Horticulture Australia (HAL) Return on Investment

FINAL REPORT
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Horticulture Australia Limited

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Executive Summary

The Challenge

Over the past 15 years Horticulture Australia Limited (HAL) expenditure on research and development (R&D) has increased to an estimated total of $72.68 million in 2006-07. A recent Productivity Commission Report (2007) highlighted Government concerns regarding the lack of evidence supporting a positive return on R&D investment. In line with newly released Council for Rural Research and Development Corporation Chairs (CRRDCC) guidelines, HAL is now required to annually review selected case studies to assist in demonstrating the return on investment provided from R&D expenditures.

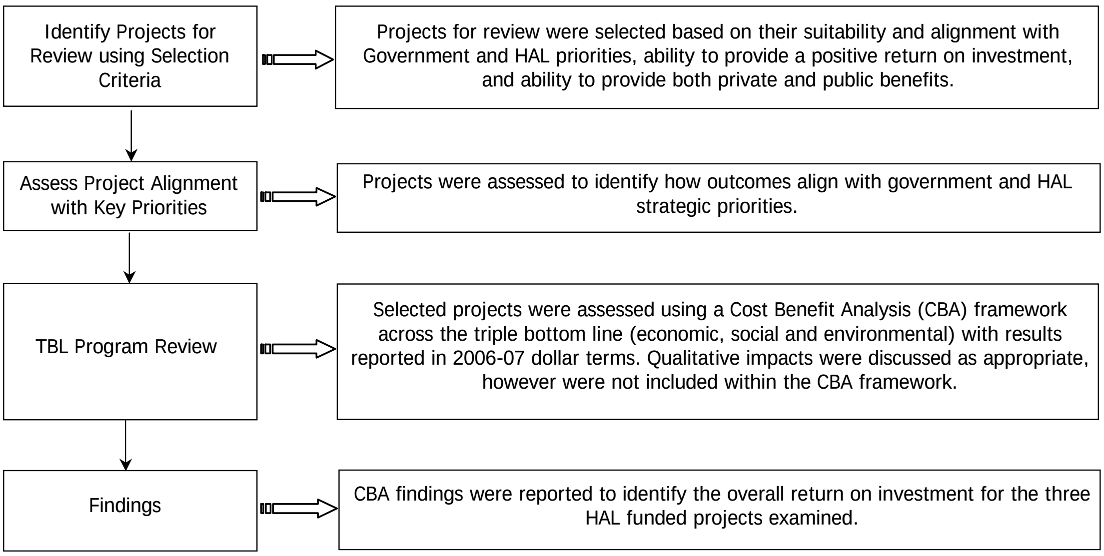
The Response

HAL commissioned the AEC*group* to undertake an analysis of a selected number of research and development projects using cost-benefit analysis methodologies to identify the return on investment for these projects across the triple bottom line. The objective of this report is to review three successful, HAL funded projects over current, five, ten and twenty year time horizons using a cost benefit framework to determine the return on investment (ROI) from HAL funding for these projects. The factual ('with' project) and counterfactual ('without' project) scenarios are examined with public and private impacts identified where appropriate.

The Process

The following framework was used to assess the return on investment for the selected projects.

Figure E.1. Evaluation Framework



Source: AEC*group*, 2007

All projects were assessed regarding their alignment with Government and HAL strategic priorities. Projects were assessed to be economically desirable if the project achieved a positive net present value (NPV) and a benefit cost ratio (BCR) of greater than one. This assessment is expected to be an underestimate of the actual benefits from project R&D outcomes as not all benefits could be readily quantified in dollar terms. Impacts not readily quantifiable in dollar terms were assessed qualitatively.

This report investigates the return on investment of the following three HAL projects:

- The Biology, Ecology and Control of Citrus Jassid;
- Control of Bacterial Blight in Walnuts; and
- Insect Pest Management in Sweet Corn.

THE BIOLOGY, ECOLOGY AND CONTROL OF CITRUS JASSID

THE PROBLEM

The citrus leafhopper had become a major pest in citrus in the Central Burnett (Gayndah – Mundubbera) production region in the late 1980s and early 1990s, and in some years resulted in total crop loss for Imperial mandarin and Navel orange species using traditional control measures. The aim of this project was to enhance the understanding of the biology and ecology of the citrus jassid and subsequently identify improved control methods.

THE RESPONSE AND OUTCOME

This project resulted in the development of two low toxicity and high efficiency pesticides, endosulfan and buprofezin, which have currently been adopted by virtually all growers. Cost Benefit Analysis (CBA) indicates that a total expenditure to date of $461,992 (in 2006-07 dollar terms) in the research and development project, which occurred over seven years from 1996-97 to 2002-03, provided the following outcomes:

- A NPV of $35.35 million and a BCR of 102.54 at a discount rate of 9.16%[1], which implies that the project returns $102.54 for every dollar of research and development invested;
- An internal rate of return of 114.6%;
- A positive return in investment across all discount rates between 6% and 12%;
- A positive return on investment from the eighth year from commencement of the research and its release in year seven;
- Key impacts driving this positive result include:
  - An annual increase in gross value of production (GVP) of $7.89 million;
  - An annual reduction in cost of control of $241,500; and
  - An annual reduction in the social impact of odour (based on public WTP to avoid contact with odour) valued at $3,808 per annum for the estimated 1,874 exposed households in the Gayndah/ Mundubberah area;
- Additional unquantified beneficial impacts include:
  - Reduced toxicity to the environment resulting in reduction in non-targeted insect and animal death (environmental benefit); and
  - Reduced toxicity to workers and consumers of citrus products (social benefit).

To date (year 11 of the assessment) the project is estimated to have contributed a cumulative net present value of $15.18 million in social and economic benefits to both the public and private sectors.

CONTROL OF BACTERIAL BLIGHT IN WALNUTS

THE PROBLEM

Walnut orchards in Tasmania were losing an estimated 55% of the walnut harvest per annum as a result of bacterial blight, or an estimated loss of $1.4 million per annum. Losses arise due to aborted blossoms (resulting in yield reduction) and blemished hulls which reduce quality of the walnuts produced.

THE RESPONSE AND OUTCOME

Prior to this project, management regimes were costly, time consuming, didn't provide the desired level of control and produced adverse environmental effects. The primary objective of this project was to identify potential fungicides and application procedures for improved control of bacterial blight in walnuts. The secondary objective of the

[1] For this analysis a base discount rate of 9.16% was used which represents the long term bond rate of 6.16% plus 3% as required by CRRDCC (2007).

program was the identification of non-copper based treatments to reduce environmental impacts and resistance concerns.

This project resulted in the development a non-copper based, reduced toxicity chemical (mankocide) that has an increased efficiency of control compared to previous control methods. Cost Benefit Analysis (CBA) indicates that a total expenditure of $151,225 (in 2006-07 dollar terms) in the research and development project, which occurred over five years between 1999-2000 and 2003-04, resulted in the following outcomes:

- A NPV of $7.96 million and a BCR of 7.57 at a discount rate of 9.16%, which implies that the project returns $7.57 for every dollar of research and development invested;
- An internal rate of return of 103.4%;
- A positive return in investment across all discount rates between 6% and 12%;
- A positive return on investment from the sixth year following commencement of the research;
- The key impact driving this positive result is an average annual increase in gross value of production (GVP) of $1.70 million, which may be increased if mankocide can be produced and sold at a reduced cost;
- Additional unquantifiable impacts include:
    - Reduced toxicity to the environment from copper leaching into the soil, with benefits to plants and vertebrates (environmental benefit); and
    - Increased land use flexibility due to a reduction in the amount of copper (used in previous treatments) leaching into the soil (economic benefit).

To date (year eight of the assessment) the project is estimated to have contributed a cumulative net present value of $1.89 million in economic benefits to both the public and private sectors.

Insect Pest Management in Sweet Corn

The Problem

Heliothis and heliothis larvae cause significant pest damage to sweet corn crops, with some crops reporting 100% losses in some years. This reduced the ability of growers in Queensland, New South Wales and Victoria to maintain contracts with domestic and export markets due to high quarantine risk, low reliability of supply and poor quality of product.

The Response and Outcome

The aim of the project was to discover methods to control heliothis and reduce the risk of crop failure due to heliothis infestation. The outcome of this project was the development of best management options (BMOs) for control of heliothis and the development of two alternative biologically specific pesticides, gemstar and success.

Cost Benefit Analysis (CBA) indicates that a total expenditure of $1.69 million (in 2006-07 dollar terms) in the research and development project, which occurred over six years between 1997-98 and 2002-03, resulted in the following outcomes:

- A NPV of $82.71 million and a BCR of 5.88 at a discount rate of 9.16%, which implies that the project returns $5.88 for every dollar of research and development invested;
- An internal rate of return of 137.1%;
- A positive return in investment across all discount rates between 6% and 12%;
- A positive return on investment from the fifth year from commencement of the research;
- The key impact driving this positive result is an annual increase in gross value of production (GVP) of $15.76 million;

- Additional unquantifiable impacts include:
  - A reduced reliance on broad spectrum pesticides resulting in reduced environmental toxicity (environmental benefit);
  - An improvement in the consistency of supply to the market place due to a reduction in crop losses (social benefit); and
  - Re-establishment of the export market due to a reduction in quarantine risk and contamination of products (economic benefit).

To date (year 10 of the assessment) the project is estimated to have contributed a cumulative net present value of $44.15 million in economic benefits to both the public and private sectors.

SUMMARY OF FINDINGS

Each of the three projects assessed in this report were found to be economically desirable projects producing a combined net benefit to date (2006-07) of $61.22 million and an estimated net present value of $126.02 million over a twenty year time horizon.

All evaluated projects were recognised to have addressed an identified industry need and were aligned with established Government and HAL strategic objectives. Projects also contribute public and private benefits across the economic, social and environmental triple bottom line.

Combined annual benefits of the three projects in steady state of adoption is estimated to be $25.81 million, or an average net benefit of $8.60 million per annum. It is estimated that to fully offset current annual expenditure by HAL on R&D ($72.68 million), depending on the rate of discounting, another 3.9 to 7.3 projects (with an average annual benefit of $8.60 million) is required. HAL currently invest in between 300 to 350 new research and development projects annually and at any one time have approximately 1,200 active research and development projects.

To put this another way, this implies that approximately one in 40-80 projects would be required to deliver benefits in the order of those examined in this assessment to provide a positive return on investment for the HAL investment portfolio.

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1. Introduction

1.1 Background

Science and innovation is one of the strategic priorities identified by the Australian Government as a significant contributor to Australian economic and social prosperity. Horticulture Australia Limited (HAL) expenditure on research and development (R&D) has increased over the last 15 years, with approximately $72.68 million spent on R&D in 2006/07 over a broad spectrum of projects providing varying degrees of economic, social and environmental impacts to private and public parties.

A recent Productivity Commission Report (2007) highlighted Government concerns regarding the lack of evidence supporting a positive return on R&D investment. As a result, new monitoring and review programs have been developed in order to build and gather the data required to monitor the progress of rural research and development outcomes in Australia.

To monitor and determine the long-term outcomes and return on investment from Research and Development Corporation (RDC) portfolios, the Council for Rural Research and Development Corporation Chairs (CRRDCC) requires RDC's to annually review selected case studies to determine the return on investment (ROI) from their R&D initiatives. The aim of this is to build up a pool of consistent cost benefit analyses (CBA's) across all RDC's, which can be used to identify the trends in returns from RDC investments over time and demonstrate that the RDC investment portfolio produces positive private and public benefits.

1.2 Scope and Objectives

HAL commissioned the AEC*group* to undertake an analysis of a selected number of research and development projects using cost-benefit analysis methodologies to identify the return on investment for these projects across the triple bottom line. The analysis will examine returns over current, five, ten and twenty year time horizons. This process will compare the factual ('with' project scenario) to the counterfactual ('without' project scenario) to determine the net present value of the project in 2006-07 dollar terms, with public and private impacts identified where appropriate.

