Investment in Natural Resources R&D: a Synthesis of Life-of-Project Evaluations

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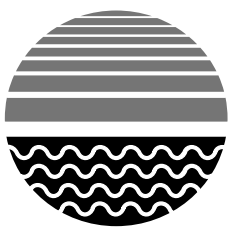

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Glossary and Abbreviations

Benefit–cost analysis (BCA) – A conceptual framework for the economic evaluation of project programs in the public sector. It differs from a financial appraisal or evaluation in that it considers all gains (benefits) and losses (costs), regardless of to whom they accrue. The aim is to express social benefits and social costs in terms of money.

Benefit–cost ratio (B/C ratio) – The ratio of the expected present value of project benefits to the expected present value of project costs.

CRCSLM – Cooperative Research Centre for Soil and Land Management

CSIRO – Commonwealth Scientific and Industrial Research Organisation

Discounting – The process of relating the costs and benefits of a project to a base year using a stated discount rate.

DRDC – Dairy Research and Development Corporation

GRDC – Grains Research and Development Corporation

Historical or *ex-post* analysis – Occurs after the research project has been completed. It analyses the project after completion with respect to benefits and cost outcomes attributable to it.

IFPRI – International Food Policy Research Institute

INR – CSIRO Institute of Natural Resources and Environment

Internal rate of return (IRR) – The discount rate at which a project has a net present value of zero, i.e. where present value of benefits = present value of costs.

Investment criteria – Measures of the economic worth of an investment such as net present value, benefit–cost ratio, and internal rate of return.

ISNAR – International Service for National Agricultural Research

LWRRDC – Land and Water Resources Research and Development Corporation

Net present value (NPV) – The discounted value of the expected benefits of a project, less the discounted value of the expected costs, ie. present value of benefits – present value of costs.

NSW – New South Wales

NZ – New Zealand

PRDC – Pig Research and Development Corporation

Present value of benefits (PVB) – The discounted value of benefits.

Present value of costs (PVC) – The discounted value of costs.

Prospective or ex-ante analysis – Evaluates a potential project based on a number of assumptions of the likely level of inputs and outputs (and their values) that will occur as the project proceeds.

R&D – research and development

RD&E – research, development and extension

RIRDC – Rural Industries Research and Development Corporation

Sensitivity analysis – A technique involving changes to the parameters of a project evaluation to see how they affect the investment criteria; a straightforward and rapid technique to gauge the robustness of investment criteria.

SRDC – Sugar Research and Development Corporation

TOR – terms of reference

UK – United Kingdom

UQ – University of Queensland

US – United States

Executive Summary

The results achieved so far in the life-of-project evaluations supported by LWRRDC are demonstrating positive returns to research and development (R&D) investment in natural resource management. The investment by LWRRDC and its partners over the past five years appears to be providing significant value for money and a high rate of return.

Simple averages of investment criteria produced by the evaluations show that the average net present value (NPV) for 29 projects analysed was $23 million per project, the average benefit to cost (B/C) ratio was 17 to 1 and the average internal rate of return (IRR) was 36%.

While evaluation studies of natural resource management R&D are not common in Australia or overseas, some comparisons with several other Australian R&D evaluation studies suggest that the LWRRDC investment returns are roughly in accord with other Australian estimates of investment returns in natural resource management and agricultural research. With respect to overseas, one major review of such studies reported that the average IRR over 16 natural resource R&D studies was around 40%. IRRs from LWRRDC projects are similar at 36%.

Differences exist between analysts as to their estimates of the applicability and extent of the benefits that might arise from a particular project, the method of valuation of such benefits, and the adoption characteristics associated with capturing those benefits.

The revisions of the analyses for each group of projects are providing increases in the accuracy of estimates of the investment returns. However, even when projects are completed and the outputs are known, there is generally little or no information on adoption of outputs. Few processes are in place to remedy this situation.

There remain considerable difficulties in applying benefit–cost techniques to research evaluation in natural resource management, largely due to the complex systems involved, the lack of information on the value of non-market benefits, an uncertain policy environment, and the time taken for the benefits of remedial actions to become apparent. Other major difficulties, not restricted to evaluation of natural resource management R&D, include the specification of the 'without' scenario and the defining of boundaries of individual research projects so that what is contained within each project or R&D area is consistent with the definitions of benefits and costs assumed.

To further strengthen its life-of-project assessments, LWRRDC should ensure:

- that investment criteria are estimated and reported for only those benefits that have actually accrued to the date of the analysis, as well as for all benefits (to-date plus future);
- greater consistency in reporting methods, in terms of explicitness of assumptions about adoption and probability of success;
- all three common investment criteria are reported (net present value, benefit–cost ratio, and internal rate of return) for each project wherever possible, together with the present values of benefits; and
- improved information is available for analysis of technology adoption.

1 Introduction

In 1992–93, the Land and Water Resources Research and Development Corporation (LWRRDC) initiated "life-of-project" evaluations of the projects it funds.

The major objective of these evaluations is to assess the outputs and define and quantify the benefits of selected projects in order to carry out a social benefit–cost analysis. A further objective of the evaluations is to identify the main risks to the production of technical outputs from each project and to their adoption and effective use, as well as recommend steps that LWRRDC could take to manage those risks. Another objective is the identification of information that should be collected by project managers to ensure that later evaluations of the project, including *ex-post* evaluations, are based on the most relevant and useful data possible.

Each project is initially analysed in its first year of funding. The decision to fund each project had already been made when it was analysed for the first time.

There have now been four groups of projects evaluated, each group consisting of seven to eight projects. It was intended that the evaluations for each group of projects would be reviewed approximately every two years in order to assess the impact of each project selected for evaluation throughout its life. So far, revisions have been carried out for two of the four groups of projects.

The aim of this report is to present a synthesis of the results of the four life-of-project evaluations. The report, in draft form, was presented to participants at a workshop on 15 December 1999. The objective of the workshop was to demonstrate the benefits from LWRRDC investment in natural resources R&D. In addition, some of the comments and discussion at the workshop might be useful in LWRRDC's evaluation program in the future.

Section 2 presents a brief description of the evaluations, including the project groups, the parties undertaking the evaluations, the phases of each evaluation, and the terms of reference for each evaluation. Section 3 outlines the methods used by each group to select the projects to be evaluated, as well as the methods used in the evaluations by each of the groups. Section 4 summarises the results of the investment analyses, while Section 5 presents a discussion of the qualitative results obtained. Section 6 compares the results of the LWRRDC evaluations with those from other studies in Australia and elsewhere. Section 7 identifies some issues that might be considered by LWRRDC in its future evaluation strategy. A set of conclusions is presented in Section 8.

In preparing this paper, three projects — CEN4, CWE13 and UQL13 (see Appendix 1) were selected as case studies for short articles that exemplify the range of issues and challenges facing natural resources research, development and extension. These articles appear as boxes in the text at pages 16, 26 and 30.

2 Brief Description of Evaluations

2.1 Evaluation Groups

Each of the four groups of projects was evaluated by a different analyst. The evaluation of the first group of projects was undertaken by Temtac Pty Ltd in 1994 on projects initiated in 1993–94 (Temtac Pty Ltd 1994). This evaluation has been updated twice, ie. there have been three evaluations of the same group of projects at three different times. The second and third phases of this evaluation were undertaken in 1996 (Harrison and Tisdell 1997) and 1998 (LWRRDC Occasional Paper, in preparation), respectively.

The second group of projects was analysed in 1996 by ACIL Economics and Policy Pty Ltd on projects initiated in 1995–96 (ACIL 1997)). A second phase of this evaluation was undertaken in 1998 (LWRRDC Occasional Paper, in preparation) by the same research group.

The third group of projects was analysed in 1997 by Sloane, Cook and King Pty Ltd on projects initiated in 1996–97 (Sloane, Cooke & King 1999). At this stage there has been no re-evaluation of this group of projects.

Atech Group Pty Ltd was commissioned to undertake the analysis of the last group of projects in 1998 (Atech Group Pty Ltd 1999). Those projects analysed were selected from projects that started after 1 January 1998.

An additional evaluation was commissioned in 1996 and was carried out by Sloane, Cook and King Pty Ltd. This was, however, a series of *ex-post* evaluations and is therefore not included in the current synthesis.

The projects evaluated in all four groups are listed in Appendix 1.

2.2 Terms of Reference

The terms of reference for the analysis of each group and phase of projects are presented in Appendix 2. Overall, the terms of reference (TOR) for the four groups were similar. The major differences are outlined below.

A significant addition was made to the TOR following the first evaluation undertaken by Temtac. The next three evaluators were asked to identify the main risks to the production of technical outputs and to their adoption and effective use, as well as to recommend steps that LWRRDC could take to manage those risks. Temtac had been asked to include in its investment analysis only an assessment of the likelihood of the project achieving its technical outputs.

The first two groups of analysts (Temtac and ACIL) were required to develop and recommend evaluation techniques appropriate to natural resource issues. These techniques were to be used by the Corporation, its stakeholders and researcher clients in formulating and assessing R&D projects and programs. This was not included in the TOR for the third and fourth group of evaluations.

Finally, an addition to the TOR for the fourth group (Atech) was the requirement to assess the evaluations of the previous three groups.

3 Overview of Methods Used

3.1 Selection of Projects

The four groups of projects to be evaluated were selected by slightly different methods. The overall goal was to achieve an appropriate representation across different research areas and different project sizes (represented by level of funding). A detailed description of the selection process used by each group is given in Appendix 3.

The first group of projects to be evaluated was selected by the LWRRDC Board, and the researchers were asked to comment on the selection of projects and their representativeness of the entire LWRRDC portfolio. The other three groups of projects were selected by the analysts themselves, using a stratified sampling technique.

ACIL, which conducted the evaluation of the second group of projects, developed an approach whereby the population of projects was defined and projects classified into strata based on whether they were commissioned or general call, and on whether they were biophysical or sociological projects. Each stratum was then divided into substrata based on budget size, and the median from each was selected for analysis. The number of projects selected from a stratum was based on its share of the budget.

The means of selecting the third and fourth groups of projects was similar to that used by ACIL.

The projects selected within each group were thus an appropriate representation of different research areas and programs across the LWRRDC portfolio. There were no projects selected *a priori* on the basis of expected outputs or outcomes. There is also no evidence that those projects selected by the LWRRDC Board for the first evaluation were selected on the basis of expected outputs or outcomes. However, this first sample selected was not entirely representative of the LWRRDC portfolio, with the analysts concluding that "there is some under-representation with respect to sustainable management of vegetation, sustainable management of land resources and projects with LWRRDC funding less than $100,000". This bias was subsequently addressed in the selection of the next three groups of projects.

3.2 Methods for Investment Analysis

All analysts were required to assess and quantify the benefits and costs of each of the projects evaluated. While the methods varied slightly, all analysts followed a social benefit–cost analysis framework. The process included identifying research costs and outputs, and then linking the outputs to benefits, which were valued. This allowed the definition and comparison of a 'with' R&D scenario with a 'without' R&D scenario.

R&D costs

Several different costs were included in total 'R&D costs':

- R&D costs of the specific project being evaluated (including LWRRDC research costs and the costs of other collaborators);
- costs of extension of project outputs where necessary: and
- costs of related projects (parallel, follow-up) needed to achieve the project benefits identified.

This last component refers to the situation when benefits from a single project were linked to the success of a parallel project, or when a follow-up project was necessary to translate the analysed project results into benefits. Some analysts included an estimate of the costs of a parallel or follow-up project where it was assumed to be necessary.

Research benefits

In order to identify project benefits, all analysts identified technical and other outputs, and made estimates of the resulting benefits. In some cases where a particular benefit was defined, a number of factors may have contributed to the achievement of the benefit. In these cases, the analysts often found it difficult to define the proportion of the benefits that could be attributed to the project being evaluated. Research benefits reported were, in the main, net of implementation costs incurred in captruing the benefits.

Dilution of benefits

Most analysts diluted the potential benefits by applying a dilution factor for the probability of research success. Also considered explicitly in some cases, were estimates of the profile of adoption of project outputs. However, in other cases dilution for less-than-complete adoption was implicitly included in the level of net benefits assumed.

In addition to determining the returns to all project resources, the analyst for the second group of projects also estimated the returns to the investment provided by LWRRDC. A dilution factor was estimated and applied for the likelihood of the project progressing without

LWRRDC's research investment, and a second dilution factor applied based on the proportion of total R&D investment contributed by LWRRDC.

