Rural and Regional Affairs and Transport Legislation Committee

ANSWERS TO QUESTIONS ON NOTICE

Supplementary Budget Estimates October 2016

Agriculture and Water Resources

Question: 82

Division: Corporate Strategy and Governance Division

Topic: Election Commitments

Proof Hansard page: 85

Senator McCARTHY asked:

Senator McCARTHY: Can you provide an update on all other election commitment policies that will be administered by the department? And by all means take this as a question on notice.

Mr Quinlivan: I think that would be the best idea, yes.

Answer:

Refer to **Table 1** for an update on all election commitment policies that are administered by the department.

Table 1 – Election Commitments administered by the department

ELECTION COMMITMENT	STATUS
National Institute for Forest Products Innovation The Government is providing $4 million toward the National Institute for Forest Products Innovation to assist with collaboration in the Forestry R&D sector across Australia. Announced total funds: $4 million	The department is working with South Australian and Tasmanian state government officials, the Australian Forest Products Association and Forest and Wood Products Australia to implementation this commitment. Funding will be considered in the budget/MYEFO context.
Fisheries Representation To amend the *Fisheries Management Act 1991* to ensure Australian Fisheries Management Authority takes into account the interests of all fisheries users—commercial, recreational and indigenous fishers. Announced total funds: $ No funding provided	The government is currently considering approaches for implementing the commitment in advance of introducing relevant legislative amendments into Parliament.
Dairy Recovery Package—Commodity milk price index and Dairy Symposium The Government will invest up to $2 million to establish a commodity milk price index to deliver greater transparency and market signals in domestic and global market prices. The Government will also convene a symposium of dairy farmers, processors and retailers to discuss industry solutions to the challenges that have been exposed by Murray Goulburn's retrospective farm gate milk price reductions and cheap supermarket milk. Announced total funds: $2 million	Information gathering and consultation with industry has commenced. The dairy commodity price index was discussed at the Dairy Symposium on 25 August 2016. Funding will be considered in the budget/MYEFO context.
Beef Australia Expo and Casino Beef Week The Government will support the beef industry's pre-eminent trade and promotional Beef Australia expo to be held in 2018. The Government will also boost support of the Casino Beef Week to ensure the event continues to flourish and grow into the future. Announced total funds: $3 million and $1 million	These commitments will be considered in the budget/MYEFO context.

Thoroughbred levy, biosecurity and research and development. The Government will invest in research and development intended to boost disease control, biosecurity, and reproductive capabilities in the Australian thoroughbred industry and support the industry's plan by legislating to establish the Thoroughbred levy by 1 July 2017. Announced total funds: $1.2 million over the forward estimates and $0.4 million per year ongoing	The department is working with Thoroughbred Breeders Australia to confirm the implementation approach for the levy.
Working Holiday Maker Review (Backpacker Tax) The Government committed to undertake a review of the broad range of issues affecting the supply and taxation of working holiday maker 417 and 462 visas. Announced total funds: $ No funding provided	The Treasurer announced the review outcomes on 27 September 2016.
Relocation of APVMA The Government will establish Centres of Excellence in Agriculture in regional areas, with government agencies partnering with regional universities and industry research organisations to become agricultural research hubs. The Government will proceed with the relocation of the Australian Pesticides and Veterinary Medicines Authority (APVMA) to Armidale, New South Wales. Announced total funds: $24.1 million	The department is working with the APVMA to progress the relocation. Refer Deputy Prime Minister's announcement of 25 November 2016 (http://minister.agriculture.gov.au/joyce/Pages/Media-Releases/armidale-welcomes-apvma.aspx)
Northern Australian Rice Industry The Government will support the development of the rice industry in Northern Australia building on successful initial research trials growing crops in Queensland. Announced total funds: $4 million	This commitment will be considered in the budget/MYEFO context.
Leadership in Agricultural Industries Support efforts to develop leadership capacity within the agricultural industries to enhance the ability of emerging farm leaders to advocate agricultural and rural issues to the Australian community. Announced total funds: $5 million	The department is in the early stages of planning the project to deliver this programme. Funding will be considered in the budget/MYEFO context.
Clean Energy Finance Corporation Continue to support jobs and growth in the agriculture sector by encouraging investment by the Clean Energy Finance Corporation (CEFC) in agriculture. Announced total funds: $ No funding provided	The department has commenced consultation with industry stakeholders and the Department of the Environment and Energy.
Establishing a Regional Investment Corporation The government will establish a Regional Investment Corporation to administer funds relating to farm business concessional loans, the National Water Infrastructure Loan facility and loans already delivered under the drought, drought recovery and farm finance concessional loans schemes. Announced total funds: $ No funding provided	The department has provided advice to the Deputy Prime Minister on entity options and delivery arrangements.

Invasive Pest Research and Development and Invasive Animal Solutions The government will boost research and development aimed at eradicating invasive pest species, through support of the transition of the Invasive Animals Cooperative Research Centre (IA CRC) into Invasive Animals Solutions in 2017. Announced total funds: $20 million	The department is working with the Invasive Animals Cooperative Research Centre to design and deliver this commitment. Funding will be considered in the budget/MYEFO context.
Construction of Water Infrastructure and Water Infrastructure Feasibility Studies The Government has committed to co-fund with state governments the construction of economically viable water infrastructure including Rookwood Weir; the new Dungowan Dam; the upgrade of the Macalister Irrigation District; the South West Loddon Pipeline and McLaren Vale wastewater storage project. The Government will also invest infeasibility studies into a new dam at Hells Gate and improving Walcha's water security. Announced total funds: $249.8 million	The department is consulting with relevant state governments. The department is also working with the Queensland Government, Department of Energy and Water Services and Townsville Enterprise Limited to agree the scope of the Hells Gate Dam feasibility study.

Rural and Regional Affairs and Transport Legislation Committee

ANSWERS TO QUESTIONS ON NOTICE

Supplementary Budget Estimates October 2016

Agriculture and Water Resources

Question: 83

Division/Agency: Corporate Strategy and Governance Division

Topic: Vacancies

Proof Hansard page: Written

Senator BILYK asked:

Please provide a list of all statutory, board and legislated office vacancies and other significant appointments vacancies within the portfolio, including length of time vacant and current acting arrangements.

Answer:

A list of all statutory, board and legislated office vacancies and other significant appointments vacancies within the portfolio, as at 31 October 2016, is summarised in the table below.

PORTFOLIO BODY	**VACANCY DETAILS**
Grains Research and Development Corporation (GRDC)	1 director Vacant since 30 September 2016. No acting arrangements in place.
Lake Eyre Basin Community Advisory Committee (LEBCAC)	3 members 1. Vacant since 23/08/2015. 2. Vacant since 02/12/2014. 3. Vacant since 24/10/2012. No acting arrangements in place for these positions.
Lake Eyre Basin Scientific Advisory Panel (LEBSAP)	1 member Vacant since 20/01/2015. No acting arrangements in place.

Rural and Regional Affairs and Transport Legislation Committee

ANSWERS TO QUESTIONS ON NOTICE

Supplementary Budget Estimates October 2016

Agriculture and Water Resources

Question: 84

Division/Agency: Corporate Strategy and Governance Division

Topic: Media Monitoring

Proof Hansard page: Written

Senator BILYK asked:

a) How much has the Department spent on media monitoring since 1 January 2016?

b) Can a list of all Contract Notice IDs for the Austender website in relation to media monitoring contracts please be provided?

Answer:

a) Between 1 January and 30 September 2016, the department has spent $146 759.85 (inc. GST) on media monitoring services.

b) The department has one current contract for media monitoring services. The contract is with iSentia Pty Ltd and the contract notice ID is CN3289020.

Rural and Regional Affairs and Transport Legislation Committee

ANSWERS TO QUESTIONS ON NOTICE

Supplementary Budget Estimates October 2016

Agriculture and Water Resources

Question: 85

Division/Agency: Corporate Strategy and Governance Division

Topic: Advertising and Information Campaigns

Proof Hansard page: Written

Senator BILYK asked:

How much has the department spent on advertising and information campaigns since 1 January 2016?

a) Can a list of all Contract Notice IDs for the AusTender website in relation to advertising and information campaign contracts please be provided?

Answer:

The department has not undertaken any advertising and information campaigns to date.

Rural and Regional Affairs and Transport Legislation Committee

ANSWERS TO QUESTIONS ON NOTICE

Supplementary Budget Estimates October 2016

Agriculture and Water Resources

Question: 86

Division/Agency: Corporate Strategy and Governance Division

Topic: Ministerial functions

Proof Hansard page: Written

Senator BILYK asked:

In relation to any functions or official receptions hosted by Ministers or Assistant Ministers in the portfolio since 1 January 2016, can the following please be provided:

a) List of functions;

b) List of attendees including departmental officials and members of the Minister's family or personal staff;

c) Function venue;

d) Itemised list of costs;

e) Details of any food served;

f) Details of any wines or champagnes served including brand and vintage;

g) Details of any floral arrangements or other decorations; and

h) Details of any entertainment provided.

Answer:

Please see details at Attachments A, B, C and D.

Attachment A provides a list of functions including costs. Attachments B-D provides a list of attendees and details of food and beverages served for each function.

Question: 86 (continued) **ATTACHMENT A**

Date	**Function venue**	**Purpose of Function**	**List of attendees including departmental officials and staff/family of the Minister**	**Cost of Meals (including details of food served)**	**Cost of Drinks (including details of wines/ champagnes served including brand and vintage)**	**Details of any entertainment provided and floral arrangements or other decorations**
31 March 2016	Quality Hotel Powerhouse Armidale	Agricultural Industry Advisory Council networking function and members dinner	See Attachment B	$2,691.00 See Attachment C for details of food served	$2,377.50 See Attachment C for details of beverages served	Nil
25 August 2016	Marriott Melbourne	Symposium on the Australian Dairy Industry	See Attachment D	Included in $6700.00 venue hire **Morning tea –** croissants, fruit salad, orange and macadamia slice **Lunch –** green curry, pork stir-fry, Asian greens, range of salads, strawberry cheesecake, fruit and cheese platters	Included in $6700.00 venue hire Coffee, tea and selection of fruit juices	Nil

Question: 86 (continued) **ATTACHMENT B**

31 March 2016
Agricultural Industry Advisory Council attendees
* The Hon. Barnaby Joyce MP (Chair)
* Hamish McLaren – New South Wales
* David Moon – Queensland
* Lenore Johnstone – Queensland
* Stuart Richey – Tasmania
* Luke Bowen – Northern Territory
* Rob de Fegely – New South Wales
* Eliza Brown – Victoria
* Kevin Sorgiovanni – Western Australia
* Dean Wormald – Western Australia
* Andrew Inglis – South Australia
* Susan Bower – New South Wales
* Perin Davey – New South Wales
Ministerial staff and family members
* Natalie Joyce
* Richard Hyett
* Judith Laffan
Brett Chant
Departmental staff
* Daryl Quinlivan
Melissa Brown
Guests
* Mrs Moon (AIAC member David Moon's wife)
Mr Adam Marshall MP
Oliver Knox
David Lamb
Paul Arnott
Byrony Hackett
Noel Woodbury
Rebel Thomson
Pauline Smith
Richard Flavel
Rhiannon Smith
Paul Martin
Brendan Griffiths

Question: 86 (continued) **ATTACHMENT B**

Guy Ballard
Sarah Burrows
Heiko Daniel
Guests
James Harris
Annabelle Duncan
Trevor Goldstone
Brian Sindel
Stuart McCulloch
Peta Slack-Smith
Mat Onslow
Annette Cowie
Robyn Hean
John Gibson
Bec Onslow
Hutton Oddy
Peter Parnell
Rob Banks
Mingan Choct
Peter Betts
Bev Betts
Hugh Nivison
Janelle Archdale
Miles Archdale
Nick Hall
Tim Norton
Peter King
Jock Nivision
Peter O'Keefe
Sam White
Tim Bower
Anthony Uren
Peter Cull
Susan Cull
Graeme Mitchell
Alex Hunter
Professor Jim Scott
Sir Robert Gordon

Professor Iain Young
Dr Robert Banks
Marc Greening
Grayson Wolfgang
John Christensen
Lia Christensen
Grant Nivison
Darryl Carter
Guests
Robyn Cater
Jen Smith
Mark Morton
Amanda Doughty
Laura Kemmis
Greg Falzon
Michael Field
Phil Holmes
Patrick Fagan
Sarah Foulsham
Lachlan Macarthur-Onlsow
John Jackson
Graham Jackson

* Attended the member dinner following the networking function

Question: 86 (continued) **ATTACHMENT C**

Agricultural Industry Advisory Council networking function – 1 hour

Catering package

Hot – Crab, lemon and coriander arancini balls
Hot – Satay chicken skewers and peanut dipping sauce
Hot – Haloumi and zucchini frittata
Cold – Turkish breads with an assortment of dips and local olive oil
Cold – Tomato, red onion and basil tart

Beverage package included:

* Stony Peak Sparkling
* Stony Peak Chardonnay
* Stony Peak Shiraz Merlot

Agricultural Industry Advisory Council member's dinner

Menu
Dinner bread rolls

Entrée options
Smoked Thai beef salad, cashew nuts, palm sugar dressing
Roast pumpkin, feta and sage tart, roast pine nut dressing

Mains options
Grilled chicken breast, Lyonnaise potato with tarragon, smoked bacon and mushroom cafe au lait sauce
Braised country fresh lamb shanks, roast chat potatoes, roquette and parmesan salad

Dessert options
Sticky date pudding, toffee sauce, vanilla ice cream
Apple and cinnamon crumble, caramel ice cream

Beverage package included:

* Stony Peak Sparkling
* Stony Peak Chardonnay
* Stony Peak Shiraz Merlot

* vintage not known

Question: 86 (continued) **ATTACHMENT D**

Symposium on the Australian Dairy Industry

Name	Organisation
Farmer representative bodies	
John McQueen, Interim CEO	Australian Dairy Farmers
David Basham, Acting President	Australian Dairy Farmers
Simone Jolliffe, Vice President	Australian Dairy Farmers
Erika Chesworth, Dairy Committee Chair	NSW Farmers
Amy Williams, Policy director economics	NSW Farmers
Shaughn Morgan, CEO	Dairy Connect
George Davey AM, Chair	Dairy Connect
Graham Forbes, Farmers Group President	Dairy Connect
Brian Tessmann, CEO	Queensland Dairyfarmers' Organisation
Andrew Curtis, CEO	South Australian Dairyfarmers' Association
John Hunt, Incoming president	South Australian Dairyfarmers' Association
Alan Davenport, Board member	Tasmanian Farmers and Graziers Association
Andrew Lester, Chair	Tasmanian Farmers and Graziers Association
Adam Jenkins, President	United Dairy Farmers of Victoria
Vin Delahunty	United Dairy Farmers of Victoria
Stephen Brown, CEO	Western Australia Farmers
Michael Partridge, President	Western Australia Farmers Dairy Council
Charles Thomas, General Manager, Rural Affairs and Agribusiness	National Farmers' Federation
Farmer Representatives	
Neil Pankhurst	Farmer, Campaspie Shire Councillor
Tony Marwood, Chairman	Bonlac Supplier Group
Martin Wilson	Farmer, QLD
Peter de la Hunty	Farmer, VIC
Paul Mundy	Farmer, VIC
James Geraghty	Farmer, QLD
Jeremy Bayard	ACE Farming Company, VIC
Andrew Paton	Farmer, VIC
Kevin Matheson	Farmer, VIC
Mark Billing	Farmer, VIC
Michael Perich, Managing Director	Leppington Pastoral Company, NSW
Raelene Hanratty	Farmer, VIC
Basil Brock	Farmer, VIC
Shane Paulger	Farmer, QLD
Tim Bale, Chair	Manning Valley Fresh Group, Taree Collective Bargaining Group NSW
John Cochrane, Chair	Premium Milk

Question: 86 (continued) **ATTACHMENT D**

Name	Organisation
Processors	
Peter Stahle, Executive Director	Australian Dairy Products Federation
Robert Poole, President	Australian Dairy Products Federation
Aidan Coleman, CEO	Bega
Barry Irvin AM, Executive Chairman	Bega
David Mallinson, Interim CEO	Murray Goulburn
Philip Tracy, Chairman	Murray Goulburn
Ben Gursansky, General Manager Policy Industry and Government	Murray Goulburn
Abhy Maharaj, Commercial Director	Fonterra
Matt Watt, General Manager Milk Supply	Fonterra
Richard Wallace, Senior Vice President and General Manager	Warrnambool Cheese & Butter
John Wilson, General Manager Consumer Brands	Warrnambool Cheese & Butter
Anthony Cook, General Manager Milk Supply	Warrnambool Cheese & Butter
Brett Kelly, CEO	Norco
Grant Crothers, CEO	Burra Foods
Peter West, Managing Director	Lion Dairy and Drinks
Elise Gare, External Relations Director	Lion Dairy and Drinks
Vince Houlihan, General Manager Supply Chain	Parmalat
Paul Lorimer, General Manager (Harvey Fresh)	Parmalat (Harvey Fresh)
Peter Nathan, CEO	A2
Chris Sharpe, Managing Director	Richmond Dairies
Duncan McInnes, Chairman	Dairy Farmers Milk Co-operative
Allan Hood, CEO	Bulla
Retailers	
Simon Talbot, Head of Public Affairs and Export	Coles
Richard Pearson, Director of Strategy	Coles
Steven Donohue, Head of Buying	Woolworths
Teresa Rendo, Head of Perishables	Woolworths
Sanjay Kumar, Government Relations Manager	Woolworths
Ian Morrice, CEO, Executive Director	Metcash

Question: 86 (continued) **ATTACHMENT D**

Name	Organisation
Other	
Geoff Akers, Chair	Dairy Australia
Ian Halliday, Managing Director	Dairy Australia
Charlie McElhone	Dairy Australia
Iain Stewart, Chairman	Macalister Irrigation District Customer Consultative Committee
Timothy Moses, General Manager Group Operations	Freedom Foods
Government	
The Hon. Barnaby Joyce MP	Deputy Prime Minister and Minister for Agriculture and Water Resources
The Hon. Dr David Gillespie MP	Assistant Minister for Rural Health, Member for Lyne
Nola Marino MP	Federal Member for Forrest
Senator Bridget McKenzie	Senator for Victoria
Russell Broadbent MP	Member for McMillan
Sarah Henderson MP	Member for Corangamite
The Hon. Dan Tehan MP	Minister for Veterans' Affairs
The Hon. Jaala Pulford	Victorian Minister for Agriculture
The Hon. Peter Walsh MP	Leader of the Nationals Victoria, Victorian Shadow Minister for Agriculture
Kevin Sorgiovanni	Deputy Prime Minister's Agriculture Industry Advisory Council
Simon Price, Senior Adviser	Office of the Deputy Prime Minister
Vikki Campion, Media Adviser	Office of the Deputy Prime Minister
Officials	
Mick Keogh, Agricultural Commissioner	Australian Competition and Consumer Commission
Gabrielle Ford, Acting General Manager Agricultural Enforcement and Engagement Unit	Australian Competition and Consumer Commission
Amy Bellhouse	Australian Competition and Consumer Commission
Craig Latham, Deputy Commissioner	Australian Small Business and Family Enterprise Ombudsman

Question: 86 (continued) **ATTACHMENT D**

Name	Organisation
Michael Taylor AO FTSE	Dairy Food Safety Victoria
Andrew Reynolds, General Manager	Murray Darling Basin Authority
David Williamson, Deputy Secretary	Department of Agriculture and Water Resources
Fran Freeman, First Assistant Secretary	Department of Agriculture and Water Resources
Peter Gooday, Assistant Secretary	Department of Agriculture and Water Resources
Luke Wilson, Deputy Secretary	Department of Economic, Development, Jobs, Transport and Resources
Rob Solomon, Director	Department of Agriculture and Water Resources
Vincent Tulley, Policy Officer	Department of Agriculture and Water Resources
Trish Gleeson, A/g Assistant Secretary	Department of Agriculture and Water Resources

Rural and Regional Affairs and Transport Legislation Committee

ANSWERS TO QUESTIONS ON NOTICE

Supplementary Budget Estimates October 2016

Agriculture and Water Resources

Question: 87

Division/Agency: Corporate Strategy and Governance Division

Topic: Implementation of the Agricultural Competitiveness White Paper

Proof Hansard page: Written

Senator STERLE:

Provide an update on the implementation of the White Paper.