2. Methodology

2.1 Evaluation Framework

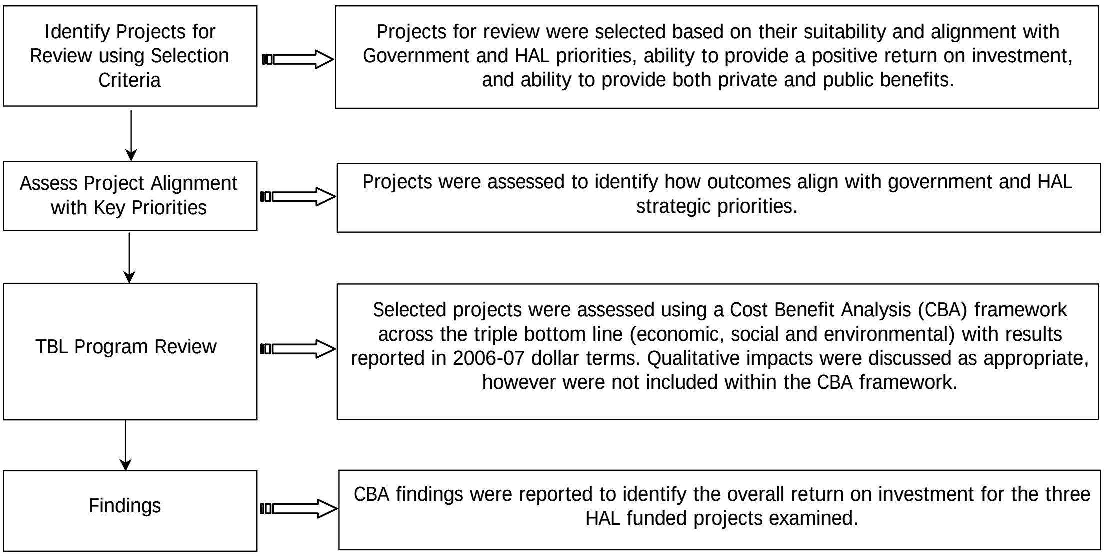
The evaluation framework followed a four step process: selection of projects, assessment of project alignment with key priorities, evaluation of projects across the triple bottom line and reporting of findings against the evaluation criteria.

The CRRDCC guidelines for evaluation stipulates that RDC's are required to provide the following three reporting outcomes:

1) Overall returns from RDCs collectively to industry;
2) Public and spillover returns from the collective program; and
3) Identified public and spillover returns that are conditional on public contributions to RDCs.

While public impacts are identified, the focus of this report is to provide an estimate of returns to industry from HAL funded R&D projects, in line with CRRDCC reporting requirement 1. The evaluation framework used for this assessment is outlined in the diagram below.

Figure 2.1: Evaluation Framework



Source: AEC*group*, 2007

2.2 Project Selection

The three projects selected for examination are updated and augmented to fit within the CRRDCC guidelines from previous assessment in the report "*Quantifying the Return on Investment of Horticulture Australia Supported Projects – AH4019 Volume 1 & Volume 2*" (AEC*group* Ltd, 2005). Projects were selected based on their ability to produce a positive return on investment (as identified in the previous assessment), the availability of appropriate data to assess the project under CRRDCC guidelines, the project's ability to contribute both public and private benefits and the project's alignment with Government and Horticulture Australia priorities. The selection criteria framework is located in Appendix A.

The three projects selected as case studies for assessment based on this selection criteria are:

- Biology, Ecology and Control of the Citrus Jassid;
- Control of Bacterial Blight in Walnuts; and
- Insect Pest Management in Sweet Corn.

2.3 Evaluation Criteria

2.3.1 Summary of Criteria

The assessed projects must meet the following criteria to be considered a desirable investment.

- **Strategic Priorities:** The project must align with at least one Government and one HAL strategic priority;
- **Public & Private Benefit Criteria:** The project should provide some benefits to both public and private stakeholders; and
- **Economic Criteria (CBA):** To be evaluated as economically desirable the project should generate a Net Present Value (NPV) greater than zero and a Benefit Cost Ratio (BCR) greater than one. Please refer to Appendix B and the CRRDCC guidelines for an overview of the CBA process.

2.3.2 Alignment with Government & HAL Priorities

The projects were assessed for their alignment with Government and HAL priorities as outlined below.

Australian Government Priorities

Each project must align with at least one of the following Australian Government priorities for research and development:

- Productivity and adding value;
- Supply chain and markets;
- Natural resource management;
- Climate variability and climate change;
- Biosecurity;
- Supporting the rural research and development priorities; and
- Promote the development of new and existing technologies.

Horticulture Australia Limited

Each project must align with at least one of the following HAL priorities for research and development:

- Improve production efficiency and sustainability in response to market needs;
- Enhance efficiency, responsiveness and product integrity of the supply chain;
- Consistently meet requirements of consumers and key customers;
- Breakdown trade barriers and develop markets for products;
- Provide high quality value for money services;
- Develop plant biosecurity plans; and
- Ensure ongoing supply of skilled horticulture resources by attracting appropriately skilled people, horticulture research institutions and industry bodies. Develop an analytical framework for horticulture industries to enable strategic plan investment strategies.

2.3.3 Triple Bottom Line Return on Investment

The following approach has been used to assess the return on investment (ROI) for each project across the Triple Bottom Line (TBL) – economic, social and environmental.

Identification of Costs and Benefits

A comprehensive assessment of the benefits and costs for each project was undertaken to identify all economic, environmental and social impacts for the factual (with) and counterfactual (without) scenarios. Each impact was then assessed in terms of whether its value can be quantified, whether it provides a public and/ or private impact, and whether it is aligned with Government or HAL priorities.

Valuation of Costs and Benefits

All benefits and costs have been quantified where possible in order to identify their impact in 2006-07 dollar terms. Where an impact does not have a readily identifiable value, proxies and other measures have been used to provide an indicative or approximate value.

Benefits and costs not able to be readily quantified using market or non-market methods have been discussed qualitatively in terms of their likelihood and consequence of occurring, but are not included in the Cost Benefit Analysis. The framework used for assessing impacts qualitatively has been adapted from Crawford (2003) and Fletcher *et. al.* (2004), and is included as Appendix C.

Analysing Return on Investment

Cost Benefit Analysis (CBA) has been undertaken using all quantified benefits and costs to identify the return on investment of the three selected projects. A description of the CBA methodology used is included in Appendix B.

3. Biology, Ecology & Control of Citrus Jassid

3.1 Introduction

3.1.1 Background

The citrus leafhopper has become a major pest in citrus in the Central Burnett (Gayndah – Mundubbera) production region in the last ten years as a result of developing resistance to organophosphate insecticides and insecticidal suppression of its egg parasitoids. Citrus leafhopper damages green-mature and colouring fruit of the early varieties of Imperial mandarins and Navel oranges. Poor efficiency and inconsistency of control of organophosphate insecticides has previously resulted in high levels of infestation and substantial losses to citrus crops, in some years resulting in up to 100% of Imperial and Navel losses in infested areas.

3.1.2 Aim

The aim of this project was to **enhance the understanding of the biology and ecology of the citrus jassid and, subsequently, identify improved control methods**. The project encompassed two research programs (Project References CT98002 and CT616) with a combined project duration of seven years and a total research and development investment of $461,992 (in 2006-07 prices).

3.1.3 Outcome

The project resulted in the development of two pesticides – buprofezin and endosulfan – that provide a reduction in toxicity levels compared to previous control pesticides as well as a higher consistency of result and reduction in crop losses. Each of these pesticides could be applied individually to the crop, producing a reduction in losses to approximately 5% (endosulfan) and 2% (buprofezin). By comparison, the previous spray management regime resulted in average annual crop losses of approximately 20%.

The biology, ecology and control of citrus jassid research program also contributed significantly to the understanding and awareness of the threat posed by citrus jassid.

3.1.4 Adoption

This technique was adopted by effectively 100% of the regional industry on completion of the research program as the preferred alternative to higher toxicity and less effective pesticides.

3.2 Project Alignment with Key Priorities

The Biology, Ecology and Control of Citrus Jassid (control of citrus jassid) project has been identified to align with three of the seven Government priorities as outlined in the table below.

Table 3.1: Project Alignment with Government Priorities

Government Priority	Alignment	Description
Productivity & value adding to the industry	Yes	**Increased crop production:** The pesticides developed as a result of this project reduce total crop losses from 20% using existing control methods to between 2% (buprofezin) and 5% (endosulfan) loss. **Reduction in cost of treatment:** One of the two pesticides developed (endosulfan) results in a considerably lower treatment cost than using the existing control methods.

Government Priority	Alignment	Description
Supporting research & development priorities	Yes	**Improvement of basic research knowledge and application of findings:** The control of citrus jassid project was undertaken in two consecutive programs. The first program was aimed at understanding the basic biology and ecology of the citrus jassid, with the findings of this research applied to the development of targeted control methods.
Promote the development of new & existing technologies	Yes	**Development of two new pesticides:** The control of citrus jassid project resulted in the development of more targeted pesticides for the control of citrus jassid than were available prior to the research.

The project aligns with one of the seven HAL priorities as outlined in the table below.

Table 3.2: Project Alignment with HAL Priorities

HAL Priority	Alignment	Project Priority Alignment
Improve production efficiency & sustainability in response to market needs	Yes	**Reduction in cost of treatment:** One of the two pesticides developed (endosulfan) results in a considerably lower treatment cost than using the existing control methods. **Increased crop production:** The pesticides developed as a result of this project reduce total crop losses from 20% using existing control methods to between 2% (buprofezin) and 5% (endosulfan) loss.

The Biology, Ecology and Control of Citrus Jassid project satisfies the strategic priority evaluation criteria by meeting at least one Government and one HAL Priority.

3.3 Identification of Impacts

The following project benefits were identified across the triple bottom line (economic, environmental and social).

Table 3.3: Project Benefits

Project Benefit	Description	Assessment Type (Qualitative/ Quantitative)	Impact Type		Alignment with Priorities	
			Private	Public	Government	HAL
Environmental						
Increased selectivity of control	The use of endosulfan and buprofezin results in a lower level of toxicity to non-targeted vertebrates and insects compared to the use of previous control methods, reducing the level of non-targeted death of beneficial insects and animals.	Qualitative	N/a	Yes	Yes	Yes
Social						
Reduced toxicity to workers and end users	The use of endosulfan and buprofezin reduces the chemical hazard to humans, both handlers and consumers of products sprayed with the pesticides, when compared to the previous pesticides used (e.g. dimethoate and supracide).	Qualitative	Yes	Yes	Yes	N/a
Reduced odour	Reduced impact on surrounding households from odour due to the identification of alternative pesticides with a less offensive odour compared to previous pesticides used (dimethoate and supracide).	Quantitative	Yes	Yes	Yes	N/a

Project Benefit	Description	Assessment Type (Qualitative/ Quantitative)	Impact Type		Alignment with Priorities	
			Private	Public	Government	HAL
Economic						
Increased citrus production	Endosulfan and buprofezin reduce crop losses from an average of approximately 20% using previous control methods to around 5% for endosulfan and 2% for buprofezin.	Quantitative	Yes	N/a	Yes	Yes
Reduction in cost of treatment	Endosulfan has a lower cost of application per hectare than the previously used pesticides.	Quantitative	Yes	N/a	Yes	Yes

The following project costs were identified across the triple bottom line (economic, environmental and social). Only economics costs are detailed in the table below as no social or environmental costs were identified.

Table 3.4: Project Costs

Project Benefit	Description	Assessment Type (Qualitative/ Quantitative)	Impact Type		Alignment with Priorities	
			Private	Public	Government	HAL
Economic						
Cost of Research	The citrus jassid research and development program included two research projects across seven years equating to a present value of investment in 2006-07 of $461,992.	Quantitative	Yes	Yes	N/a	N/a
Increase in cost of treatment[(a)]	Buprofezin has a higher cost of application per hectare than the previously used pesticides.	Quantitative	Yes	Yes	N/a	N/a

Note: (a) Despite the increased cost of buprofezin, use of buprofezin and endosulfan has resulted in a net reduction in cost of treatment compared to previous treatments due to the lower cost of endosulfan.

The Biology, Ecology and Control of Citrus Jassid project satisfies the public-private benefit evaluation criteria by providing benefits to both public and private stakeholders.

3.4 Quantitative Assessment

3.4.1 Key Data & Inputs

Unless otherwise stated, all key data and inputs for this analysis were sourced from the previous report *Quantifying the Return on Investment for Horticulture Australia Supported Projects, Volume 1 and 2* (AEC*group*, 2005). The data of this report was sourced from the final project report for project CT98002 and/or direct correspondence with project team manager Dr James Freebairn.

Project Costs

The control of citrus jassid project (encompassing the programs CT616 and CT98002) ran for a combined seven years from 1996-97 to 2002-03 with a total investment in research and development of $461,992 (in 2006-07 dollar terms). The current year of assessment (2006-07) represents the eleventh year since commencement of the project, and the fourth year since the release of the research findings.

Area of Infestation

The citrus jassid is estimated to infest approximately 750 hectares of Imperial mandarin crops and 250 hectares of Navel orange crops in Queensland (1,000 hectares total).

Gross Value of Production (per Hectare)

The gross value per hectare (assuming no losses from citrus jassid) in 2006-07 dollar terms for Imperial mandarins and Navel oranges in the Central Burnett region is approximately $52,000 and $34,000 per hectare per annum, respectively.