Investment criteria calculated

The investment criteria calculated for the first three groups of projects were:

- net present value (NPV);
- internal rate of return (IRR); and
- benefit to cost ratio (B/C ratio).

Individual investment criteria were not presented for some projects.

IRR was not reported for the fourth group of projects.

All analysts recognised that, because of a lack of reliable information on which to base their estimates of likely outputs and therefore of benefits and implementation costs, calculating investment criteria early in a project can be difficult and results variable. While in most cases the investment criteria were calculated, it was stated that the results were only indicative, and not necessarily reliable.

Identification of risks

While the Group 1 analysts were not asked to explicitly identify risks, they did include an assessment of risk in their investment analysis. Also, for about half of their projects, they initially used the @RISK program in their analysis. However, by their second revision (1998) they were only using it for just one of their projects.

Group 2 analysts "used expected values (based on event probabilities) for individual variables, based on specific research and experience, making these transparent in the analysis to allow for the judgement of others and provide a basis for sensitivity analysis".

The analysts for Groups 3 and 4 both present a slightly more extended discussion of the possible risk associated with a project's success, and in most cases present possible strategies LWRRDC and the project managers could take to ameliorate those risks.

Discount rate

Analysts used a 7% discount rate, with some sensitivity analyses effected at 4% and 10%.

Dollar terms

All analysts measure benefits and costs in dollars of the initial year of funding. Those groups that have had revisions have continued to use the same base year and dollar terms.

Time frame

The analyses of Groups 1 and 3 are based on a 20-year period, with year 1 being the first year of the project. The Group 2 analysis uses a 30-year period, while the analysis for Group 4 uses both 20 and 30-year periods, depending on the particular project.

Curtailing of benefits

The analyst for Group 2 curtailed benefits for some projects before the end of the standard investment analysis period.

4 Results of Quantitative Analyses

4.1 Summary Results for Each Group

Table 1 shows the NPV estimated for each project by group. These results apply to the first evaluation for each group, carried out in the first year of the project. The total and average NPV for each group are also shown. It should be noted that NPVs for three projects were not estimated initially for Group 1. Two of these were subsequently estimated in the revisions of Group 1 and were assessed as being in the relatively low range ($0–5m). This has possibly biased upwards the average for Group 1 in Table 1.

Tables 2 and 3 present summaries of each of the IRR and B/C ratios, including the simple average, number of projects analysed, and the ranges for the investment criteria in each group.

Table 4 shows the simple averages of the three investment criteria for each group. The simple averages for the NPV suggest that there may have been significant differences between the population averages or between analysts of the four groups of projects, although the sample sizes are small. While the averages for the IRR and B/C ratio are calculated here as simple averages, it is recognised this may be less meaningful than if they were calculated on aggregated costs and benefits for all projects within a group. Details of all investment criteria for individual projects are given in Appendix 4.

Table 2. Summary of simple average IRRs for initial evaluation for each group[a]

Group	Average IRR (%)	n	Range of IRRs
Group 1	49.7	3	29 – 81
Group 2	27.1	8	8 – 74
Group 3	48.1	8	26 – 94

[a] IRRs not calculated by Group 4

Table 3. Summary of simple average B/C ratios for initial evaluation for each group

Group	Average B/C ratio	n	Range of B/C ratios
Group 1	12 to 1	4	4–22
Group 2	7 to 1	8	1–17
Group 3	12 to 1	8	2–45
Group 4	29 to 1	8	10–53

Table 1. Individual project NPVs ($m) for initial evaluation for each group

Group 1		Group 2		Group 3		Group 4	
Project	NPV	Project	NPV	Project	NPV	Project	NPV
Pesticide program	107.0	GRU18	0.2	UAD14	7.9	CLW7	28.5[a]
UMO18	b	UOC9	3.4	CSF1	3.0	MIL1	92[a]
DEP1	b	AGS1	6.4	UQ13	0.5	UMO36	85[a]
UNE11	9.3	VCA1	1.7	MDB4	7.2	GBC1	62[a]
CWW18	88.3	CWE11	0.5	UQL10	2.7	CEN4	31
MDR	2.8	UAD12	2.4	UME25	2.9	CPI7	190
CPI4	b	UAD10	2.8	CWE13	1.3	CWE23	34
QPI14	94.8	CWW22	1.0	DAV21	0.8	ANU11	9[a]
Total	195.2[c]	Total	18.4	Total	26.3	Total	531.5
n[d]	4	n	8	n	8	n	8
Average	48.8[c]	Average	2.3	Average	3.3	Average	66.4
Range	3–95	Range	0.2–6	Range	0.5–8	Range	9–190

[a] Group 4 analysts reported a range of NPVs for most of the results. Where this was so the midpoint is presented. b Not derived

[c] Total and average calculated excluding the Pesticide Program. [d] Number of observations

Table 4. Simple average investment criteria for initial evaluation for each group

Group	NPV ($m)	IRR (%)	B/C ratio
Group 1	48.8	49.7	12 to 1
Group 2	2.3	27.1	7 to 1
Group 3	3.3	48.1	12 to 1
Group 4	66.4	not calculated	29 to 1
Overall average[a]	27.5	39.5	15 to 1

[a] Simple average over all projects for which the particular investment criterion was calculated.

Table 5 shows the distribution of the NPVs by group. As mentioned earlier, for Group 1 it is likely that two more projects could be added to the $0–5m category, based on the results of projects analysed in the revisions but not analysed in the initial evaluation.

Table 5. Distribution of NPVs by group

NPV range ($m)	Group 1	Group 2	Group 3	Group 4[a]
0–5	1	7	6	0
6–10	1	1	2	1
11–20	0	0	0	0
21–50	0	0	0	3
51–100	2	0	0	3
>100	0	0	0	1

[a] Group 4 analysts reported a range of NPVs for the majority of the individual project results. Where this is so the midpoint has been used

It can be seen that the NPVs for projects in Groups 1–3 tend to be smaller than those for Group 4 projects.

4.2 Change in Results over Time

Group 1 has had three phases of evaluations (two revisions). A summary of changes in average distribution of investment criteria over these three phases is presented in Tables 6 and 7.

Tables 6 and 7 show that there is a large reduction in the size of the investment criteria, particularly the NPV, in the first review of the analysis. The average NPV falls from $48.8m in 1994 to $8.6m in 1996. This fall was caused by the addition of three projects not reporting investment criteria at all in 1994, as well as by downward revisions of the NPV for the other four projects. When moving from the first review to the second review, the average NPV increases slightly (from $8.6m to $9.3m), but all of the individual project NPVs decrease or remain the same and the average B/C ratio and IRR both fall. The average NPV increases because two projects included in the first revision were excluded from the second revision. The reason for this exclusion is not clear.

Table 6. Simple average investment criteria for Group 1

Phase	NPV ($m)	IRR (%)	B/C ratio
1 (1994)	48.8 (n = 4)	50 (n = 3)	12 (n = 4)
2 (1996)	8.6 (n = 7)	30 (n = 5)	9 (n = 5)
3 (1998)	9.3 (n = 5)	24 (n = 4)	6 (n = 7)

Table 7. Distribution of NPVs for Group 1

NPV range ($m)	Initial	1st review	2nd review
0–5	1	5	4
6–10	1	1	0
11–20	0	0	0
21–50	0	1	1
51–100	2	0	0
>100	0	0	0

The evaluators for Group 1 identify a number of minor factors contributing to the reduction in investment criteria between the initial evaluation and the first and second revisions. These include:

- a number of projects were given extra funding which was not fully matched by additional project objectives and technical outputs; and
- delayed technical outputs and technology transfer led to greater discounting of project benefits relative to costs. Delays experienced were due to factors such as
  - — staff changes,
  - — unforeseen equipment problems, and
  - — adverse weather.

More importantly, the researchers further state that "the findings suggest that initial objectives of researchers and beliefs about outcomes may have been too ambitious". Further reasons identified for the decline in investment criteria included:

(i) earlier estimates of adoption turning out to be over-optimistic — this has been a factor in about half of the projects analysed, with for example the timing of adoption for UNE11 moving back five years.

(ii) uncertainty in estimated values of social and collective goods — an example of a project where this has been a factor is DEP1, which requires the valuation of wetlands and floodplains; and

(iii) refinement of valuation methods.

Group 2 has had two evaluations (one revision). A summary of changes in average and distribution of investment criteria over the two evaluations is presented in Tables 8 and 9.

Unlike Group 1, the averages of the investment criteria for Group 2 are higher in the first review than in the initial evaluation. The average NPV increases from $2.3m to $7.5m because the investment criteria increase for all projects. An example of a project which experiences a slight increase is UOC9; the increase is from $3.4m to $5.5m. This is attributable to several factors. Firstly, because the project was successfully completed, there was increased certainty about project benefits, and several of the risk factors were removed. Also, the benefits calculated in the initial evaluation were based on likely cost savings from use of the technology developed in the project. Since project completion, the technology has been adopted and is being used in addition to other methods. The evaluation method changed from one of cost savings to a willingness to pay for benefits being realised earlier than they would have otherwise. The average B/C ratio and IRR were both similarly influenced for this project.

Table 8. Simple average investment criteria for Group 2 projects

Phase	NPV ($m)	IRR(%)	B/C ratio
1	2.3 (n = 8)	27 (n = 8)	7 (n = 8)
2	7.5 (n = 8)	31 (n = 8)	18 (n = 8)

Table 9. Distribution of NPVs for Group 2 projects

NPV range ($m)	Initial	1st review
0–5	7	3
6–10	1	4
11–20	0	0
21–50	0	1
51–100	0	0
>100	0	0

A project to experience a significant increase in the investment criteria calculated was CWW22. Here the NPV increased from $1m to $27m, while the IRR increased from 22% to 60% and the B/C ratio from 1:1 to 55:1. This increase is largely attributable to an increased certainty about project benefits following its successful completion. Also influencing the change is a significant increase in the estimated cost of dryland salinity (from $14m per year in 1990 to $270m per year for the Murray–Darling Basin alone).

The results for one project (CWE11) did not change at all, as the analysts felt there was no reason to change the assumptions. The results for the other five projects increased slightly.

However, in Group 2's summary they state that "the ex-ante assessment (the initial analysis) was more optimistic in delineating the specific use, time path and valuation of the total benefits. Specifically, actual users were often a smaller group than originally suspected and the information benefits or cost savings were not as significant as postulated". This appears to be at variance with the increase in investment criteria calculated for each project. However, the downward revisions in these assumptions are offset by other factors, including the reduction or removal of probabilities of success.

Based on the above information, it is assumed that the most recent set of results from projects in Groups 1 and 2 is the best estimate of investment criteria. This is because these estimates were determined after implementation, and in some cases completion, of the projects. More information is available about the expected outputs and benefits, and the associated risks of achieving those outputs and benefits.

The averages of the investment criteria for each group are presented in Table 10, with project results for Groups 1 and 2 now including the latest estimates of the investment criteria, as opposed to the initial estimates presented in Table 4.

Table 10. Simple average investment criteria by group, using the latest estimates

Group	NPV ($m)	IRR (%)	B/C ratio
Group 1	9.3 (n = 5)	24 (n = 4)	6 to 1 (n = 7)
Group 2	7.5 (n = 8)	31 (n = 8)	18 to 1 (n = 8)
Group 3	3.3 (n = 8)	48 (n = 8)	12 to 1 (n = 8)
Group 4.	66.4 (n = 8)	not calculated	29 to 1 (n = 8)
Overall average[a]	23 (n = 29)	36 (n = 20)	17 to 1 (n = 31)

[a] Simple average over all projects for which the particular investment criterion was calculated.

Table 11 presents a comparison of the simple average B/C ratios presented in Table 10 and the B/C ratio of the total present value of benefits (PVB) and the total present value of costs (PVC) for projects within each group. A total B/C ratio for all projects in Groups 2, 3 and 4 is also presented.

Table 11. Ratio of total PVB to total PVC compared with simple average B/C ratio[a]

Group	Simple average B/C ratio	Ratio of total PVB to total PVC
Group 2	18 to 1	11 to 1
Group 3	12 to 1	8 to 1
Group 4	29 to 1	23 to 1
Average	20 to 1	19 to 1

[a] No PVB or PVC estimates available for Group 1 projects.

4.3 Differences Between Groups

Differences between the average investment criteria of the four groups of projects could be due to sampling error, to changes in the populations of new projects from year to year, or to differences between analysts in terms of their overall methods and assumptions used.

