and knowledge, it has been necessary to quantify the benefits of the research using a broad framework. The analysis has shown that the potential for benefits from the research is high, but is very sensitive to assumptions regarding NAIF's influence on the timing of any development decision.

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Keith Bristow, CSIRO
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Gary Everson, Sunwater

References

Kimberley Development Commission http://www.kdc.wa.gov.au/kimberley/tk_ord.asp

Addendum 1: An Economic Analysis of Investment in Northern Australian Irrigation Futures (Project No. CDS23): Results for CRRDCC Process

All past costs and benefits were expressed in 2007/08 dollar terms using the CPI. All benefits after 2007/08 were expressed in 2007/08 dollar terms. All costs and benefits were discounted to the year of analysis (2007/08) using a discount rate of 5%. These results are shown in Tables A.1 and A.2 and are reported for different periods of benefits with year 0 being the last year of investment. All analyses ran for a maximum period of 30 years from year 0. Investment criteria were estimated for both total investment and for the Program investment alone.

Table A.1: Investment Criteria for Total Investment and Total Benefits

(discount rate 5%)

	0 years	5 years	10 years	15 years	20 years	25 years
Present value of benefits ($ m)	0	0	3.46	10.58	16.16	20.54
Present value of costs ($ m)	1.97	1.97	1.97	1.97	1.97	1.97
Net present value ($ m)	-1.97	-1.97	1.48	8.61	14.19	18.56
Benefit-cost ratio	-	-	1.75 to 1	5.36 to 1	8.19 to 1	10.40 to 1
Internal rate of return (%)	-	-	11.4	21.0	22.8	23.4

Table A.2: Investment Criteria for LWA Investment and LWA Benefits

(discount rate 5%)

	0 years	5 years	10 years	15 years	20 years	25 years
Present value of benefits ($ m)	0	0	0.16	0.49	0.74	0.94
Present value of costs ($ m)	0.10	0.10	0.10	0.10	0.10	0.10
Net present value ($ m)	-0.10	-0.10	0.06	0.39	0.64	0.85
Benefit-cost ratio	-	-	1.63 to 1	4.99 to 1	7.63 to 1	9.69 to 1
Internal rate of return (%)	-	-	9.8	18.4	20.2	20.8

The flow of annual benefits is shown in Figure A.1 for both the total investment and for the LWA investment.

Figure A.1: Annual Benefits