Cost of Control

The prices and application rates of buprofezin and endosulfan (new treatments), as well as dimethoate and supracide (old treatments), have been estimated based on current retail prices (2006-07) and manufacturers' recommended application volume per hectare.

Buprofezin and endosulfan are estimated to cost $483.75 and $24.75 per hectare per annum, respectively, while dimethoate and supracide (previous control treatment) have a combined treatment cost $375 per hectare per annum. All three of these treatments require, on average, two applications per annum (G. North, Caboolture Elders, *pers. comm.*, 2007).

Effectiveness of Control

Research findings comparing pre-adoption and post-adoption crop losses indicate that buprofezin and endosulfan reduces the amount of damage to citrus crops due to citrus jassid to approximately 2% and 5%, respectively. Dimethoate and supracide (previous control treatment) resulted in, on average, 20% damage to the crop due to citrus jassid.

Willingness to Pay to Avoid Odour

It has been assumed that the willingness to pay (WTP) by households to avoid one contact per week with the odour of dimethoate and supracide is equivalent to the willingness to pay of households to avoid the smell of diesel fumes as assessed by Lareau and Rae (1989) of $8.13 per annum (in 2006-07 prices). Spraying is conducted over a 13 week period each year (or one quarter of the year) and as such the annual WTP to avoid one contact per week with supracide and dimethoate is estimated to be approximately $2.03 per household over the course of the year.

The number of households in the Gayndah/ Mundubberah area is estimated to be 1,874 (Australian Bureau of Statistics, 2007) and it is assumed that 100% of households in the region would be exposed at least weekly during the spraying season.

Adoption of Buprofezin and Endosulfan

Previous consultation with Dr James Freebairn indicated that endosulfan and buprofezin were adopted by effectively 100% of the Imperial mandarin and Navel orange industry in the Gayndah/ Mundubberah region upon completion of the research project (year 8). In the Gayndah/ Mundubberah region there are an estimated 750 hectares of Imperial mandarins and 250 hectares of Navel oranges. It is estimated that buprofezin has been adopted across approximately 500 hectares of the Imperial mandarin crop, and endosulfan has been adopted over approximately 250 hectares of Imperial mandarin and 250 hectares of the Navel orange crop.

3.4.2 Model

The CBA model used in the analysis compares the factual ('with') scenario of benefits and costs to the counterfactual ('without') scenario of benefits and costs. The overall net benefit of the project was determined by netting the overall 'with' scenario against the 'without' scenario. The net benefit of the program is estimated by the equation below:

$$NB = RC + CT + VPI + VPN + OD$$

Where:

NB	=	Net benefit of the control of citrus jassid project ($)
RC	=	The cost of the research ($)
CT	=	The change in the cost of treatment using buprofezin and endosulfan compared to the previous control method of dimethoate and supracide ($)
VPI	=	The change in value of production for Imperial mandarins due to the new control ($)
VPN	=	The change in value of production for Navel oranges due to the new control ($)
OD	=	The social benefit based on WTP for a reduction in odour ($)

Values for the above variables are calculated by subtracting the counterfactual ('without') variable from the factual ('with').

Cost of Research

The cost of research (RC) is estimated using the following equation:

$$RC = RCF - RCCF$$

Where:

RCF	=	The cost of research in the factual (with) scenario ($)
RCCF	=	The cost of research in the counterfactual (without) scenario ($)

The factual and counterfactual estimates for research costs are estimated using the equations below:

$$RCF = -\sum_{t=20}^{1} REF_t$$

$$RCCF = -\sum_{t=20}^{1} RECF_t$$

Where:

REF	=	Research expenditure in the factual scenario in year t ($)
RECF		Research expenditure in the counterfactual scenario in year t ($)
T	=	Time period (Year)

Cost of Treatment

The cost of treatment (CT) is estimated using the following equation:

$$CT = CTF - CTCF$$

Where:

CTF	=	The cost of treatment in the factual (with) scenario ($)
CTCF	=	The cost of treatment in the counterfactual (without) scenario ($)

The factual and counterfactual estimates for the cost of treatment are estimated using the equations below:

$$CTF = -\sum_{t=20}^{1} \left[\left(CH_E \times APP_E \times ADF_{E,t} \right) + \left(CH_B \times APP_B \times ADF_{B,t} \right) + \left(CH_{DS} \times APP_{DS} \times ADF_{DS,t} \right) \right] \times AI_{IM+NO}$$

$$CTCF = -\sum_{t=20}^{1} CH_{DS} \times APP_{DS} \times ADCF_{DS,t} \times AI$$

Where:

CH	=	The cost per hectare for specified pesticide ($/ha)
APP	=	Number of applications required for specified pesticide (number/year)
ADF	=	Adoption rate in the factual (with) scenario (%)
ADCF	=	Adoption rate in the counterfactual (without) scenario (%)
AI	=	Area infested by citrus jassid for specified crop (ha)
E	=	Endosulfan (pesticide descriptor)
B	=	Buprofezin (pesticide descriptor)
DS	=	Dimethoate and supracide (pesticide descriptor)
IM	=	Imperial mandarins (crop descriptor)
NO	=	Navel oranges (crop descriptor)

Value of Production for Imperial Mandarins

The value of production of Imperial mandarins (VPI) is estimated using the following equation:

$$VPI = VPIF - VPICF$$

Where:

VPIF	=	The value of production for Imperial mandarins in the factual (with) scenario ($)
VPICF	=	The value of production for Imperial mandarins in the counterfactual (without) scenario ($)

The factual and counterfactual estimates for the value of production of Imperial mandarins are estimated using the equations below:

$$VPIF = \sum_{t=20}^{1} \left(VP_{IM} - \left(VP_{IM} \times CL_{E}\right) \times AI_{IM} \times ADF_{E,IM,t}\right) + \left(VP_{IM} - \left(VP_{IM} \times CL_{B}\right) \times AI_{IM} \times ADF_{B,IM,t}\right) + \left[\left(VP_{IM} - \left(VP_{IM} \times CL_{DS}\right) \times AI_{IM} \times ADF_{DS,IM,t}\right)\right]$$

$$VPICF = \sum_{t=20}^{1} VP_{IM} - \left(VP_{IM} \times CL_{DS}\right) \times AI_{IM} \times ADCF_{IM,DS,t}$$

Where:

VP	=	Base value of production (i.e. assuming no losses due to citrus jassid) for specified crop ($/ha/year)
CL	=	Crop losses using specified pesticide (%)

Value of Production for Navel Oranges

The value of production of Navel oranges (VPN) is estimated using the following equation:

$$VPN = VPNF - VPNCF$$

Where:

VPNF	=	The value of production for Navel oranges in the factual (with) scenario ($)
VPNCF	=	The value of production for Navel oranges in the counterfactual (without) scenario ($)

The factual and counterfactual estimates for the cost of treatment are estimated using the equations below:

$$VPNF = \sum_{t=20}^{1} \left(VP_{NO} - \left(VP_{NO} \times CL_E\right) \times AI_{NO} \times ADF_{E,NO,t}\right) + \left(VP_{NO} - \left(VP_{NO} \times CL_B\right) \times AI_{NO} \times ADF_{B,NO,t}\right) + \left(VP_{NO} - \left(VP_{NO} \times CL_{DS}\right) \times AI_{NO} \times ADF_{DS,NO,t}\right)$$

$$VPNCF = \sum_{t=20}^{1} VP_{NO} - \left(VP_{NO} \times CL_{DS}\right) \times AI_{NO} \times ADCF_{IM,NO,t}$$

Reduced Odour

The social benefit based on WTP of reduced odour is estimated using the following equation:

$$OD = ODF - ODCF$$

Where:

ODF	=	The cost of odour from dimethoate and supracide in the factual (with) scenario ($)
ODCF	=	The cost of odour from dimethoate and supracide in the counterfactual (without) scenario ($)

The factual and counterfactual estimates for the cost of treatment are estimated using the equations below:

$$ODF = -\sum_{t=20}^{1} WTP \times HH \times ADF_{DS,t}$$

$$ODCF = -\sum_{t=20}^{1} WTP \times HH \times ADCF_{DS,t}$$

Where:

WTP	=	The willingness to pay of households to avoid one contact per week with an offensive odour ($/household/annum)
HH	=	The number of households in the study region (number)

3.4.3 Results

The analysis examined the change in industry income following the recommendations of the citrus jassid control research. The results of the analysis are presented in the table below. Over a 20 year project timeline, the citrus jassid control program is estimated to provide a net present value (NPV) of $35.35 million and BCR of 102.54, which implies a return of $102.54 for every dollar invested at a discount rate of 9.16%. The net present value of the project is positive across all discount rates and the program has an internal rate of return of approximately 114.6%.

Table 3.5: Summary

Discount Rate	Present Value of Benefits (PVB) ($M)	Present Value of Costs (PVC) ($M)	Net Present Value (NPV) ($M)	Benefit Cost Ratio (BCR)
6.00%	$50.78	$0.38	$50.40	132.90
8.00%	$40.53	$0.36	$40.17	112.56
9.16%	**$35.70**	**$0.35**	**$35.35**	**102.54**
10.00%	$32.63	$0.34	$32.29	95.98
12.00%	$26.48	$0.32	$26.16	82.37
IRR (%)	114.6%			

Note: The NPV may not exactly equal the PVB minus the PVC reported in the above table due to rounding. A base discount rate of 9.16% was selected for this analysis, which represents the long term bond rate of 6.16% plus 3% as required by CRRDCC (2007).

The table below outlines the cumulative present value of benefits and costs of the project, as well as the NPV and BCR, for five, ten and twenty year time horizons since commencement of the project as well as the current year (year 11 since project commencement in 1996-97). The net present value to date, four years since the release of the R&D findings, is estimated to be $15.18 million, with a present value of benefits equal to $15.53 million and a present value costs equal to $0.35 million.

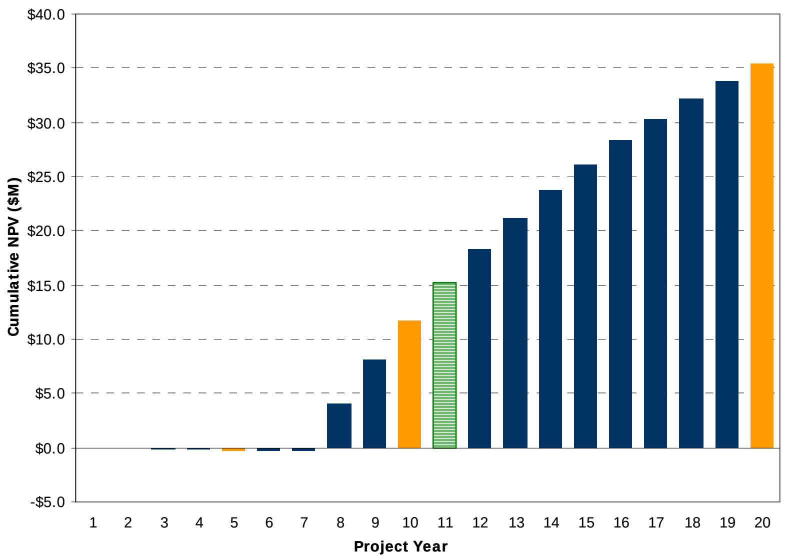
Table 3.6: Net Benefits, Net Costs and Net Present Value for Selected Time Horizons

Project Year	PV Benefits ($M)	PV Costs ($M)	NPV ($M)	BCR
Year 5	$0.00	$0.28	-$0.28	0.00
Year 10	$12.14	$0.35	$11.79	34.87
Year 11 (current)	**$15.53**	**$0.35**	**$15.18**	44.60
Year 20	$35.70	$0.35	$35.35	102.54

Note: The NPV may not exactly equal the PVB minus the PVC reported in the above table due to rounding.

The figure below illustrates the estimated cumulative net present value of the project over a 20 year timeline at a discount rate of 9.16%. The current year (year 11) is represented in patterned green. As can be seen, the project provides a positive return on investment from year 8 onwards.

Figure 3.1: Cumulative NPV Over 20 Years at 9.16% Discount Rate



Source: AEC*group*

> *The Biology, Ecology and Control of Citrus Jassid project satisfies the economic evaluation criteria by returning a positive NPV and a BCR greater than one.*

3.4.4 Sensitivity Analysis

The sensitivity analysis uses breakeven analysis (the point where a change in that variable results in a NPV of $0) to assess how significantly each of the key variables impact the CBA findings. Breakeven analysis has been conducted using the upper and lower discount rates to assess the sensitivity of that variable to the discount rate used. For the control of citrus jassid project the following variables were selected for the sensitivity analysis:

- Area receiving benefit; and
- Reduction in damage to crop using buprofezin and endosulfan.