Although the sample sizes were small, an analysis of variance of the project NPVs was carried out and showed that there were likely to be differences between analysts ($p = 0.05$). This was the case whether the groups of projects included the initial estimates or the revised estimates (after the revisions for Groups 1 and 2). Table 12 presents the averages and standard deviations of the NPVs and B/C ratios for the initial analysis of each group. Table 13 presents the same information for the best-bet (most recent) analyses.

4.4 Interpretation of Results

The results demonstrate a likely high rate of return for LWRRDC and its partners to their investment in natural resource management R&D. While there are necessarily significant uncertainties regarding assumptions made in these analyses, the number of projects evaluated across a range of geographical areas, land and water systems, disciplines and research types, and the fact that a number of independent analysts have been involved, suggest that a reasonable degree of confidence can be held in the results.

A conclusion therefore might be that the investment in R&D by LWRRDC and others is paying off. However, even for earlier projects, some of the assumptions made about the adoption and extent of benefits may still lie in the "yet to be captured arena". Thus, it would be of interest to calculate additional investment criteria that rely only on the benefits that have actually accrued to date.

There are several generic issues associated with the approach, most of which were raised by one or more of the analysts. These include:

- the lack of information in general for valuing benefits, particularly non-market benefits;
- the difficulty in tracing through the expected outputs of the research, through outcomes to benefits, and the number of alternative pathways that can be defined and valuation methods that can be used, particularly for analyses early in the project;

Table 12. Analysis of NPVs and B/C ratios for initial analysis by group

	NPV				B/C ratio		
	Total	n	Average	Standard deviation	n	Average	Standard deviation
Group 1	195.2	4	48.8	49.4	4	12.2	8.7
Group 2	18.4	8	2.3	2.0	8	17.0	6.4
Group 3	26.3	8	3.3	2.8	8	12.0	13.8
Group 4	531.5	8	66.4	57.7	8	29.1	14.3
Overall average	771.4	28	27.5[a]	45.6[b]	28	15.0[a]	14.2[b]

[a] Simple average over all projects for which the particular investment criterion was calculated.

[b]Calculated for all projects for which the particular investment criterion was calculated

Table 13. Analysis of NPVs and B/C ratios incorporating latest estimates

	NPV				B/C ratio		
	Total	n	Average	Standard deviation	n	Average	Standard deviation
Group 1	46.6	5	9.32	17.8	7	6.6	8.7
Group 2	59.9	8	7.5	8.6	8	18.4	18.3
Group 3	26.3	8	3.3	2.8	8	12.0	13.8
Group 4	531.5	8	66.4	57.7	8	29.1	14.3
Overall average	664.3	29	23[a]	40.6[b]	31	16.8[a]	16.1[b]

[a] Simple average over all projects for which the particular investment criterion was calculated.

[b]Calculated for all projects for which the particular investment criterion was calculated

- the paucity of information on adoption and the lack of a process for assembling such information as projects are completed;
- whether institutional impediments to adoption are sufficiently accounted for in dilution factors;
- the time taken for biophysical changes in the environment to become evident; and
- the critical values for the degree of intervention required for some improvements in the environment to be realised (eg. respective reductions in blue-green algae or dryland salinity in response to lowered nutrient run-off or tree planting across a catchment).

The two analysts who have carried out revisions both concluded that their initial evaluations were perhaps optimistic in terms of applicability and adoption, timing, and magnitude of cost savings. However, for one analyst, despite this conclusion, the actual investment criteria increased mainly because of greater certainty of research outputs being realised.

Nevertheless, the results should certainly be interpreted as indicating a very positive return to past investment in natural resource R&D, and should provide confidence for future investment.

Case Study — Project CEN4

Putting the Earthworm to Work

As a result of research by CSIRO Entomology, the common European earthworm may prove to be the technical solution to a problem facing many Australian primary producers.

Soil acidity is slowly encroaching on many farms with the result that plants grow less well and some plants cannot be grown at all. Moreover, as acidification increases, there is a greater chance that toxic metals will be released. These can be taken up by pasture and crops and so get into the food chain. They can also pose a threat to urban water supplies.

The traditional means of combatting acidification is to apply lime to the soil. That is certainly effective, but it has its difficulties. The lime has to penetrate the soil, but if it is simply spread and left to leach in, the process can be very slow. Worse still, much of the lime may wash off into water courses before it has a chance to enter the soil at all.

On the other hand, digging the lime in mechanically is too expensive unless it can be combined with cultivation for crop-sowing. Grazing land and horticulture cannot be mechanically limed at reasonable cost.

One answer to these problems is the earthworm. Earlier research has shown that the deep-burrowing European earthworm *Aporrectodea longa* can be very useful in burying lime that has been spread over the surface. At present these earthworms are established in agricultural soils only in Tasmania, but it seems likely that they could be introduced to many parts of southern Australia where the rainfall exceeds 600 mm a year.

Field trials

That of course needs to be verified and CSIRO proposes to conduct field trials in a range of locations in South Australia, New South Wales, Victoria and Tasmania. Scientists need to know how well the earthworms will fare in different soils and at varying temperatures and moisture content. What food do the earthworms need to find in the soil, and will that itself be affected by acidity?

If the trials prove to be a success, the benefits to farmers in high rainfall areas could be considerable. The introduction of the earthworms could mean that farmers would be able to grow the same amount of produce with less land and without having to spend as much on fertilisers and fuel. Pastoral properties in particular would benefit if the earthworms buried the lime effectively and the quality of the pasture improved.

The researchers also want to find the best means of producing enough earthworms to do the job and the best ways of introducing them to the soil. There are already firms which specialise in the production of earthworms and these will be able to carry out the necessary mass rearing of the creatures with the benefit of the knowledge gained from the project's research findings. But do the farmers know the best way of introducing the earthworms to the soil and will this be a process that needs to be repeated?

Trial and error?

Previous research has already shown that the earthworms can help to bury lime to a depth of 15 to 20 cm in one winter and there are properties in Tasmania where new pastures are routinely 'inoculated' with the European earthworm. This obviously raises the question whether further research and development is needed or whether earthworm producers and farmers can be left to get on with the job and solve any problems by trial and error.

There are considerable risks in that approach. There would be little incentive for the people involved to disseminate the results of their work and in any case they would lack the scientific base to deal with unforeseen problems.

The earthworms might die, for instance, or fail to

colonise certain areas. It could also happen that the process would be commercialised before the right way of getting the earthworms into the soil had been established. They cannot simply be scattered around in the hope that they will colonise the soil. The earthworms need to be at the right stage of maturity, the inoculation needs to take place at the time of year when they are most active, and there needs to be a sufficient quantity of them to deliver benefits within a reasonable time. Unless all these factors are understood and the appropriate methods applied, trial-and-error attempts could easily produce more error than success. That of course would mean that the whole process could be dismissed as ineffective.

By combining scientific and practical research, this project can offer farmers an effective and relatively cheap means of rectifying soil acidification by getting lime into the soil at the depth where it is really needed.

The farmers' interest and estimated benefits

But will farmers be interested? One of the characteristics of soil acidification is that it is often so gradual that farmers scarcely realise that it is happening; and when they do, they may very well decide that the answer is to change crops. When this proves ineffective, they may take remedial action or, if the worst comes to the worst, abandon the land. The remedial action is usually to apply lime by top-dressing and since this is a time-honoured practice and often shows some quick effects, it will again take some time before the farmer realises that the soil is slowly but surely becoming more acid and less productive.

LWRRDC's role here is likely to be that of finding out from farmers what their priorities are and what reasons there may be for taking no action or too little action to counter acidification. At the same time, LWRRDC would need to research and document the facts about irreversible damage to land from acidification and the downstream costs of it and then to let the farming community know the results.

Meanwhile, it is proposed to go ahead with the earthworm project so that a positive and constructive solution can be offered to farmers who are aware of their acid soil problems. The principal researcher is entomologist Dr Geoff Baker of CSIRO and that organisation is bearing three-quarters of the cost of the research. Other organisations are also involved, such as Landcare groups and the Soil Action Program of NSW Agriculture.

The project is expected to cost about half a million dollars, but the benefits could be considerable. Assuming that the innovation is applied to dairying properties in high rainfall areas, farmers could expect to find that a single inoculation with earthworms would make the future application of lime a much cheaper and more effective means of improving pasture. And the community at large would have less to worry about from the effects of soil acidity on water supplies and the food chain.

Return on investment

Net present value	$31 M
Benefit–cost ratio	53:1

5 Other Results from the LWRRDC Evaluations

5.1 Impact of Evaluations on Project Design

The analysts for Group 2 note that the objectives several projects in their group have changed significantly, for two reasons:

- revisions in initial project design in the light of peer reviewer comments on project proposals or additional research by researchers themselves; and
- adaptation in the light of project research or as a result of developments in the external environment.

However, there is no indication that the life-of-project evaluations have had any major impact on project design. As the evaluations were initiated after the project contracts were finalised, this is not surprising. Other evaluation processes (eg. milestone reporting) are in place to accommodate changes in project objectives and design as the need arises. Nevertheless, it is possible that the economic evaluations may have indirectly influenced particular emphases applied in some projects as they progressed. This could likely be best assessed by LWRRDC Program Managers.

5.2 Enhanced Information Assembly

All groups have identified and made recommendations about what information would be useful in any further investment analysis.

For Group 1, information and monitoring requirements that would enhance future analyses are identified for each project. However, no formal recommendations are made on how this information is to be collected. In the first review for Group 1, the analysts note that no systematic monitoring procedures had been introduced beyond the normal reporting requirements of researchers to LWRRDC. The analysts further note that further monitoring and information collection by the principal investigator may not be practicable. They recommend that, where research outputs have been commercialised, information on sales and revenue should be supplied.

In the second review for Group 1, the analysts further recommend that, where new life-of-project evaluations are commissioned, a more formal approach to monitoring, to which the researcher must contribute, may be desirable. If this were implemented, there would be a time cost to researchers. One suggestion is that a minimal critical data set for economic evaluations be negotiated with researchers.

There was no identification of specific information and monitoring requirements in the initial evaluation for Group 2 projects. The analysts identified key information gaps as being "subsequent adoption" or "utilisation of the research output". The Group 2 analysts recommend that researchers should be encouraged to document, as part of final reports, the use being made of the research findings, and follow up with researchers may include a short questionnaire one or two years after completion of the project. The researchers recognise allowance for such follow up should be explicit in initial contractual and financial arrangements.

Group 3 analysts clearly identify information for each project valuable for future evaluations. They also make the general comment that ongoing data collection for projects should be directed at confirming the original project objectives. They recommend that the type of data to be collected, and the method by which they are to be collected should be clearly defined in the project proposal. Further, the analysts make the comment that any *ex-ante* evaluation by an independent evaluator should be able to be conducted entirely from the information contained in the project proposal.

Group 4 analysts identify information gaps for each project, particularly in relation to information required to value benefits. The information seen as lacking may not need to be supplied by the project manager, It may be general information about natural resources, eg. valuation of the costs to Australia of different natural resource issues.

Overall, it appears there have been difficulties in ensuring that key information for evaluation is monitored and assembled within projects. The time and cost for overcoming these difficulties, the value of information produced in terms of the future ease, consistency and accuracy of analyses, and who should perform the activity, all require further thought.

5.3 Risk Assessment

Three aspects of risk assessment were addressed to varying degrees by the four analysts:

- inclusion of risk in investment analysis;
- identification of risks to individual projects; and
- recommendations for managing risk.

Risk assessment was not explicitly included in the TOR for Group 1, but one element of risk is included in the assumptions used in the analyses about probabilities of success. The analysts note that, in general, these probabilities refer to risks, particularly in the early stages of a project, relating to staff, weather and equipment problems. The analysts were not asked to make recommendations for managing risk.

Analysts for Group 2 identify two types of risks: technical and operational. These risks are identified and discussed for most projects, and are explicitly included as probabilities in the initial evaluation. Probabilities are not presented as explicitly in the first review. For many projects that are complete or nearing completion the technical risks are no longer included as the project has successfully delivered the expected outputs, but risks still apply to adoption and use of outputs. Generally, t few recommendations for managing risks are given for individual projects in the Group 2 reports.

Group 3 analyses do not appear to allow for risk in the form of explicit probabilities of success in the individual project investment analyses. Risks are identified, however, for individual projects under two headings: adoption risk and benefit measurement risk. Benefit measurement risk refers to risks associated with accurately measuring benefits to the project with the data available. The analysts make recommendations on how some of these risks can be managed. They generally do not make recommendations in relation to adoption risk.