Answer:

A summary of initiatives announced in the Agricultural Competitiveness White Paper including the implementation status, as at 31 October 2016, is at Attachment A.

Attachment A

Agricultural Competiveness White Paper

Measure	Implementation status
National Water Infrastructure Development Fund.	The Fund has been successfully established. Feasibility component of the fund has been implemented. Details for the capital component were released to the public on 27 October 2016.
Productivity Commission inquiries into agricultural and fisheries regulations.	Implemented.
Reforms to country of origin labelling regulations.	In progress. The new reforms commenced on 1 July 2016, with a two year transition period for businesses to adjust.
Streamline the approval of agricultural and veterinary chemicals.	In progress. The APVMA has commenced a 12-month pilot programme examining the benefits of increasing the use of third-party assessments for efficacy and in coming months will release its final policy document and guide on enhancing the use of international data, standards and assessments.
A two-year co-operatives and innovative business models pilot programme.	Implemented.
Australian Competition and Consumer Commission (ACCC) engagement with the agricultural sector. Appoint a new Agriculture Commissioner.	Implemented.

Measure	Implementation status
Allowing farmers to opt back into income tax averaging.	In progress. The Bill is currently listed for introduction in the Spring 2016 parliamentary sittings.
Increase the deposit limit for Farm Management Deposits to $800,000.	Implemented.
Allowing FMD accounts to be used as a farm business loan offset.	Implemented.
A more simplified accelerated depreciation regime for fencing (at a cost of $56 million).	Implemented.
$1 million for improvements to the CSIRO's TRAnsport Network Strategic Investment Tool (TRANSIT).	Implemented.
$3.3 million for improved seasonal forecasting.	Implemented.
Immediate tax deduction for new water facilities and depreciation of capital expenditure on fodder storage assets over three years.	Implemented.
Farm insurance advice and risk assessment grants.	Implemented.
$250 million per year drought concessional loans.	Transitional programme: implemented for 2015–16. Ongoing arrangements: In progress.2016-17 loans programme commenced on 1 November 2016. Future years loan programme to be implemented in a transitional manner associated with the establishment of the RIC election commitment.
Early access provisions for the Farm Management Deposits Scheme in times of drought.	Implemented.
Increased Farm Household Allowance case management.	Implemented.

Measure	Implementation status
Advice and assistance from the Australian Taxation Office to taxpayers in drought-affected communities.	Implemented.
$1.8 million for additional resources for Rural Financial Counselling Service providers in drought-affected areas.	Implemented.
$20 million for additional mental health and community support services for rural communities in drought-affected areas.	Implemented.
$35 million for local projects to provide short-term help to communities that are suffering economic downturn due to drought.	Implemented.
$25.8 million for pest animals and weeds in drought-affected areas.	Implemented.
Development of clear, farmer-oriented priorities to target rural research, development and extension (RD&E) funding.	Implemented.
$100 million to extend the Rural R&D for Profit programme to 2021–22.	Implemented.
Improving the efficiency of RDCs by improving governance.	Implemented.
New agricultural levies. $1.2 million additional funding for RD&E in small agricultural industries.	Tea Tree Oil: On-track to be implemented by 1 July 2017. Export Fodder: Implemented. RIRDC funding for Small Agricultural Industries: Implemented.
$50 million to boost our emergency pest and disease eradication and national response capability.	Implemented.

Measure	Implementation status
$50 million to manage established pest animals and weeds.	In progress. Successfully negotiated Project Agreements with six state and territory governments.
Improve access by reducing technical trade barriers.	Implemented.
Strengthening Australia's biosecurity.	Surveillance: The 10 priority marine pests and 10 aquatic diseases for northern Australia have been identified. Surveillance kits and training has been provided to Timor-Leste counterparts. Community-based action: Tropical biosecurity training curriculum delivered to Indigenous ranger groups. Scientific capability: Implementation of import review recommendations for soil and water, hides and skins, live rabbits and seafood. Information systems: Subject to government consideration.
Enhanced traceability systems.	On track for delivery by 2019.

Rural and Regional Affairs and Transport Legislation Committee

ANSWERS TO QUESTIONS ON NOTICE

Supplementary Budget Estimates October 2016

Agriculture and Water Resources

Question: 88

Division/Agency: Corporate Strategy and Governance Division

Topic: Correspondence

Proof Hansard page: Written

Senator STERLE asked:

Please provide the following information:

a) Provide all correspondence between the Minister and Gina Rinehart?

b) Provide all correspondence between the Minister's staff and Gina Rinehart?

c) Provide all correspondence between the Minister and Sophie Mirabella?

d) Provide all correspondence between the Minister's staff and Sophie Mirabella?

e) Provide all correspondence between the Department and Gina Rinehart?

f) Provide all correspondence between the Department and Sophie Mirabella?

Answer:

a) Nil.

b) Nil.

c) One result: letter of 12 December 2014 from Sophie Mirabella to the Minister for Agriculture regarding 'equal opportunities for women to fully participate in Australian Democracy' (**Attachment A**).

d) Nil.

e) Nil.

f) Nil.

THE UNIVERSITY OF
MELBOURNE

The School of Social and Political Sciences
John Medley (Building 191)
The University of Melbourne
Parkville, VIC 3010
Australia

12 December 2014

Dear Minister,

We write to you in the hope that you will join together with us and many others in our aspiration for an Australia that has equal opportunities for women to fully participate in our democracy.

Although women are 50.2% of the population, less than 1/3 of all parliamentarians in Australia are women and less than 1/5 of all ministers in Australian Governments are women.

On 10 December 2014, the first ever bi-partisan Women in Politics forum was held at the University of Melbourne. A consensus of women from both the Liberal and Labor parties agreed that we can all do more to increase the number of women in our parliaments and in senior political appointments. As a starting point the *Melbourne Declaration on Women's Participation in Australian Politics* was launched at the forum.

Your leadership as an elected representative in acknowledging the importance of this mainstream issue is a significant part of a national journey to enhance our democracy.

We have enclosed a copy of the *Melbourne Declaration* with this letter. You can join us in being part of the change for a better Australia by going online and singing on at **http://go.unimelb.edu.au/9myn**.

Yours sincerely,

Sophie Mirabella
Public Policy Fellow
University of Melbourne

Nicholas Reece
Public Policy Fellow
University of Melbourne

MELBOURNE SCHOOL OF GOVERNMENT

THE MELBOURNE DECLARATION ON WOMEN'S PARTICIPATION IN AUSTRALIAN POLITICS

We the undersigned believe in the inherent dignity, responsibility and potential of all Australians. We share an ambition for an Australia of equal opportunities and a society that is tolerant and diverse.

This declaration reflects our concern that in this day and age the representation of women in Australian politics does not reflect this vision. We believe that the number of women who are parliamentarians, ministers and shadow ministers remains lower than where Australia should be as an advanced democracy.

Some key facts:

- Less than one in three of all parliamentarians in Australia are women;
- Less than one in five of all ministers in Australian governments are women;
- Women account for 50.2 per cent of the Australian population;
- The United Nations regards one third as the minimum level necessary for women to influence decision making in parliament.

We believe that the current approach to the selection and promotion of women in Australian politics is flawed and has failed to achieve the full participation of women in our democracy.

At a minimum, we commit to the ambition that 40 per cent of party official, parliamentarian, ministerial and shadow ministerial appointments across all political parties and parliaments are women over the next two candidate selection cycles or by 2020, whichever is sooner.

To achieve this we commit to helping women rise through the ranks of public life. This must include the provision of a genuine career path for all female political aspirants free from discrimination and in full recognition of the challenges women face.

We encourage women to pursue their political ambitions and are committed to offering women support structures and inspiration to help them achieve their goals. We are committed to improving cultural attitudes to women in leadership roles in Australian politics and improving the workplace and parliamentary environment itself.

We want all women to have the confidence and know-how to "lean in" and fulfil their potential.

We want nothing less than to change the trajectory of women in Australian politics and create a better Australia for everyone.

Rural and Regional Affairs and Transport Legislation Committee

ANSWERS TO QUESTIONS ON NOTICE

Supplementary Budget Estimates October 2016

Agriculture and Water Resources

Question: 89

Division/Agency: Corporate Strategy and Governance Division

Topic: Staffing

Proof Hansard page: Written

Senator MCALLISTER asked:

The following questions ask for information regarding the Department of Agriculture and Water Resources and the following agencies: Grains Research and Development Corporation, Australian Pesticides and Veterinary Medicines Authority Australian Grape and Wine Authority, and the Australian Fisheries Management Authority.

1. Please provide a breakdown of staffing levels as at 30 June 2016, nationally and for each state and territory, in a spreadsheet format by the following categories:
    a) Full time equivalent (FTE);
    b) Head count;
    c) Gender;
    d) Ongoing;
    e) non-ongoing; and
    f) classification level.
2. How many engagements occurred in the 2015-16 financial year, by:
    a) Classification;
    b) State or territory;
    c) Ongoing staff; and
    d) Non-ongoing staff.
3. How many separations occurred in the 2015-16 financial year, by:
    a) Classification;
    b) State or territory;

Question: 89 (continued)

c) Ongoing staff;

d) Non-ongoing staff; and

e) Reason for separation.

4. What was the total expenditure on contractors and consultants in the 2015-16 financial year?

5. For each contract or consultancy in the 2015-16 financial year, please outline:

   a) The project or engagement;

   b) The value of the contract;

   c) The name of each firm or contractor engaged; and

   d) The purpose of the contract.

6. For each contract or consultancy in the 2015-16 financial year, please outline:

   a) The names of each firm or contractor engaged; and

   b) Total payments made to each contractor or consultant.

7. For the 2015-16 financial year, please outline:

   a) How many staff were employed through labour hire arrangements;

   b) Total expenditure on labour hire staff;

   c) The contractors or labour hire firms engaged to supply these staff;

   d) Total payments to each of the organisations that provided staff through either a labour hire arrangement or other contractual arrangement; and

   e) The nature of the work performed by labour hire staff.

Answer:

Department of Agriculture and Water Resources

1. Staffing Levels

a) d) and e) **Full-time equivalent** by employment type as at 30 June 2016 is as follows:

Question: 89 (continued)

State	Ongoing	Non-Ongoing	Casual [1]	Total
ACT	1 910.5	137.8		2 048.3
NSW	649.7	7.0		656.7
VIC	477.0	19.1		496.1
QLD	537.0	41.2		578.2
WA	217.7	3.2		220.9
SA	156.0			156.0
NT	46.3	4.3		50.6
TAS	7.8			7.8
Overseas	18.0			18.0
Other			163.8	163.8
Total	**4 019.9**	**212.6**	**163.8**	**4 396.4**

[1] Casual FTE could not be split by State

[2] Totals may not add up due to rounding

b) d) and e) **Headcount** by employment type as at 30 June 2016 is as follows:

State	**Ongoing**	**Non-Ongoing**	**Casual**	**Total**
ACT	2 092	148	32	2 272
NSW	728	7	54	789
VIC	532	20	83	635
QLD	588	43	84	715
WA	246	4	80	330
SA	175		32	207
NT	53	5	2	60
TAS	8		4	12
Overseas	18			18
Total	**4 440**	**227**	**371**	**5 038**

Question: 89 (continued)

c) **Full-time equivalent** by gender as at 30 June 2016 is as follows:

State	Female	Male	Casual [1]	Total
ACT	1 173.5	874.7		2 048.3
NSW	262.4	394.3		656.7
VIC	199.4	296.7		496.1
QLD	196.1	382.1		578.2
WA	93.2	127.8		220.9
SA	50.9	105.1		156.0
NT	26.2	24.4		50.6
TAS	1.8	6.0		7.8
Overseas	6.0	12.0		18.0
Other			163.8	163.8
Total	**2 009.5**	**2 223.1**	**163.8**	**4 396.4**

[1] Casual FTE could not be split by State

[2] Totals may not add up due to rounding

Headcount by gender as at 30 June 2016 is as follows:

State	Female	Male	Total
ACT	1 344	928	2 272
NSW	338	451	789
VIC	262	373	635
QLD	257	458	715
WA	160	170	330
SA	74	133	207
NT	33	27	60
TAS	4	8	12
Overseas	6	12	18
Total	**2 478**	**2 560**	**5 038**

Question: 89 (continued)

f) **Full-time equivalent** by substantive classification as at 30 June 2016 is as follows:

State	APS 1	APS 2	APS 3	APS 4	APS 5	APS 6	EL 1	EL 2	SES 1	SES 2	SES 3	SEC	Casual [1]	Total
ACT	3.4	9.0	72.6	252.7	285.3	542.7	506.2	300.0	53.4	18.0	4.0	1.0		2 048.3
NSW	2.0	3.0	163.8	294.5	81.2	73.4	25.2	12.5	1.0					656.7
VIC	0.4	1.3	159.1	154.8	68.3	71.5	22.6	17.0	1.0					496.1
QLD		4.0	138.3	205.2	91.2	86.6	30.0	22.0	1.0					578.2
WA		0.6	45.4	93.1	35.9	28.1	12.0	4.0	2.0					220.9
SA			29.1	69.7	23.2	21.0	9.0	3.0	1.0					156.0
NT			5.6	22.5	9.5	9.0	4.0							50.6
TAS				3.8	1.0	3.0								7.8
Overseas								11.0	7.0					18.0
Other													163.8	163.8
Total	**5.8**	**17.8**	**614.0**	**1 096.3**	**595.6**	**835.2**	**609.1**	**369.4**	**66.4**	**18.0**	**4.0**	**1.0**	**163.8**	**4 396.4**

[1] Casual FTE could not be split by State

[2] Totals may not add up due to rounding

Question: 89 (continued)

Headcount by substantive classification as at 30 June 2016 is as follows:

State	APS 1	APS 2	APS 3	APS 4	APS 5	APS 6	EL 1	EL 2	SES 1	SES 2	SES 3	SEC	Total
ACT	5	9	96	283	318	604	557	318	56	20	5	1	2 272
NSW	2	4	228	343	86	84	27	14	1				789
VIC	1	2	213	212	73	91	25	17	1				635
QLD		7	189	250	100	113	31	24	1				715
WA		20	96	116	41	39	12	4	2				330
SA		10	45	83	26	30	9	3	1				207
NT			7	25	10	12	5	1					60
TAS			2	4	1	5							12
Overseas								11	7				18
Total	**8**	**52**	**876**	**1 316**	**655**	**978**	**666**	**392**	**69**	**20**	**5**	**1**	**5 038**

Question: 89 (continued)

2. Engagements

In October 2015 the Water functions from the Department of Environment were transferred to the Department of Agriculture and Water Resources. The below engagements include employees who transferred through these machinery of government changes.

a) **Engagements (headcount)** by substantive classification in the 2015-16 financial year are as follows:

Classification	Staff Numbers (Headcount)
APS 1	22
APS 2	10
APS 3	165
APS 4	190
APS 5	112
APS 6	199
EL 1	139
EL 2	52
SES 1	12
SES 2	2
SES 3	3
Total	**906**

b) **Engagements (headcount)** by State or Territory in the 2015-16 financial year are as follows:

State	Staff Numbers (Headcount)
ACT	679
NSW	35
VIC	71
QLD	72
WA	31
SA	3
NT	15
TAS	
Total	**906**

Question: 89 (continued)

c) and d) **Engagements (headcount)** by employment type in the 2015-16 financial year are as follows:

Employment Type	Staff Numbers (Headcount)
Ongoing	493
Non-Ongoing	296
Casual	117
Total	**906**

3. Separations

a) **Separations (headcount)** by substantive classification in the 2015-16 financial year are as follows:

Classification	Staff Numbers (Headcount)
APS 1	20
APS 2	5
APS 3	63
APS 4	107
APS 5	67
APS 6	91
EL 1	66
EL 2	31
SES 1	3
SES 2	
SES 3	2
Total	**455**

Question: 89 (continued)

b) **Separations (headcount)** by State or Territory in the 2015-16 financial year are as follows:

State	Staff Numbers (Headcount)
ACT	319
NSW	35
VIC	42
QLD	35
WA	13
SA	4
NT	6
TAS	1
Total	**455**

c) and d) **Separations (headcount)** by employment type in the 2015-16 financial year are as follows:

Employment Type	Staff Numbers (Headcount)
Ongoing	288
Non-Ongoing	129
Non-Ongoing Casual	38
Total	**455**

e) **Separations (headcount)** by reason in the 2015-16 financial year are as follows:

Separation reason	Staff Numbers (Headcount)
Contract Cessation	161
Death/Invalidity	12
Movement to other organisation	114
Redundancy	49
Retired/resigned from the APS	115
Terminated due to non-performance	4
Total	**455**

4. Information is provided in the department's 2015-16 Annual Report, chapter 5 page 163.

5. Information is available from AusTender at www.tenders.gov.au.

Question: 89 (continued)

6. a) Information is available from AusTender at www.tenders.gov.au

b) The provision of this information would entail a substantial diversion of resources.

7. a) The number of new temporary personnel contracts with a value greater than $10 000 entered into during 2015-2016 was 396.

b) Total expenditure on labour hire staff was $26.428m.

c) Information is available from AusTender at www.tenders.gov.au

d) The provision of this information would entail a substantial diversion of resources.

e) The nature of the work performed by labour hire staff varies depending on the operational need of the employing area. Over 2015-16 the majority of labour hire staff worked in information technology, finance, service delivery and human resource areas of the department.

Australian Fisheries Management Authority (AFMA)

1. Staffing Levels

a) d) and e) **Full-time equivalent** by employment type as at 30 June 2016 is as follows:

State	Ongoing	Non-Ongoing	Casual	Total
ACT [3]	123.0	6.0	17.0	**146.0**
NSW				
VIC				
QLD	3.0	1.0		**4.0**
WA				
SA				
NT	25.8			**25.8**
TAS				
Overseas				
Total	**151.8**	**7.0**	**17.0**	**175.8**

[2] Totals may not add up due to rounding

[3] These figures include 17 Observers who are engaged as intermittent/irregular casual employees and are reported in the ACT but are based in numerous locations around Australia.

Question: 89 (continued)

b) d) and e) **Headcount** by employment type as at 30 June 2016 is as follows:

State	Ongoing	Non-Ongoing	Casual	Total
ACT [3]	125	6	17	148
NSW				
VIC				
QLD	4	1		5
WA				
SA				
NT	28			28
TAS				
Overseas				
Total	**157**	**7**	**17**	**181**

[3] These figures include 17 Observers who are engaged as intermittent/irregular casual employees and are reported in the ACT but are based in numerous locations around Australia.

c) **Full-time equivalent** by gender as at 30 June 2016 is as follows:

State	Male	Female	Total
ACT [3]	90.8	55.2	**146.0**
NSW			
VIC			
QLD	2.0	2.0	**4.0**
WA			
SA			
NT	20.0	5.8	**25.8**
TAS			
Overseas			
Total	**112.8**	**63.0**	**175.8**

[2] Totals may not add up due to rounding

[3] These figures include 17 male Observers who are engaged as intermittent/irregular casual employees and are reported in the ACT but are based in numerous locations around Australia.

Question: 89 (continued)

Headcount by gender as at 30 June 2016 is as follows:

State	Male	Female	Total
ACT [3]	89	59	148
NSW			
VIC			
QLD	3	2	5
WA			
SA			
NT	20	8	28
TAS			
Overseas			
Total	**112**	**69**	**181**

[3] These figures include 17 male Observers who are engaged as intermittent/irregular casual employees and are reported in the ACT but are based in numerous locations around Australia.

f) **Full-time equivalent** by substantive classification as at 30 June 2016 is as follows:

State	APS 1	APS 2	APS 3	APS 4	APS 5	APS 6	EL 1	EL 2	SES	Other	Total
ACT [3]		14.9	7.0	19.3	9.5	47.8	31.6	14.0	1.0	1.0	**146.0**
NSW											
VIC											
QLD		1.0		1.0			1.0	1.0			**4.0**
WA											
SA											
NT		0.8		9.0		11.0	3.0	1.0	1.0		**25.8**
TAS											
Total		**16.7**	**7.0**	**29.3**	**9.5**	**58.8**	**35.6**	**16.0**	**2.0**	**1.0**	**175.8**

[2] Totals may not add up due to rounding

[3] These figures include 17 Observers who are engaged as APS 2/3 intermittent/irregular casual employees and are reported in the ACT but are based in numerous locations around Australia.