Area Receiving Benefit

The breakeven value (where NPV is equal to $0 following the conduct and application of findings from the research program) with respect to the area receiving benefits from reduced crop losses ranges from 7.1 hectares (6.0% discount rate) to 11.7 hectares (12.0% discount rate). This equates to approximately 1.0% of the 1,000 hectares to which the benefit is expected to apply. As this equates to such a small proportion of the estimated area of infestation, it is unlikely that any discrepancy between the actual area receiving benefits and the data used in the analysis will significantly alter the outcome of the analysis. As such this is not considered a critical variable.

Reduction in Damage to Crop Using Buprofezin and Endosulfan

Research findings indicate that buprofezin, which is reported to be used over 500 hectares of the Imperial mandarin crop, and endosulfan, which is used over 250 hectares of both Imperial mandarin and Navel orange crops, provide a reduction in crop losses of approximately 18% and 15%, respectively, when compared to the previous management regime. Sensitivity analysis of the overall reduction in crop losses indicates that for the research and development investment to breakeven, buprofezin would only be required to increase the efficiency of control compared to previous treatment by approximately 1.0% across all discount rates, while the lower cost of endosulfan enables a positive return on investment even with a 2.0% increase in crop damage compared to supracide and dimethoate treatment. Variation in crop damage using endosulfan and buprofezin is therefore unlikely to significantly alter the outcome of the analysis and as such is not considered to be a critical variable.

Table 3.7: Summary of Sensitivity Analysis

Critical Variable	Units	Base Case	Breakeven Point	
			Lower Bound (6.0% discount rate)	Upper Bound (12.0 % discount rate)
Area Receiving Benefit	Hectares (Ha)	1,000	7.1	11.7
Reduction in Crop Damage:				
• Buprofezin	Percent (%)	18.0	1.0	1.0
• Endosulfan	Percent (%)	15.0	-2.0	-2.0

3.4.5 Limitations of Analysis

There was limited data available on the actual breakdown of Navel oranges and Imperial mandarins grown in the infested area. Such data would enable a more accurate analysis, however, this data has been determined to not be a critical variable in the analysis and as such is unlikely to materially affect the outcomes of the analysis.

The quality of citrus produce is assumed to remain the same under the new control methods. This analysis excludes any potential benefits from an increase in quality as price responsiveness data was unavailable. As a result, the benefits of the project presented in this evaluation are expected to be an underestimate of those actually delivered.

Environmental and social benefits such as reduced toxicity are not readily quantifiable by market methods and as such have not been included in the quantitative CBA but are identified in the following qualitative analysis to be significant. The return on investment presented in this case study is therefore considered to be a minimum estimate.

3.5 Qualitative Assessment

The following impacts of the project are not quantified in dollar terms due to limited data availability, and as such have been assessed qualitatively below:

- Reduced toxicity (environmental benefit); and
- Reduced toxicity to workers and end users (social benefit).

These impacts have been assessed using a likelihood and consequence framework adapted from Crawford (2003) and Fletcher *et. al.* (2004), with the likelihood and consequence ratings highlighted in bold (refer to Appendix B for an outline of the qualitative assessment framework used).

Environmental Benefits

Reduced Toxicity: The developed pesticides, buprofezin and endosulfan, are biologically specific pesticides for citrus jassid. Due to the high level of specificity of these pesticides it is **likely** that non-targeted impacts to other insects and vertebrates resulting from the use of supracide and dimethoate has been reduced, providing a detectable reduction in vertebrate and insect death over the medium term (**moderate** consequence). This would be expected to provide an improvement in the structure and composition of local lifecycles and overall biodiversity of the affected area.

These benefits are expected to be localised to the control area as treatments do not affect insect and vertebrate lifecycles outside of the control zone.

Social Benefits

Reduced Toxicity to Workers and End Users: Dimethoate and supracide (previous treatments) are highly toxic chemicals to all vertebrates including humans. During citrus harvesting season citrus harvesters and handlers of unwashed citrus produce are exposed to high levels of toxic chemical on a daily basis. The use of reduced toxicity buprofezin and endosulfan is **likely** to decrease human exposure to toxic chemicals.

It is possible that benefits of reduced toxicity would be detectable (in terms of reduced illness and potentially decreased fatalities from exposure), although this is anticipated to be **minor** when considered in the context of the overall industry. Impacts are expected to be predominantly localised to citrus harvesters and handlers in the region.

3.6 Summary of Assessment

The control of citrus jassid project resulted in the development of two pesticides that provide an improved level of control of citrus jassid when compared to existing methods of control. Cost Benefit Analysis (CBA) indicates that a total expenditure to date of $461,992 (in 2006-07 dollar terms) in the research and development project, which occurred over seven years from 1996-97 to 2002-03, provided the following outcomes:

- A NPV of $35.35 million and a BCR of 102.54 at a discount rate of 9.16%, which implies that the project returns $102.54 for every dollar of research and development invested;
- An internal rate of return of 114.6%;
- A positive return in investment across all discount rates between 6% and 12%;
- A positive return on investment from the eighth year from commencement of the research and its release in year seven;
- Key impacts driving this positive result include:
  - An annual increase in gross value of production (GVP) of $7.89 million;
  - An annual reduction in cost of control of $241,500; and
  - An annual reduction in the social impact of odour (based on public WTP to avoid contact with odour) valued at $3,808 per annum for the estimated 1,874 exposed households in the Gayndah/ Mundubberah area;
- Additional unquantified beneficial impacts include:
  - Reduced toxicity to the environment resulting in reduction in non-targeted insect and animal death (environmental benefit); and
  - Reduced toxicity to workers and consumers of citrus products (social benefit).

As the project has a positive NPV and a BCR above one, the project can be identified as being economically desirable.

To date (year 11 of the assessment) the project is estimated to have contributed a cumulative net present value of $15.18 million in economic benefits to both the public and private sectors.

This analysis is expected to under-represent the actual benefits of the project as it does not include unquantifiable social and environmental benefits from a reduction in toxicity. These benefits have not been quantified due to limited data availability.

4. Control of Bacterial Blight in Walnuts

4.1 Introduction

4.1.1 Background

Walnut orchards in Tasmania were losing an estimated 55% of the walnut harvest per annum as a result of bacterial blight. This was a significant loss on an industry that produced approximately 400 tonnes in 2004 (Australian Walnut Industry, 2005) of walnut crops, equating to an estimated loss of $1.4 million per annum for this level of production. Losses arise due to aborted blossoms (resulting in yield reduction) and blemished hulls which reduce the quality of the walnuts produced.

Prior to this project the strategies for control of the disease were based on the use of copper-manganese-zinc sprays at weekly intervals throughout the growing season. This program was costly, time consuming, didn't provide the desired level of control and produced adverse environmental effects. Additionally, there were fears that the efficacy of copper-based controls would be hampered by the emergence of copper-resistant strains of the disease.

4.1.2 Aim

The major objective of the Control of Bacterial Blight in Walnuts project was **to identify potential fungicides and application procedures for improved control of bacterial blight on walnuts**. The secondary objective of the program was the **identification of non-copper based treatments** to reduce environmental impacts and resistance concerns. The project (NT99001) ran for five years, commencing in the year 1999-2000, and had a total investment of $151,225 (in 2006-07 prices).

4.1.3 Outcome

The outcome of the project was the development of a non-copper based control technique (mankocide) for bacterial blight in walnuts. This treatment was found to reduce losses to 10.0% of the crop compared to previous losses of 55.0%.

4.1.4 Adoption

This control technique was adopted by effectively 100% of the industry on completion of the research program as the preferred alternative to less effective copper-based treatment.

4.2 Project Alignment with Key Priorities

The Control of Bacterial Blight in Walnuts project has been identified to align with two of the seven Government priorities as outlined in the table below.

Table 4.1: Project Alignment with Government Priorities

Government Priority	Alignment	Description
Productivity & value adding to the industry	Yes	**Increased crop production:** The treatments developed as a result of this project reduce total crop losses from 55% using existing control methods to approximately 10% loss.
Natural resource management	Yes	**Improved environmental sustainability:** Development of a non-copper based treatment will reduce the amount of copper leaching into the soil for previously copper treated walnut plantations. Copper based treatment is toxic to both plants and vertebrates and a reduction in use increase the environmental and farm production sustainability.

The project aligns with one of the seven HAL priorities as outlined in the table below.

Table 4.2: Alignment with HAL Priorities

HAL Priority	Alignment	Description
Improve production efficiency & sustainability in response to market needs	Yes	**Improved environmental sustainability:** Development of a non-copper based treatment will reduce the amount of copper leaching into the soil for previously copper treated walnut plantations. Copper based treatment is toxic to both plants and vertebrates and a reduction in use increase the environmental and farm production sustainability. **Increased crop production:** The treatments developed as a result of this project reduce total crop losses from 55% using existing control methods to approximately 10% loss. The outcome of this research is increased productivity of crop production through increased yield per hectare.

The Control of Bacterial Blight in Walnuts project satisfies the strategic priority evaluation criteria by meeting at least one Government and one HAL Priority.

4.3 Identification of Impacts

The following project benefits were identified across the triple bottom line (economic, environmental and social).

Table 4.3: Project Benefits

Project Benefit	Description	Assessment Type (Qualitative/ Quantitative)	Impact Type		Alignment with Priorities	
			Private	Public	Government	HAL
Environmental						
Reduced toxicity	A reduction in copper use for disease control which is highly toxic to both plants and vertebrates and increases the risk of tree burn from the sun.	Qualitative	N/a	Yes	Yes	Yes
Social						
Increased flexibility in land use	Improved land flexibility with the reduction in copper in the soils which restricts land use from alternative production activities such as grazing.	Qualitative	Yes	Yes	Yes	Yes
Economic						
Increased walnut production	Use of Mankocide reduces crop losses to 10% of the annual crop compared to copper based treatments (previously used), which only reduce losses to 55% of the annual crop.	Quantitative	Yes	N/a	Yes	Yes

The following project costs were identified across the triple bottom line (economic, environmental and social). Only economics costs are detailed in the table below as no social or environmental costs were identified.

Table 4.4: Project Costs

Project Benefit	Description	Assessment Type (Qualitative/ Quantitative)	Impact Type		Alignment with Priorities	
			Private	Public	Government	HAL
Economic						
Cost of research	The control of bacterial blight in walnuts research and development program occurred over five years equating to a present value of investment of $151,225.	Quantitative	Yes	Yes	N/a	N/a

Project Benefit	Description	Assessment Type (Qualitative/ Quantitative)	Impact Type		Alignment with Priorities	
			Private	Public	Government	HAL
Increased cost of control	Mankocide is estimated to be three times more expensive per hectare with the same number of annual applications than previously used copper based treatments.	Quantitative	Yes	Yes	N/a	N/a

The Control of Bacterial Blight in Walnuts project satisfies the public-private benefit evaluation criteria by providing benefits to both public and private stakeholders.

4.4 Quantitative Assessment

4.4.1 Key Data & Inputs

Unless otherwise stated, all key data and inputs for this analysis were sourced from the previous report *Quantifying the Return on Investment for Horticulture Australia Supported Projects, Volume 1 and 2* (AEC*group*, 2005). The data of this report was sourced from the final project report for project NT99003 and/or direct correspondence with project team manager Dr James Hills.

Project Costs

The initial costs of research and development of project NT99003 occurred over a five year period, commencing in 1999-2000. The project is estimated to have cost a total of approximately $151,225 (in 2006-07 dollar terms). The current year of assessment (2006-07) represents the eighth year since commencement of the project, and the third year since the release of the research findings.

Area of Walnut Crop Infested with Blight

Tasmania is estimated to have had approximately 650 hectares of walnut crop in 2004 (Adem & Jerie, 2004). Industry reports indicate that new plantations have been developed in Tasmania since 2004, increasing the walnut crop area by approximately 200 hectares, with a further 200 hectares expected to be planted over the next five to ten years to 2017 (Adem, 2007; Adem & Jerie, 2004).

This analysis assumes that the walnut crop grew at an average annual rate of 9.4% per annum between 2004 and 2007 to 850 hectares, and that over the next 10 years (to 2017) the walnut crop will increase by an additional 200 hectares (average annual rate of 2.1%) to reach a total of 1,050 hectares.

It is assumed that effectively 100% of the crop area in Tasmania is treated to prevent or reduce damage from bacterial blight.