Group 4 analyses, like Groups 1 and 2, included risks in the form of probabilities of research success in the evaluations. Group 4 identifies and discusses risk management issues for each project as part of three separate sections:

1. Is there a need for the project?
2. Is the project an appropriate response to the need?
3. Did LWRRDC need to get involved?

6 Comparison with Investment Criteria Produced in Other Studies

The results presented here are compared with the results of a selection of other benefit–cost studies of R&D investment undertaken in Australia and elsewhere.

This section is in three parts. The first part compares the most recent results for each of the life-of-project evaluations with four other sets of analyses concerned with investment in natural resource management R&D in Australia. The second part compares the LWRRDC results with a number of other studies on returns to investment in agricultural R&D in Australia. The third part compares the LWRRDC results with analyses undertaken outside Australia.

6.1 Other Australian Natural Resource Management R&D Analyses

It is difficult to make comparisons with other studies because of the different contexts in which those studies may have been made, the sample of projects selected, and the way in which investment analysis parameters have been derived and reported from study to study. With respect to the last-mentioned, examples of where differences may occur include the investment criteria actually reported, the discount rate, the base year to which the benefits and costs are discounted, and the dollar terms of the analysis. We have attempted to present comparisons of the three investment criteria with respect to their distributions across a range.

Table 14 presents the distribution of NPV results for a number of other studies including those by the CRC for Soil and Land Management (CRCSLM), the CSIRO Institute of Natural Resources and Environment (INR), the Sugar R&D Corporation (SRDC in conjunction with LWRRDC) and the Dairy R&D Corporation (DRDC in conjunction with LWRRDC). The last two studies were prospective, assessing potential natural resource management research areas for investment. Tables 15 and 16 present the distribution of IRRs and B/C ratios for the same studies where these criteria were available.

Table 14 shows that for the 29 LWRRDC projects reporting NPVs, 20 were estimated to have NPVs of less than $10 million, whereas of the 29 non-LWRRDC projects, only 7 were less than $10 million. Factors contributing to this difference were that the projects in the CRCSLM study were selected rather than random and PVB was used as a surrogate for NPV; also, the SRDC and DRDC studies were prospective and were assumed to be larger projects. It is interesting to note that the CSIRO analyses included productivity benefits as their primary source of benefits.

Table 15 shows that the LWRRDC IRRs were in fact greater than those estimated in the other studies. The LWRRDC IRRs show 55% of estimates were greater than 30%, whereas the other studies had only 27% greater than 30%. The simple average of the IRRs for the LWRRDC analyses was 36%, whereas for the other

Table 14. Comparison of NPVs – natural resource management R&D

Range of NPV ($m)	Number of projects within range								
	LWRRDC (Group 1)	LWRRDC (Group 2)	LWRRDC (Group 3)	LWRRDC (Group 4)	Total LWRRDC	CRCSLM (1998)*	CSIRO INR (1990)	SRDC (1997)	DRDC (1997)
Discount rate (%)	7	7	7	7	7	5	5	5	7
Negative	0	0	0	0	0	0	1	1	2
0–5	4	3	6	0	13	1	0	0	2
5–10	0	4	2	1	7	0	0	0	0
10–15	0	0	0	0	0	1	1	1	0
15–50	1	1	0	3	5	2	5	4	2
50–100	0	0	0	3	3	0	0	2	0
100–300	0	0	0	1	1	2	0	1	1
>300	0	0	0	0	0	0	0	0	0
Total	5	8	8	8	29	6	7	9	7

* These are PVBs.

projects, the simple average was 30% (excluding those that were negative).

For the B/C ratios, LWRRDC results showed that 32% of projects had ratios of greater than 20 to 1, and 37% of the other studies reported B/C ratios of greater than 20 to 1. However, the simple average B/C ratio for the LWRRDC studies was 17 to 1, whereas the simple average for the other studies was 46 to 1.

Bearing in mind the caution that should be exercised in such comparisons, it would appear that the LWRRDC results are not dissimilar to the other results reported.

At least two other evaluation studies have been undertaken by LWRRDC outside the life-of-project evaluations. These include an analysis of the Wagga Effluent Irrigation Plantation R&D (Sultech 1999) where the NPV was estimated conservatively at $132.6 million at a discount rate of 7.5%, and the benefit–cost ratio at 7 to 1. A second was a study of three projects from the National Program for Irrigation R&D (ACIL 1997,1999), performed in addition to the life-of-project evaluations. For these projects, the NPV at a 7% discount rate varied from $m –0.6 to 6 million, the B/C ratio from 0.3:1 to 18:1, and the IRR from 0 to 40%.

6.2 Other Australian Agricultural R&D Analyses

A second set of comparisons is made with results reported by other R&D Corporations. These encompass mainly productivity benefits, although in some cases natural resource benefits are included. Again, it should be noted that the following is not meant to be a comprehensive account of results of benefit–cost analyses in Australian agricultural R&D. Tables 17, 18 and 19 present the distributions of NPVs, IRRs and B/C ratios for both the LWRRDC life-of-project evaluations and for studies by other R&D Corporations.

The NPV comparisons suggest no major differences between the NPV distributions. LWRRDC results showed that 69% of the NPVs were less than $10 million while the results for the other studies (62 projects) showed 54% were less than $10 million.

Table 15. Comparison of IRRs — natural resource management R&D

Range of IRR (%)	Number of projects within range					
	LWRRDC (Group 1)	LWRRDC (Group 2)	LWRRDC (Group 3)	Total LWRRDC[a]	CSIRO INR (1990)	DRDC (1997)
Negative	0	0	0	0	0	2
0–10	0	1	0	1	0	0
10–20	2	2	0	4	1	4
20–30	1	1	2	4	0	1
30–40	0	2	2	4	0	0
40–60	1	2	2	5	1	0
60–100	0	0	2	2	2	0
>100	0	0	0	0	0	0
Total	4	8	8	20	4	7

[a] IRRs not calculated by group 4.

Table 16. Comparison of B/C ratios — natural resource management R&D

Range of B/C ratio (to 1)	Number of projects within range							
	LWRRDC (Group 1)	LWRRDC (Group 2)	LWRRDC (Group 3)	LWRRDC (Group 4)	Total LWRRDC	CSIRO INR (1990)	SRDC (1997)	DRDC (1997)
Negative	0	0	0	0	0	0	0	2
0–5	5	3	2	0	10	3	2	2
5–10	1	1	4	1	7	2	0	1
10–20	1	0	1	2	4	2	0	1
20–50	0	3	1	4	8	0	2	0
50–100	0	1	0	1	2	0	2	0
>100	0	0	0	0	0	0	4	1
Total	7	8	8	8	31	7	10	7

Table 17. Comparison of NPVs — R&D Corporations

Ranges of NPV ($m)	Number of projects in range							
	LWRRDC (total)	RIRDC[a] (Emerging Industries) (1998)	DRDC (1995) random	DRDC (1995) selected	GRDC[b] (1992) selected	PRDC[c] (1995) random	SRDC (1993) random	SRDC, BSES, SRI (1998) random
Discount rate (%)	7	7 & 10	7	7	10	5	5	5
Negative	0	0	1	0	0	0	0	0
0–5	13	6	2	1	3	0	1	6
5–10	7	0	2	0	2	3	1	5
10–15	0	0	0	0	3	0	1	0
15–50	5	0	0	4	2	3	2	3
50–100	3	0	0	0	2	1	0	0
100–300	1	0	1	4	3	0	0	0
>300	0	0	0	0	1	0	0	0
Total	29	6	5	9	16	7	5	14

[a] Rural Industries Research and Development Corporation [b] Grains Research and Development Corporation [c] Pig Research and Development Corporation

Table 18. Comparison of IRRs — R&D Corporations

Ranges of IRR (%)	Number of projects in range							
	LWRRDC (total)	RIRDC (Emerging Industries) (1998)	DRDC (1995) random	DRDC (1995) selected	GRDC (1992) selected	PRDC (1995) random	SRDC (1993) random	SRDC, BSES, SRI (1998) random
Negative	0	0	1	0	0	0	0	0
0–10	1	0	0	0	0	0	0	1
10–20	4	2	2	0	0	0	0	3
20–30	4	0	1	1	0	1	2	2
30–40	4	0	0	0	3	2	0	2
40–60	5	2	0	0	4	1	2	1
60–100	2	1	0	0	4	2	0	2
>100	0	0	1	3	5	2	1	2
Total	20	5	5	4	16	8	5	13

Table 19. Comparison of B/C ratios — R&D Corporations

Ranges of B/C ratios (to 1)	Number of projects in range							
	LWRRDC (total)	RIRDC (Emerging Industries) (1998)	DRDC (1995) random	DRDC (1995) selected	GRDC (1992) selected	PRDC (1995) random	SRDC (1993) random	SRDC, BSES, SRI (1998) random
Negative	0	0	0	0	0	0	0	0
0–5	10	3	3	2	3	0	0	3
5–10	7	0	2	0	3	0	1	4
10–20	4	1	0	1	1	2	0	3
20–50	8	2	0	3	5	4	1	1
50–100	2	0	0	0	2	2	2	3
>100	0	0	1	0	2	0	1	0
Total	31	6	6	6	16	8	5	14

Fifty-five percent of the LWRRDC projects had IRRs greater than 30% whereas 71% of the projects analysed by the other Corporations had estimates of IRRs of greater than 30%.

For the B/C ratios, the LWRRDC results showed that 32% of projects had ratios of greater than 20 to 1, whereas 48% of the other Corporation studies reported B/C ratios of greater than 20 to 1.

Taking into account that some of the other Corporation projects analysed were selected, it would appear that the LWRRDC analyses have produced results not unlike those from other R&D Corporations.

6.3 Overseas Investment Criteria for Natural Resource Management R&D

A literature search was undertaken to identify benefit–cost analyses made in other countries on the returns to investment in natural resource management R&D.

6.3.1 Search methods

Search methods used to identify relevant literature included:

(i) Bibliographical database search using Infotrac and WinSPIRS 2.1:
- AGRICOLA
- ABI/Inform
- BAOD:FIBLIN (economics, finance, management)
- EconLit
- CAB Abstracts

(ii) Library Search

The University of Queensland (UQ) database of holdings was searched independently, as well as by an experienced UQ librarian. A general, key word search for references in the library was undertaken. Journal articles, books and reports relevant to the topic were identified and reviewed.

(iii) Internet search

An Internet search was undertaken using a number of search engines and a range of key words. 'Alta Vista' and 'Hotbot – advanced search' were found to be the most useful search engines. This search resulted in the identification of several useful US, Canadian, UK and European university web-sites. Also, for a range of countries, government departments (of agriculture/natural resources or similar), private consultancy groups, environment and natural resource government centres, economic departments within particular organisations, research evaluation groups, conservation groups, etc. were identified.

For each relevant web-site, a search was undertaken to identify individual staff members and/or departments of greatest relevance to the topic. Where email addresses were available, a request for assistance was sent to the individual and/or department.

(iv) Email queries

Following the Internet search and bibliographical database search, over 180 email queries were directed to relevant persons and institutions in the USA, Canada, UK, NZ and several European and other countries. Appendix 5 details the institutions from which responses were gained. Responses were received from over 90 individuals.

6.3.2 Results

Very few quantitative evaluations of natural resource R&D have been identified as a result of the overseas literature review despite the wide range of experts and relevant organisations contacted.

The most useful finding was a discussion paper (Alston et al. 1998) published by the US-based International Food Policy Research Institute (IFPRI). Some 289 studies of returns to agricultural research, development and extension (RD&E) are compiled in this paper. Only 16 of the 289 studies reported returns to research with a natural resource focus. Further, the natural resource focus was defined as projects associated with forestry and fisheries. Within the 16 natural resource studies, a 61 observations of rates of return were identified. The mean rate of return of the 61 observations is reported to be 41.96% and the standard deviation 71.35.

A previous draft of the paper identified two data-sets:

1. The first data-set reports the results for natural resource research projects from which the lowest and highest 2.5% of observations of all rates of return were excluded (95% data-set). The average rate of return for RD&E projects within this data-set was 32.9% with a standard deviation of 46.5.
2. The second data-set was compiled by identifying and excluding projects where the observations of rates of return were greater than 500% per annum. The average rate of return for RD&E projects within this data-set was 38.6% with a standard deviation of 69.0.