Question: 89 (continued)

Headcount by substantive classification as at 30 June 2016 is as follows:

State	APS 1	APS 2	APS 3	APS 4	APS 5	APS 6	EL 1	EL 2	SES	Other	Total
ACT [3]		15	7	19	10	48	33	14	1	1	148
NSW											
VIC											
QLD		1		1		1	1	1			5
WA											
SA											
NT		1		9		13	3	1	1		28
TAS											
Total		**17**	**7**	**29**	**10**	**62**	**37**	**16**	**2**	**1**	**181**

[3] These figures include 17 Observers who are engaged as APS 2/3 intermittent/irregular casual employees and are reported in the ACT but are based in numerous locations around Australia.

2. Engagements

a) **Engagements (headcount)** by substantive classification in the 2015-16 financial year are as follows:

Classification	Staff Numbers (Headcount)
APS 1	
APS 2	2
APS 3	
APS 4	6
APS 5	3
APS 6	6
EL 1	2
EL 2	
SES	
Other	
Total	**19**

Question: 89 (continued)

b) **Engagements (headcount)** by State or Territory in the 2015-16 financial year are as follows:

State	Staff Numbers (Headcount)
ACT	18
NSW	
VIC	
QLD	1
WA	
SA	
NT	
TAS	
Total	**19**

c) and d) **Engagements (headcount)** by employment type in the 2015-16 financial year are as follows:

Employment Type	Staff Numbers (Headcount)
Ongoing	12
Non-Ongoing	7
Non-Ongoing Casual	
Total	**19**

3. Separations

a) **Separations (headcount)** by substantive classification in the 2015-16 financial year are as follows:

Classification	Staff Numbers (Headcount)
APS 1	
APS 2	3
APS 3	
APS 4	5
APS 5	3

APS 6	13
EL 1	6
EL 2	1
SES	
Other	
Total	**31**

b) **Separations (headcount)** by State or Territory in the 2015-16 financial year are as follows:

State	**Staff Numbers (Headcount)**
ACT	24
NSW	
VIC	
QLD	2
WA	
SA	
NT	5
TAS	
Total	**31**

c) and d) **Separations (headcount)** by employment type in the 2015-16 financial year are as follows:

Employment Type	**Staff Numbers (Headcount)**
Ongoing	28
Non-Ongoing	3
Non-Ongoing Casual	
Total	**31**

Question: 89 (continued)

e) **Separations (headcount)** by reason in the 2015-16 financial year are as follows:

Separation reason	**Staff Numbers (Headcount)**
Contract Cessation	3
Death/Invalidity	
Movement to other organisation	11
Redundancy	
Retired/resigned from the APS	14
Terminated due to non-performance	
Other	3
Total	**31**

4. The total expenditure on contractors and consultants in the 2015-16 financial year was $4.776 million.
5. Information regarding contracts and consultancies is reported on Austender
6. Information regarding contracts and consultancies is reported on Austender
7. Information regarding contracts and consultancies is reported on Austender. It would require an unreasonable diversion of resources to provide further information.

Question: 89 (continued)

Australian Pesticides & Veterinary Medicines Authority

1. Staffing Levels

a) d) and e) **Full-time equivalent** by employment type as at 30 June 2016 is as follows:

State	Ongoing	Non-Ongoing	Casual	Total
ACT	177.0	7.8	1.0	185.8
NSW				
VIC				
QLD				
WA	1.0			1.0
SA				
NT				
TAS				
Overseas				
Total	**178.0**	**7.8**	**1.0**	**186.8**

[2] Totals may not add up due to rounding

b) d) and e) **Headcount** by employment type as at 30 June 2016 is as follows:

State	Ongoing	Non-Ongoing	Casual	Total
ACT	181	8	1	190
NSW				
VIC				
QLD				
WA	1			1
SA				
NT				
TAS				
Overseas				
Total	**182**	**8**	**1**	**191**

Question: 89 (continued)

c) **Full-time equivalent** by gender as at 30 June 2016 is as follows:

State	Male	Female	Total
ACT	73.3	112.6	185.8
NSW			
VIC			
QLD			
WA		1.0	1.0
SA			
NT			
TAS			
Overseas			
Total	**73.3**	**113.6**	**186.8**

[2] Totals may not add up due to rounding

Headcount by gender as at 30 June 2016 is as follows:

State	Male	Female	Total
ACT	74	116	190
NSW			
VIC			
QLD			
WA		1	1
SA			
NT			
TAS			
Overseas			
Total	**74**	**117**	**191**

Question: 89 (continued)

f) **Full-time equivalent** by substantive classification as at 30 June 2016 is as follows:

State	APS 1	APS 2	APS 3	APS 4	APS 5	APS 6	EL 1	EL 2	SES	Other	Total
ACT			9.5	12.0	23.9	50.5	55.9	27.0	4.0	3.0	185.8
NSW											
VIC											
QLD											
WA						1.0					1.0
SA											
NT											
TAS											
Total			**9.5**	**12.0**	**23.9**	**51.5**	**55.9**	**27.0**	**4.0**	**3.0**	**186.8**

[2] Totals may not add up due to rounding

Question: 89 (continued)

Headcount by substantive classification as at 30 June 2016 is as follows:

State	APS 1	APS 2	APS 3	APS 4	APS 5	APS 6	EL 1	EL 2	SES	Other	Total
ACT			10	12	24	52	58	27	4	3	190
NSW											
VIC											
QLD											
WA						1					1
SA											
NT											
TAS											
Total			**10**	**12**	**24**	**53**	**58**	**27**	**4**	**3**	**191**

Question: 89 (continued)

2. Engagements

a) **Engagements (headcount)** by substantive classification in the 2015-16 financial year are as follows:

Classification	Staff Numbers (Headcount)
APS 1	
APS 2	
APS 3	8
APS 4	6
APS 5	9
APS 6	22
EL 1	16
EL 2	6
SES	1
Other	
Total	**68**

b) **Engagements (headcount)** by State or Territory in the 2015-16 financial year are as follows:

State	Staff Numbers (Headcount)
ACT	68
NSW	
VIC	
QLD	
WA	
SA	
NT	
TAS	
Total	**68**

Question: 89 (continued)

c) and d) **Engagements (headcount)** by employment type in the 2015-16 financial year are as follows:

Employment Type	Staff Numbers (Headcount)
Ongoing	56
Non-Ongoing	11
Non-Ongoing Casual	1
Total	**68**

3. Separations

a) **Separations (headcount)** by substantive classification in the 2015-16 financial year are as follows:

Classification	Staff Numbers (Headcount)
APS 1	
APS 2	
APS 3	4
APS 4	3
APS 5	5
APS 6	13
EL 1	13
EL 2	9
SES	1
Other	
Total	**48**

Question: 89 (continued)

b) **Separations (headcount)** by State or Territory in the 2015-16 financial year are as follows:

State	Staff Numbers (Headcount)
ACT	48
NSW	
VIC	
QLD	
WA	
SA	
NT	
TAS	
Total	**48**

c) and d) **Separations (headcount)** by employment type in the 2015-16 financial year are as follows:

Employment Type	Staff Numbers (Headcount)
Ongoing	32
Non-Ongoing	15
Non-Ongoing Casual	1
Total	**48**

d) **Separations (headcount)** by reason in the 2015-16 financial year are as follows:

Separation reason	Staff Numbers (Headcount)
Contract Cessation	15
Death/Invalidity	
Movement to other organisation	19
Redundancy	
Retired/resigned from the APS	14

Terminated due to non-performance	
Other	
Total	**48**

4. The total expenditure on contractors and consultants in the 2015-16 financial year was $6.396m.

5. The table below outlines contracts and consultants in the 2015-16 financial year.

Firm Name (5c)	Project or Engagement (5a), Contract Purpose (5d)	Contract Values (5b)
AGS	Legal	149,502
DLA Piper	Legal	11,000
Sparke Helmore	Legal	9,727
Maddocks Lawyers	Legal	15,817
Australian Public Service Commission	APS Employees Census	6,000
Callida Consulting	Mapping Initiatives	85,206
CPM Reviews	Documentation Review	11,013
Direct 2	Audit Committee	7,220
Gallagher Bassett Services	Risk	45,430
Growcom	Label Products	66,300
KPMG	Cyber Intrusions Mitigation	25,000
Layer 127	IT Hardware Consultancy	4,840
M Harkness	Mapping Stats	5,200
Oakton	Internal Audit	98,274
Pegasus Economics	Stocktake Reforms	46,020
Quality Management	Investigations	39,900
Red 29	IT Support	13,545
Resolution Consulting	Audit Committee	11,477
Sedger + Co	Web work	2,750

Seftons	Strategy workshop	8,599
Melbourne University	Risk Framework	37,727
Usability 1	Website review	58,840
UXC Connect	Switchboard Configuration	4,366
Workplace Research	HR Capability Review	47,600
Yellow Edge	ICT Leadership	3,421
Minor Consultancies and Contracts	Minor work	363,961
Various Providers	Scientific Assessment Research	5,067,000
Various Providers	Building/ business services	151,000
TOTAL		**6,396,000**

NOTE: The APVMA is unable to provide the names of the providers for the scientific research assessment as this is commercial in confidence information

6. a) See 5 c)

   b) See 5 b)

7. a) It would require an unreasonable diversion of resources to obtain this information.

   b) The name of each firm: Total expenditure on labour hire staff. $3,091,901

   c) Labour hire companies:

	1	INFINITE CONSULTING PTY LTD	$672,323
	2	HAYS PERSONNEL SERVICES	$604,908
	3	RANDSTAD PTY LTD	$370,940
	4	MY OFFICE 24 x 7	$355,973
	5	UXC CONSULTING PTY LTD	$345,394
	6	THE ONE UMBRELLA	$293,277
	7	NEOPERANDI PTY LTD	$193,482
	8	CAPITAL RECRUIT	$96,414
	9	MOSAIC RECRUITMENT	$77,746
d) Hire	10	AGILEWARE PTY LTD	$74,981
e)	12	LAYER 127 PTY LTD	$5,808
	13	OPC IT LTY LTD	$754

company costs, see 7 c).

Temporary labour hire

Question: 89 (continued)

Australian Grape and Wine Authority

1. Staffing Levels

a) d) and e) **Full-time equivalent** by employment type as at 30 June 2016 is as follows:

State	Ongoing	Non-Ongoing	Casual	Total
ACT				
NSW	7.0	0.8		7.8
VIC				
QLD				
WA				
SA	36.4	1.5		37.9
NT				
TAS				
Overseas	9.5	7.0		16.5
Total	**52.9**	**9.3**		**62.2**

b) d) and e) **Headcount** by employment type as at 30 June 2016 is as follows:

State	Ongoing	Non-Ongoing	Casual	Total
ACT				
NSW	7	1		8
VIC				
QLD				
WA				
SA	41	2		43
NT				
TAS				
Overseas	10	7		17
Total	**58**	**10**		**68**

Question: 89 (continued)

c) **Full-time equivalent** by gender as at 30 June 2016 is as follows:

State	Male	Female	Total
ACT			
NSW	3.0	4.8	7.8
VIC			
QLD			
WA			
SA	14.0	23.9	37.9
NT			
TAS			
Overseas	14.0	2.5	16.5
Total	**31.0**	**31.2**	**62.2**

Headcount by gender as at 30 June 2016 is as follows:

State	Male	Female	Total
ACT			
NSW	3	5	8
VIC			
QLD			
WA			
SA	14	29	43
NT			
TAS			
Overseas	3	14	17
Total	**20**	**48**	**68**

Question: 89 (continued)

f) **Full-time equivalent** by substantive classification as at 30 June 2016 is as follows:

State	APS 1	APS 2	APS 3	APS 4	APS 5	APS 6	EL 1	EL 2	SES	Other[4]	Total
ACT											
NSW										7.8	7.8
VIC								p			
QLD											
WA											
SA										37.9	37.9
NT											
TAS											
Overseas										16.5	16.5
Total										**62.2**	**62.2**

[4] This agency does not have the APS classification structure

Headcount by substantive classification as at 30 June 2016 is as follows:

State	APS 1	APS 2	APS 3	APS 4	APS 5	APS 6	EL 1	EL 2	SES	Other[4]	Total
ACT											
NSW										8	8
VIC											
QLD											
WA											
SA										43	43
NT											
TAS											
Overseas										17	17
Total										**68**	**68**

[4] This agency does not have the APS classification structure

Question: 89 (continued)

2. Engagements

a) **Engagements (headcount)** by substantive classification in the 2015-16 financial year are as follows:

Classification	Staff Numbers (Headcount)
APS 1	
APS 2	
APS 3	
APS 4	
APS 5	
APS 6	
EL 1	
EL 2	
SES	
Other [4]	15
Total	**15**

[4] This agency does not have the APS classification structure

b) **Engagements (headcount)** by State or Territory in the 2015-16 financial year are as follows:

State	Staff Numbers (Headcount)
ACT	
NSW	4
VIC	
QLD	
WA	
SA	7
NT	
TAS	
Overseas	4

Total	**15**

c) and d) **Engagements (headcount)** by employment type in the 2015-16 financial year are as follows:

Employment Type	Staff Numbers (Headcount)
Ongoing	7
Non-Ongoing	8
Non-Ongoing Casual	
Total	**15**

3. Separations

a) **Separations (headcount)** by substantive classification in the 2015-16 financial year are as follows:

Classification	Staff Numbers (Headcount)
APS 1	
APS 2	
APS 3	
APS 4	
APS 5	
APS 6	
EL 1	
EL 2	
SES	
Other [4]	7
Total	**7**

[4] This agency does not have the APS classification structure

Question: 89 (continued)

b) **Separations (headcount)** by State or Territory in the 2015-16 financial year are as follows:

State	Staff Numbers (Headcount)
ACT	
NSW	2
VIC	
QLD	
WA	
SA	3
NT	
TAS	
Overseas	2
Total	**7**

c) and d) **Separations (headcount)** by employment type in the 2015-16 financial year are as follows:

Employment Type	Staff Numbers (Headcount)
Ongoing	5
Non-Ongoing	2
Non-Ongoing Casual	
Total	**7**

e) **Separations (headcount)** by reason in the 2015-16 financial year are as follows:

Separation reason	Staff Numbers (Headcount)
Contract Cessation	
Death/Invalidity	
Movement to other organisation	
Redundancy	2

Retired/resigned from the APS	5
Terminated due to non-performance	
Other	
Total	**7**

4. What was the total expenditure on contractors and consultants in the 2015-16 financial year? $101,728

5. For each contract or consultancy in the 2015-16 financial year, please outline:

    a) contract engagement - $51,183 AUD for a Canadian event Co-ordinator to run Canadian events

    b) consultant - $25,850 AUD to Sustained – a employee coaching/mentoring sessions

    c) consultant - $24,695 AUD to The Timing and Angles Group - coaching, project management workshops

6. For each contract or consultancy in the 2015-16 financial year, please outline:

    a) $51,183 AUD for a Canadian event Co-ordinator to run Canadian events

    b) $25,850 AUD to Sustained – a employee coaching/mentoring sessions

    c) $24,695 AUD to The Timing and Angles Group - coaching, project management workshops

7. For the 2015-16 financial year, please outline:

    a) 5

    b) $302,394 AUD

    c) FESCO – a Chinese labour company

    d) $302,394 AUD – office and marketing employees to run the operations of our China office and Chinese marketing events.

    e) Office and marketing employees to run the operations of our China office and Chinese marketing events.

Question: 89 (continued)

Grains Research and Development Corporation

1. Staffing Levels

a) d) and e) **Full-time equivalent** by employment type as at 30 June 2016 is as follows:

State	Ongoing	Non-Ongoing	Casual	Total
ACT	42.0	8.0	2.0	48.1
NSW	2.0	1.0		3.0
VIC				
QLD	4.0	1.0		5.0
WA	4.0	1.0		4.7
SA	5.0	1.0		6.0
NT				
TAS				
Total	**57.0**	**12.0**	**2.0**	**64.8**

b) d) and e) **Headcount** by employment type as at 30 June 2016 is as follows:

State	Ongoing	Non-Ongoing	Casual	Total
ACT	42	8	2	50
NSW	2	1		3
VIC				
QLD	4	1		5
WA	4	1		5
SA	5	1		6
NT				
TAS				
Total	**57**	**12**	**2**	**71**

Question: 89 (continued)

c) **Full-time equivalent** by gender as at 30 June 2016 is as follows:

State	Male	Female	Total
ACT	17.6	28.5	46.1
NSW	1.0	2.0	3.0
VIC			
QLD	2.0	3.0	5.0
WA	3.0	1.7	4.7
SA	3.0	3.0	6.0
NT			
TAS			
Total	**26.6**	**38.2**	**64.8**

Headcount by gender as at 30 June 2016 is as follows:

State	Male	Female	Total
ACT	18	34	52
NSW	1	2	3
VIC			
QLD	3	2	5
WA	3	2	5
SA	3	3	6
NT			
TAS			
Total	**28**	**43**	**71**

Question: 89 (continued)

f) **Full-time equivalent** by classification as at 30 June 2016 is as follows:

State	APS 1	APS 2	APS 3	APS 4	APS 5	APS 6	EL 1	EL 2	SES	Other[4]	Total
ACT										46.1	46.1
NSW										3.0	3.0
VIC											
QLD										5.0	5.0
WA										4.7	4.7
SA										6.0	6.0
NT											
TAS											
Total										**64.8**	**64.8**

[4] This agency does not have the APS classification structure

Headcount by classification as at 30 June 2016 is as follows:

State	APS 1	APS 2	APS 3	APS 4	APS 5	APS 6	EL 1	EL 2	SES	Other[4]	Total
ACT										52	52
NSW										3	3
VIC											
QLD										5	5
WA										5	5
SA										6	6
NT											
TAS											
Total										**71**	**71**

[4] This agency does not have the APS classification structure

Question: 89 (continued)

2. Engagements

a) **Engagements (headcount)** by classification in the 2015-16 financial year are as follows:

Classification	Staff Numbers (Headcount)
APS 1	
APS 2	
APS 3	
APS 4	
APS 5	
APS 6	
EL 1	
EL 2	
SES	
Other [4]	27
Total	**27**

[4] This agency does not have the APS classification structure

b) **Engagements (headcount)** by State or Territory in the 2015-16 financial year are as follows:

State	Staff Numbers (Headcount)
ACT	15
NSW	1
VIC	
QLD	3
WA	3
SA	5
NT	
TAS	
Total	**27**

Question: 89 (continued)

c) and d) **Engagements (headcount)** by employment type in the 2015-16 financial year are as follows:

Employment Type	Staff Numbers (Headcount)
Ongoing	16
Non-Ongoing	10
Non-Ongoing Casual	1
Total	**27**

3. Separations

a) **Separations (headcount)** by classification in the 2015-16 financial year are as follows:

Classification	Staff Numbers (Headcount)
APS 1	
APS 2	
APS 3	
APS 4	
APS 5	
APS 6	
EL 1	
EL 2	
SES	
Other [4]	33
Total	**33**

[4] This agency does not have the APS classification structure

b) **Separations (headcount)** by State or Territory in the 2015-16 financial year are as follows:

State	Staff Numbers (Headcount)
ACT	30
NSW	1

VIC	
QLD	1
WA	1
SA	
NT	
TAS	
Total	**33**

c) and d) **Separations (headcount)** by employment type in the 2015-16 financial year are as follows:

Employment Type	**Staff Numbers (Headcount)**
Ongoing	21
Non-Ongoing	12
Non-Ongoing Casual	
Total	**33**

e) **Separations (headcount)** by reason in the 2015-16 financial year are as follows:

Separation reason	**Staff Numbers (Headcount)**
Contract Cessation	
Death/Invalidity	
Movement to other organisation	
Redundancy	1
Retired/resigned from the APS	
Terminated due to non-performance	2
Other	30
Total	**33**

4. Nil. The GRDC does not engage contractors or consultants for business as usual type activities

5. Not applicable

Question: 89 (continued)

6. Not applicable

7. a) Nil. The GRDC does not engage contractors or consultants for business as usual type activities

   b) Not applicable

   c) Not applicable

   d) Not applicable

   e) Not applicable

Rural and Regional Affairs and Transport Legislation Committee

ANSWERS TO QUESTIONS ON NOTICE

Supplementary Budget Estimates October 2016

Agriculture and Water Resources

Question: 90

Division/Agency: Corporate Strategy and Governance Division

Topic: Program analysis

Proof Hansard page: Written

Senator STERLE asked:

Please provide the following information for every program administered by the department and all portfolio agencies within it:

a) Copies of any evaluation reports or program analysis prepared by external advisers in the last five years;

b) Copies of any evaluation reports or program analysis prepared within the department in the last five years.