Walnut Production

The Australian walnut industry is estimated to have produced approximately 400 tonnes of walnuts in 2004 (Australian Walnut Industry, 2005), the year before research findings were adopted by industry. As outlined above, the walnut crop area is estimated to increase at an average annual rate of 9.4% to 850 hectares between 2004 and 2007, and a rate of 2.1% to 1,050 hectares between 2007 and 2017. These growth rates have been applied to walnut production over the respective time periods.

Gross Value of Walnuts

The gross value per tonne of walnuts, as estimated by the Australian Bureau of Statistics (2006), is estimated to have fallen from an average of approximately $4,234 per tonne between 2001-02 to 2003-04 to an average of $3,590 per tonne in 2004-05, the first year that increased production is estimated to have been achieved due to the use of mankocide. The decline in value per tonne is likely a reflection of the increase in domestic walnut supply. The value per tonne of walnuts is assumed to average $3,590 per tonne over the 20 years of analysis in the factual scenario, while the counterfactual scenario assumes the value per tonne is maintained at $4,234 per tonne.

Control Efficacy

The use of copper-based treatment (the control method used pre-project) of bacterial blight resulted in losses of approximately 55% of the walnut harvest per annum and required eight applications annually.

Mankocide (the control method used post-project) reduces losses to approximately 10% of the walnut harvest and requires four applications annually (in the first two years of adoption eight applications were required).

Cost of Controls

Copper-based treatments (the standard control treatment used prior to the research project) cost an estimated $16 per hectare, while mankocide costs an estimated $73 per hectare (G. North, Caboolture Elders, *pers. comm.*, 2007).

Adoption

Mankocide is estimated to have been adopted by close to 100% of the industry in the first year upon completion of the research project (year 6 of the analysis) as a more effective and reduced toxicity management practice.

4.4.2 Model

The CBA model used in the analysis compares the factual ('with') scenario of benefits and costs to the counterfactual ('without') scenario of benefits and costs. The overall net benefit of the project was determined by netting the overall 'with' scenario against the 'without' scenario. The net benefit of the program is estimated by the equation below:

$$NB = RC + CT + VP$$

Where:

NB	=	Net benefit of the control of bacterial blight in walnuts ($)
RC	=	The cost of the research ($)
CT	=	The change in the cost of treatment using mankocide compared to the previous control method ($)
VP	=	The change in value of production for walnuts due to the new control ($)

Values for the above variables are calculated by subtracting the counterfactual ('without') variable from the factual ('with').

Cost of Research

The cost of research (RC) is estimated using the following equation:

$$RC = RCF - RCCF$$

Where:

RCF	=	The cost of research in the factual (with) scenario ($)
RCCF	=	The cost of research in the counterfactual (without) scenario ($)

The factual and counterfactual estimates for research costs are estimated using the equations below:

$$RCF = -\sum_{t=20}^{1} REF_t$$

$$RCCF = -\sum_{t=20}^{1} RECF_t$$

Where:
REF = Research expenditure in the factual scenario in year t ($)
RECF Research expenditure in the counterfactual scenario in year t ($)
t = Time period (Year)

Cost of Treatment

The cost of treatment (CT) is estimated using the following equation:

$$CT = CTF - CTCF$$

Where:
CTF = The cost of treatment in the factual (with) scenario ($)
CTCF = The cost of treatment in the counterfactual (without) scenario ($)

The factual and counterfactual estimates for the cost of treatment are estimated using the equations below:

$$CTF = -\sum_{t=20}^{1}\left(CH_M \times AI_t \times APP_M \times ADF_{M,t}\right) + \left(CH_{CB} \times AI_t \times APP_{CB} \times ADF_{CB,t}\right)$$

$$CTCF = -\sum_{t=20}^{1} CH_{CB} \times AI_t \times APP_{CB} \times ADCF_{CB,t}$$

Where:
CH = Cost of treatment per hectare for specified treatment ($/ha)
AI = Area of walnut crops infested with bacterial blight in year *t* (ha)
APP = Number of pesticide applications for specified treatment (no.)
ADF = Adoption rate in the factual (with) scenario for specified treatment (%)
ADCF = Adoption rate in the counterfactual (without) scenario for specified treatment (%)
M = Mankocide (pesticide descriptor)
CB = Copper-based treatment used prior to research project (pesticide descriptor)

Value of Production of Walnuts

The value of production of walnuts (VP) is estimated using the following equation:

$$VP = VPF - VPCF$$

Where:
VPF = The value of production for walnuts in the factual (with) scenario ($)
VPCF = The value of production for walnuts in the counterfactual (without) scenario ($)

The factual and counterfactual estimates for the cost of treatment are estimated using the equations below:

$$VPF = \sum_{t=20}^{1}\left[\left(BVP_t - \left(BVP_t \times CL_M\right)\right) \times AI_t \times ADF_{M,t}\right] + \left[\left(BVP_t - \left(BVP_t \times CL_{CB}\right)\right) \times AI_t \times ADF_{CB,t}\right]$$

$$VPCF = \sum_{t=20}^{1}\left(BVP_t - \left(BVP_t \times CL_{CB}\right)\right) \times AI_t \times ADCF_{CB,t}$$

Where:
CL = Crop losses using specified control treatment (%)
BVP = Base value of production of walnuts (i.e. assuming no losses due to bacterial blight) ($/ha/year)

The base value of production of walnuts (BVP) outlined above is estimated using the following equation:

$$BVP_t = GVW \times \frac{WP_t}{(1 - CL_{CB})}$$

Where:
GVW = The gross value per tonne in 2004-05 ($/tonne)
WP = Estimated walnut production in year *t* (assuming copper-based treatment is used) (tonnes)

4.4.3 Results

The analysis examined the change in industry income following adoption of the walnut blight control research recommendations. The results of the analysis are presented in the table below. Over a 20 year project timeline, the walnut blight control program is estimated to provide a net present value (NPV) of $7.96 million and BCR of 7.57, which implies a return of $7.57 for every dollar invested at a discount rate of 9.16%. The net present value of the project is positive across all discount rates and the program has an internal rate of return of 103.4%.

Table 4.5: Summary

Discount Rate	Present Value of Benefits (PVB) ($M)	Present Value of Costs (PVC) ($M)	Net Present Value (NPV) ($M)	Benefit Cost Ratio (BCR)
6.00%	$12.71	$1.58	$11.13	8.05
8.00%	$10.31	$1.33	$8.98	7.75
9.16%	**$9.17**	**$1.21**	**$7.96**	**7.57**
10.00%	$8.44	$1.13	$7.31	7.45
12.00%	$6.98	$0.98	$6.00	7.15
IRR (%)	103.4%			

Note: The NPV may not exactly equal the PVB minus the PVC reported in the above table due to rounding. A base discount rate of 9.16% was selected for this analysis, which represents the long term bond rate of 6.16% plus 3% as required by CRRDCC (2007).

The table below outlines the cumulative present value of benefits and costs of the project, as well as the NPV and BCR for five, ten and twenty year time horizons since commencement of the project as well as the current year (eight years since the project commenced in 1999-2000). The net present value to date, three years since the release of the R&D findings, is estimated to be $1.89 million, with an approximate present value of benefits equal to $2.51 million and a present value of costs equal to $0.62 million.

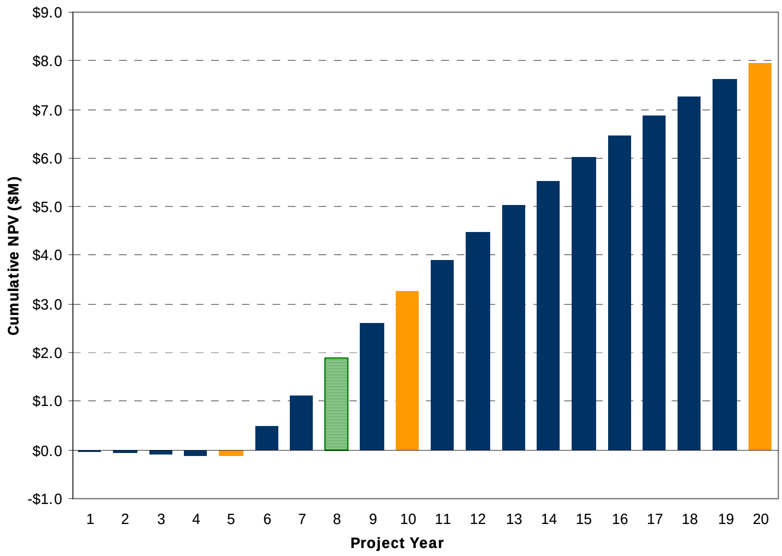
Table 4.6: Net Benefits, Net Costs and Net Present Value for Selected Time Horizons

Project Year	PV Benefits ($M)	PV Costs ($M)	NPV ($M)	BCR
Year 5	$0.00	$0.13	-$0.13	0.00
Year 8 (current)	**$2.51**	**$0.62**	**$1.89**	**4.04**
Year 10	$4.02	$0.75	$3.27	5.33
Year 20	$9.17	$1.21	$7.96	7.57

Note: The NPV may not exactly equal the PVB minus the PVC reported in the above table due to rounding.

The figure below illustrates the estimated cumulative net present value of the project over a 20 year timeline at a discount rate of 9.16%. The current year (year eight) is represented in patterned green. As can be seen, the project provides a positive return on investment from year 6 onwards.

Figure 4.1: Cumulative NPV Over 20 Year Time Horizon at 9.16% Discount Rate



Source: AEC*group*

The Control of Bacterial Blight in Walnuts project satisfies the economic evaluation criteria by returning a positive NPV and a BCR greater than one.

4.4.4 Sensitivity Analysis

For the control of walnut blight project the following variable was selected for the sensitivity analysis:

- Increase in production volume.

Increase in Production Volume

For the control of walnut blight project to breakeven (where NPV is equal to $0 following adoption of research findings), a minimum average annual increase in production of between 71.3 tonnes (6.0% discount rate) and 80.4 tonnes (12.0% discount rate) is required from year six onwards (the first year that research findings were adopted). This equates to approximately 12.4% to 14.0% of the estimated average annual increase in walnut production of 574.5 tonnes. As this equates to such a small proportion of the estimated increase in production, it is unlikely that any discrepancy between the actual increase and the data used in the analysis will significantly alter the outcome of the analysis. As such this is not considered a critical variable.

Table 4.7: Summary of Sensitivity Analysis

Critical Variable	Units	Base Case	Breakeven Point	
			Lower Bound (6.0% discount rate)	Upper Bound (12.0 % discount rate)
Increase in Production Volume [(a)]	Tonnes	574.5 [(a)]	71.3	80.4

Note: (a) This is the average annual increase in production volume following adoption of research findings in the with and without scenarios. Note that the actual increase in production volume varies by year due to the expansion in the industry between 2004 and 2017.

4.4.5 Limitations of Analysis

The use of mankocide significantly reduces the use of copper for treating bacterial blight in walnuts, providing both environmental and social benefits by reducing the amount of copper leaching into the soil, which is toxic to both plants and vertebrates. High copper content in the soil precludes use of the soil for other purposes, such as livestock grazing and organic products due to toxicity. In the longer term, copper toxicity in the soil will lead to tree damage, especially through increased susceptibility to sunburn. These benefits are difficult to quantify in dollar terms and as such have not been quantified in the CBA.

Other walnut crops, such as those in Victoria, that are currently not as severely affected by bacterial blight also have the potential to benefit from this project. Due to limitations in data on production losses in these crops and adoption of mankocide, any potential benefits accruing outside of Tasmania have not been included. As such the benefits and return on investment identified in this analysis is considered to be a conservative estimate of those delivered by the program.

4.5 Qualitative Assessment

The following impacts of the project are not quantified in dollar terms due to limited data availability, and as such have been assessed qualitatively below:

- Reduced toxicity (environmental benefit); and
- Increased land flexibility (economic benefit).

These impacts have been assessed using a likelihood and consequence framework adapted from Crawford (2003) and Fletcher *et. al.* (2004), with the likelihood and consequence ratings highlighted in bold (refer to Appendix B for an outline of the qualitative assessment framework used).

Environmental Benefits

Reduced Toxicity: Previously used treatments for bacterial blight were copper based chemicals which are highly toxic to plants and vertebrates. The use of mankocide, a non-copper based control treatment, is **almost certain** to have reduced the level of copper that was previously leaching into the soils. Reduced copper contamination and associated negative impacts is expected to provide a detectable improvement in the structure and composition of local lifecycles of vertebrates and plants, as well as the overall biodiversity of the affected area (**moderate** consequence).

The impact on reduced copper contamination is anticipated to be localised to the control area as treatments do not affect plant and vertebrate lifecycles outside of the control zone.