Further details on the individual natural resource projects assessed within the Alston et a. (1998) study were requested, but were not made available to Agtrans Research. The Netherlands-based International Service for National Agricultural Research (ISNAR) reports that the Alston et al. (1998) paper is expected to be followed by a string of further publications, thus additional details may be forthcoming in the future. However, based upon

the information published to date, it could be concluded the average rate of return to natural resource R&D projects as determined by Alston et al. (1998) is around 40%. No details are available for other investment criteria.

A second overseas study of lesser relevance was identified. This study evaluated the impact of integrated pest management (IPM) research in the International Agricultural Research Centres (Waibel 1999). This study concluded the rate of return to investment in IPM R&D is in the order of 15 to 40%. Both productivity and environmental implications were included within the study, although details regarding the actual benefit and cost items were not published.

Apart from the Alston et al. (1998) study, the literature search identified a substantial number of BCA studies undertaken to determine the costs and benefits of particular actions to conserve or sustainably manage wildlife/ vegetation or other natural resources. For example, one study determined the economic values and tropical forest functions of the Korup National Park, Cameroun. Benefits of conservation were compared with the costs of the conservation project plus any forgone timber revenues (Pearce 1993). Another study investigated the benefits of afforestation in northern Nigeria. Two analyses were undertaken to determine the returns to investment in shelterbelts (for wind protection) and farm forestry (Pearce 1993). A further study investigated the costs and benefits of reducing acid rain, but the potential impacts of R&D were not analysed (Burtraw et al. 1997). A number of other studies were identified. Table 20 presents a sample of the studies identified.

As shown in Table 20, results are typically incomplete, with many published studies failing to report the time frame over which the analysis was undertaken, the discount rate applied, and the individual cost and benefit items included in the analysis. Further, the IRR results were reported for all studies identified, but NPV and B/C ratio were often omitted. The results of these analyses indicate returns to investment in management practices to improve the sustainability of natural resource use or to conserve/preserve the environment are typically marginal to positive (ie. between 5 and 19%). However, it is possible the returns could be underestimates, as some benefits may be difficult to quantify and may not have been included.

Based upon the results of the literature review, it appears that more studies have been undertaken overseas than in Australia to determine the returns to investment in particular environmental and natural resource management strategies. The Envalue database published by the Environmental Protection Agency in NSW is the main source of environmental values in Australia, and many values within it are based upon studies undertaken overseas. As environmental values differ significantly between regions, this finding could suggest the need for further studies to be undertaken within Australia to determine the returns to investment in particular actions with environmental/natural resource benefits.

Despite the large number of overseas studies identified that quantify in economic terms the benefits and costs of adopting particular environmental and natural resource management strategies, it appears there have been limited analyses undertaken to determine the returns to investment in natural resource R&D.

An article published within a key economic journal (*Oxford Review of Economic Policy*) in 1988 reported that the use of BCAs by the UK Environment Agency has been limited. Despite the *Environment Act 199*5 requiring the Environment Agency take account of the costs and benefits of its activities, in practice little attention has been given to such assessments. It is reported that of the 9,000 employees of the Environment Agency, currently only five are economists (Helm 1988).

Table 20. Results of a sample of benefit–cost analyses undertaken to determine returns to investment in environmental/ natural resource management

Study	NPV	B/C ratio	IRR (%)
Cameroon: Korup Forest Project[a]	–CFA 1,852 million	NA	6
Afforestation in Northern Nigeriaa	NA	NA	5
Nepal: Phewa Tal Watershed Development[b]	NA	NA	8.5
Philippines: Palawan environmental protection and management[b]	NA	NA	7
Morocco: Loukkos Basin Watershed Management[b]	NA	NA	15.9
Analysis of the Maissade, Haiti, integrated watershed management project[c]	US$ 336,600 (at 12% discount rate)	1.5 : 1	19
Economic evaluation, land/water use and sustainable nature conservation of 'De Vechtstreek' Wetlands, The Netherlands[d]	NA	NA	18

[a] Pearce (1993); [b] Winpenny, (1991); [c]White and Quinn (1992); [d] Bos and van den Bergh (1998); NA Not available within the reference.

George Norton, co-author of the 1995 publication "Science Under Scarcity, Principles and Practice for Agricultural Research Evaluation and Priority Setting" provided some comment via email on why there are few benefit–cost analyses undertaken for natural resource R&D in the USA. He identified four crude, non-published studies and a few journal articles but commented that these analyses stopped short of calculating rates of return. It was noted there would not be many carefully undertaken BCAs for natural resource R&D, and most would be 'quick, seat-of-the-pants' B/C studies that would not stand up to peer review.

Stan Divorski, Natural Resources Canada commented there is an "international community of professionals who have been struggling with the issue of how to evaluate research and development programs". This comment suggests research evaluation may not be as well developed overseas as it is in Australia. The results of the current literature review support this hypothesis.

Professor John Strasma, University of Wisconsin, USA, provided comment that many studies are done in-house and are often marked "preliminary, do not cite or quote". Further, "an awful lot of feasibility studies are in-house…", thus reinforcing the difficulties associated with identifying BCA studies that determine returns to investment in natural resource R&D.

Kelly Day-Rubenstein from the Economic Research Service (ERS), Resource Economics Division of the US Department of Agriculture commented "I am unaware of any rate of return studies for environmental and natural resource R&D". Reasons suggested for the apparent lack of studies in this area in the US included:

- the difficulty in defining natural resource and environmental R&D;
- establishing the measure of improvement resulting from R&D is more difficult to establish for many resource and environmental amenities; and
- the difficulties in establishing values for natural resource and environmental benefits is complicated by the non-market nature of these goods, and the limits of many non-market valuation techniques.

Furthermore, Jet Yee, Economist within the ERS confirmed the main reason why BCAs are not used to assist in determining the returns to investment in natural resource R&D in the US is that it is too difficult to measure the output or value of benefits from natural resource R&D expenditure.

Other relevant comments provided by various individuals include:

- "In general people don't do retrospective analyses of natural resources investments except for extractive industries." (USA university representative)
- "I imagine the natural resource R&D (ie. investigations into the benefits and costs of new practices for environmental conservation) is still fairly unknown, as it is a fairly new concept." (USA university representative)
- "I have seen one or two studies done to provide an indication of the economic return to investment in R&D in the natural resource/environmental area in the US when I was there." (UK university representative)

The process of searching for literature on the topic of returns to investment in natural resource R&D was very time consuming. Much information was not easily accessible and was fragmented across a large number of sources. There may be considerable value in somehow linking the relevant data sources, or compiling a reference document that concentrates the various sources of information at one location. This task could be undertaken by LWRRDC in the future, as it appears Australia may be responsible for a high proportion of the published research evaluation work on natural resource R&D.

In summary, very few BCAs were identified in the overseas literature that reported returns to investment in natural resource R&D and the average return to investment (IRR) for these evaluation studies was about 40%. Further, a significant number of studies was identified that reported returns to investment in actions to preserve, conserve or more sustainably manage natural resources and the environment, but these studies were seldom carried out in a research evaluation framework.

It may be no more than coincidence that the only average IRR that has been produced so far for overseas studies is similar to that produced by the LWRRDC evaluations.

Case Study — Project CWE13

Saving What's Left of Biodiversity

Most Australians nowadays are aware that since human beings began to farm, cultivate and build, the continent has lost much of its biodiversity. It has been estimated that by 1990 some 103 million hectares of forest and woodland had been cleared. More than 48% of the entire continent has been disturbed and there is not a single type of vegetation that has not been disturbed by human activity.

The introduction of foreign species has been particularly disruptive because the native plants and creatures have never developed the defence mechanisms needed to survive in competition with the outside strains. So plants, animals, birds and insects have all succumbed to a greater or lesser extent. At the same time, the loss of their natural habitat has rendered them even more vulnerable. Many species have disappeared altogether, others are under threat, and many more have an uncertain future if action is not taken speedily. At the same time, retaining biodiversity is now recognised as an important means of achieving ecological sustainability — an insurance policy for future generations of Australians. For that reason, Australia signed and ratified the Convention on Biological Diversity, which came into effect in 1993, and so accepted an international obligation to protect its biodiversity.

One of the principal ways of stopping the rot is to take action to preserve what is left of the continent's original vegetation ('native vegetation'); and this is the theme of a project developed by LWRRDC in conjunction with Environment Australia.

Words are cheap, action may cost

Attempts to make the public aware of the dangers have been relatively successful. Education campaigns in schools and through the media have brought the matter firmly to national attention. But taking effective action is another, and often costly, question.

What government needs at this stage is not more talk but policies on which it can act effectively and at acceptable cost. These are what the research team proposes to develop.

Drawing the line?

There has already been a great deal of action, of course. The traditional way of preserving remnant vegetation was to create reserves. Governments would acquire tracts of land, draw a line around them and strictly control the activities that were permitted inside the boundaries. Preferably, the tracts of land would contain the widest possible biodiversity.

To some extent this policy has been successful, though expensive. But it is now realised that it has a serious limitation. Many of the threats to biodiversity originate outside the reserves and so cannot be mitigated simply by on-reserve policies and practices. New regional mechanisms are needed which will integrate activities on the reserves and off them and so control the dangers wherever they may occur. Means must be found to encourage people to protect the habitat and to apply land management principles that will maintain our natural resources.

The five threads

The research team sees the necessary policies as consisting of five interwoven threads. With these the Commonwealth, State and Territory, and local government system should be able to rescue some at least of the remnant vegetation which otherwise will disappear as it has in the past.

The five threads are: direct payment guidelines, incentives for local government, perverse rating incentives, incentives for NGOs, and taxation incentives.

Covenants and agreements

Direct payment guidelines will be directed towards covenants and heritage agreements, which bind all future landowners, and management agreements which hold for an agreed period.

Under these covenants and agreements, landholders agree to take action (or refrain from it) for the sake of preserving biodiversity and are reimbursed for the incremental costs of conforming with these agreements. The researchers will examine whether this approach will prove less costly to government than direct acquisition and subsequent management.

Local government and local authorities also need encouragement to become more active in preserving remnant vegetation. Since the temptation for local government is usually to increase revenue by encouraging development, the local government grant formulae may need to be adjusted to provide the incentive for positive action in preservation.

For similar reasons, landholders are often encouraged to clear as much land as possible by the State and local government tax and rating systems. This is what the researchers mean by 'perverse rating' and its basis and implementation must be carefully studied so that practicable alternatives can be recommended.

At the local level also, there are many non-government organisations (NGOs) with an interest in various forms of conservation. Local knowledge and enthusiasm is often a most effective means of ensuring that policies are actively pursued and to good effect; but local groups need money and have to compete for funds with many other worthy organisations. The researchers hope to find ways of making their fundraising more effective.

Finally, the team will look at the possibilities of tax incentives for the preservation of remnant vegetation, especially on land that is not used to produce assessable income. After all, landholders reasonably expect to earn a living and to get a return on their land. If public policy decrees that it is not to be used for productive purposes, then government should somehow reimburse them for the income forgone.

The project has made a significant input into Commonwealth policy measures for managing native vegetation. The government instigated taxation measures in 1999 to encourage philanthropic investment in nature conservation on private lands. The project also influenced Commonwealth support through the Natural Heritage Trust for local government incentive programs for conserving native vegetation.

Who wins?

If practical policies can be developed, everybody wins. The Commonwealth will be able to comply with its international obligations at lower cost; and local government councils and authorities, local non-government groups interested in conservation, and private landowners will all gain from mechanisms that reimburse them for the non-market costs of preserving native vegetation.

In a more indirect way, local communities will also benefit because where remnant vegetation is kept in quantity and in good condition, the resultant preservation of biodiversity helps to improve the attractiveness of the locality. Apart from aesthetic considerations, this also has concrete rewards in terms of tourism and recreation.

Most important of all, this 'from the bottom up' approach to preserving remnant vegetation can only help to make Australians generally more aware of the value of their natural heritage and to wish to preserve it. It will be another step towards maintaining the distinctiveness of Australia itself.

Return on investment

Net present value	$1,311,000
Benefit–cost ratio	2:1

7 Considerations for LWRRDC in Future R&D Evaluation

One of the objectives of the workshop on 15 December was to provide feedback for LWRRDC to take into account in developing its future evaluation strategy, particularly in relation to the role of benefit–cost analysis. The following questions were used to initiate discussion at the workshop:

- What is the objective of evaluation using benefit–cost analysis?
- Is benefit–cost analysis appropriate to use in natural resource management R&D evaluation and what are the alternatives?
- How can the consistency of methods and the information base for carrying out benefit–cost analyses be improved?
- What lessons could LWRRDC take from the workshop that could impact on its future evaluation strategy?