Answer:

Department of Agriculture and Water Resources:

As the department has implemented and evaluated (internally and with external assistance) a large number of programmes over the past five years, it would require an unreasonable diversion of resources to obtain this information.

Information on the department's current and past programmes, including performance information, is available through our Corporate Plan, Annual Performance Statement, and Annual Report, as well as the internet site www.agriculture.gov.au.

Australian Grape and Wine Authority (Wine Australia):

Attached are reviews and evaluations of AGWA research are on the following topics:

- Winery Wastewater projects
- Yeast projects
- Rootstock projects
- Germplasm collections
- Extension

Question: 90 (continued)

- A further report is available at: http://research.wineaustralia.com/wp-content/uploads/2012/11/AWRI-review-report.pdf

Australian Fisheries Management Authority (AFMA):

It would require an unreasonable diversion of resources to provide this information.

Australian Pesticides and Veterinary Medicines Authority (APVMA):

It would require an unreasonable diversion of resources to obtain this information.

Cotton Research and Development Corporation (CRDC):

Please refer CRDC website and annual reports which include overviews of evaluations.

Annual report:

http://www.crdc.com.au/publications/crdc-annual-report-2014-15

Fisheries Research & Development Corporation (FRDC):

Please refer FRDC website and annual reports which include overviews of evaluations.

Evaluations:

http://frdc.com.au/research/benefits_of_research/Pages/default.aspx

Annual report:

http://frdc.com.au/about_frdc/corporate-documents/Pages/annual_rep.aspx

Grains Research and Development Corporation (GRDC):

It would require an unreasonable diversion of resources to obtain this information within the timeframe provided.

Murray Darling Basin Authority:

Providing specific reports about every program administered by the Murray-Darling Basin Authority (MDBA) over the last five years would involve an extensive manual process and therefore, in the context of existing workloads, an unreasonable diversion of resources.

Rural Industries Research and Development Corporation (RIRDC):

There are too many programmes to review and the resources aren't available to obtain this information in the required timeframe.

Cost Benefit Analysis of a GWRDC Project Cluster: Wastewater Management

A report prepared for

Grape and Wine Research and Development Corporation

Prepared by

15 October 2012

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List of Tables

Abbreviations

ABS	Australian Bureau of Statistics
AWRI	Australian Wine Research Institute
BCR	benefit cost ratio
CBA	cost benefit analysis
COD	chemical oxygen demand
CRCV	Cooperative Research Centre for Viticulture
CRRDCC	Council of Rural Research and Development Corporation Chairs
EC	Electrical Conductivity,
GWRDC	Grape and Wine Research and Development Corporation
IRR	internal rate of return
NPV	net present value
SAR	Sodium absorption ratio
TOC	total organic carbon

Document History and Status

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1. Introduction

EconSearch Pty Ltd was contracted by GWRDC to undertake cost-benefit analysis (CBA) of three project clusters, namely:

- Yeasts (six component projects);
- Winery Wastewater Management Accelerated Adoption Model (five component projects); and
- Extension and Adoption (three component projects).

The results of the CBA for each project cluster will be reported separately and those for the 'Winery Wastewater Management Accelerated Adoption Model', henceforward referred to as 'Wastewater Management' cluster are presented in this report. This cluster was comprised of five GWRDC funded projects, namely[1]:

- CSL 02/03- impact of the winery wastewater on ecosystem health
- CSL 05/01-Winery Wastewater research to Practice
- CSL 05/02- developing a systematic approach to winery wastewater management
- SAR 07/01
- GWR 0915- Recycled water- project 1 communication and extension

A sixth project (SAR 05/01) was originally included in this cluster but has been excluded from the analysis as the outcomes of the project had a different focus from that of the other projects.

In previous evaluations for GWRDC, a separate CBA was prepared and reported for each component project within the cluster, as well as for the aggregate results (EconSearch 2008a, 2008b, 2009). This approach assists GWRDC with developing a database of individual project evaluations and in fulfilling their reporting requirements to the Council of Rural Research and Development Corporation Chairs (CRRDCC). However, because the projects assessed in the Wastewater Management cluster are tightly linked, attempts to attribute the benefits to individual projects would be arbitrary. Outputs of early projects are used as inputs into later projects and findings from research and extension materials produced are often used in multiple projects. This high level of integration makes it difficult to meaningfully demarcate the benefits produced by each project. Assigning only the direct outputs of each project within the cluster to the benefits is likely to result in an undervaluation of earlier research based projects and an overvaluation of later extension based projects. However, given that decisions on extension projects are often made after research projects have been completed, i.e. when the costs of research projects are 'sunk', a consideration of the benefits of the extension projects in isolation from the other work will have meaning.

An outline of the key characteristics of the CBA method employed in this study is provided in Section 2 of the report. In Section 3, the scope of each project within the cluster and the costs and benefits stemming from the project are described. Section 4

[1] EconSearch has already completed a cost benefit analysis of project number CRV 03/07S (Influence of irrigation and fertiliser management on movement of water and nutrient within and below the root zone of vines for sustainable grape production) as part of the 'vine physiology – water' project cluster and, based on consultation with Geoff Crook (GWRDC, pers. comm.), this project was removed from this cluster.

outlines the data sources/assumptions and results of the CBA, including key indicators and sensitivity analysis, are detailed for the entire cluster. A summary and some concluding remarks are provided in Section 5 of the report.

2. Method of Analysis

The CBA conducted for this project was undertaken according to the principles and method outlined in:

- the Council for Rural Research and Development Corporation Chairs *Guidelines for Evaluation* (ACIL Tasman 2009);
- the Commonwealth Government's *Introduction to Cost-Benefit Analysis and Alternative Evaluation Methodologies* (Department of Finance and Administration 2006a);
- the Commonwealth Government's *Handbook of Cost-Benefit Analysis* (Department of Finance and Administration 2006b); and
- Land and Water Australia's *Methodology for Evaluating Return on Investment from Natural Resource Management Research and Development* (Chudleigh et al. 2007).

The key characteristics of the CBA method employed in this study include the following.

- The CBA includes a base case or counterfactual scenario, that is, the benchmark against which the 'with GWRDC investment' scenario was compared. The base case was defined as what would have occurred without GWRDC investment in the technology or research.
- The CBA was conducted over a 30 year time period and results were expressed in terms of net benefits, that is, the incremental benefits and costs of the 'with GWRDC investment' scenarios relative to those generated by the base case scenario[2].
- Costs and benefits were specified in real terms (i.e. constant 2011 dollars). Past and future values were converted to present values by applying a discount rate of 5 per cent.
- In order to account for uncertainty, sensitivity analysis was undertaken using a range of values for key variables, including adoption profiles.
- The evaluation criteria employed in the analysis include net present value (NPV)[3], benefit-cost ratio (BCR)[4] and internal rate of return (IRR)[5].
- Reporting requirements for the analysis were based on a Microsoft Excel® spreadsheet template developed by ACIL Tasman for the broader Rural Research and Development Corporation evaluation project (Mark Barber, pers. comm.). These requirements include:
  - reporting NPV for 5, 10, 20 and 30 year time horizons;
  - reporting on the returns to total (public and private) investment and returns to GWRDC investment in the technology or research; and;

[2] Where incremental benefits = ('with GWRDC' benefits – 'without GWRDC' benefits) and incremental costs = ('with GWRDC' costs – 'without GWRDC' costs).

[3] NPV was defined as discounted net benefits, where net benefits = (incremental benefits – incremental costs).

[4] The BCR was defined as (discounted net benefits subsequent to the GWRDC investment phase) / (discounted net benefits during the GWRDC investment phase). This was consistent with the spreadsheet template developed by ACIL Tasman.

[5] The discount rate at which the NPV of an investment scenario is equal to zero.

- allocation of NPVs to the Rural Research Priorities.

- For the CBA, costs and benefits for both the 'with' and 'without' GWRDC investment scenarios have been listed in tabular form and include those that can be readily identified and valued in monetary terms as well as those which cannot be easily valued in monetary terms because of the absence of market signals. The tables provide an indication of the likely distribution of the costs and benefits between stakeholder groups and the source of the information.

3. Project descriptions

3.1 CSL 02/03[6]

3.1.1 Description of the project and research

The project described in this section of the report relates to research findings that were developed as a consequence of investment by GWRDC and collaborators in the project; CSL 02/03 – *Impact of Winery Wastewater on Ecosystem health*.

The main objective of this project was to assess the ecotoxicological impact of winery wastewater on aquatic and terrestrial ecosystems. Specific objectives were to:

- characterise the winery wastewater;
- establish baseline levels of toxicity and variability of toxicity in winery wastewater;
- identify the classes of contaminants responsible for the toxicity of the winery wastewater;
- assess the performance of artificial wetlands in decreasing pollution;
- evaluate the toxicity of three commonly used polymers to selected aquatic fauna; and
- assess the soil health of vineyards and woodlots during and after the application of wastewater.

3.1.2 Key outcomes

The main outcomes of the project were the:

- characterisation of winery wastewater;
- identification of the role of biological solids on the health of aquatic ecosystems; and
- identification of the impact of salt levels of wastewater on long term soil health.

3.2 CSL 05/02[7]

3.2.1 Description of the project and research

The overall aim of this project was to provide an integrated "systems approach" to sustainable winery wastewater management that combines a comprehensive account of wastewater characteristics, the most cost-effective treatment and recovery/reuse strategies for nutrients, organic and chemical loads, and the best salt management options to meet desired environmental specifications. Some of the key objectives were to:

- characterise and quantify liquid wastes within selected wineries;

[6] More details on this project are available in the project final report, Kumar et al (2006).

[7] More details on this project are available in the project final report, Kumar et al (2009).

- assess efficiency of current treatment technologies based on the winery wastewater physico-chemical characteristics;
- assess the environmental impact of cleaning agents used by wineries;
- assess the re-use potential of treated wastewater; and
- communicate research findings to GWRDC and industry via integration with research to practice extension modules.

3.2.2 Key outcomes

The main outcomes of the project were the:

- characterisation of wastewater quality including variation between: wineries; classes of wineries; and vintage and non-vintage periods; and
- identification of key parameters required to assess the health of winery wastewater (pH, EC, COD, SAR and TOC).

3.3 CSL 05/01[8]

3.3.1 Description of the project and research

The overall aim of the project was to develop a training program on winery wastewater management know-how to increase the industry's awareness and knowledge on matters of regulation and good practice for effective and informed stakeholder engagement.

The specific objectives were to:

- use the 'Research to Practice TM' model to develop and deliver training that comprises complex research results on wastewater management know-how to practical options that can be adopted and practised in the viticulture industry;
- prepare carefully constructed modules or topics on the wastewater issues and their management for delivery;
- collate existing information and research findings on wastewater topics in a handout booklet;
- provide information in a form that is consistent with 'best practice adult learning principles';
- increase environmental awareness of wine-makers, consultants and other stakeholders through this training program; and
- address regional-specific issues into training and education materials for use across the industry.

3.3.2 Key outcomes

The main outcomes of the project were:

[8] More details on this project are available in the project final report, Kumar et al (2010)

- workshops conducted in 17 sites in wine-producing areas across Western Australia, South Australia, Victoria and New South Wales;
- participation of approximately 326 wine makers, operators, environmental managers in the learning and improved practice experience over the life of the project;
- dissemination of winery wastewater management related information to an additional 390 people at seminars and special wastewater recycle and reuse workshops and conferences;

The feedback from the workshops provided to EconSearch was very positive, with most participants indicting that the workshops fulfilled their needs. Consultation conducted by EconSearch confirmed that most participants had a positive view of the workshops. A proportion of workshop attendees have implemented changes to wastewater management strategies that they had learned at the workshops.

A proportion of workshop attendees suggested that they had been able to save a significant amount of time as a result of attending the workshop.

3.4 SAR 07/01[9]

3.4.1 Description of the project and research

This scoping study was undertaken to determine the feasibility of irrigating with recycled water for the wine industry. The project provides an assessment of recycled water use in the wine industry, identifies gaps in knowledge and issues that may arise in the expansion of its use in the viticultural sector in order to assist GWRDC to make an informed decision on future investment in this area.

3.4.2 Key outcomes

The project recommended that following investigations of the opportunities for specific viticultural regions to secure recycled water.

- Confirm potassium (K) concentration in recycled water in Australia and determine if an excess to vine requirements will be applied with recycled water; and if so:
    - determine critical K concentration in petioles, soils and recycled water related to changes in grape/wine quality from excess K applied in recycled water to help manage these impacts.
- Plant pathogens relevant to the viticultural sector should be assessed in a range of recycled water qualities (effluent, classes A to D), to allow better assessment of these risks.
- A risk assessment for chemicals of concern (e.g. endocrine disruptors and pharmaceuticals) focused specifically at pathways within the viticultural sector environment should be undertaken. This would include identifying hazards that could pose a significant risk to vines, soil contamination, soil microbes, aquatic systems, berry or wine quality and human health. The Australian Guidelines for Water Recycling provide a framework for undertaking this type of risk assessment

[9] More details on this project are available in the project final report, Stevens (2009).

- Publication of a handbook for growers who irrigate grapevines with recycled water.

3.5 GWR 0915[10]

3.5.1 Description of the Project and Research

This project was borne out of industry consultation which highlighted the existence of vast amounts of disparate material on wastewater management. The purpose of the project was to provide an easy to use resource for industry (primarily for small to medium wineries) which would facilitate the adoption of 'best practice' wastewater management processes across industry. The project relied heavily upon previous research, and utilised connections with industry including wineries and consultants to help provide and improve materials. ,

3.5.2 Key outcomes

The main outcomes of the project were the:

- production of a written resource including case studies, a framework for wineries assessing their wastewater management and a compilation of key indicators, such as water quality benchmarks for different categories of water use;
- production of an electronic resource including interactive tools for assessing consequences of changing wastewater management strategies; and
- production of a web based resource including all of the above.

A small proportion of winemakers contacted in EconSearch analysis were aware of the resources produced. The resource was well regarded by those who were aware of it.

[10] The full package of resources produced by this project is available at http://www.gwrdc.com.au/site/page.cfm?u=130.

4. Cost Benefit Analysis

4.1 The Scope of Costs and Benefits

Tables 4.1 and 4.2 list, in qualitative terms, the costs and benefits associated with the 'with GWRDC investment' scenario and the base case ('without GWRDC investment') scenario.

Table 4.1 The costs of the cluster of wastewater management projects

Scenario	Cost	Bearer of the Cost	Valued in Monetary Terms	Source of Information
Base case (without GWRDC investment) scenario	Project R & D costs (assumed to be nil)	GWRDC	Yes	See text in Section 4.5
	In kind R & D costs (assumed to be nil)	Wineries (primarily large)	No	See text in Section 4.5
With GWRDC investment scenario	Project R&D costs	GWRDC and collaborators	Yes	GWRDC
	In kind R & D costs	Wineries (primarily large)	No	See text in Section 4.3

Table 4.2 The benefits of the cluster of wastewater management projects

Scenario	Benefit	Beneficiary	Valued in Monetary Terms	Source of Information
Base case (without GWRDC investment) scenario	Benefits to individual wineries realised at a slower rate. Benefits to the environment and whole industry unlikely to be realised.	Wineries	As per 'with GWRDC investment' scenario	See text in Section 4.5
With GWRDC investment scenario	Reduced search costs	Wineries (primarily small to medium)	Yes	See text in Section4.4.1
	Cost savings through reduced use of cleaning products	Wineries (primarily small to medium)	Yes	See text in Section4.4.1
	Cost savings through reduced wastewater processing requirements	Wineries (primarily small to medium)	Yes	See text in Section4.4.1
	Cost savings through reuse of wastewater for irrigation	Wineries (primarily small to medium)	Yes	See text in Section4.4.1
	Reduced incidence of odour	Wineries (primarily small to medium)	No	See text in Section 4.4.2

Scenario	Benefit	Beneficiary	Valued in Monetary Terms	Source of Information
	Reduced risk of environmental degradation (soil and aquatic health)	The environment/ wineries	No	See text in Section 4.4.3
	Reduced risk of damage to the reputation of Australian wine industry through environmental damage	Australian wine industry	No	See text in Section 4.4.3
	Increased certainty within the wine industry around 'best practice'	Australian wine industry	No	See text in Section 4.4.3
	Increased awareness of/ motivation to improve wastewater management strategies	Australian wine industry	No	See text in Section 4.4.3

4.2 Consultation

The consultation for this report was conducted in two phases. In the first phase, conversations were held with research scientists and government staff (GWRDC, CSIRO, AWRI and SA Water staff) and members of industry (scientists, operations managers, winery owners and consultants) who had been involved in one or several of the projects. In the second phase the focus for consultation was on representatives from small to medium wineries in the following regions: Margaret River, Swan Valley, Geelong, McLaren Vale, Clare Valley, Barossa Valley and Hunter Valley. Contact details for wineries were obtained from records of workshop attendance, suggestions from other industry contacts and industry searches.

This section of the report details the method, sources of information and assumptions used to estimate the costs and benefits included in the model. For those costs and benefits which were difficult to estimate in monetary terms, some qualitative description is provided. This information was based on consultation with fifteen individuals who had been involved in some capacity with one or more of the projects.

4.2.1 Extent of industry impact

Both phases of consultation strongly suggested that the quantifiable benefits resulting from the project were primarily of benefit to small and medium sized wineries, as the larger wineries tended to optimise their own wastewater management systems through either in-house research or the engagement of consultants for customised system design.

While it was commonly felt that large wineries did receive some benefits from the group of projects, these benefits did not tend to be related to changes in wastewater management practices, and were difficult to quantify. As such, only small to medium wineries (representing approximately 20 per cent of the national crush) were considered in the CBA. Of this 20 per cent, only a small proportion of wineries appear to have implemented changes to wastewater management strategies following

workshop participation. Also, only a small proportion of wineries appear to be aware of the presence of the wastewater management resources created by project GWR 0915.

4.2.2 Potential effects of drought on industry impact

The first phase of consultation suggested that while wastewater management is an ongoing issue for wineries to consider, the need to efficiently use water resources becomes much more pressing when water supplies are short. It seems likely that the presence or absence of drought conditions has a significant effect on the interest of wineries in reducing or reusing their wastewater.

This proposition was supported by the second phase of industry consultation. This consultation revealed that wineries in the Swan Valley (a relatively dry grape growing region in WA) had a much higher rate of water recycling and uptake of wastewater management strategies from the workshop than wineries from other regions who participated in the workshops at a similar time (within the last three months of 2007).

Due to the unpredictable nature of drought events, an average annualised expected uptake term has been included in the analysis. It is based on the expected frequency of drought events in Australia (10 per cent per year[11]) and the expected proportion of small to medium wineries in drought prone areas using GWRDC materials to improve their wastewater management systems (17 per cent per year[12]).

Table 4.3 Assumptions about rates of uptake of wastewater management strategies in small to medium wineries

With GWRDC investment			
	reduction in cleaning products	reduced processing	recycling water
Workshop motivated	2.0%	2.0%	2.0%
Drought motivated	1.7%	1.7%	1.7%
Intrinsic motivation	1.0%	1.0%	1.0%
Without GWRDC investment			
	reduction in cleaning products	reduced processing	recycling water
Workshop motivated	0.0%	0.0%	0.0%
Drought motivated	1.7%	1.7%	1.7%
Intrinsic motivation	1.0%	1.0%	1.0%

Source: EconSearch analysis.