Economic Benefits

Increased land use flexibility: Previously, copper based treatments for bacterial blight in walnut crops resulted in high levels of toxic copper residues leaching into the soil, preventing the use of this land for potentially higher value production purposes. The use of the non-copper based mankocide has **almost certainly** reduced the amount of toxic copper residues leaching into the soil. Over the long term it is possible the reduced copper leaching may result in overall soil copper levels decreasing to enable alternative productive uses (**minor** consequence).

The impact of increased land use flexibility is anticipated to be localised to the direct property owners and surrounding properties of the treatment area where copper contamination has been detected.

4.6 Summary of Assessment

The control of bacterial blight in walnuts project resulted in the development of a non-copper based pesticide that improved level of control of bacterial blight when compared to existing methods of control. Cost Benefit Analysis (CBA) indicates that a total expenditure of $151,225 (in 2006-07 dollar terms) in the research and development project, which occurred over five years between 1999-2000 and 2003-04, resulted in the following outcomes:

- A NPV of $7.96 million and a BCR of 7.57 at a discount rate of 9.16%, which implies that the project returns $7.57 for every dollar of research and development invested;
- An internal rate of return of 103.4%;

- A positive return in investment across all discount rates between 6% and 12%;
- A positive return on investment from the sixth year following commencement of the research;
- The key impact driving this positive result is an average annual increase in gross value of production (GVP) of $1.70 million, which may be increased if mankocide can be produced and sold at a reduced cost;
- Additional unquantifiable impacts include:
    - Reduced toxicity to the environment from copper leaching into the soil, with benefits to plants and vertebrates (environmental benefit); and
    - Increased land use flexibility due to a reduction in the amount of copper (used in previous treatments) leaching into the soil (economic benefit).

As the project has a positive NPV and a BCR above one, the project can be identified as being economically desirable.

To date (year eight of the assessment) the project is estimated to have contributed a cumulative net present value of $1.89 million in economic benefits to both the public and private sectors.

This analysis is expected to under-represent the actual benefits of the project, as it does not include unquantifiable environmental and economic benefits from a reduction in toxicity and an increase in land flexibility. These benefits have not been quantified due to limited data availability.

5. Insect Pest Management in Sweet Corn

5.1 Introduction

5.1.1 Background

Heliothis and heliothis larvae cause significant pest damage to sweet corn crops, with some crops in the early 1990s reporting 100% losses in some years. This was largely due to the high levels of insecticide resistance which occur in heliothis. The inability of growers in Queensland, New South Wales and Victoria to produce cobs free from heliothis larvae and insect damage reduced their ability to maintain contracts with domestic and export markets due to low reliability of supply, poor quality of product and high quarantine risks.

5.1.2 Aim

The aim of the project was to discover methods to **control heliothis and reduce the risk of crop failure due to infestation of crops** with this species. High levels of damage to crops was limiting the industries capacity to meet demands of the sweet corn export market and produce a consistent supply for the domestic market. The project (VG97036) had a duration of 6 years commencing in 1997-98 and a total cost of $1.69 million (in 2006-07 prices).

5.1.3 Outcome

The outcome of this project was the development of best management options (BMOs) for the management of heliothis. The project resulted in the development of two alternative biological pesticide products – Gemstar and Success – which were found to be specific to heliothis. Prior to development of heliothis specific pesticides broad spectrum pesticides were employed, however, the use of broad spectrum pesticides were often inconsistent and resulted in high levels of non-specific and beneficial insect deaths.

The use of BMOs for control of insect pest management in sweet corn, including Gemstar and Success, was found to reduce crop losses from an average of approximately 35.0% per annum to 15.0% per annum, as well as improving the overall quality of produce and providing environmental benefits within treatment zones. This has allowed for an increase in consistency of supply to the domestic market, and has enabled the reopening of the export market through the consistent production of sweet corn free from insects and insect damage.

5.1.4 Adoption

BMOs for insect pest management in sweet corn are estimated to have been adopted by approximately 95% of the industry in Queensland within the first two years. New South Wales and Victoria have also adopted BMOs for pest management in sweet corn. It has been assumed for this analysis that the adoption rates for these States are similar to the Queensland rate.

5.2 Project Alignment with Key Priorities

The insect pest management in sweet corn project has been identified to align with four of the seven Government priorities as outlined in the table below.

Table 5.1: Project Alignment with Government Priorities

Government Priority	Alignment	Description
Productivity & value adding to the industry	Yes	**Increased crop production:** The BMOs developed as a result of this project reduce total crop losses from 35% using existing control methods to 15% loss.

Government Priority	Alignment	Description
Supply Chain & Markets	Yes	**Improved reliability of supply to domestic and international markets:** The development of BMOs has resulted in an increased quality of product and reliability of supply to both the domestic and international markets. Prior to development, crop losses of up to 100% had been recorded in some years, and poor quality of crops due to heliothis damage presented serious implications for the supply of sweet corn and the maintenance of supply contracts.
Biosecurity	Yes	**Ability to meet quarantine standards:** Heliothis and heliothis larvae present serious quarantine implications to domestic and international markets. Previous contracts with international markets were discontinued due to these quarantine risks from damaged or contaminated produce, however, the development of more effective control techniques have resulted in the re-establishment of market contracts and reduction of quarantine risks.
Promote the development of new & existing technologies	Yes	**Improved heliothis knowledge and development of controls:** The research and development program has resulted in innovative management options targeting heliothis. The program has resulted in development of improved monitoring programs, procedures and results for biosecurity in Australia.

The project aligns with four of the seven HAL priorities as outlined in the table below.

Table 5.3: Project Alignment with HAL Priorities

HAL Priority	Alignment	Description
Consistently meet requirements of consumers & key customers	Yes	**Improved reliability of supply to domestic and international markets:** The development of BMOs for heliothis has resulted in an increased quality of product and reliability of supply to both the domestic and international markets. Prior to development, large crop losses and poor quality of crops due to heliothis and heliothis larvae presented serious implications for the supply of sweet corn.
Breakdown trade barriers & develop markets for products	Yes	**Re-establishment of export markets:** Severe damage to the sweet corn crop due to heliothis and heliothis larvae previously resulted in poor quality product, unreliable supply and significant quarantine risk to export markets. The development of BMOs has reduced crop losses and has resulted in reestablishment of contracts with export markets where quarantine issues previously made these untenable.
Develop plant biosecurity plans	Yes	**Improved biosecurity procedures and controls:** As heliothis poses a serious quarantine risk, the research into BMOs for heliothis in sweet corn has resulted in the development of improved quarantine monitoring programs and procedures for biosecurity in Australia.
Improve production efficiency and sustainability in response to market needs	Yes	**Increased crop production:** The BMOs developed as a result of this project reduce total crop losses from 35% using pre-research control methods to 15% percent loss providing the opportunity for high value for return on investment.

The Pest Management in Sweet Corn project satisfies the strategic priority evaluation criteria by meeting at least one Government and one HAL Priority.

5.3 Identification of Impacts

The following project benefits were identified across the triple bottom line (economic, environmental and social).

Table 5.4: Project Benefits

Project Benefit	Description	Assessment Type (Qualitative/ Quantitative)	Impact Type		Alignment with Priorities	
			Private	Public	Government	HAL
Environmental						
Reduced reliance on broad spectrum insecticides	Use of the biological insecticides that are specific to heliothis minimises the impact on the environment caused by using broad spectrum pesticides, in particular losses of non-targeted beneficial insects and vertebrates (including humans).	Qualitative	Yes	N/a	Yes	Yes
Social						
Consistent supply of sweet corn to the market place	Decreased risks of crop failure and reduced heliothis and larvae damage has improved the consistency of supply to the domestic market.	Qualitative	Yes	Yes	Yes	Yes
Economic						
Increased sweet corn production	Previous crop losses averaged approximately 35% of production per annum, and were as high as 100% in some years.This has been reduced to an estimated average annual crop loss of 15% through the introduction of alternative control techniques.	Quantitative	Yes	N/a	Yes	Yes
Re-establishment of the export market	The development of BMOs has reduced heliothis and larvae damage and allowed for the re-establishment of valuable contracts with the Asian export market that were previously discontinued.	Qualitative	Yes	N/a	Yes	Yes

The following project costs were identified across the triple bottom line (economic, environmental and social). Only economic costs are detailed in the table below as no social or environmental costs were identified.

Table 5.5: Project Costs

Project Benefit	Description	Assessment Type (Qualitative/ Quantitative)	Impact Type		Alignment with Priorities	
			Private	Public	Government	HAL
Economic						
Cost of research	The insect pest management in sweet corn research and development program occurred over six years equating to a present value of investment of $1.7 million.	Quantitative	Yes	Yes	N/a	N/a
Additional growing expenses	New management techniques are estimated to result in an additional cost of $239 per hectare compared to previous control techniques.	Quantitative	Yes	Yes	N/a	N/a

The Pest Management in Sweet Corn project satisfies the public-private benefit evaluation criteria by providing benefits to both public and private stakeholders.

5.4 Quantitative Assessment

5.4.1 Key Data & Inputs

Unless otherwise stated, key data was sourced from the project report VG97036 and the report *Quantifying the Return on Investment for Horticulture Australia Supported Projects, Volume 1 and 2* (AEC*group*, 2005). The data of this report was sourced from the final project report for VG97036 and/or direct correspondence with Dr Peter Deuter.

Project Costs

The project VG97036 ran for six years from 1997-98 to 2002-03 with a total investment in research and development of $1.69 million (in 2006-07 dollar terms). The majority of project costs occurred over the first four years of the project, with research findings released by the fifth year of the R&D project. The current year of assessment (2006-07) represents the tenth year since commencement of the project, and the third year since the release of the research findings.

Adoption Rate

Industry-wide adoption of BMOs for heliothis in sweet corn is estimated to have started in 2001-02 (the fifth year of the analysis), increasing over a two year period to approximately 95.0%. Adoption is assumed to remain steady for the remainder of the assessment period.

Gross Value of Sweet Corn

According to data from the Australian Bureau of Statistics (2007), the gross value of sweet corn in 2005-06 was estimated to be approximately $985.89 per tonne (Queensland), $471.64 per tonne (New South Wales) and $1,150.23 per tonne (Victoria). The gross value of sweet corn is assumed to be maintained into the future in each State.

Crop Losses

Anecdotal evidence indicates that crop losses averaged between 30% and 40% per annum (35% used in this analysis) prior to this project and have been reduced to approximately 15% per annum where the new pest management techniques have been introduced.

Volume of Production

In 2005-06 the estimated volume of production for sweet corn was 40,814 tonnes in Queensland, 50,891 tonnes in New South Wales and 5,451 tonnes in Victoria (Australian Bureau of Statistics, 2007), which is the third year of adoption of new treatments following completion of the research project (and therefore represents production levels at 95% adoption of BMOs with an annual estimated crop loss of 15%).

Area of Sweet Corn Crop Infested

Data from the Australian Bureau of Statistics (2007a and 2007b) indicates that there were 2,903 hectares of sweet corn crops in Queensland in 2005-06 (post adoption of BMOs), considerably greater than the average crop area of 1,880 hectares between 1996-97 and 1999-2000 (pre adoption). Anecdotal evidence (AUSVEG, 2005) suggests that the project has contributed to this increase in crop area due to improved confidence of producers in the Queensland sweet corn industry, however, there is little information available to quantify the direct contribution of the research project in increasing the crop area. To ensure a conservative assessment, it has been assumed that this increase in crop area would have occurred regardless of the findings of the research project. The crop area in Queensland is assumed to average 2,903 hectares from 2005-06 onwards.

The sweet corn crop area in New South Wales (1,554 hectares) and Victoria (542 hectares) in 2005-06 (post adoption of BMOs) has remained relatively similar to the average crop area between 1996-97 and 1999-2000 (pre-adoption), and is assumed to maintain a similar average crop area over the 20 years of the analysis.

Production Costs

The adoption of BMOs is estimated to have increased the cost of production per hectare by $239 to $1,585 per hectare.

5.4.2 Model

The CBA model used in the analysis compared the factual ('with') scenario of benefits and costs to the counterfactual ('without') scenario of benefits and costs. The overall net benefit of the project was determined by netting the overall 'with' scenario against the 'without' scenario. The net benefit of the program is estimated by the equation below:

$$NB = RC + CT + VPS$$

Where:

NB	=	Net benefit of pest management in sweet corn ($)
RC	=	The cost of the research ($)
CT	=	The change in the cost of treatment using gemstar and success compared to the previous control method ($)
VPS	=	The change in value of production for sweet corn due to the new control ($)

Values for the above variables are calculated by subtracting the counterfactual ('without') variable from the factual ('with').