The following sections provide some elaboration on the questions.

7.1 Objectives of Using Benefit–Cost Analysis in Evaluation

Various objectives are given for the use of benefit–cost analysis in research evaluation. As always it is important to be clear about overall objectives before proceeding too far in judging a process. The LWRRDC life-of-project evaluations appear mainly to do with accountability. The key question they address is 'are we getting good value for money from this investment?' Secondary objectives were associated with project design, risk management and identifying information for improved economic analyses.

Project design and selection can be influenced by prospective benefit–cost analyses. In this regard, our experience is that those selecting a portfolio of projects where benefit–cost analyses are available at the project level are not so much influenced by the size of investment criteria as by the process of linking objectives, outputs and benefits and the assumptions stated in the analysis. This also can have impact on project design.

Prospective analyses may also be helpful in research priority setting, and historical analyses may give some indication of future investment priorities, although caution needs to be exercised in such extrapolation.

The LWRRDC approach has been to carry out prospective analyses *after* project selection and when the chance to influence project design is reduced. One of the advantages of the life-of-project approach was the potential to assemble information that might have been lost if direct historical evaluations were conducted.

7.2 Appropriateness of, and Alternatives to, Benefit–Cost Analysis

Is benefit–cost analysis appropriate to research evaluation? Some scientists think not, at least for prospective analyses for strategic research.

Is it appropriate to use benefit–cost analysis in natural resource management when so many of the values are difficult to determine? Are there more basic arguments as to why benefit–cost analysis might be inappropriate? Some ecological economists think, for example, that "the application of benefit–cost analysis as a foundation resource policy decision making process in the past is clearly to blame for many of the world's current environmental problems" (LWRRDC Occasional Paper 09/96).

What other methods of valuing impact and value are available? One could assess the impact in terms of the extent of adoption of sustainable practices, or the impact on a series of environmental indicators. Technology audits, surveys and benchmarking could all have a role. Can such activities be applied at a project level or would they be more suited to a program level of evaluation? Attribution would still pose problems. Would there still have to be a trade-off between different environmental values such as, for example, improved water quality, improved biodiversity and loss of productive land to dryland salinity? Can such trade-offs be made without attempting some form of comparative valuation?

Multiple criteria analysis can help in assessing value within a framework that considers more than monetary estimates. It can incorporate both dollar values and qualitative information. It could be used for project selection and research priority setting.

7.3 Improvement to Methods and Information Bases

Is it possible to improve the methods and consistency of approach to benefit–cost analysis? The major issues identified in the LWRRDC analyses included:

- where to draw boundaries around a single project when it is interlinked with other projects, both in terms of what R&D costs should be included, and what benefits should be attributed to the project or projects;
- how to value non-market goods since techniques are usually costly to implement and results are not always recognised as being trustworthy;
- should information assembly aids such as ENVALUE be strengthened or are the potential inaccuracies in transferring the results of listed studies to other situations too great;
- how best to assemble information on adoption and use of R&D outputs applicable both to on-ground application and policy;
- how to standardise the approach to best defining the applicability of research outputs to other regions and natural resource situations; and
- how to encourage explicit presentation of assumptions used in analyses so that others can comment and debate the assumptions made.

7.4 Inputs to Future Evaluation Strategies for LWRRDC

Some of the questions associated with the life-of-project evaluation framework that might be addressed by LWRRDC are:

- should LWRRDC continue with the same or a similar process?
- if so, how often should revised evaluations be made to project groups?
- can selection methods for the sample of projects be improved?
- when should the final evaluation of a project be made?
- are there alternative frameworks that might be used, for example, analysis of a sample of projects across one program each year or a larger sample of projects across the total portfolio every five years?
- should more emphasis be on prospective analysis where the opportunity to influence project design may be greater and where the analysis may be used in project selection?

Case Study — Project UQL13

Catching the Drift

Cotton is a crop of increasing importance to the Australian economy. Today almost four times as much cotton is grown as in the 1980s, but there is one big drawback. Cotton is susceptible to pests which at present can be controlled successfully only by the application of chemicals, even though research is well advanced into alternatives such as the use of transgenic breeding material.

Given that cotton growing also requires large quantifies of water (8–10 ML per hectare), it tends to be located on or near rivers and streams with the obvious risk of pesticides getting into such water courses. That poses dangers to wildlife, stock and people. Cotton growers are very well aware of two occasions when Australia's export beef market was interrupted because of the discovery of pesticide residues in meat. The residue was shown to derive from crop residues and in one case consisted of residues from the chemicals used in cotton-growing.

A specialist team is proposing research to combat these risks by establishing the best way to use pesticides in the neighbourhood of water courses. In particular, the researchers want to measure how far pesticides drift when applied from the air and how effective low-volume and ultra-low volume spraying can be.

The project is funded from a collaborative program of LWRRDC, the Murray–Darling Basin Commission and the Cotton Research and Development Corporation.

A varied team

A team of researchers has been organised for this purpose by The Centre for Pesticide Application and Safety (C-PAS) which is a unit of the University of Queensland, Gatton College. Some notion of the complex nature of the research emerges from the composition of the team. It consists of experts trained in physics, plant protection, pesticide chemistry, bioaeronautics, agricultural engineering, agriculture and biometrics. Other participants in the project with C-PAS are Australian Water Technologies, NSW Agriculture, and CSIRO/ University of Sydney.

The major purpose of the team is to develop means of managing aerial spraying that will reduce the drift of spray beyond the crops that need it. In particular, they will aim to reduce the quantity of endosulfan that reaches water courses and their surrounds.

Achieving those goals will require a concentration of a great deal of multidisciplinary research. The team will need to have a clear picture of how pesticides are applied from the air to cotton crops and whether the size of the droplets makes much difference to the extent of drift or to the absorption of the pesticide by the crop when aerial spraying is used. How much falls onto the soil and is there a risk of that ending up in a waterway? Can buffer zones be established to cope with potential drift?

Clean water

The community at large has obviously a considerable interest in clean water. Pollution can affect not only the water that we drink but also the food we eat. Of course, pollution from chemicals like the endosulfan used by cotton growers is only one small part of the current threat to Australia's water supplies, but the results that are hoped for from this research would be a valuable contribution to the whole research effort to eliminate pesticide chemicals from waterways. The discovery of new management techniques for aerial spraying may be applicable to other pastoral and agricultural activities, with consequent benefits both to growers and consumers.

Can it be done?

The Centre for Pesticide Application and Safety has already shown that, given the right meteorological conditions at appropriate times, Low Volume (LV) and Ultra Low Volume (ULV) products can be successfully applied by aerial spraying. Moreover, if biological buffer zones are correctly designed, they can be used to reduce the movement of pesticide droplets. However, in the search for best practice management techniques, the researchers need to determine how the application techniques can be changed in the field to respond to environmental pressures. How, for instance, is spraying, either from the air of by booms, going to be affected when conditions are not ideal and the crops are growing close to sensitive areas?

The answers to these and similar critical questions can be found only by carefully constructed field tests and the consequent use of predictive models based on the data yielded by those experiments.

The benefits

The extent of community benefit from a successful outcome for this research project may be estimated by the fact that the shutdown of Australia's beef export in 1987, because of pesticide residues in the meat, cost the industry some $40 million. But apart from the direct costs, the public is nowadays acutely conscious of the necessity of avoiding that sort of pollution.

It is because of such concern that a minor breach of environmental regulations by an individual can incur a fine of up to $3,000 while in the case of a corporation the fine could amount to more than $1 million.

The cotton industry and the agricultural aviation industry clearly have to minimise the risk of activities which, even inadvertently, might cause environmental damage that would be penalised so heavily. The development of management practices that would minimise or eliminate that risk would be of major benefit to those industries. But they are not the only ones. The incidents of contamination of beef by pesticide residues affected the beef industry not merely by temporary loss of export earnings but also by some loss of confidence on the part of the Australian public. A food industry has a poor future if consumers fear that they will be poisoned by eating its products.

The benefits should also flow to everyone who is concerned about the increasingly polluted state of so many of our inland waterways. The nature of that pollution is complex, but any relief such as the reduction of contamination by spray drift will be a welcome contribution to the efforts of those trying to clean up our streams and rivers. Inevitably, too, the public do not only react to the pollution of water as consumers of the food that it is used to produce; the tourist and recreation industries are also affected, although to an incalculable extent, by public aversion to contaminated waterways.

If a money figure is to be placed on the benefits of reducing or eliminating spray drift, the researchers estimate this as around $134,000 every year for the foreseeable future. But no price can be placed on public confidence in the cotton industry or on reassuring the public about its own safety.

Return on investment

Net present value	$467,000
Benefit–cost ratio	4:1

8 Conclusions

1. Based on the assumptions made in the evaluations of 31 projects, R&D investment in natural resource management by LWRRDC and its partners is providing significant value for money and a high rate of return. While caution should be taken in calculating simple averages of investment criteria, using the latest evaluation results for each of the projects shows that the average NPV for 29 projects analysed was $23 million, the average B/C ratio 17 to 1 and the average IRR 36%.
2. A comparison with several other R&D evaluation studies for natural resource management carried out in Australia suggests that the LWRRDC investment returns are roughly in accord with other estimates. Similarly, the results are not dissimilar to the results produced by analyses of the mainly commodity focused R&D Corporations.
3. Benefit–cost analyses for natural resource management R&D investment in other countries appear to be uncommon or are difficult to access. One major review of such studies reported that the average IRR over 16 natural resource R&D studies was around 40%, similar to that found for LWRRDC projects.
4. The revisions of the analyses for the groups of projects are providing more accurate estimates of the investment returns. It is not surprising to see the investment criteria change, particularly between the initial evaluation and the first revision. However, it is likely that the second and any third revisions will generally change less.
5. Information on adoption of improvements emanating from R&D is critical information for making credible estimates of investment criteria and is generally lacking, with few processes in place to remedy the situation.
6. It would be useful if, in future evaluations, additional investment criteria are estimated and reported for only those benefits that have actually accrued to the date of the analysis.
7. Significant difficulties exist in applying benefit–cost techniques to research evaluation and these are exacerbated in R&D associated with natural resource management. This is largely because of the complex natural systems involved, the lack of information on the value of non-market benefits, an uncertain policy environment, and the time lags for benefits from remedial actions to make impacts.
8. Differences no doubt exist between analysts as to their estimates of the applicability and extent of the benefits that might arise from a particular project, the method of valuation of such benefits, and the adoption characteristics associated with capturing those benefits.
9. Defining boundaries of individual research projects and deciding whether or not to bundle associated projects together in relation to defining project costs and benefits have been common problems faced in most of the life of project evaluations.
10. In terms of future analyses, greater consistency in reporting methods in terms of explicitness of assumptions and the criteria reported would be helpful. For example, the present value of benefits and present value of costs were not separately reported for one group of projects, thus preventing estimation of an aggregate B/C ratio for that group. For another group of projects, the IRR was not reported.