4.3 Costs

Project costs - GWRDC investment

[11] The Australian Bureau of Meteorology defines a **serious** rainfall deficiency as lying in the lowest 10 per cent of historical records for a three month or longer period .http://www.bom.gov.au/climate/drought/livedrought.shtml

[12] This proportion is based on an estimated 85 per cent of wineries in drought areas who will take action to improve waste water management in case of drought, and multiplied by 20 per cent to account for the poor spread of knowledge within industry about the winery waste water management products.

Estimates of annual investment in each of the projects by GWRDC were provided in final financial statements and, where these were unavailable, estimates were provided by Adrian Loschiavo (GWRDC, pers. comm. 09/08/2012.). These data are summarised in Table 4.4.

Table 4.4 Research and development costs for projects in the wastewater management cluster [a]

	GWRDC Investment by project (nominal)				
	CSL 02/03[b]	CSL 05/01[b]	CSL 05/02[b]	SAR 07/01[b]	GWR 0915[c]
2002/03	$97,792	0	0	0	0
2003/04	$114,866	$0	$0	$0	$0
2004/05	$91,853	$0	$0	$0	$0
2005/06	$55,565	$29,948	$193,036	$0	$0
2006/07	$0	$68,353	$677,591	$0	$0
2007/08	$0	$122,957	$444,402	$29,950	$0
2008/09	$0	$128,557	$143,443	$0	$0
2009/10	$0	$48,153	$0	$0	$40,000
2010/11	$0	$0	$0	$0	$131,455
2011/12	$0	$0	$0	$0	$30,000
Total	$262,284	$397,968	$1,458,472	$29,950	$201,455

[a] In nominal dollars and excluding GST. For the purpose of the CBA these values were expressed in 2011 dollars using the Consumer Price Index for Adelaide (ABS 2012a).

[b] Cost estimates for this project taken from final financial statement to GWRDC for this project

[c] Cost estimates for this project taken from GWRDC budget estimates provided by Adrian Loschiavo

Source: Adrian Loschiavo (GWRDC, pers. comm. 09/08/2012), and final financial statements to GWRDC

It was also assumed that ongoing updating and management of the wastewater management resource would require continued investment of $20,000 every 5 years.

Project costs - in-kind contributions

The magnitude of in-kind contributions from industry participants in research and compilation of the best practice material were discussed with representatives from several wineries who had participated in the project cluster. Providing researchers with access to wineries and employees' time were the most common and significant contributions wineries made to the projects. Estimates of time spent assisting researchers varied between wineries. Several representatives remarked that there were intangible benefits for the wineries from associating with and participating in the GWRDC-funded research with research organisations. The general view was that these intangible benefits at least offset the time costs (the in-kind contributions) of participating in the research. As such, neither the in-kind contributions nor the intangible benefits of project participation have been included in the CBA.

Adoption costs

Installing or upgrading wastewater management systems creates a significant cost for a winery. However, industry consultation (phases 1 and 2) suggested that the

extension material is unlikely to alter the timing of an upgrade or introduction of a wastewater management system. Wineries generally wait until their systems are due for upgrade, or replacement before implementing any significant or costly changes to infrastructure. Changes which are taken up more immediately as a result of access to workshops or extension material tend to be low-cost, low-technology options, which can often actually save the wineries money. Consequently, adoption costs have not been quantified and therefore not included in the CBA.

4.4 Benefits

Because winery wastewater management varies significantly between wineries, the benefits of the project are also highly variable between wineries. Factors such as surrounding landscape, local rainfall, size of the winery, length of vintage, types of wine produced, local legislation and the presence of staff motivated to manage wastewater effectively all affect wastewater management, and the scope for wineries to improve their wastewater management practices. Industry consultation identified a few areas of benefit which could, potentially, be relevant to a high proportion of wineries as they involve strategies that could be implemented by almost any winery.

These areas of benefit have been included in the cost benefit analysis, however, the extent of benefits, and whether these benefits are actually realised, will vary significantly between wineries. While extensive consultation was undertaken to ascertain the values described below, there remains a high level of uncertainty around the exact magnitude of the benefits. It is also worth noting that while large wineries have been excluded from the CBA (see section 4.2.1) it is possible that some of the benefits described below would have accrued to some of the larger wineries.

There were also a large number of benefits reported which have not been included in the CBA, as they were difficult to quantify. Some of these benefits accrued primarily to small and medium wineries which had participated in workshops, while some were of benefit to the entire industry. Some qualitative description of these benefits is provided.

4.4.1 Quantifiable benefits

Reduced Search Costs

Industry consultation (phase two) suggested that one of the most significant benefits of attending a workshop, or accessing the extension material, was the time that winery operators were able to save searching for and collating material on wastewater management. The values used to calculate search costs within the cost benefit analysis are outlined in Table 4.5

Table 4.5 Values used to calculate search costs in CBA [a]

Search costs with GWRDC investment	
Days spent searching	3
Price of a day of labour (2011 $)	450
Number of small to medium wineries	310
Proportion of wineries searching 2007/08 to 2009/10+	4.5%
Proportion of wineries searching 2010/11 onwards	2.5%
Search costs without GWRDC investment	
Days spent searching	50
Price of a day of labour (2011 $)	450
Number of small to medium wineries	310
Proportion of wineries searching 2007/08 to 2009/10	2.5%
Proportion of wineries searching 2020/11 onwards	2.5%

[a] Proportion of wineries searching in GWRDC investment case includes workshop attendees.

Source: ABS (2012b), Industry consultation and EconSearch analysis.

Reduced expenditure on cleaning products

One of the most commonly adopted strategies for improving wastewater quality was the recycling of caustic cleaning products. This was a popular strategy for wastewater management because it creates savings for the winery rather than additional costs. An estimate for reduced costs to cleaning products was obtained through industry consultation. This benefit was reasonably easy to quantify, as expenditure on cleaning products is separately itemised and documented in winery accounts.

Reduction in water treatment costs

A variety of easily implemented strategies, such as separating wastewater streams or filtering biological solids out of wastewater prior to introduction into the processing plant, allow better management of wastewater treatment facilities. Because the strategies implemented vary between wineries, it is difficult to describe an individual strategy, or set of strategies, used by all or a significant proportion of wineries. However, it is likely that any uptake of these strategies will improve the operation of the wastewater treatment system.

A conservative estimate for the reduced costs resulting from improved operations was obtained during industry consultation. This estimate included factors such as reduced electricity demand. There is, however, a high level of uncertainty around this parameter, as it is difficult to precisely link costs such as electricity to the waste processing system. It is also difficult to quantify the time and resources saved through reduced incidence of system failure during vintage. Despite these difficulties, estimates of reduced water treatment costs were made using the information supplied by a range of small and medium wineries.

Reduction in irrigation costs

Improved management of wastewater within wineries can in principle make possible the use of wastewater for irrigation of crops. Potentially this can reduce demand for irrigation water within winery/vineyards, or create opportunities to sell water to other irrigators where wineries are not integrated with vineyards. These strategies can be viable alternatives to disposing of treated wastewater onto woodlots or into nearby water systems.

However, there are some psychological barriers to the use of recycled water within wineries, as there is a perceived risk associated with on-site recycled water. Consequently, the uptake of this wastewater management strategy is much lower than the reduction in cleaning products and wastewater treatment costs (Table 4.6). However, it is expected that in times of drought, a combination of higher water prices, and changing public perceptions of wastewater from 'possibly dirty' to 'environmentally friendly' are likely to improve the ability of wineries to reuse or on-sell their treated wastewater.

Table 4.6 Efficiency of uptake of wastewater management strategies relative to 'optimal' case study

Asssumptions about efficacy of waste water mangement strategies relative to case study			
Assumptions with GWRDC investment year one			
	reduction in cleaning products	reduced processing	recycling water
Workshop motivated	40.0%	40.0%	5.0%
Drought motivated	40.0%	40.0%	40.0%
Intrinsic motivation	25.0%	25.0%	5.0%
Assumptions with GWRDC investment year two[a]			
	reduction in cleaning products	reduced processing	recycling water
Workshop motivated	80.0%	80.0%	25.0%
Drought motivated	80.0%	80.0%	80.0%
Intrinsic motivation	75.0%	75.0%	25.0%
Assumptions without GWRDC investment year one			
	reduction in cleaning products	reduced processing	recycling water
Workshop motivated	40.0%	40.0%	0.0%
Drought motivated	20.0%	20.0%	20.0%
Intrinsic motivation	5.0%	5.0%	5.0%
Assumptions without GWRDC investment year two[b]			
	reduction in cleaning products	reduced processing	recycling water
Workshop motivated	0.0%	0.0%	0.0%
Drought motivated	27.7%	27.7%	27.7%
Intrinsic motivation	10.0%	10.0%	7.2%

[a] It was assumed that wineries utilising GWRDC extension material will reach a high level of efficacy by the second year and that this level will be maintained indefinitely. A lower level is assumed for recycling of irrigated water because of cultural/psychological barriers associated with using recycled water. It is assumed that as the price of water rises and water scarcity becomes more of a concern, these barriers will be overcome so efficacy in the drought motivated case is higher.

[b] It is assumed that wineries that do not have access to GWRDC extension materials (i.e. in the base case) will take ten years to reach a high level of efficacy in wastewater management strategies. In the case of drought motivated improvements to wastewater management, it is assumed 20% efficacy will be reached in the first year, with 6.7% being added every year for the subsequent nine years until 80% is reached. In the case where change is intrinsically motivated, final efficacy without GWRDC is 50%, 50% and 25%, for each of the strategies, with efficacy increasing by 5%, 5% and 2.2% each year after the first year, until efficacy is reached.

Source: Industry consultation and EconSearch analysis.

4.4.2 Operating benefits: unquantifiable

Reduced incidence of Odour

During consultation, several wineries commented on the improvement in the odour of their processing plants that resulted from improving their wastewater management

strategies. Having a reduced level or incidence of odour was beneficial to staff morale and to relations with neighbours which, in the words of one operations manager, 'could not be bought'. In the case where income from tourists was important (e.g. cellar door sales) there was also likely to be some direct monetary impact on the winery, although it was not possible to quantify this.

4.4.3 Industry wide benefits

Large wineries process the vast majority of wine grapes in Australia, making up 80 per cent of total tonnes crushed. Industry consultation suggested that most procedural improvements stemming from the research and extension projects would have been taken up by small to medium wineries, as the majority of large wineries were well on top of their wastewater management processes, although some spillover of knowledge or strategies is not unlikely (see sensitivity analysis). Despite the consensus that the majority of benefits from the project accrued to small wineries, representatives of large wineries had a highly positive view of the project. This positive view was due, in part, to a number of industry wide benefits which would be difficult to quantify. These are discussed, in turn, below.

Increased certainty around legislation

Several individuals, from both large wineries, and government organisations commented that the compilation of a best practice standard was of benefit to the industry as a whole. In particular, it was mentioned that due to the many layers of government involved in wastewater management and the disparity in legislation between regions, it was helpful to have a uniform set of guidelines to work from. It is likely that having these guidelines in place will improve the position of the wine industry when negotiating legislation, if national legislation is introduced. It will decrease negotiation and transaction costs and increase the likelihood that legislation introduced will be well suited to meeting environmental needs and be appropriate for the wine industry.

Avoided risks to reputation

The successful development of 'environmentally friendly' production methods and branding has played an important role in the expansion of some brands of Australian wines into international markets (Pugh and Fletcher 2002). The importance of environmental credentials is increasing as consumers place increasing importance on the environmental and social impacts of products they consume. This is particularly important for luxury goods. It was suggested during consultation that in time, establishment of environmental credentials could be a prerequisite for entry into some international markets. This could be likened to the rapid expansion of 'Fair Trade' chocolate products in the UK.

The high profile of 'Brand Australia' in international markets, creates significant benefits for the Australian Wine Industry, but also makes the industry vulnerable to damage to this brand. According to industry consultation, any instances of environmental damage caused by wineries in Australia, however isolated or small, have the potential to do significant damage to 'Brand Australia' if they were embraced by the media. The research and extension undertaken in these projects both minimises the risks of such an occurrence and has the potential to improve the ability of industry to control damage to reputation.

Avoided risks to soil health

One of the key research outcomes of these projects was the finding that winery wastewater often had high salt levels (a result of use of caustic cleaning products with high levels of sodium and other cations). This has implications for salinisation of ground or river water, as well as potential for damage to soil structure through increased sodicity (which causes clay particles to flocculate). Simple measures to control levels of wastewater within wineries were included in the extension programs, such as recycling of caustic cleaning agents. These measures have had some level of uptake as they can lower winery operating costs.

The benefits of reduced risk to soil health, however, have not been quantified as the level of risk depends on many factors including soil type, land use and pre-existing levels of salt, and it was difficult for winery managers to quantify the reduced risk of damage to soil structure. Several winery managers described an improved peace of mind that came from 'doing the right thing' that they associated with greater knowledge of and control over the composition of their wastewater and its impact on soil health.

4.5 The Base Case

Costs

It is unlikely that, in the absence of GWRDC funding, consolidation of knowledge of wastewater management would have occurred on a wide scale. Consultation (phase one) strongly suggested that large wineries were able to conduct their wastewater management efficiently through in-house research and management, or through the engagement of specialised consultants. There are a few examples of local groups working collectively to improve wastewater management and environmental outcomes within regions where the GWRDC materials have not been well promoted, but these are the exception rather than the norm and remain on a local scale.

Benefits

Values for assumptions used in both the 'with GWRDC investment', and the 'without GWRDC investment' cases are detailed in Section 4.3 and 4.4.

It was assumed that search costs for wineries introducing changes to their wastewater management practices would be much higher in the absence of GWRDC investment (Table 4.5).

It was assumed that there would be some interest in improving wastewater management in the absence of drought based motivation, or GWRDC investment (Table 4.) but that these improvements would take longer to be achieved, and would settle at a lower level than with the existence of GWRDC investment (
Table 4.6). These assumptions were made because, while GWRDC did not develop techniques such as recycling of caustic cleaning products or separating waste streams, their research into the long term effects on soil and aquatic health of high organic solids and salts are likely to have increased motivation and facilitated the adoption of such measures.

It was also assumed that drought motivated improvements to wastewater management would occur more slowly in the absence of GWRDC investment but that they would eventually reach the same level of efficacy as in the case with GWRDC investment. It was further assumed that irrigating with recycled wastewater would be a more commonly used strategy in drought conditions, both in the with and without GWRDC investment scenarios (Table 4.6). The time frames used for reaching certain standards were based on industry consultation.

4.6 Results of the Analysis

4.6.1 Key Indicators

The results of the CBA, in terms of returns to GWRDC investment in the project, are provided in Table 4.7. These results are based on the expected values for key variables, as outlined in Section 4.3.

Table 4.7 Returns to investment in the cluster of projects[a]

	Year 0	Year 5	Year 10	Year 15	Year 20	Year 30
NPV ($m)	-$3.0	-$2.0	-$1.1	-$0.4	$0.2	$1.0
IRR						8%
BCR						1.3

[a] In 2011 dollars.

Source: EconSearch analysis.

Based on the assumptions outlined above and relative to the base case, it is apparent that investment in the project in aggregate would generate modest net benefits to the wider community (i.e. NPV of $1.0m over 30 years, IRR of 8 per cent and BCR of 1.3 in Table 4.8). The monetary value of net benefits that could be attributed to other industries, the environment or social impacts (i.e. spillovers) have not been included in the CBA calculations.

Attribution of the results of the analysis to the Australian Government's Rural Research and Development Priorities is outlined in Table 4.8, based on the assumption that 40 per cent of the GWRDC investment in the projects was allocated to the 'Productivity and adding Value' priority, 30 per cent of the GWRDC investment in the projects was allocated to the 'Natural Resource Management' priority and 30 per cent was allocated to the 'Climate variability and climate change' priority.

Table 4.8 Attribution of net present values to Rural Research and Development Priorities Wastewater Management cluster

Rural Research Priority	NPV at Year 30 ($m)[a]	
	Total	GWRDC share
Productivity and adding Value	0.4	0.4
Supply Chain and markets	0	0
Natural Resource Management	0.3	0.3
Climate variability and climate change	0.3	0.3
Biosecurity	0	0

[a] In 2011 dollars.

Source: EconSearch analysis.

Given the highly integrated nature of the projects (outcomes from research and knowledge based projects feed into later extension projects) it is difficult to sensibly

demarcate the costs and benefits from each of the projects. However, given that the decision to invest in extension projects often occurs after research has been conducted (i.e. research costs are 'sunk') there is some merit in considering the returns to investment in the extension projects.

The tables below show returns to investment of the 'Research to Practice' extension workshops, and the 'Communication and Extension' compiled materials. Tables 4.9 to 4.10 highlight how including additional uptake based on annualised expected drought events increases the calculated value of the materials produced by project GWR 0915.

Table 4.9 Returns to investment on (GWR 0915) with drought parameter [a]

	Year 0	Year 5	Year 10	Year 15	Year 20	Year 30
NPV ($m)	$0.0	$0.8	$1.5	$2.1	$2.5	$3.0
IRR						200%
BCR						12.8

[a] In 2011 dollars.

Source: EconSearch analysis.

Table 4.10 Returns to investment on (GWR 0915) without drought parameter [a]

	Year 0	Year 5	Year 10	Year 15	Year 20	Year 30
NPV ($m)	-$0.1	$0.4	$0.8	$1.2	$1.5	$2.0
IRR						91%
BCR						9.0

[a] In 2011 dollars.

Source: EconSearch analysis.

4.6.2 Sensitivity Analysis

The results of the analysis were re-estimated using values for key variables that reflect the uncertainty of those variables. Sensitivity analyses were undertaken for different values of the following variables.

- Investment in research into environmental impacts of winery wastewater occurs in the absence of GWRDC. Use equivalent GWRDC values at 10 years.
- Average time spent searching for wastewater management information without GWRDC investment low and high values of 25 and 75 days respectively due to high uncertainty.
- Proportion of total Australian crush with potential to benefit from projects. Used low and high values of 25 and 35 per cent, respectively.
- Proportion of wineries adopting changes from workshops low and high values of 1 and 3 per cent respectively due to high uncertainty.

- Proportion of wineries accessing website materials to improve wastewater management strategies low and high values of 0.5 and 2 per cent respectively due to high uncertainty.
- Expected annual average frequency of drought in the next thirty years. Used low and high values of one in twenty (5 per cent) and one in seven (14 per cent), respectively[13].
- Potential savings from reduced demand for water treatment ($ per tonne of crush). Used 50 and 150 per cent of expected value ($0.67 per tonne of crush), due to difficulty estimating these values.
- Potential savings from reduced use of cleaning products ($ per tonne of crush). Used low and high values of 1.3 and 2.5 kL/tonne respectively.
- Potential reuse of irrigation water (kL per tonne of crush). Used low and high values of $1.0 and $1.60 per tonne respectively. These values are slightly outside the highest and lowest estimates obtained during industry consultation.
- Average price of irrigation water. Used low and high values of $0.07 and $0.14 respectively.
- Average increase in the price of irrigation water in drought conditions. Used 50 and 150 percent of expected value ($0.61 per tonne of crush), due to high uncertainty about extent of future droughts.

The results of the sensitivity analyses are provided in Table 4.11 and Table 4.12 below. For each sensitivity analysis, values have been calculated by holding all other variables constant at their expected levels.

It was assumed in the model, that research into environmental impacts of winery wastewater would not be likely to be carried out as environmental impacts are either an externality (ecosystems) or a long term problem (soil health). However, it is possible that this work would have eventually been conducted, either by an environmental agency, or by wineries, or both. As such, the costs of project CSL 02/03 were included with a ten year time lag but no benefits were attributed to this as they are unquantifiable (regardless of when the expenditure occurs). The results presented in Table 4.12 show a moderate increase to return on investment, when these research costs are included in the 'without GWRDC investment' scenario.

Table 4.11 Returns to investment, if research into environmental impacts had been conducted with a ten year lag

	Year 0	Year 5	Year 10	Year 15	Year 20	Year 30
NPV ($m)	-$3.0	-$1.5	-$0.6	$0.2	$0.7	$1.6
IRR						10%
BCR						1.5

[a] NPVs are in 2011 dollars and relate to aggregate investment in the project.