Cost of Research

The cost of research (RC) is estimated using the following equation:

$$RC = RCF - RCCF$$

Where:

RCF	=	The cost of research in the factual (with) scenario ($)
RCCF	=	The cost of research in the counterfactual (without) scenario ($)

The factual and counterfactual estimates for research costs are estimated using the equations below:

$$RCF = -\sum_{t=20}^{1} REF_t$$

$$RCCF = -\sum_{t=20}^{1} RECF_t$$

Where:

REF	=	Research expenditure in the factual scenario in year t ($)
RECF		Research expenditure in the counterfactual scenario in year t ($)
t	=	Time period (Year)

Cost of Treatment

The cost of treatment (CT) is estimated using the following equation:

$$CT = CTF - CTCF$$

Where:

CTF	=	The cost of treatment in the factual (with) scenario ($)
CTCF	=	The cost of treatment in the counterfactual (without) scenario ($)

The factual and counterfactual estimates for the cost of treatment are estimated using the equations below:

$$CTF = -\sum_{t=20}^{1} \left[CH_{BM} \times \left(QAI_t + NAI_t + VAI_t\right) \times ADF_{BM,t}\right] + \left[CH_{PT} \times \left(QAI_t + NAI_t + VAI_t\right) \times ADF_{PT,t}\right]$$

$$CTCF = -\sum_{t=20}^{1} CH_{PT} \times \left(QAI_t + NAI_t + VAI_t\right) \times ADCF_{PT,t}$$

Where:

CH	=	The cost per hectare for specified treatment ($/ha/annum)
QAI	=	Area infested in Queensland (ha)
NAI	=	Area infested in New South Wales (ha)
VAI	=	Area infested in Victoria (ha)
ADF	=	Adoption rate in the factual (with) scenario for specified treatment (%)
ADCF	=	Adoption rate in the counterfactual (without) scenario for specified treatment (%)
BM	=	Best Management Options (treatment descriptor)
PT	=	Pre-research management technique (treatment descriptor)

Value of Production of Sweet Corn

The value of production of sweet corn (VP) is estimated using the following equation:

$$VPS = VPF - VPCF$$

Where:

VPF	=	The value of production for sweet corn in the factual (with) scenario ($)
VPCF	=	The value of production for sweet corn in the counterfactual (without) scenario ($)

The factual and counterfactual estimates for the cost of treatment are estimated using the equations below:

$$VPF = \sum_{t=20}^{1} \left[\left(QVP \times QP_t + NVP \times NP_t + VVP \times VP_t \right) \times \left(1 - CL_{BM} \right) \times ADF_{BM,t} \right] + \left[\left(QVP \times QP_t + NVP \times NP_t + VVP \times VP_t \right) \times \left(1 - CL_{PT} \right) \times ADF_{PT,t} \right]$$

$$VPCF = \sum_{t=20}^{1} \left[\left(QVP \times QP_t + NVP \times NP_t + VVP \times VP_t \right) \times \left(1 - CL_{PT} \right) \times ADCF_{PT,t} \right]$$

Where:

QVP	=	Value of production per tonne of sweet corn in Queensland ($/tonne)
QP	=	Volume of production in Queensland in year t for specified treatment (tonnes)
NVP	=	Value of production per tonne of sweet corn in New South Wales ($/tonne)
NP	=	Volume of production in New South Wales in year t for specified treatment (tonnes)
VVP	=	Value of production per tonne of sweet corn in Victoria ($/tonne)
VP	=	Volume of production in Victoria in year t for specified treatment (tonnes)
CL	=	Crop losses for specified treatment (%)

5.4.3 Results

The analysis examined the change in industry income following the adoption of the insect pest management in sweet corn R&D recommendations. The results of the analysis are presented in the table below. Over a 20 year project timeline, the pest management in sweet corn program is estimated to provide a net present value (NPV) of $82.71 million and BCR of 5.88, which implies a return of $5.88 for every dollar invested at a discount rate of 9.16%. The net present value of the project is positive across all discount rates and the program has an internal rate of return of 137.1%.

Table 5.6: Summary

Discount Rate	Present Value of Benefits (PVB) ($M)	Present Value of Costs (PVC) ($M)	Net Present Value (NPV) ($M)	Benefit Cost Ratio (BCR)
6.00%	$133.65	$22.29	$111.37	6.00
8.00%	$110.67	$18.68	$91.99	5.92
9.16%	**$99.67**	**$16.96**	**$82.71**	**5.88**
10.00%	$92.58	$15.84	$76.74	5.85
12.00%	$78.17	$13.57	$64.61	5.76
IRR (%)	137.1%			

Note: The NPV may not exactly equal the PVB minus the PVC reported in the above table due to rounding. A base discount rate of 9.16% was selected for this analysis, which represents the long term bond rate of 6.16% plus 3% as required by CRRDCC (2007).

The table below outlines the cumulative present value of benefits and costs of the project, as well as the NPV and BCR for five, ten and twenty year time horizons since commencement of the project as well as the current year (year ten since the commencement of the project). The net present value to date, six years since the initial release of the R&D findings in 2001-02, is estimated to be $44.15 million, with a present value of benefits equal to $54.03 million and a present value of costs equal to $9.87 million.

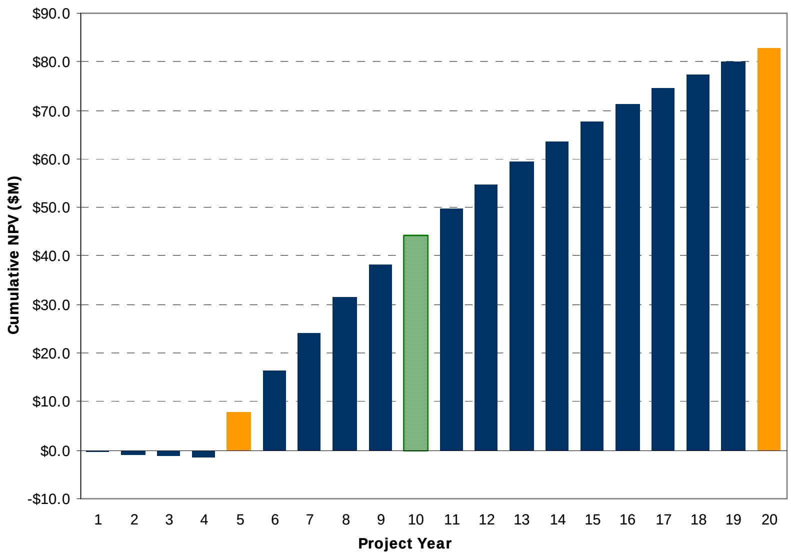
Table 5.7: Net Benefits, Net Costs and Net Present Value for Selected Time Horizons

Project Year	PV Benefits ($M)	PV Costs ($M)	NPV ($M)	BCR
Year 5	$11.03	$3.20	$7.83	3.45
Year 10 (current)	**$54.03**	**$9.87**	**$44.15**	**5.47**
Year 20	$99.67	$16.95	$82.71	5.88

Note: The NPV may not exactly equal the PVB minus the PVC reported in the above table due to rounding.

The figure below illustrates the estimated cumulative net present value of the project in million dollars over a 20 year timeline at a discount rate of 9.16%. The current year (year ten) is represented in patterned green. As can be seen, the project provides a positive return on investment from year five onwards.

Figure 5.1: Cumulative NPV Over 20 Year Time Horizon at 9.16% Discount Rate



Source: AEC*group*

The Pest Management in Sweet Corn project satisfies the economic evaluation criteria by returning a positive NPV and a BCR greater than one.

5.4.4 Sensitivity Analysis

For the pest management in sweet corn project the following variables were selected for the sensitivity analysis:

- Reduction in damage to crop using BMOs; and
- Adoption rate.

Reduction in Damage to Crop Using BMOs

The use of BMOs in the control of heliothis is estimated to have a higher cost of production per hectare in comparison to the previous treatment. To achieve a minimum break even NPV of $0 the crop requires a reduction in crop damage from the previous treatment of 3.0 percentage points (from 35.0% to 32.0% crop loss) for all discount rates ranging between 6% and 12%.

BMOs are estimated to reduce crop damage from approximately 35.0% (previous treatment methods) to approximately 15.0% (new treatment methods) which is a 20.0 percentage point reduction in crop losses, well above the minimum required damage reduction to justify the investment. As such, any discrepancy between the actual reduction in damage to the crop using BMOs and that used in the analysis is not likely to significantly alter the outcome of the analysis and is thereby not considered a critical variable.

Adoption Rate

The breakeven value with respect to the adoption rate ranges between 29.7% (6.0% discount rate) and 39.9% (12.0% discount rate), which is approximately one third of the estimated adoption rate of 95.0%. As such, any discrepancy between the actual adoption rate and the adoption rate used in this analysis is unlikely to have a significant impact on the outcome of the analysis.

Table 5.8: Summary of Sensitivity Analysis

Critical Variable	Units	Base Case	Breakeven Point	
			Lower Bound (6.0% discount rate)	Upper Bound (12.0 % discount rate)
Reduction in Crop Damage: Gemstar & Success	Percent (%)	20.0	3.0	3.0
Adoption Rate	Percent (%)	95.0	29.7	39.9

5.4.5 Limitations of Analysis

Anecdotal evidence (AUSVEG, 2005) suggests that the project has contributed to a considerable increase in crop area in Queensland due to improved producer confidence in the Queensland sweet corn industry. However, there is little information available to quantify the direct contribution of the research project in increasing the crop area. To ensure a conservative assessment, it has been assumed that this increase in crop area would have occurred regardless of the findings of the research project.

Information regarding crop losses prior to the project was limited, and varied significantly from year to year. Based on anecdotal evidence a crop loss rate of 35% was applied across Queensland, New South Wales and Victoria.

5.5 Qualitative Assessment

The following impacts of the project are not quantified in dollar terms due to limited data availability, and as such have been assessed qualitatively below:

- Reduced reliance on broad spectrum insecticides (environmental benefit); and
- Improved consistency of market supply (social benefit).

These impacts have been assessed using a likelihood and consequence framework adapted from Crawford (2003) and Fletcher *et. al.* (2004), with the likelihood and consequence ratings highlighted in bold (refer to Appendix B for an outline of the qualitative assessment framework used).

Environmental Benefits

Reduced Reliance on Broad Spectrum Insecticides: Prior to the research project, heliothis was traditionally controlled using broad spectrum synthetic pesticides, which resulted in considerable non-targeted death in other insects, some of which are beneficial in the control of heliothis. Broad spectrum pesticides are also toxic to vertebrates and can result in illness and potentially death where absorbed.

The research project resulted in the development of management options that reduced the need for insecticide use, and also resulted in the development of two biologically targeted pesticides (Gemstar and Success). This has **almost certainly** reduced the level of non-targeted death in other insects caused by broad spectrum pesticides, and reduced the level of toxicity to vertebrates. Research findings from the Pest Management in Sweet Corn project indicate that non-targeted insect numbers have increased considerably, including a number of beneficial insects and spiders that are natural predators of heliothis. This is anticipated to have resulted in a considerable impact the structure and composition of the local environment, and in some cases has enabled growers to now rely on natural ecosystems to control heliothis (**outstanding** consequence). This is expected to provide growers with an economic benefit in terms of reduced costs of treatment, and is captured in the cost of production used in the CBA analysis.

The benefits of the development and use of BMOs for the control of heliothis are expected to be localised to the habitats and ecology in the control zones and nearby areas.

Social Benefits

Consistent Market Supply: Prior to this research project, damage to sweet corn crops was high and becoming increasingly variable each year, reducing the product quality and reliability of supply. The development of BMOs for the control of heliothis has **almost certainly** improved the consistency of supply, with production estimates having stabilised post research.

Improved consistency of supply for the domestic market may potentially provide social benefits throughout the supply chain in terms of improved confidence in product quality and availability (**minor** consequence). Where these benefits occur, they are expected to be widespread throughout the Australian sweet corn supply chain.

Economic Benefits

Re-Establishment of the Export Market: Prior to this research project, high levels of heliothis damage and presence of heliothis larvae present in sweet corn had resulted in the discontinuation of the high value export market. The development of BMOs for the control of heliothis has **almost certainly** reduced the level of insect damage and larvae presence in sweet corn, and has resulted in the re-establishment of the export market.

The ability to provide a consistent, high quality, insect free product to high value overseas markets where producers can receive a price premium is believed to have been a key catalyst in recent expansion activities in the Queensland sweet corn industry (AUSVEG, 2005), and is expected to result in a considerable increase in domestic production over the long term (**major consequence**). These benefits are expected to be widespread throughout the sweet corn industry along the east coast of Australia.