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Appendixes

1 Projects Selected for Evaluation

Group 1: Temtac (1994,1996,1998)

Code	Project title
Pesticide Program	Minimising the impact of pesticides on the riverine environment , using the cotton industry as a model
UMO18	Effects of salinity on riverine and wetland biota
DEP1	Ecological processes for the management of wetlands and floodplains. Practical management systems
UNE11	The integration of wetlands water supply and demand management in a market environment using capacity sharing
CWS18	Management of a regional groundwater discharge zone in an area of dryland agriculture
MDR8	Nutrient limitation of algal growth: physiological assays and chemical analyses
CPI4	Onsite monitoring of agro-chemical residues: a valuable tool for irrigation management
QPI4	Compaction control and repair practices for cropping lands in the sub-tropics

Group 2: ACIL (1996,1998)

Code	Project title
GRU18	Rapid procedure for practical in-stream flow assessments
UOC9	National River Health Program predictive modelling (RIVPACS)
AGS1	Improving dryland salinity management through integrated catchment scale modelling
VCA1	Landholder perceptions of remnant vegetation in the Box–Ironbark region of northern Victoria
CWE11	Patterns of sustainable use of rangelands for the 21st century
UAD12	Liquid beam methodologies for groundwater environmental analysis
UAD10	Measurement and treatment of phosphorus and carbon subsoil movement
CWW22	Developing methods for assessing the effectiveness of whole catchment management

Group 3: Sloane, Cook and King (1997)

Code	Project title
UAD14	An evaluation of the applicability of genetic algorithm technology to flow management of open-channel gravity systems
CSF1	The interaction of physics, biology and nutrient regimes on the initiation and development of algal blooms
UQL13	The aerial application of pesticides: development of guidelines for best management practice in the riverine environment
MDB4	Improving awareness of best management practice in investing, planning and managing dryland salinity
UQL10	Integrated information management system for catchment managers
UME25	Improving market outcomes: The case of native grasslands
CWE13	Opportunities for the use of incentive payments to conserve remnant vegetation
DAV21	Economic assessment of water market reform using the water policy model (WPM)

Group 4: Atech (1998)

Code	Project title
CLW7	Biogeochemical processes induced by groundwater–surface water interactions
MIL1	Improving hydraulic efficiency of irrigation and drainage systems through benchmarking
UMO36	Nutrient release from river sediments: Phase II validation and application of sediment-release model
GBC1	Demonstration/evaluation of riparian management: Victoria – Goulburn–Broken region
CEN4	Introducing earthworms to reduce soil acidity and increase pasture production
CPI7	Innovative soil and water management for sustainable agriculture in the Mediterranean climatic zone, WA
CWE23	Do government policy instruments support sustainable grazing on-farm?
ANU11	Citizens' juries for environmental management: an alternative to CBA

2 Terms of Reference

Group 1, Phase 1 1994 (Temtac)

1. The consultant is required to comment on the INITIAL selection of projects and programs for impact assessment in light of the total spread of projects funded by the Corporation.
2. The consultant is required to carry out an initial prospective (*ex-ante*) impact assessment analysis, including:
   - a definition of the technical outputs expected (products, processes, improved management techniques or other information);
   - an assessment of the likelihood of the project/ program achieving such technical outputs;
   - an examination of the linkages between the technical outputs projected and how they may be used to manage resources and to effect change;
   - an examination of the profiles of adoption of such technical outputs by resource users and managers in order to effect change;
   - an estimation of social investment criteria for each project, using the project cost and valuation of benefits through the market, or by using non-market valuations.
3. The consultant is required to identify information, which can be collected during the course of the project or program, that can be used in a final impact evaluation for each project. These data should refer not only to variables defined in the linkages stated in the prospective analysis, but also to others which may affect achievement of project outcomes.
4. The consultant is required to develop a set of guidelines to assist the analysis of benefits and costs of natural resource research and development, to be used by the Corporation, its stakeholders and researcher clients in formulating and assessing research and development projects/programs.
5. The consultant is required to report to the Corporation on each of the four topics listed above. It is intended that the report will form the basis for a process of life-of-project evaluation of the selected research and development.

Group 1, Phase 2 1996 and Phase 3 1998

1. Revise the assessment of technical outputs, risks, resource management linkages, adoption patterns and social cost–benefit payoff from each of the seven projects and one program which were included in the initial evaluations.
2. Compare updated project performance characteristics against those predicted in the initial evaluations, and examine reasons for differences.
3. Review information being collected during the course of the projects (and program) and define any changes needed in information collection for any subsequent evaluations.
4. Report to the Corporation on each of the topics listed above.

Group 2, Phase 1 1996 (ACIL Group)

The evaluation is intended to help LWRRDC achieve the following objectives:

1. Identify at the initial assessment on project commencement the risks associated with achieving the technical outputs of the project and its translation into required outcomes, thus enabling the researchers and LWRRDC to address these issues while the project is underway;
2. Identify whether risks are being managed adequately and whether other factors may influence achievement of project objectives and the rate of return;
3. Through an assessment of the project at completion determine whether it has achieved its technical outputs, whether they were translated into practical outcomes and what factors influenced success or failure. An impact analysis at that time would aim to assess the actual return on investment of public funds;
4. Develop evaluation techniques appropriate for natural resource issues, in particular effectively assessing the environmental values and benefits from a project and also improve LWRRDC's approaches to managing risk; and
5. Using a random stratified sample, enable LWRRDC to extrapolate results to give an indication of the overall success of its investment portfolio.

Group 2, Phase 2 1998

Update previous analysis reporting specifically on:

- the assessment of technical outputs, risks, adoption and social cost benefit analysis of each project;
- the updated performance characteristics against the previous evaluation and reasons for differing; and
- information being collected during the course of the projects and outline any changes required for subsequent life-of-project evaluations.

Group 3, 1997 (Sloane, Cook & King)

1. The consultants will be required to identify a random, stratified sample of eight projects from the LWRRDC portfolio; these must be a representative sample of the overall portfolio. The sample will be stratified within projects funded from within the 'general call' or within commissioned R&D Programs. All projects sampled are to commence from 1 July 1996.
2. The consultants will be required to carry out an initial prospective (ex-ante) assessment including:
   - the definition of technical outputs expected (products, processes, improved management techniques or other information);
   - the likelihood of each project achieving such technical outputs and main risks involved;
   - the linkages between technical outputs achieved and how they may be used to manage resources and to effect change;
   - the profiles of adoption of such technical outputs by resource users and managers in order to effect change; and
   - the estimation of social investment criteria for each project, given the project cost and given the valuation of benefits through utilising market or non-market valuation.
3. The consultant will be required to define information that should be collected during the course of the projects that can be used in a final impact evaluation for each project. These data should not refer not only to variables defined in the linkages stated in the prospective analysis, but also to others which may affect the achievement of project outcomes.
4. The consultant will be required to clearly identify the main risks associated with the project itself, and with the uptake and implementation of project results and comment on steps that LWRRDC could take in order to manage them.

Group 4, 1998 (Atech Group)

1. Evaluate the methodologies employed in the three earlier studies and other studies as specified, and recommend a suitable methodology for this study.
2. Select a random stratified sample of projects to be representative of recent additions to LWRRDC's portfolio. (These are ex-ante evaluations, that is, evaluations conducted in the very early stages of the projects.)
3. Identify the technical outputs of research and trace the linkages from the production of technical outputs of research through to adoption and use of those outputs by resource managers.
4. Estimate the social investment criteria (net present value, rate of return, and benefit–cost ratio) including non-market valuations where appropriate
5. Identify the information that will need to be collected during the project in order to conduct a final evaluation, including information about adoption and use.
6. Identify the main risks to the production of technical outputs and to their adoption and effective use.
7. Recommend steps that LWRRDC can take to manage those risks.

3 Selection of Projects within Each Group

Group 1 (Temtac)

One program and seven projects were selected by the LWRRDC Board to give a fair representation of the total portfolio. The researchers were asked to comment on the selection of projects and their representativeness of the entire LWRRDC portfolio. They used the following criteria to make this assessment;

- Research topic
- Type of research issue
- Mechanism of funding
- State of Australia in which the principal researcher resides
- Agro-ecological zone
- LWRRDC funding contribution
- Total funding including LWRRDC, third party and host research institution funding
- Duration of project.

The researchers concluded that the "selection of projects for review is reasonably representative of LWRRDC's total research portfolio although there is some under-representation with respect to sustainable management of vegetation, sustainable management of land resources and projects with LWRRDC funding less than $100,000."

The projects evaluated did not change in the following two phases. It was noted however, that the case studies have become less representative as there had been a major change in the LWRRDC portfolio from individual projects under the 'general call' to commissioned research programs.

Group 2 (ACIL)

The researchers were asked to select projects using a random stratified sample. ACIL adopted a non-probabilistic approach to sampling to provide, which is more akin to a case study approach.

The population was identified as being projects commencing in 1995–96. The sample size was fixed at eight.

- Firstly, the projects were classified into four strata:
  - commissioned/biophysical;
  - commissioned/sociological;
  - general call/biophysical;
  - general call/sociological.
- Projects in each stratum were then ranked by budget size.
- Five commissioned projects were to be selected as the commissioned project budget represented 64% of the portfolio.
- The number of commissioned/biophysical projects was set at three and commissioned/sociological at two projects (based on respective budget shares).
- The commissioned/biophysical stratum was divided into three substrata based on budget size and the median from each selected for analysis. The same was done for the commissioned/sociological stratum (two substrata).

The same process was used for the general call projects.

Overall, the sample gave a representation of subject areas except that land projects were under-represented and vegetation over-represented. To ameliorate this an alternative project was selected from the commissioned/biophysical stream.

This study also evaluates three irrigation projects jointly supported by LWRRDC and a number of irrigation bodies. These projects were selected by the Program Management Committee for NPIRD. These three projects are not included in this synthesis

The same projects are evaluated in the ACIL groups second phase.

Group 3 (Sloane, Cook and King)

The projects to be evaluated were chosen by the consultants through a stratified sampling process similar to that used for Group 2. Because of the structure of the sample population, the sampling methodology was simplified to eliminate an excessive number of small categories. Projects with total costs under $50,000 or with a duration of less than one year were eliminated.

- The projects were firstly classed as biophysical or socio-economic.
- Secondly, the projects were divided into the major research program areas of Land, Water and Vegetation (Irrigation was considered a sub-category of Water).
- After analysing the distribution of projects between the three program areas the Corporation decided that the allocation should be 2:2:4 between Land, Vegetation and Water. A decision was also made to allocate three of the four Water projects to biophysical and one to socio-economic. All Land and Vegetation projects were to be drawn from the socio-economic class.
- Next, the projects were sorted by program within their functional categories and then ranked by total value. Within each category the median project in each stratum was selected.

(Group 4, Atech Group)

The population sampling frame was defined as follows:

- only LWRRDC funded projects managed by LWRRDC were included.
- no Audit-funded projects managed through LWRRDC were included.
- only R&D projects were included (i.e. excluding postgraduate scholarships, travelling or visiting fellowships and consultancies).
- only projects started after 1 January 1998 were included.
- only projects with budgets equal to or greater than $50,000 were included.

The eight projects in the sample were selected randomly subject to the following constraints:

- four projects selected from each of the Water and Land research areas (Land then included Vegetation);
- no more than two projects from any one R&D program area;
- at least one project to be selected from R&D program areas with more than five projects in the sampling frame.

4 Individual Investment Criteria

Summary of Investment Criteria – Group 1

Project	Total investment ($m) [c]	Phase	NPV ($m)	IRR (%)	B/C ratio
Pesticide program	7.31	1	107.0	71.5	16.8
		2	30.2	35.1	6.0
		3	89.8	47.6	14.8
UMO 18	1.49	1	b	b	b
		2	3.2	b	b
		3	b	b	2.1
DEP 1	0.49	1	b	b	15.0
		2	2.3	b	b
		3	b	b	25.6
UNE 11	1.55	1	9.3	81.0	22.2
		2	7.2	43.4	21.4
		3	2.4	b	2.4
CWW 18	0.95	1	88.3	b	b
		2	3.1	25.2	4.8
		3	1.7	16.4	2.5
MDR 8	0.52	1	2.8	28.6	7.9
		2	1.6	29.4	4.9
		3	0.6	15.1	2.4
CPI 4	0.98	1	b	b	b
		2	1.5	23.9	2.7
		3	0.71	24.7	2.0
QPI 14	4.91	1	94.8	39.5	3.6
		2	41.0	35.2	9.4
		3	41.2	40.9	8.5
Overall average[a]	1.56	1	48.8	49.7	12.2
		2	8.6	31.4	8.6
		3	9.3	24.3	6.5

[a] Pesticide program not included in calculation of averages; b not derived; [c]Total investment by all parties

Summary of Investment Criteria – Group 2

Project	Total investment ($)[c]	Phase	NPV ($m)	IRR (%)	B/C ratio
GRU 18	109,857	1	0.2	18	3
		2	0.3	15	3.4
UOC 9	229,227	1	3.4	74	17
		2	5.5	56	27
AGS 1	1,170,800	1	6.4	30	7
		2	8.9	35	9
VCA 1	123,630	1	1.7	23	15
		2	3.1	32	26
CWE 11	1,693,284	1	0.5	8	1
		2	0.5	8	1
UAD 12	468,721	1	2.4	13	2
		2	5.5	19	3
UAD 10	322,800	1	2.8	29	10
		2	9.14	23	23
CWW 22	456,740	1	1.0	22	1
		2	27	60	55
Overall average	570,632	1	2.3	27.1	7.0
		2	7.5	31	18.4

[c] Total investment for all parties

Summary of Investment Criteria – Group 3

Project code	Total investment ($)[c]	NPV ($m)	IRR (%)	B/C ratio
UAD 14	650,010	7.9	61	15
CSF 1	566,790	3.0	36	7
UQ 13	199,994	0.5	26	4
MDB 4	177,722	7.2	94	45
UQL 10	574,397	2.7	29	6
UME 25	416,384	2.9	55	8
CWE 13	777,005	1.3	34	2
DAV 21	117,500	0.8	50	9
Overall average	434,100	3.3	48.1	12