Source: EconSearch analysis.

[13] NB variation in this parameter has the same effect on NPV as a proportional variation in the use of extension material by wineries in drought affected areas.

The results of the other sensitivity analyses, presented in Table 4.12 indicate that the estimated NPV is highly sensitive to a number of the variables and assumptions used in the analysis, particularly the expected frequency of drought events, the time spent searching in the absence of GWRDC investment, and the proportion of individuals expected to use the web based materials to improve their wastewater management strategies, who would otherwise attempt to do so in an inefficient way (Table 4.12).

Table 4.12 Sensitivity of net present values to a range of other uncertain variables [a]

	Low	medium	high
Days spent searching in the absence of GWRDC investment			
Assumed value for variable (days)	25	**50**	75
NPV $(m) at year 30	-0.5	**1.0**	2.6
Proportion of wineries for whom extension material will not			
Assumed value for variable (percent)	**80%**	75%	65%
NPV $(m) at year 30	**1.0**	1.4	2.3
Proportion of wineries making changes due to workshops			
Assumed value for variable (percent)	1%	**2%**	3%
NPV $(m) at year 30	0.8	**1.0**	1.3
Proportion of wineries accessing website materials independently			
Assumed value for variable (percent)	0.5%	**1.0%**	1.5%
NPV $(m) at year 30	0.2	**1.0**	1.9
Expected frequency of drought			
Assumed value for variable (expected frequency in years	one in twenty	**one in ten**	one in seven
NPV $(m) at year 30	-0.4	**1.0**	2.3
Potential savings on waste water treatment in small wineries annually($ per tonne of crush)			
Assumed value for variable ($ per tonne of crush)	0.33	**0.67**	1.00
NPV $(m) at year 30	0.9	**1.0**	1.2
Potential savings on cleaning products in small wineries annually ($ per tonne of crush)			
Assumed value for variable ($ per tonne of crush)	1.00	**1.33**	1.60
NPV $(m) at year 30	0.8	**1.0**	1.2
Potential volume of waste water potentially available for irrigation (kL per tonne of crush)			
Assumed value for variable (kL per tonne of crush)	1.3	**2.0725**	2.5
NPV $(m) at year 30	0.9	**1.0**	1.1
Average price of irrigation water non drought ($/kL)			
Assumed value for variable ($ per kL)	0.07	**0.09**	0.14
NPV $(m) at year 30	1.0	**1.0**	1.1
Average price increase of irrigation water due to drought ($/ kL)			
Assumed value for variable ($ per kL)	0.305	**0.61**	0.915
NPV $(m) at year 30	0.8	**1.0**	1.3

[a] NPVs are in 2011 dollars and relate to aggregate investment in the project. For each sensitivity analysis, values have been calculated by holding all other variables constant at their expected levels. Values in bold indicate expected parameter values and expected NPVs.

Source: EconSearch analysis.

The estimated NPV is more sensitive to variation in search costs (expressed as days taken to search) than to variation in any other cost parameter (e.g. savings on wastewater treatment, cleaning products and irrigation water). This is partly because the search costs are larger than the other costs/savings and partly because of the high level of uncertainly about actual search costs.

The high sensitivity of NPV to variation in the drought frequency parameter results from its link to reduced search costs (which are the main benefit in the model), and from the assumption that both the price of irrigation water and the demand for water for irrigation will increase in drought areas. There is much uncertainty about the future likelihood of drought. The low parameter value was chosen to represent 'extreme' drought which is a one in twenty year occurrence, as opposed to moderate drought which is a 1/10 yearly occurrence. The high parameter was chosen arbitrarily, to reflect a possible increase in drying conditions into the future.

Sensitivity analysis was not conducted on the proportion of individuals utilising GWRDC resources in drought conditions, as the effects would be exactly proportion to the expected frequency of drought, i.e. halving the proportion of people in drought affected areas utilising GWRDC based assistance would result in the same NPV as changing the expected frequency of drought from one in ten to one in twenty years.

If large wineries are in fact able to benefit from the extension program in quantifiable ways, then it is likely that the NPV presented is undervalued. Even relatively modest increases in the proportion of Australian crush which can potentially benefit from the extension work, result in significant increases to NPV.

The sensitivity of the model to values relating to use of the website in non-drought scenarios, and the frequency of drought (which could also be interpreted as the proportion of people using extension materials in drought scenarios), suggests that promotion of the resources, in particular in drier areas of the country, will be an important in the successful further leveraging of GWRDC's investment.

5. Summary and Conclusions

Based on the data and assumptions utilised in this analysis it is apparent that there are modest positive returns to GWRDC investment in the projects grouped within the 'wastewater management' project cluster. Whilst much of the knowledge compiled for the extension projects was already in existence within industry, the compilation of the knowledge reduced search costs and accelerated the rate of successful adoption for small wineries, resulting in modest returns to investment (NPV of $1.0m over 30 years in Table 4.7). However, the high level of uncertainty around many of the key parameters in the analysis made quantification of the net benefits of the set of projects difficult.

It is important to note that there are a range of spillover benefits of the research findings and compilation of materials, which are difficult to quantify in monetary terms and have therefore been excluded from the CBA calculations. Many of the unquantifiable benefits of this project were diffuse or accrued to a third party (such as the environment). For example, adoption of the research findings from the project within the cluster could generate net environmental benefits through improved soil quality and through reduced leaching of nutrients (particularly salts) into water supplies and ecosystems. Reduced incidence of odour is also a significant unquantified social benefit likely to stem from uptake of strategies discussed.

Also, the consolidation of materials on 'best practice wastewater management' has whole industry benefits which may benefit wineries that are already implementing advanced winery wastewater management strategies. These benefits include: reduced risk of damage to reputation through environmental mismanagement and improved understanding of environmental management requirements for industry given the various legislative bodies involved in environmental regulation in this area. It was also suggested that the industry's proactive development of standards is likely to have benefits by reducing negotiation and transaction time if a consolidation of environmental management legislation does occur.

Participants in the workshops and winery representatives who had used the website materials were consistent in their positive evaluations of the workshops, and of the materials produced by project GWR 0915. However, industry consultation suggested that overall promotion of the extension materials has been poor. Even among wine makers with a particular interest in wastewater management, awareness of the website and its materials remains low. As such, we would suggest that the GWRDC could further leverage its existing investment by improved promotion of the existing resources.

References

Australian Bureau of Statistics (ABS) 2012a, *Consumer Price Index, Australia,* ABS Cat. No. 6401.0, Canberra.

Australian Bureau of Statistics 2012b and previous issues, *2010-11 Australian Wine and Grape Industry,* ABS Cat. No. 1329.0, Canberra.

ACIL Tasman 2009, *Guidelines for Evaluation,* a report prepared for the Council of Rural Research and Development Corporation Chairs, April.

Chudleigh, P., Simpson, S. and Schofield, N. 2007, *A Methodology for Evaluating Return on Investment from Natural Resource Management Research and Development,* a report prepared for Land and Water Australia, March.

Department of Finance and Administration 2006a, *Introduction to Cost-Benefit Analysis and Alternative Evaluation Methodologies,* Financial Management Reference Material No. 5, January.

Department of Finance and Administration 2006b, *Handbook of Cost-Benefit Analysis,* Financial Management Reference Material No. 6, January.

EconSearch 2008a, *Cost Benefit Analysis of a GWRDC Project Cluster: Vine Physiology - Flowering,* a report prepared for GWRDC, May.

EconSearch 2008b, *Cost Benefit Analysis of a GWRDC Project Cluster: Control of Measurable Grape Characteristics,* a report prepared for GWRDC, August.

EconSearch 2009, *Cost Benefit Analysis of a GWRDC Project Cluster: Vine Physiology - Water,* a report prepared for GWRDC, September.

Kumar A., Saison C., Grocke S., Doan H., COrrell R., Kookana R., 2006 *Impact of Winery Wastewater on ecosystem health- an introductory assessment.* Final report to Grape and Wine Research and Development Corporation

Kumar A., Arienzo M., Quayle W., Christen E., Grocke S., Fattore A., Doan H., Gonzago D., Zandonna R., Kirstin B., Smith L., Correll R., Kookana R., 2009 Developing a Systematic Approach to Winery Wastewater Management. Final report to Grape and Wine Research and Development Corporation.

Kumar A., Correll, R., Grocke S., Kookana R., Young J., Gongzago D., Doan H., 2010 *Winery Wastewater Research to Practice Workshops* Final report to Grape and Wine Research and Development Corporation

Pugh M., Fletcher R., 2002 *'*Green International Marketing' *Australasian Marketing Journal* 10 (3).

Stevens., 2009 *Irrigating with reclaimed water A scoping study to investigate feasibility for the wine industry* Arris Pty Ltd

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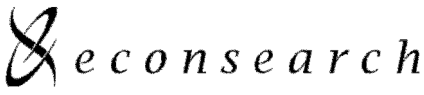
Cost Benefit Analysis of a GWRDC Project Cluster: Yeasts

A report to

Grape and Wine Research and Development Corporation

Prepared by



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ABBREVIATIONS

ABS	Australian Bureau of Statistics
AWRI	Australian Wine Research Institute
BCR	benefit cost ratio
CBA	cost benefit analysis
CRRDCC	Council of Rural Research and Development Corporation Chairs
GWRDC	Grape and Wine Research and Development Corporation
IRR	internal rate of return
NPV	net present value
UA	University of Adelaide

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1. INTRODUCTION

EconSearch Pty Ltd was contracted by GWRDC to undertake cost-benefit analysis (CBA) of three project clusters funded by the GWRDC, namely:

- Yeasts (seven component projects);
- Winery Wastewater Management Accelerated Adoption Model (five component projects); and
- Extension and Adoption (three component projects).

The results of the CBA for each project cluster will be reported separately and those for the "Yeasts" cluster are presented in this report.

This cluster has seven research projects concerned with the properties of yeast and its effect on wine-making in regard to wine quality, alcohol content, style and sensory properties. The projects are:

A) Adelaide University project UA 05/01 *Better wine through novel and better informed application of microbiology*

B) AWRI Stream 1.3: *Microbial modulation of wine composition to increase wine value*. The stream is comprised of the following five projects:

- 1.3.1 *Flavour enhancing yeast: developing wine yeast as a tool to adjust wine flavour and aroma to market specifications*
- 1.3.2 *Generating wine yeast that make reduced levels of ethanol during wine fermentations*
- 1.3.3 *Interspecies hybrid yeast to provide flavour diversity in Australian wines*
- 1.3.4 *Managing fermentation nutrients to meet wine composition and sensory specification*
- 1.3.6 *Nutrition* (started 1 July 2011, a merger of projects 1.3.4 and 2.1.1)
- 2.1.1 *Improving stress tolerance in wine to reduce the incidence of suboptimal fermentations*

As with previous reporting (EconSearch 2007, 2008a, 2008b, 2009, 2010a and 2010b) a separate CBA has been prepared and reported for each component project within the cluster, as well as the results of the component projects presented in aggregate. This approach assists GWRDC with developing a database of individual project evaluations and in fulfilling their reporting requirements to the Council of Rural Research and Development Corporation Chairs (CRRDCC).

The evaluation considers whether the research outcomes have increased wine value and led to increased net benefits to the winemaking industry. With the exception of the University of

Adelaide project, all projects are ongoing and involve an element of both ex-post and ex-ante evaluation.

As well as reporting the results of the CBA for the 'Yeasts' cluster in aggregate, a separate CBA has been prepared and reported for each project within the cluster.

An outline of the key characteristics of the CBA method employed in this study is provided in Section 2 of the report. The results of the CBA for the project cluster in aggregate are presented in Section 3. In Section 4 the scope of costs and benefits, data sources/assumptions and results of the CBA for the University of Adelaide project, including key indicators and sensitivity analysis, is detailed. Explanatory notes for the analyses of the AWRI projects are provided in Section 5. The results of the individual CBAs for the AWRI projects within the cluster are presented in Sections 6 to 11. A summary and some concluding remarks are provided in Section 12 of the report.

2. METHOD OF ANALYSIS

The CBA conducted for this project was undertaken according to the principles and method outlined in:

- the Council for Rural Research and Development Corporation Chairs *Guidelines for Evaluation* (ACIL Tasman 2009);
- the Commonwealth Government's *Introduction to Cost-Benefit Analysis and Alternative Evaluation Methodologies* (Department of Finance and Administration 2006a);
- the Commonwealth Government's *Handbook of Cost-Benefit Analysis* (Department of Finance and Administration 2006b); and
- Land and Water Australia's *Methodology for Evaluating Return on Investment from Natural Resource Management Research and Development* (Chudleigh et al. 2007).

The key characteristics of the CBA method employed in this study include the following.

- The CBA includes a base case or counterfactual scenario, that is, the benchmark against which the 'with GWRDC investment' scenario was compared. The base case was defined as what would have occurred without GWRDC investment in the technology or research.
- The CBA was conducted over a 30 year time period and results were expressed in terms of net benefits, that is, the incremental benefits and costs of the 'with GWRDC investment' scenarios relative to those generated by the base case scenario[1].
- Costs and benefits were specified in real terms (i.e. constant 2012 dollars). Past and future values were converted to present values by applying a discount rate of 5 per cent.
- In order to account for uncertainty, sensitivity analysis was undertaken using a range of values for key variables.
- The evaluation criterion employed in the analysis is net present value (NPV)[2], benefit-cost ratio (BCR)[3] and internal rate of return (IRR)[4].

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1 Where incremental benefits = ('with GWRDC' benefits – 'without GWRDC' benefits) and incremental costs = ('with GWRDC' costs – 'without GWRDC' costs).

2 NPV was defined as discounted net benefits, where net benefits = (incremental benefits – incremental costs).

3 The BCR was defined as (discounted incremental benefits) / (discounted incremental costs).

4 The discount rate at which the NPV of an investment scenario is equal to zero.

- Reporting requirements for the analysis were based on a Microsoft Excel® spreadsheet template developed by ACIL Tasman for the broader Rural Research and Development Corporation evaluation project (Mark Barber, pers. comm.). These requirements include:
    - reporting NPV for 5, 10, 20 and 30 year time horizons;
    - reporting on the returns to total (public and private) investment and returns to GWRDC investment in the technology or research; and
    - allocation of NPVs to the Rural Research Priorities.
- For the CBA, costs and benefits for both the 'with' and 'without' GWRDC investment scenarios have been listed in tabular form and include those that can be readily identified and valued in monetary terms as well as those which cannot be easily valued in monetary terms because of the absence of market signals. The tables provide an indication of the likely distribution of the costs and benefits between stakeholder groups and the source of the information.

3. RESULTS OF THE CBA FOR THE YEASTS CLUSTER

The results of the CBA for the 'Yeasts' project cluster are provided below. In Section 4 the scope of costs and benefits, data sources/assumptions and results of the CBA for the University of Adelaide project, including key indicators and sensitivity analysis, is detailed. Explanatory notes for the analyses of the AWRI projects are provided in Section 5. The results of the individual CBAs for the AWRI projects within the cluster are presented in Sections 6 to 11. A summary and some concluding remarks are provided in Section 12 of the report.

The results of the CBA for the 'Yeasts' project cluster, in terms of returns to aggregate investment, are provided in Table 3–1.

Table 3–1 Returns to aggregate investment in the 'Yeasts' project cluster

	Year 0	Year 5	Year 10	Year 15	Year 20	Year 30
NPV ($m) [a]	147.15	351.45	419.83	443.71	462.41	488.56
IRR	-	-	-	-	-	undefined
BCR	-	-	-	-	-	7.4

[a] In 2012 dollars.

Source: EconSearch analysis.

Based on the assumptions outlined Sections 4 and 5 and relative to the base case, it is apparent that investment in the project cluster in aggregate is likely to generate substantial net benefits to the wider community (i.e. NPV of $488.56m over 30 years and BCR of 7.4 in Table 3–1).

The results of the CBA for the 'Yeasts' project cluster, in terms of GWRDC investment in the projects, are provided in Table 3–2.

Table 3–2 Returns to GWRDC investment in the 'Yeasts' project cluster [a]

	Year 0	Year 5	Year 10	Year 15	Year 20	Year 30
NPV ($m) [b]	73.58	135.38	146.68	149.22	150.72	152.29

[a] The IRR and BCR evaluation criteria for returns to GWRDC investment in the project are not reported as they are not directly comparable with those for aggregate investment in the project (Table 3–1).

[b] In 2012 dollars.

Source: EconSearch analysis.

Assuming that annual net benefits of the research findings are attributable to the GWRDC on the basis of its cumulative investment in the research relative to cumulative costs incurred by all parties, returns to GWRDC investment in the research findings would also be substantially positive (i.e. NPV of $152.29m over 30 years in Table 3–2).

Attribution of the results of the analysis to the Rural Research and Development Priorities is outlined in Table 3–3.

Table 3–3 Attribution of net present values to Rural Research and Development Priorities, 'Yeasts' project cluster

Rural Research Priority	NPV at Year 30 ($m) [a]	
	Total	GWRDC share
Productivity and adding value	488.56	152.29
Supply chain and markets	0.00	0.00
Natural Resource Management	0.00	0.00
Climate Variability and Climate Change	0.00	0.00
Biosecurity	0.00	0.00

[a] In 2012 dollars.

Source: EconSearch analysis.

4. CBA OF PROJECT UA 05/01

4.1 Description of the Project and Research

The CBA described in this section of the report relates to research findings that were developed as a consequence of investment by GWRDC and collaborators in the following project: *Better wine through novel and better informed application of microbiology* (project number UA 05/01).

This project was a successor to UA 01/04 and predecessor to project UA 11/01 undertaken by Professor Jiranek and associates at the University of Adelaide. This project sought to increase knowledge concerning the contribution of microorganisms to fermentation kinetics and wine composition. In addition it sought to define the basis for these contributions and to develop strategies and strains or treatments which could be used to tailor wine-making in a predictable manner (Jiranek 2011).

The outcomes of the project for yeast microbiology were:

- Improved yeast strain FM16-C7 (that was generated in Project 04/01) and adaptively evolved mixed cultures FM16 and FM5 characterised. FM16-C7 performed as well as or better than its parent (commercial wine yeast Rhone 2056) in fermentation time, and also lowered lactic acid slightly in some juices. FM16-C7 performed well for a variety of grape juices. Its phenotype was shown to be stable, which is central for commercialisation. Extensive data on FM16-C7's genetic background, fermentation traits and metabolite profile were generated. Subsequently (as part of Project 11/01), FM16-C7, in wine fermentation trials, has been found to outperform industry standard - EC 1118 - for robust fermentation under high stress white grape juice fermentation conditions.

- The list of genes known to contribute to high nitrogen efficiency expanded. A set of approximately 90 genes relating to high sugar fermentation were identified. This body of work is aimed at three winemaking applications: nitrogen deficient juices, shortened fermentation duration and high sugar fermentations.

- The adaptive evolution technique using a sequential batch fermentation system developed in project 04/01 (described in McBryde et al 2006) was functionally improved through the development of a high-throughput micro fermentation screening system using robotic liquid handling. This improvement in the technique has allowed for the effective generation of multiple improved strains under Project 11/01.

- Thirteen research students (five PhDs (two completed), one Masters and seven Honours students) trained.

- Findings (six peer-reviewed journal articles, four written articles, approximately 30 conference, seminar and workshop presentations) disseminated.

The outcomes of the project for lactic acid bacteria microbiology were:

- Eight strains of lactic acid bacteria were identified which suit wine-making conditions and their glycosidase and esterase (enzyme) activities characterised. Two glucosidases

and four esterases were characterised and tested for useful traits. The glucosidases test result was inconclusive. Three of the four esterases tested had potential positive aroma effects, the fourth esterase had potential negative aroma effects (undesired ethyl acetate levels increased).

- Three PhD students (two have submitted in the project timeframe), one Masters and one Honours student trained.

- Findings (seven peer-reviewed journal articles, three conference papers) disseminated.

The priced benefit of the future (potential) commercialisation and adoption of the yeast FM16-C7 by industry was analysed.