5.6 Summary of Assessment

The pest management in sweet corn project resulted in the development of two pesticides that provide an improved level of control of heliothis when compared to existing methods of control. Cost Benefit Analysis (CBA) indicates that a total expenditure of $1.69 million (in 2006-07 dollar terms) in the research and development project, which occurred over six years between 1997-98 and 2002-03, resulted in the following outcomes:

- A NPV of $82.71 million and a BCR of 5.88 at a discount rate of 9.16% (that is, the project returns $5.88 for every dollar of research and development invested);

- An internal rate of return of 137.1%;
- A positive return in investment across all discount rates between 6% and 12%;
- A positive return on investment from the fifth year from commencement of the research;
- The key impact driving this positive result is an annual increase in gross value of production (GVP) of $15.76 million;
- Additional unquantifiable impacts include:
  - A reduced reliance on broad spectrum pesticides resulting in reduced environmental toxicity (environmental benefit);
  - An improvement in the consistency of supply to the market place due to a reduction in crop losses (social benefit); and
  - Re-establishment of the export market due to a reduction in quarantine risk and contamination of products (economic benefit).

As the project has a positive NPV and a BCR above one, the project can be identified as being economically desirable.

To date (year 10 of the assessment) the project is estimated to have contributed a cumulative net present value of $44.15 million in social and economic benefits to both the public and private sectors.

This analysis is expected to under-represent the actual benefits of the project as it does not include unquantifiable social and environmental benefits from a reduction in toxicity and economic benefits in terms of increased value and production as a result of re-establishment of the high value export market. These benefits have not been quantified due to limited data availability.

6. Findings

The three projects assessed in this report were found to be economically desirable projects producing a combined net benefit of $61.22 million to date (2006-07) and an expected net present value of $126.02 million over a twenty year time horizon.

All evaluated projects were recognised to have addressed an identified industry need and were aligned with established Government and HAL strategic objectives. Projects assessed were selected out of a range of HAL funded projects based on their ability to contribute public and private benefits across the economic, social and environmental triple bottom line.

Limitations such as availability of data (e.g. regional infestation and adoption rate data) has resulted in conservative estimates of input variables which is likely to result in an underestimation of the actual returns on investment for the three projects assessed. Environmental and social benefits such as reduced toxicity are not readily quantifiable in dollar terms and as such have not been included in the quantitative CBA for the case studies. The benefits identified in the three case studies are considered to be minimum estimates.

Overall, HAL makes an annual investment of approximately $72.68 million. The three projects assessed in this study have a total annual benefit of $25.81 million, which equates to an average annual benefit of $8.60 million each. For HAL's research and development program to break even (NPV = $0) an additional 3.9 (6.0% discount rate) to 7.3 (12.0% discount rate) projects that produce equivalent benefits (i.e. an additional average annual benefit of $8.60 million) are required or, alternatively, an additional $13.63 million to $27.95 million in annual benefits to be produced by each of the three projects in this assessment.

HAL currently invest in between 300 to 350 new research and development projects annually and at any one time have approximately 1,200 active research and development projects. This implies that approximately one in 40-80 projects would be required to deliver benefits in the order of those examined in this assessment to provide a positive return on investment for the HAL investment portfolio.

The findings of this assessment can be summarised as follows:

- Horticulture Australia has an annual expenditure on research and development of approximately $72.68 million in 2006-07;
- To date the combined net present value of three projects assessed is estimated to be approximately $61.22 million;
- A combined net present value of the three projects assessed is estimated to be approximately $126.02 million over a 20 year time horizon and is attributed to:
    - A NPV of $35.35 million for the Biology, Ecology and Control of Citrus Jassid;
    - A NPV of $7.96 million for the Control of Bacterial Blight in Walnuts; and
    - A NPV of $82.71 million for the Pest Management in Sweet Corn project.
- An average annual net benefit of $8.60 million for the three projects; and
- An additional 3.9 to 7.3 projects with an average annual return of $8.60 million for the HAL research and development program to break even.

Individually, the projects examined in this assessment were identified to be economically desirable investments providing economic, social and environmental benefits across both public and private stakeholder groups. However, these projects alone do not cover the total costs of investment for Horticulture Australia research and development investment projects.

It should be noted that previous analysis of 23 HAL funded R&D projects indicates that the entire HAL portfolio provides a positive return on investment (AEC*group*, 2005).

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Appendix A: Selection Criteria for Case Studies

The R&D projects selected for evaluation were assessed regarding their ability to meet the criteria in the table below. These criteria were applied to the results of the previous report by AEC*group* (2005).

Table 1.1: Selection Criteria for Case Studies

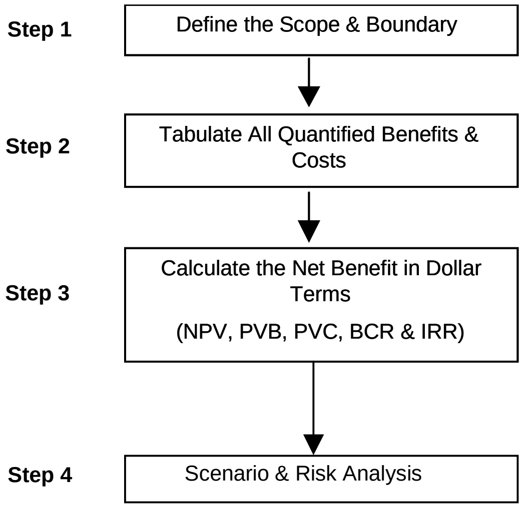
Criteria	Criteria (Score= Yes/No to meeting criteria)
Positive Return on Investment (ROI)	**The selected project for evaluation must have previously shown to have a positive return on investment**
	Positive Net Present Value (NPV > 0)
	Benefit Cost Ratio (BCR) >1
Ability to meet CRRDCC Guidelines with consideration of actual and/or spillover public and private benefits	
Public Benefit	**Must have one or more public benefits**
Private Benefit	**Must have one or more private benefits**
HAL Priorities	**Must meet one or more Government priorities**
Improve production efficiency and sustainability in response to market needs	
Enhance efficiency, responsiveness and product integrity of the supply chain	
Consistently meet requirements of consumers and key customers	
Breakdown trade barriers and develop markets for products	
Provide high quality value for money services	
Develop plant biosecurity plans	
Ensure ongoing supply of skilled horticulture resources by attracting appropriately skilled people; horticulture research institutions and industry bodies. Develop an analytical framework for horticulture industries to enable strategic plan investment strategies	
Government Priorities for R&D	**Must meet one or more HAL priorities**
Productivity and adding value	
Supply chain and markets	
Natural resource management	
Climate variability and climate change	
Biosecurity	
Supporting the rural research and development priorities	
Promote the development of new and existing technologies	

Source: AEC*group* (2007)

Appendix B: Cost Benefit Analysis

A Cost Benefit Analysis (CBA) model has been applied to the quantifiable components of the three selected projects to identify their return on investment. The process of steps to conduct each CBA is summarised in Figure C.1, with the key steps of the process discussed below. The CBA framework outlined below does not include the identification and valuation of benefits and costs as these processes are undertaken in earlier phases of the evaluation framework for this project.

Figure C.1. Cost Benefit Analysis Methodology



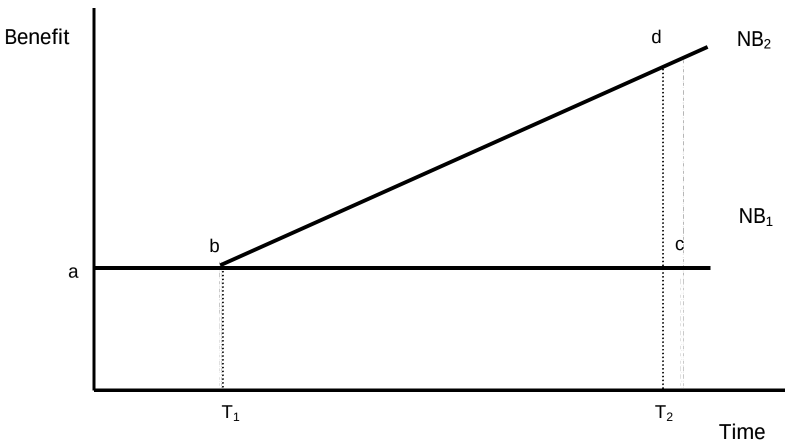
Source: AEC*group*

Step 1: Define the Scope and Boundary

To enable a robust determination of the net benefits of undertaking a given project, it is necessary to specify base case and alternative case scenarios. The base case scenario represents the “without project” scenario and the alternative or “with project” scenario examines the impact with the program in place.

The base case (without) scenario is represented by line NB_1 (bc) over time T_1 to T_2 (Figure 9.2). The investment in R&D initiatives at time T_1 is likely to generate a benefit, which is represented by line NB_2 (bd). Therefore the net benefit flowing from investment in the R&D initiatives is identified by calculating the area (bcd) between NB_1 and NB_2.

Figure C.2. With and Without Scenarios



Source: AEC*group*

Step 2: Tabulate Annual Costs and Benefits

All identified and quantified benefits and costs are tabulated to identify where and how often they occur. Tabulation provides an easy method for checking that all the issues and outcomes identified have been addressed and provides a picture of the flow of costs, benefits and their sources.

Step 3: Calculate the Net Benefit in Dollar Terms

This step adjusts for the time preference of money to enable the comparison of investment options by a common measure and requires the choice of a suitable discount rate.

The selection of appropriate discount rates is of particular importance because they apply to much of the decision criteria and consequently the interpretation of results. The higher the discount rate, the less weight or importance is placed on future cash flows.

The choice of discount rates should reflect the weighted average cost of capital. For this analysis a base discount rate of the long term bond rate plus 3% (or 9.16%) was used to be consistent with CRRDCC (2007), with two standard discount rates either side of the base rate (6%, 8%, 10% and 12%).

Step 4: Scenario and Risk Analysis

Scenario and risk analysis allows for the testing of the key assumptions and the identification of the critical variables within the analysis to gain greater insight into the drivers to the case being examined. Variables such as the adoption rate or percentage of uptake may have a significant impact on the outcome of the analysis.

Decision Criteria and Interpretation

The decision criteria that are investigated in the CBA include:

- Net present value (NPV), which represents the present value of all benefits minus the present value of all costs;
- Benefit cost ratio (BCR), which is the present value of benefits divided by the present value of the costs; and
- Breakeven point, which indicates value of a critical variable required for the project to “breakeven” or return a NPV of zero.

These decision criteria allows the determination of the most economically desirable investment alternative, as well as the level of benefits that can be expected to flow from the research and development initiative from the investment. These results may be applied to future expenditure to identify the level of return that may be expected.

Appendix C: Qualitative Assessment Framework

The following assessment framework (modified from Crawford, 2003 and Fletcher *et. al.* 2004) has been used to assess the likelihood and consequence of positive and negative impacts unable to be quantified as part of the analysis in dollar terms.

Table 3.1 Qualitative Measure of Likelihood

Descriptor	Description
Almost certain	It is expected to occur in most circumstances
Likely	It will probably occur in most circumstances
Possible	Might occur at some time
Unlikely	Could occur but not expected
Rare	May only occur in very exceptional circumstances
Remote	Never heard of, but not impossible

Source: Modified from Crawford (2003) and Fletcher *et al.* (2004)

Table 3.2 Qualitative Measure of Consequence

Descriptor	Description: Benefits	Description: Costs
Negligible	Very insignificant impacts. Unlikely to be measurable against benchmarks.	Very insignificant impacts. Unlikely to be measurable against benchmarks.
Minor	Possibly detectable impacts but minimal changes to the established structure and function. The impact and its magnitude are small relative to the wider context of the population/area being impacted. Benefits maintained over the short term without extended management and/ or works	Possibly detectable impacts but minimal changes to the established structure and function. The impact and its magnitude are small relative to the wider context of the population/area being impacted. Return to pre impact levels achievable and expected to occur over the short term once management initiatives are implemented.
Moderate	Detectable impacts, characterised by significant changes in structure, composition and function. The benefit is maintained over the medium term with minimal management and/or works.	Detectable impacts, characterised by significant changes in structure, composition and function. Recovery from impacts is achievable over the medium term once management initiatives are implemented.
Major/ Severe	Wider and longer term impacts occurring and likely to result in a highly changed structure, composition and function. The benefit is maintained over the longer term with minimal management and/or works.	Wider and longer term impacts occurring and likely to result in a highly changed structure, composition and function. Recovery from impacts possible with sustained effort over the long term.
Outstanding/ Catastrophic	Wider and longer term impacts occurring and likely to result in a highly changed structure, composition and function. The benefit is maintained over the longer term without management and/or works.	Wider and longer term impacts occurring and likely to result in a highly changed structure, composition and function. Return to pre impact levels unlikely to occur even with mitigation and intervention.

Source: Modified from Crawford (2003) and Fletcher *et al.* (2004)

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