[c] Total investment for all parties

Summary of Investment Criteria – Group 4

Project code	Total Investment ($)[c]	NPV ($m)	B/C ratio
CLW 7	979,528	7–50 (28.5)	9–57 (33)
MIL 1	481,000	34–150 (92)	9–38 (23.5)
UMO 36	423,700	65–105 (85)	13–20 (16.5)
GBC 1	105,000	26–98 (62)	18–66 (42)
CEN 4	630,337	31	53
CPI 7	601,711	190	20
CWE 23	557,322	34	35
ANU 11	205,980	6–12 (9)	7–13 (10)
Overall average	498,072	66.4	29.1

[c] Total investment for all parties

5 List of Organisations Responding to Email Request for Information

- Agricultural Economists Association Mail List
- Agricultural Economics Research Unit, Lincoln University, NZ
- Agriculture On-Line Talk Groups
- American Agricultural Economics Association
- Canadian Arctic Resources Committee, Canada
- Centre for Rural Economy, UK
- Centre for the Economics and Management of Aquatic Resources, University of Portsmouth, UK
- Centre for International Forestry Research (CIFOR), Bogor, Indonesia
- CIRAD, France
- Consultative Group on International Agricultural Research (CGIAR), Vietnam
- Colorado State University, USA
- Committee for the National Institute for the Environment
- Cornell University, New York, USA
- Department of Agricultural and Applied Economics, University of Wisconsin, USA
- Department of Agricultural Economics & Food Marketing, The University of Newcastle upon Tyne, UK
- Department of Agricultural and Food Economics, University of Reading, UK
- Department of Economics, Lund University, Sweden
- Department of Science and Economics, Université de Montreal, Canada
- Earth Network for Sustainable Development
- EcoSecurities, UK
- Economic Development Branch, Saskatchewan Environment & Resource Management, Canada
- Economic Research Service, Resource Economics Division, US Department of Agriculture, USA
- EIA Training and Research Network (ETAR), UK
- Environmental Protection Agency, USA
- Environmental Research Information Exchange (ERIE)
- Environmental Sciences Department, The University of Greenwich, UK
- Forest Service, US Department of Agriculture, USA
- International Centre for Agricultural Research in Dry Areas (ICARDA), Aleppo, Syrian Arab Republic
- International Centre for Living Aquatic Resources Management (ICLARM), Manila, Philippines
- International Centre for Research in Agroforestry (ICRAF), Nairobi, Kenya
- International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, India
- International Food Policy Research Institute (IFPRI), Washington DC, USA
- International Association of Agricultural Economists, UK
- International Rivers Network
- International Water Management Institute (IWMI), Colombo, Sri Lanka
- Morrison School of Agribusiness, Arizona State University East, USA
- Natural Resources Canada, Canada
- Natural Resources Institute, Kent, UK
- National Science Foundation, USA
- North Carolina University, USA
- North Dakota State University, USA
- Northern Prairie Wildlife Research Centre, USA
- Ohio State University, USA
- Quebec Association for Impact Assessment, Canada
- Resources for the Future, USA
- Technopolis, UK
- Technopolis, France
- The CATO Institute, Washington DC, USA
- The Wildlife Society, USA
- The World Bank, Washington DC, USA
- Treasury Board Secretariat, Canada
- University of British Columbia, Canada
- University of California (Davis, Berkley), USA
- University of Minnesota, USA
- University of New England, Armidale, Australia
- University of Oregon, USA
- University of Queensland, Brisbane, Australia
- Utah State University, USA
- Virginia Polytechnic Institute and State University, USA
- Welsh Institute of Rural Studies, The University of Wales, UK
- World Conservation Monitoring Centre, Cambridge, UK

Note: In many cases, a number of individuals from the one organisation responded to our request for assistance.

6 Overview of Workshop

Participants

Peter Chudleigh, Agtrans Research, Facilitator

Richard Price, LWRRDC
Sandy Lolicato, LWRRDC
Nick Schofield, LWRRDC
Melanie King, LWRRDC

Andrew Campbell, EA
Peter Tucker, DIST
Amitha Senanayake, AFFA
Rowan Wylie, AFFA
Julia Curtis, AFFA

Craig Penney, Advisor to The Hon. Warren Truss, MP
Julie Austin, Advisor Senator Troeth

Jeff Davis, RIRDC
Sam Nelson, GRDC
Alex Wells, FRDC
Robert Troedson, SRDC
David Conley, DRDC

Peter Dempster, ATECH
Greg Martin, ACIL
Barry White, AGEC Consulting
Peter Sloane, Sloane, Cook & King

Tim Yapp, CSIRO
Kathy Heinze, CSIRO

Anwen Lovett, NFF
Tim Fisher, ACF

Fleur Charlton, Capital Public Affairs

Session One: The Results

Peter Chudleigh from Agtrans Research presented key findings in the draft report. The main finding in the report is that based on the assumptions made in the evaluations of 31 projects, the returns to R&D investment in natural resource management by LWRRDC and its partners is providing significant value for money and a high rate of return. Other findings included:

- The average NPV for the projects analysed was $23 million per project; the average B/C ratio was 17:1, and; the average IRR was 36%.
- Information on adoption of improvements coming from R&D is critical for making credible estimates of investment criteria and is generally lacking with few processes in place to remedy the situation.
- Difficulties exist in applying benefit–cost techniques to research evaluation and these difficulties are exacerbated in R&D associated with natural resource management, largely due to complex natural systems involved, the lack of information on the value of non-market benefits, an uncertain policy environment, and the time lags for benefits to be realised.
- There are difficulties in defining boundaries of individual research projects that are being evaluated to ensure that the bundle of projects defined is associated with the appropriate costs and benefits.
- Any future evaluations would benefit from greater consistency in reporting methods in terms of explicitness of assumptions and the investment criteria assessed and reported.

Session Two: Discussion and Implications of Results

Session two of the workshop was composed of guest speakers (Sandy Lolicato from LWRRDC; Greg Martin from ACIL; Peter Sloane from Sloane, Cook and King; and Peter Dempster from ATECH) commenting on the Life-of-Project Evaluations and their usefulness. The latter three speakers who represented three of the four consulting groups undertaking the evaluations, provided further insight and problems experienced in carrying out the evaluations. Barry White (AGEC Consulting) provided a summary at the end of the session.

Main points raised by the four speakers included:

- LWRRDC has a target of an average benefit–cost ratio of at least 5:1 across the portfolio whilst the average benefit–cost ratio for the four sets of LWRRDC projects analysed to date was at least 12:1
- Overall agreement that the key results outlined in the synthesis is generally good news for LWRRDC in that it shows that there is value for money in investment in natural resource R&D.
- When applying benefit–cost analysis, it is not cost effective to evaluate every project and therefore there needs to be reliance on a stratified random sample of projects being analysed which allows results to be extrapolated across the whole portfolio.
- There is a need to ensure that project outputs are translated into practical outcomes.
- Different techniques used in assessments can produce different results which may suggest differences between projects that do not actually exist.
- Difficulties abound in attributing benefits where project boundaries are diffuse or overlap and LWRRDC could consider evaluating groups of related projects rather than individual projects as currently manifest in the evaluation strategy.

- The nature of the available data sometimes can influence the choice of the evaluation framework applied.
- There are difficulties in measuring non-market public benefits; however, this was not just a case of placing values on amenities but included a lack of information on technical relationships that were essential in measuring benefits.
- 'Benefit transfer' needs considerable care and judgment in its use.
- One of the key challenges in carrying out the analysis was to define the 'without R&D' scenario.
- There was generally a positive and helpful response by researchers to the 'evaluations'.
- The incentive to change for resource managers was a re-occurring issue.
- For ongoing data assembly throughout a project, respective incentives and responsibilities for the researchers and analysts need to be better defined at the outset.
- There is a need for the adoption process to be constantly reassessed as the project progresses.
- LWRRDC, Program Managers and Coordinators were seen as playing key and positive roles as network facilitators.
- LWRRDC needs to distinguish between adoption problems arising from a lack of effective demand for the research and problems arising from dissemination strategies and other aspects of project design.
- LWRRDC could usefully investigate options for obtaining basic information on the market value of land and water at some reasonable level of regional disaggregation.

General Discussion

The main issue that arose in the general discussion at the conclusion of Session Two concerned the adoption of R&D outputs. The following points were raised during the discussion.

- There was some discussion on the differences in focus between LWRRDC and those carrying out projects. LWRRDC recently implemented a logical framework approach which was providing clearer project definitions and linkages between objectives, inputs and activities, outputs, and eventual outcomes and benefits.
- Why are end-users participating in some research projects and achieving results but then finishing with the project once the research has stopped? One explanation was that there was no economic pressure for them to continue; also, concepts should be constructed through how the end-user, rather than the researcher, sees them.
- Communication of the research programs and their results was seen as a key issue.
- Many potential users of information were unaware of what research was been undertaken.
- Consideration be made to reducing the adoption time, if possible, as a basis of bringing forward and increasing project benefits.
- There is a need to get information out in a more 'popular' manner rather than the lengthy and complete reports that are currently produced.
- There should be a more strategic focus in communication (ie. just use the main points rather than all points).
- LWRRDC was seen as playing a key role in the dissemination of research results.

In his summary, Barry White highlighted a number of key issues including:

- who benefits and when?
- what happened to the unfunded projects?
- where have all the project failures gone?

Session Three: Method Improvement and Approach for the Future

The afternoon session comprised discussion of four topics:

- Objectives of evaluation
- Alternative evaluation methods
- Improvements to investment analysis methods
- Implications for a future evaluation strategy for LWRRDC

Objectives of Evaluation

- Accountability was seen as a key objective of evaluation.
- Other objectives were to attract partnership funding and to improve management processes.
- Accountability was seen to exist at three levels: corporation, program and project level. The Life-of-Project evaluations process (LOPE) was seen as being aimed at the Corporation level and was strategic in nature rather than being tactical or operational.
- It was necessary to distinguish between monitoring and evaluation as opposed to planning.
- There was concern over identifying what research findings were being picked up and by whom, as well as how the information was being used.
- LOPE was seen as a subprocess of a wider approach to evaluation.
- DRDC has also carried out longitudinal studies over time.
- Benchmarks for an evaluation budget were given as up to 3%, and certainly at least 0.5 to 1% of the gross investment.
- There was also a comment that benefit–cost analysis might restrict the type of research funded.

Alternative Evaluation Methods

- One alternative to a random sampling approach was to select the projects and place the benefits from the selected 'best' projects against the total costs of the portfolio.
- A question was directed at whether implementation costs were always included in the analyses.
- Benefit–cost analyses can be interactive with project design.
- There are considerable difficulties in measuring benefits from social and institutional research.
- It may be important to measure changes in community perceptions.
- Sometimes it is possible to make do with identifying partial benefits from the R&D.
- There is a need to broaden evaluations to include all benefits, not just present numbers.
- There is a need to also assess how LWRRDC is performing and where it is heading. Is it picking the right issue at the right time?
- There was some concern over the small number of projects analysed to date and the selection process.
- No clearly superior alternatives to benefit–cost analyses were promoted.

Improvements to Investment Analysis Methods

- The issue was raised of potential double of counting benefits in previous research when projects are analysed individually.
- Use of surveys to assess use of R&D products, that is, provide qualitative measures of adoption, or at least documenting R&D products that are out there.
- Is environmental protection spending a useful surrogate for value to society?
- There is a dilemma in valuing non-market (environmental/social) benefits. Is there a need to put more emphasis on physical implications of long-term outcomes.
- Discounting works against long-term benefits.
- It is not so much the discount rate that is the problem; the future changes in values of increasingly scarce amenities should also be taken into account; that is, future environmental values and costs may increase.
- Future generations may value environmental resources more than at present.
- Some stakeholders are looking for short-term change.

Implications for a Future Evaluation Strategy for LWRRDC

- There is a need to focus on effective communication as this is seen as a link to more effective adoption.
- Adoption and scientific research should be evaluated separately as they are seen as two different entities.
- There was a consensus that the Life-of-Project Evaluations (LOPE) should not stop as the whole process was relatively new.
- Regarding frequency, perhaps projects could be re-evaluated every two years, or only when changes were manifest. As the reviews proceed it will be easier to see which projects require no further evaluation and which ones should continue.