4.2 The Scope of Costs and Benefits

Table 4–1 and Table 4–2 list, in qualitative terms, the benefits and costs associated with the 'with GWRDC investment' scenario and the base case ('without GWRDC investment') scenario.

Table 4–1 Benefits of project UA 05/01

Scenario	Benefit	Beneficiary	Valued in Monetary Terms	Source of Information
Base case (without GWRDC investment) scenario	Identical to the 'with GWRDC' scenario but with a time lag of 2 years	See below	See below	V. Jiranek
With GWRDC investment scenario	Avoided impact of attenuated ferments	Winemakers	Yes	Industry
	Pool of very current research knowledge, expertise and research infrastructure	Winemakers	No	Project report

Table 4–2 Costs of project UA 05/01

Scenario	Cost	Bearer of the Cost	Valued in Monetary Terms	Source of Information
Base case (without GWRDC investment) scenario	Identical to the 'with GWRDC' scenario but with a time lag of 2 years	See below	See below	V. Jiranek
With GWRDC investment scenario	Research, development and extension investment costs	GWRDC, collaborators	Yes	GWRDC
	Industry adoption costs	Winemakers	Yes	Industry

4.3 Data and Assumptions Used for Quantifying Costs and Benefits

This section of the report details the method, sources of information and assumptions used to estimate the costs and benefits listed in Table 4–1 and Table 4–2. For those costs and benefits which were difficult to estimate in monetary terms, some qualitative description is provided.

4.3.1 Costs of the Project

Research, development and extension costs

Estimates of annual investment in the project by GWRDC and research collaborators (cash and in-kind) were provided by GWRDC and validated by the project Principal Investigator (Vladimir Jiranek, pers. comm.). These data are summarised in Table 4–3.

Table 4–3 Research, development and extension costs for project UA 05/01[a]

	Cash and in-kind investment ($)		
	GWRDC	Collaborators	Total
2004/05	273,524	95,035	368,559
2005/06	224,998	98,836	323,834
2006/07	221,378	102,790	324,168
2007/08	210,000	120,744	330,744
2008/09	217,000	128,478	345,478
2009/10	170,000	136,700	306,700
2010/11	44,000	15,773	59,773
2011/12	0	5,000	5,000
2012/13	0	68,333	68,333
2013/14	0	18,333	18,333
2014/15	0	18,333	18,333

[a] In nominal dollars and ex GST. For the purpose of the CBA these values were expressed in 2012 dollars using the Consumer Price Index for Adelaide (ABS 2013).

Source: GWRDC

Industry adoption costs

Industry adoption costs relate to adopting yeast strain FM16-C7 (generated by this project) for use in high stress ferments.

The switching to one of these yeasts is estimated to be relevant to approximately eight per cent of the national crush (based on a survey undertaken with winemakers by the University of Adelaide into the incidence of attenuated ferments). Purchase of yeast is an ongoing cost for small wineries only. Small wineries account for approximately four per cent of national wine production. Large wineries, once they have made the initial purchase of the yeast, maintain their own cultures and the adoption costs are considered negligible. The marginal cost, to

small wineries, of purchasing a specialised strain of yeast in comparison to more traditional yeasts is approximately 1c/L.

Adoption rate

A 25 per cent probability of successfully commercializing yeast strain FM16-C7 has been assumed. FM16-C7 is estimated to have a potential market share of approximately 17 per cent (Jason Amos, pers. comm.). The likely market share, taking into account the probability of successful commercialization, is estimated to be approximately four per cent. There would be a 3-4 year development phase before the yeast would be ready for distribution and the yeast strain was assumed to be commercially available from 2016 onwards and it was assumed to take five years to reach its full market share.

4.3.2 Benefits of the Project

The main impact from attenuated ferments is the downgrading of wine. Large wineries reported a range of figures, but an average settled at approximately 20 per cent of wine value; for smaller wineries this figure was higher at approximately 55 per cent (because it included an element of loss of brand reputation).

There are additional costs, principally labour, in managing attenuated ferments. This was estimated to be approximately $1,000 per event. It was assumed that there is, on average, one event per winery per year.

Large wineries typically handle the attenuated ferment within their winery, adjusting production around to cope with the delays caused by the attenuated ferment. As there is usually spare capacity within or between wineries within the same company, the delay in throughput from an incident is unlikely to have cost implications.

Small wineries, however, do not typically have spare capacity and therefore respond by sending the affected batch away once restarted to a contract winemaker to complete fermentation. This typically costs about $0.66/L.

4.3.3 The Base Case

The base case was developed in discussion with Dr Jiranek.

There are a number of research institutions both in Australia and internationally that have access to the appropriate technology to achieve the results produced by this project. There is an incentive for solutions to be found for avoiding attenuated ferments, because currently – based on this analysis' estimates – the impact of attenuated ferments is approximately $66.5 million per year. Dr Jiranek estimated, that with currently available knowledge and technology (in this rapidly developing area of research) that another institution, working in this field, could achieve these outcomes produced by this project in two years.

It has therefore been assumed that, in the absence of GWRDC investing in this project, other research institutions working in this field would undertake this research, and a time lag of two years has been assumed for the base case.

4.4 Results of the Analysis

4.4.1 Key Indicators

The results of the CBA, in terms of returns to aggregate investment and GWRDC investment in the projects, are provided in Table 4–4 and Table 4–5. These results are based on the expected values for key variables, as outlined in Section 4.3.

Table 4–4 Returns to aggregate investment in project UA 05/01

	Year 0	Year 5	Year 10	Year 15	Year 20	Year 30
NPV ($m) [a]	-0.33	0.00	2.57	2.57	2.57	2.57
IRR	-	-	-	-	-	17%
BCR	-	-	-	-	-	9.9

[a] In 2012 dollars.

Source: EconSearch analysis.

Table 4–5 Returns to GWRDC investment in project UA 05/01 [a]

	Year 0	Year 5	Year 10	Year 15	Year 20	Year 30
NPV ($m) [b]	-0.22	0.02	1.56	1.56	1.56	1.56

[a] The IRR and BCR evaluation criteria for returns to GWRDC investment in the project are not reported as they are not directly comparable with those for aggregate investment in the project (Table 4–4).

[b] In 2012 dollars.

Source: EconSearch analysis.

Based on the assumptions outlined above and relative to the base case, it is apparent that investment in this project in aggregate would generate net benefits to the wider community (i.e. NPV of $2.57m over 30 years and BCR of 9.9 in Table 4–4). Assuming that annual net benefits of the research findings are attributable to the GWRDC on the basis of its cumulative investment in the research relative to cumulative costs incurred by all parties, returns to GWRDC investment in the research findings would also be positive (i.e. NPV of $1.56m over 30 years in Table 4–5).

Attribution of the results of the analysis to the Rural Research and Development Priorities is outlined in Table 4–6, based on the assumption that 100 per cent of the GWRDC investment in the projects was allocated to the 'productivity and adding value' priority (Adrian Loschiavo, pers. comm.).

Table 4–6 Attribution of net present values to Rural Research and Development Priorities, project UA 05/01

Rural Research Priority	NPV at Year 30 ($m) [a]	
	Total	GWRDC share
Productivity and adding value	2.57	1.56
Supply chain and markets	0.00	0.00
Natural Resource Management	0.00	0.00
Climate Variability and Climate Change	0.00	0.00
Biosecurity	0.00	0.00

[a] In 2012 dollars.

Source: EconSearch analysis.

4.4.2 Sensitivity Analysis

The results of the analysis were re-estimated using values for key variables that reflect the uncertainty of those variables. Sensitivity analyses were undertaken for different values of the following variables:

- Discount rate
- Probability of University of Adelaide technology being successful
- Impact on wine value from downgrading
- Base case, time lag.

Discount rate

A key variable is the discount rate. In the analysis a discount rate of five per cent was used and sensitivity analysis on discount rates was undertaken using discount rates of three and seven per cent. The results are presented in Table 4–7.

Table 4–7 Results of sensitivity analysis on the discount rate

Discount Rate	NPV ($m)
3%	3.13
5%	**2.57**
7%	2.06

Source: EconSearch analysis.

The results of the sensitivity analysis show some variation in the NPV, but the result is still positive.

Probability of University of Adelaide technology being successful

The probability of University of Adelaide technology being successful is a predicted figure. A sensitivity analysis was undertaken using a range of 10 per cent to 50 per cent. The results are presented in Table 4–8.

Table 4–8 Results of sensitivity analysis on the probability of UA technology being successful

Probability of UA technology being successful	NPV ($m)
10%	0.86
25%	**2.57**
50%	5.43

Source: EconSearch analysis.

The results of the sensitivity analysis shows significant variation in the NPV, but the result is still positive.

Impact on wine value from downgrading

The impact on wine value from downgrading, estimated at 65c/L was derived from a survey of a small sample of winemakers. There is potential for this figure to be an over- or under-estimate of the typical impact on industry. A sensitivity analysis was undertaken using figures ranging from 33c/L (50 per cent less) to 98c/L (50 per cent more). The results are presented in Table 4–9.

Table 4–9 Results of sensitivity analysis on the impact on wine value from downgrading

Impact on wine value from downgrading ($/L)	NPV ($m)
0.33	1.37
0.65	**2.57**
0.98	3.77

Source: EconSearch analysis.

The results of the sensitivity analysis show significant variation in the NPV, but the result is still positive.

Base case, time lag

The base case was created around the concept that, in the absence of the GWRDC's investment in this project, Australian winemakers would seek alternative forms of assistance to address stressed ferments. In the analysis, a two-year delay in the development of a capability was modelled. The time lag is a predicted figure, and therefore a sensitivity analysis was undertaken with a range of figures from one year to five years. The results are presented in Table 4–10.

Table 4–10 Results of sensitivity analysis on the time lag variable in the base case

Basecase, time lag (yr)	NPV ($m)
1	1.32
2	**2.57**
5	5.99

Source: EconSearch analysis.

The results of the sensitivity analysis show significant variation in the NPV, but the result is still positive.

5. EXPLANATORY NOTES FOR THE AWRI PROJECTS

EconSearch has been concurrently contracted by the AWRI to undertake a CBA of their microbiology capability. The work for the AWRI covers Streams 1.3 *Microbial modulation of wine composition to increase wine value* and 2.1 *Optimising fermentation performance to maximise wine production efficiency* of the 2007-2013 Investment Agreement with the GWRDC. The work for GWRDC covers projects within Stream 1.3 only of the 2007-2013 investment agreement. The analysis of the GWRDC assignment is derived from the data collected and analysed for the AWRI assignment.

During the 2007-2013 investment agreement phase the AWRI reported progress towards achieving targets at the stream level. The AWRI indicated that, as they managed and reported their research at the stream level, they were unable to provide a discussion of outcomes at the project level. The assignment for the AWRI was structured around four main industry impacts:

- Microbial taint reduction
- Flavour enhancement
- Improved ferment productivity
- Development of new products (lower ethanol wine, and New Zealand style sauvignon blanc).

In order to estimate the costs and benefits of Stream 1.3 at the project level for the GWRDC a contribution matrix was developed by AWRI, which is presented in Table 5–1.

The AWRI analysis includes the investment costs of three foundational science projects funded in the 2007-2013 Investment Agreement within Stream 2.1, namely:

- 2.1.3 Wine yeast gene deletion library
- 2.1.4 Wine microorganism culture collection
- 2.1.8 Systems biology.

AWRI has indicated that these foundational science projects were necessary to achieve the outcomes of Streams 1.3 and 2.1. The analysis of the individual projects for the GWRDC is presented with the foundational science project investment costs included. For a description of the assumptions, costs, benefits and sensitivity analysis used and presented in the analysis the reader is referred to the EconSearch (2013) report *Economic Analysis of AWRI Projects and Activities: Microbiology*, commissioned by the AWRI.

Table 5–1 Impact category contribution matrix

Project name	Project number	Impact category contribution to projects			
		Microbial taint	Flavour enhanceme	Ferment productivity	New products
Projects within GWRDC analysis					
Flavour enhancing yeast	AWRI 1.3.1	19%	20%		30%
Generating wine yeast that make reduced levels of ethanol during wine fermentation	AWRI 1.3.2				50%
Interspecies hybrid yeast to provide flavour diversity to Australian wines	AWRI 1.3.3	19%	20%	10%	20%
Managing fermentation nutrients to meet wine composition and sensory specification	AWRI 1.3.4	19%	20%	20%	
Successor to AWRI projects 1.3.4 and 2.1.1	AWRI 1.3.6	15%		10%	
Improving stress-tolerance in wine yeast to reduce the incidence of suboptimal fermentation	AWRI 2.1.1	4%		20%	
Projects outside GWRDC analysis					
Optimising malolactic fermentation and other desirable bacterial inputs in wine fermentation	AWRI 2.1.2	19%	20%	20%	
Development of a world-class microorganism culture collection for the Australian wine industry	AWRI 2.1.4	5%	20%	20%	
Total		100%	100%	100%	100%

Source: AWRI.

6. CBA OF PROJECT AWRI 1.3.1

6.1 Description of the Project and Research

The results of the CBA described in this section of the report relate to research findings that were developed as a consequence of investment by GWRDC and collaborators in the following project: *Flavour enhancing yeast: developing wine yeast as a tool to adjust wine flavour and aroma to market specifications* (project number AWRI 1.3.1).

6.2 Results of the Analysis

6.2.1 Key Indicators

The results of the CBA, in terms of returns to aggregate investment, are provided in Table 6–1.

Table 6–1 Returns to aggregate investment in project AWRI 1.3.1

	Year 0	Year 5	Year 10	Year 15	Year 20	Year 30
NPV ($m) [a]	36.71	74.18	85.65	90.41	94.13	99.33
IRR	-	-	-	-	-	undefined
BCR	-	-	-	-	-	7.5

[a] In 2012 dollars.

Source: EconSearch analysis.

Relative to the base case, it is apparent that investment in this project in aggregate is likely to generate substantial net benefits to the wider community (i.e. NPV of $99.33m over 30 years and BCR of 7.5 in Table 6–1).

The results of the CBA, in terms of returns to GWRDC investment in the projects are provided in Table 6–2.

Table 6–2 Returns to GWRDC investment in project AWRI 1.3.1[a]

	Year 0	Year 5	Year 10	Year 15	Year 20	Year 30
NPV ($m) [b]	17.81	30.09	32.25	32.84	33.20	33.58

[a] The IRR and BCR evaluation criteria for returns to GWRDC investment in the project are not reported as they are not directly comparable with those for aggregate investment in the project (Table 6–1).

[b] In 2012 dollars.

Source: EconSearch analysis.

Assuming that annual net benefits of the research findings are attributable to the GWRDC on the basis of its cumulative investment in the research relative to cumulative costs incurred by all parties, returns to GWRDC investment in the research findings would also be substantially positive (i.e. NPV of $33.58m over 30 years in Table 6–2).

Attribution of the results of the analysis to the Rural Research and Development Priorities is outlined in Table 6–3, based on the assumption that 100 per cent of the GWRDC investment in the projects was allocated to the 'productivity and adding value' priority.

Table 6–3 Attribution of net present values to Rural Research and Development Priorities, project AWRI 1.3.1

Rural Research Priority	NPV at Year 30 ($m) [a]	
	Total	GWRDC share
Productivity and adding value	99.33	33.58
Supply chain and markets	0.00	0.00
Natural resource management	0.00	0.00
Climate variability and climate change	0.00	0.00
Biosecurity	0.00	0.00

[a] In 2012 dollars.

Source: EconSearch analysis.

6.2.2 Sensitivity Analysis

The results of the analysis were re-estimated using values for key variables that reflect the uncertainty of those variables. Sensitivity analyses were undertaken for different values of the following variables:

- Discount rate
- Probability of AWRI technology being successful
- Base case, proportion of costs and benefits.

Discount Rate

A key variable is the discount rate. In the analysis a discount rate of five per cent was used and sensitivity analysis on discount rates was undertaken using discount rates of three and seven per cent. The results are presented in Table 6–4.

Table 6–4 Results of sensitivity analysis on the discount rate

Discount Rate	NPV ($m)
Low value (3%)	107
Expected value (5%)	**99**
High value (7%)	94

Source: EconSearch analysis.

The results of the sensitivity analysis show some variation in the NPV, but the result is still substantially positive.

Probability of AWRI technology being successful

The probability of AWRI technology being successful is a predicted figure. A sensitivity analysis was undertaken using a range of a lower than expected (9 per cent to 25 per cent lower) and a higher than expected (9 per cent to 25 per cent higher) value. The results are presented in Table 6–5.

Table 6–5 Results of sensitivity analysis on the probability of AWRI technology being successful

Probability of AWRI technology being successful	NPV ($m)
Low value	76
Expected value	**99**
High value	122

Source: EconSearch analysis.

The results of the sensitivity analysis show some variation in the NPV, but the result is still substantially positive.

Base case, proportion of costs and benefits

The base case was created around the concept that, in the absence of the GWRDC's investment in these AWRI capabilities, Australian winemakers would seek alternative forms of assistance. In the analysis, a delay in the development of a capability, at a reduced capacity was modelled. The proportion of capacity developed is a predicted figure, and therefore a sensitivity analysis was undertaken with a range of a lower than expected (15 per cent to 20 per cent lower) and a higher than expected (10 per cent to 20 per cent higher) value. The results are presented in Table 6–6.

Table 6–6 Results of sensitivity analysis on the base case, proportion of costs and benefits

Base case, proportion of costs and benefits	NPV ($m)
Low value	131
Expected value	**99**
High value	78

Source: EconSearch analysis.

The results of the sensitivity analysis show significant variation in the NPV, but the result is still substantially positive.

7. CBA OF PROJECT AWRI 1.3.2

7.1 Description of the Project and Research

The results of the CBA described in this section of the report relate to research findings that were developed as a consequence of investment by GWRDC and collaborators in the following project: *Generating wine yeast that make reduced levels of ethanol during wine fermentations* (project number AWRI 1.3.2).

7.2 Results of the Analysis

7.2.1 Key Indicators

The results of the CBA, in terms of returns to aggregate investment, are provided in Table 7–1.

Table 7–1 Returns to aggregate investment in project AWRI 1.3.2

	Year 0	Year 5	Year 10	Year 15	Year 20	Year 30
NPV ($m) [a]	-1.75	-0.47	-0.28	-0.13	-0.02	0.15
IRR	-	-	-	-	-	6%
BCR	-	-	-	-	-	1.0

[a] In 2012 dollars.

Source: EconSearch analysis.

Relative to the base case, it is apparent that investment in this project in aggregate is likely to generate modest net benefits to the wider community (i.e. NPV of $0.15 m over 30 years, IRR of 6 per cent and BCR of 1.0 in Table 7–1).

The results of the CBA, in terms of returns to GWRDC investment in the projects are provided in Table 7–2.

Table 7–2 Returns to GWRDC investment in project AWRI 1.3.2[a]

	Year 0	Year 5	Year 10	Year 15	Year 20	Year 30
NPV ($m) [b]	-0.44	-0.12	-0.07	-0.03	0.00	0.04

[a] The IRR and BCR evaluation criteria for returns to GWRDC investment in the project are not reported as they are not directly comparable with those for aggregate investment in the project (Table 7–1).

[b] In 2012 dollars.

Source: EconSearch analysis.

Assuming that annual net benefits of the research findings are attributable to the GWRDC on the basis of its cumulative investment in the research relative to cumulative costs incurred by all parties, returns to GWRDC investment in the research findings would be positive (i.e. NPV of $0.04m over 30 years in Table 7–2).

Attribution of the results of the analysis to the Rural Research and Development Priorities is outlined in Table 7–3, based on the assumption that 100 per cent of the GWRDC investment in the projects was allocated to the 'productivity and adding value' priority.

Table 7–3 Attribution of net present values to Rural Research and Development Priorities, project AWRI 1.3.2

Rural Research Priority	NPV at Year 30 ($m) [a]	
	Total	GWRDC share
Productivity and adding value	0.15	0.04
Supply chain and markets	0.00	0.00
Natural resource management	0.00	0.00
Climate variability and climate change	0.00	0.00
Biosecurity	0.00	0.00

[a] In 2012 dollars.

Source: EconSearch analysis.

7.2.2 Sensitivity Analysis

The results of the analysis were re-estimated using values for key variables that reflect the uncertainty of those variables. Sensitivity analyses were undertaken for different values of the following variables:

- Discount rate
- Probability of AWRI technology being successful
- Base case, proportion of costs and benefits.

Discount Rate

A key variable is the discount rate. In the analysis a discount rate of five per cent was used and sensitivity analysis on discount rates was undertaken using discount rates of three and seven per cent. The results are presented in Table 7–4.

Table 7–4 Results of sensitivity analysis on the discount rate

Discount Rate	NPV ($m)
Low value (3%)	0.55
Expected value (5%)	**0.15**
High value (7%)	-0.19

Source: EconSearch analysis.

The results of the sensitivity analysis show that changing the discount rate from 5 per cent to 7 per cent altered the NPV from a positive value to a negative value, having a significant effect on the interpretation of the results for this project.

Probability of AWRI technology being successful

The probability of AWRI technology being successful is a predicted figure. A sensitivity analysis was undertaken using a range of a lower than expected (25 per cent lower) and a higher than expected (25 per cent higher) value. The results are presented in Table 7–5.

Table 7–5 Results of sensitivity analysis on the probability of AWRI technology being successful

Probability of AWRI technology being successful	NPV ($m)
Low value	-2.35
Expected value	**0.15**
High value	2.64

Source: EconSearch analysis.

The results of the sensitivity analysis show that changing this variable from the expected value to a low value altered the NPV from a positive value to a negative value, having a significant effect on the interpretation of the results for this project.

Base case, proportion of costs and benefits

The base case was created around the concept that, in the absence of the GWRDC's investment in these AWRI capabilities, Australian winemakers would seek alternative forms of assistance. In the analysis, a delay in the development of a capability, at a reduced capacity was modelled. The proportion of capacity developed is a predicted figure, and therefore a sensitivity analysis was undertaken with a range of a lower than expected (20 per cent lower) and a higher than expected (20 per cent higher) value. The results are presented in Table 7–6.

Table 7–6 Results of sensitivity analysis on the base case, proportion of costs and benefits

Base case, proportion of costs and benefits	NPV ($m)
Low value	0.15
Expected value	**0.15**
High value	0.14

Source: EconSearch analysis.

The results of the sensitivity analysis show very modest variation in the NPV, indicating that this variable has little effect on the results.

8. CBA OF PROJECT AWRI 1.3.3

8.1 Description of the Project and Research

The results of the CBA described in this section of the report relate to research findings that were developed as a consequence of investment by GWRDC and collaborators in the following project: *Interspecies hybrid yeast to provide flavour diversity in Australian wines* (project number AWRI 1.3.3).

8.2 Results of the Analysis

8.2.1 Key Indicators

The results of the CBA, in terms of returns to aggregate investment, are provided in Table 8–1.

Table 8–1 Returns to aggregate investment in project AWRI 1.3.3

	Year 0	Year 5	Year 10	Year 15	Year 20	Year 30
NPV ($m) [a]	41.63	90.28	105.58	111.54	116.21	122.74
IRR	-	-	-	-	-	undefined
BCR	-	-	-	-	-	8.4

[a] In 2012 dollars.

Source: EconSearch analysis.

Relative to the base case, it is apparent that investment in this project in aggregate is likely to generate substantial net benefits to the wider community (i.e. NPV of $122.74m over 30 years and BCR of 8.4 in Table 8–1).

The results of the CBA, in terms of returns to GWRDC investment in the projects are provided in Table 8–2.

Table 8–2 Returns to GWRDC investment in project AWRI 1.3.3[a]

	Year 0	Year 5	Year 10	Year 15	Year 20	Year 30
NPV ($m) [b]	14.38	24.57	26.24	26.65	26.89	27.14

[a] The IRR and BCR evaluation criteria for returns to GWRDC investment in the project are not reported as they are not directly comparable with those for aggregate investment in the project (Table 8–1).

[b] In 2012 dollars.

Source: EconSearch analysis.

Assuming that annual net benefits of the research findings are attributable to the GWRDC on the basis of its cumulative investment in the research relative to cumulative costs incurred by all parties, returns to GWRDC investment in the research findings would also be substantially positive (i.e. NPV of $27.14m over 30 years in Table 8–2).

Attribution of the results of the analysis to the Rural Research and Development Priorities is outlined in Table 8–3, based on the assumption that 100 per cent of the GWRDC investment in the projects was allocated to the 'productivity and adding value' priority.

Table 8–3 Attribution of net present values to Rural Research and Development Priorities, project AWRI 1.3.3

Rural Research Priority	NPV at Year 30 ($m) [a]	
	Total	GWRDC share
Productivity and adding value	122.74	27.14
Supply chain and markets	0.00	0.00
Natural resource management	0.00	0.00
Climate variability and climate change	0.00	0.00
Biosecurity	0.00	0.00

[a] In 2012 dollars.

Source: EconSearch analysis.

8.2.2 Sensitivity Analysis

The results of the analysis were re-estimated using values for key variables that reflect the uncertainty of those variables. Sensitivity analyses were undertaken for different values of the following variables:

- Discount rate
- Probability of AWRI technology being successful
- Base case, proportion of costs and benefits.

Discount Rate

A key variable is the discount rate. In the analysis a discount rate of five per cent was used and sensitivity analysis on discount rates was undertaken using discount rates of three and seven per cent. The results are presented in Table 8–4.

Table 8–4 Results of sensitivity analysis on the discount rate

Discount Rate	NPV ($m)
Low value (3%)	133.66
Expected value (5%)	**122.74**
High value (7%)	115.01

Source: EconSearch analysis.

The results of the sensitivity analysis show some variation in the NPV, but the result is still substantially positive.

Probability of AWRI technology being successful

The probability of AWRI technology being successful is a predicted figure. A sensitivity analysis was undertaken using a range of a lower than expected (9 per cent to 25 per cent lower) and a higher than expected (9 per cent to 25 per cent higher) value. The results are presented in Table 8–5.

Table 8–5 Results of sensitivity analysis on the probability of AWRI technology being successful

Probability of AWRI technology being successful	NPV ($m)
Low value	97.89
Expected value	**122.74**
High value	147.61

Source: EconSearch analysis.

The results of the sensitivity analysis show significant variation in the NPV, but the result is still substantially positive.

Base case, proportion of costs and benefits

The base case was created around the concept that, in the absence of the GWRDC's investment in these AWRI capabilities, Australian winemakers would seek alternative forms of assistance. In the analysis, a delay in the development of a capability, at a reduced capacity was modelled. The proportion of capacity developed is a predicted figure, and therefore a sensitivity analysis was undertaken with a range of a lower than expected (15 per cent to 25 per cent lower) and a higher than expected (10 per cent to 20 per cent higher) value. The results are presented in Table 8–6.

Table 8–6 Results of sensitivity analysis on the base case, proportion of costs and benefits

Base case, proportion of costs & benefits	NPV ($m)
Low value	162.67
Expected value	**122.74**
High value	96.26

Source: EconSearch analysis.

The results of the sensitivity analysis show significant variation in the NPV, but the result is still substantially positive.

9. CBA OF PROJECT AWRI 1.3.4

9.1 Description of the Project and Research

The results of the CBA described in this section of the report relate to research findings that were developed as a consequence of investment by GWRDC and collaborators in the following project: *Managing fermentation nutrients to meet wine composition and sensory specification* (project number AWRI 1.3.4).

9.2 Results of the Analysis

9.2.1 Key Indicators

The results of the CBA, in terms of returns to aggregate investment, are provided in Table 9–1.

Table 9–1 Returns to aggregate investment in project AWRI 1.3.4

	Year 0	Year 5	Year 10	Year 15	Year 20	Year 30
NPV ($m) [a]	44.23	103.21	122.04	128.99	134.43	142.03
IRR	-	-	-	-	-	undefined
BCR	-	-	-	-	-	8.4

[a] In 2012 dollars.

Source: EconSearch analysis.

Relative to the base case, it is apparent that investment in this project in aggregate is likely to generate substantial net benefits to the wider community (i.e. NPV of $142.03m over 30 years and BCR of 8.4 in Table 9–1).

The results of the CBA, in terms of returns to GWRDC investment in the projects are provided in Table 9–2.

Table 9–2 Returns to GWRDC investment in project AWRI 1.3.4[a]

	Year 0	Year 5	Year 10	Year 15	Year 20	Year 30
NPV ($m) [b]	17.55	28.09	29.76	30.14	30.36	30.58

[a] The IRR and BCR evaluation criteria for returns to GWRDC investment in the project are not reported as they are not directly comparable with those for aggregate investment in the project (Table 9–1).

[b] In 2012 dollars.

Source: EconSearch analysis.

Assuming that annual net benefits of the research findings are attributable to the GWRDC on the basis of its cumulative investment in the research relative to cumulative costs incurred by all parties, returns to GWRDC investment in the research findings would also be substantially positive (i.e. NPV of $30.58m over 30 years in Table 9–2).

Attribution of the results of the analysis to the Rural Research and Development Priorities is outlined in Table 9–3, based on the assumption that 100 per cent of the GWRDC investment in the projects was allocated to the 'productivity and adding value' priority.

Table 9–3 Attribution of net present values to Rural Research and Development Priorities, project AWRI 1.3.4

Rural Research Priority	NPV at Year 30 ($m) [a]	
	Total	GWRDC share
Productivity and adding value	142.03	30.58
Supply chain and markets	0.00	0.00
Natural resource management	0.00	0.00
Climate variability and climate change	0.00	0.00
Biosecurity	0.00	0.00

[a] In 2012 dollars.

Source: EconSearch analysis.

9.2.2 Sensitivity Analysis

The results of the analysis were re-estimated using values for key variables that reflect the uncertainty of those variables. Sensitivity analyses were undertaken for different values of the following variables:

- Discount rate
- Probability of AWRI technology being successful
- Base case, proportion of costs and benefits.

Discount Rate

A key variable is the discount rate. In the analysis a discount rate of five per cent was used and sensitivity analysis on discount rates was undertaken using discount rates of three and seven per cent. The results are presented in Table 9–4.

Table 9–4 Results of sensitivity analysis on the discount rate

Discount Rate	NPV ($m)
Low value (3%)	155.36
Expected value (5%)	**142.03**
High value (7%)	132.47

Source: EconSearch analysis.

The results of the sensitivity analysis show some variation in the NPV, but the result is still substantially positive.

Probability of AWRI technology being successful

The probability of AWRI technology being successful is a predicted figure. A sensitivity analysis was undertaken using a range of a lower than expected (9 per cent to 25 per cent lower) and a higher than expected (9 per cent to 25 per cent higher) value. The results are presented in Table 9–5.

Table 9–5 Results of sensitivity analysis on the probability of AWRI technology being successful

Probability of AWRI technology being successful	NPV ($m)
Low value	116.90
Expected value	**142.03**
High value	167.17

Source: EconSearch analysis.

The results of the sensitivity analysis show significant variation in the NPV, but the result is still substantially positive.

Base case, proportion of costs and benefits

The base case was created around the concept that, in the absence of the GWRDC's investment in these AWRI capabilities, Australian winemakers would seek alternative forms of assistance. In the analysis, a delay in the development of a capability, at a reduced capacity was modelled. The proportion of capacity developed is a predicted figure, and therefore a sensitivity analysis was undertaken with a range of a lower than expected (15 per cent lower) and a higher than expected (10 per cent higher) value. The results are presented in Table 9–6.

Table 9–6 Results of sensitivity analysis on the base case, proportion of costs and benefits

Base case, proportion of costs and benefits	NPV ($m)
Low value	188.10
Expected value	**142.03**
High value	111.32

Source: EconSearch analysis.

The results of the sensitivity analysis show significant variation in the NPV, but the result is still substantially positive.

10. CBA OF PROJECT AWRI 1.3.6

10.1 Description of the Project and Research

The results of the CBA described in this section of the report relate to research findings that were developed as a consequence of investment by GWRDC and collaborators in the following project: *Nutrition* (project number AWRI 1.3.6, and successor to projects AWRI 1.3.4 and 2.1.1).

10.2 Results of the Analysis

10.2.1 Key Indicators

The results of the CBA, in terms of returns to aggregate investment, are provided in Table 10–1.

Table 10–1 Returns to aggregate investment in project AWRI 1.3.6

	Year 0	Year 5	Year 10	Year 15	Year 20	Year 30
NPV ($m) [a]	16.41	44.86	55.01	57.83	60.04	63.12
IRR	-	-	-	-	-	undefined
BCR	-	-	-	-	-	7.1

[a] In 2012 dollars.

Source: EconSearch analysis.

Relative to the base case, it is apparent that investment in this project in aggregate is likely to generate substantial net benefits to the wider community (i.e. NPV of $63.12m over 30 years and BCR of 7.1 in Table 10–1).

The results of the CBA, in terms of returns to GWRDC investment in the projects are provided in Table 10–2.

Table 10–2 Returns to GWRDC investment in project AWRI 1.3.6[a]

	Year 0	Year 5	Year 10	Year 15	Year 20	Year 30
NPV ($m) [b]	4.76	11.45	12.73	12.94	13.07	13.20

[a] The IRR and BCR evaluation criteria for returns to GWRDC investment in the project are not reported as they are not directly comparable with those for aggregate investment in the project (Table 10–1).

[b] In 2012 dollars.

Source: EconSearch analysis.

Assuming that annual net benefits of the research findings are attributable to the GWRDC on the basis of its cumulative investment in the research relative to cumulative costs incurred by all parties, returns to GWRDC investment in the research findings would also be substantially positive (i.e. NPV of $13.20m over 30 years in Table 10–2).

Attribution of the results of the analysis to the Rural Research and Development Priorities is outlined in Table 10–3, based on the assumption that 100 per cent of the GWRDC investment in the projects was allocated to the 'productivity and adding value' priority.

Table 10–3 Attribution of net present values to Rural Research and Development Priorities, project AWRI 1.3.6

Rural Research Priority	NPV at Year 30 ($m) [a]	
	Total	GWRDC share
Productivity and adding value	63.12	13.20
Supply chain and markets	0.00	0.00
Natural resource management	0.00	0.00
Climate variability and climate change	0.00	0.00
Biosecurity	0.00	0.00

[a] In 2012 dollars.

Source: EconSearch analysis.

10.2.2 Sensitivity Analysis

The results of the analysis were re-estimated using values for key variables that reflect the uncertainty of those variables. Sensitivity analyses were undertaken for different values of the following variables:

- Discount rate
- Probability of AWRI technology being successful
- Base case, proportion of costs and benefits.

Discount Rate

A key variable is the discount rate. In the analysis a discount rate of five per cent was used and sensitivity analysis on discount rates was undertaken using discount rates of three and seven per cent. The results are presented in Table 10–4.

Table 10–4 Results of sensitivity analysis on the discount rate

Discount Rate	NPV ($m)
Low value (3%)	69.36
Expected value (5%)	**63.12**
High value (7%)	58.48

Source: EconSearch analysis.

The results of the sensitivity analysis show some variation in the NPV, but the result is still substantially positive.

Probability of AWRI technology being successful

The probability of AWRI technology being successful is a predicted figure. A sensitivity analysis was undertaken using a range of a lower than expected (9 per cent lower) and a higher than expected (9 per cent higher) value. The results are presented in Table 10–5.

Table 10–5 Results of sensitivity analysis on the probability of AWRI technology being successful

Probability of AWRI technology being successful	NPV ($m)
Low value	55.31
Expected value	**63.12**
High value	70.95

Source: EconSearch analysis.

The results of the sensitivity analysis show some variation in the NPV, but the result is still substantially positive.

Base case, proportion of costs and benefits

The base case was created around the concept that, in the absence of the GWRDC's investment in these AWRI capabilities, Australian winemakers would seek alternative forms of assistance. In the analysis, a delay in the development of a capability, at a reduced capacity was modelled. The proportion of capacity developed is a predicted figure, and therefore a sensitivity analysis was undertaken with a range of a lower than expected (15 per cent lower) and a higher than expected (10 per cent higher) value. The results are presented in Table 10–6.

Table 10–6 Results of sensitivity analysis on the base case, proportion of costs and benefits

Base case, proportion of costs & benefits	NPV ($m)
Low value	80.47
Expected value	**63.12**
High value	51.56

Source: EconSearch analysis.

The results of the sensitivity analysis show some variation in the NPV, but the result is still substantially positive.

11. CBA OF PROJECT AWRI 2.1.1

11.1 Description of the Project and Research

The results of the CBA described in this section of the report relate to research findings that were developed as a consequence of investment by GWRDC and collaborators in the following project: *Improving stress tolerance in wine to reduce the incidence of suboptimal fermentations* (project number AWRI 2.1.1).

11.2 Results of the Analysis

11.2.1 Key Indicators

The results of the CBA, in terms of returns to aggregate investment, are provided in Table 11–1.

Table 11–1 Returns to aggregate investment in project AWRI 2.1.1

	Year 0	Year 5	Year 10	Year 15	Year 20	Year 30
NPV ($m) [a]	10.26	39.40	49.26	52.51	55.05	58.61
IRR	-	-	-	-	-	295%
BCR	-	-	-	-	-	7.5

[a] In 2012 dollars.

Source: EconSearch analysis.

Relative to the base case, it is apparent that investment in this project in aggregate is likely to generate substantial net benefits to the wider community (i.e. NPV of $58.61m over 30 years and BCR of 7.5 in Table 11–1).

The results of the CBA, in terms of returns to GWRDC investment in the projects are provided in Table 11–2.

Table 11–2 Returns to GWRDC investment in project AWRI 2.1.1[a]

	Year 0	Year 5	Year 10	Year 15	Year 20	Year 30
NPV ($m) [b]	6.09	16.27	18.07	18.42	18.62	18.83

[a] The IRR and BCR evaluation criteria for returns to GWRDC investment in the project are not reported as they are not directly comparable with those for aggregate investment in the project (Table 11–1).

[b] In 2012 dollars.

Source: EconSearch analysis.

Assuming that annual net benefits of the research findings are attributable to the GWRDC on the basis of its cumulative investment in the research relative to cumulative costs incurred by all parties, returns to GWRDC investment in the research findings would also be substantially positive (i.e. NPV of $18.83m over 30 years in Table 11–2).

Attribution of the results of the analysis to the Rural Research and Development Priorities is outlined in Table 11–3, based on the assumption that 100 per cent of the GWRDC investment in the projects was allocated to the 'productivity and adding value' priority.

Table 11–3 Attribution of net present values to Rural Research and Development Priorities, project AWRI 2.1.1

Rural Research Priority	NPV at Year 30 ($m) [a]	
	Total	GWRDC share
Productivity and adding value	58.61	18.83
Supply chain and markets	0.00	0.00
Natural resource management	0.00	0.00
Climate variability and climate change	0.00	0.00
Biosecurity	0.00	0.00

[a] In 2012 dollars.

Source: EconSearch analysis.

11.2.2 Sensitivity Analysis

The results of the analysis were re-estimated using values for key variables that reflect the uncertainty of those variables. Sensitivity analyses were undertaken for different values of the following variables:

- Discount rate
- Probability of AWRI technology being successful
- Base case, proportion of costs and benefits.

Discount Rate

A key variable is the discount rate. In the analysis a discount rate of five per cent was used and sensitivity analysis on discount rates was undertaken using discount rates of three and seven per cent. The results are presented in Table 11–4.

Table 11–4 Results of sensitivity analysis on the discount rate

Discount Rate	NPV ($m)
Low value (3%)	65.54
Expected value (5%)	**58.61**
High value (7%)	53.43

Source: EconSearch analysis.

The results of the sensitivity analysis show some variation in the NPV, but the result is still substantially positive.

Probability of AWRI technology being successful

The probability of AWRI technology being successful is a predicted figure. A sensitivity analysis was undertaken using a range of a lower than expected (9 per cent lower) and a higher than expected (9 per cent higher) value. The results are presented in Table 11–5.

Table 11–5 Results of sensitivity analysis on the probability of AWRI technology being successful

Probability of AWRI technology being successful	NPV ($m)
Low value	51.86
Expected value	**58.61**
High value	65.37

Source: EconSearch analysis.

The results of the sensitivity analysis show some variation in the NPV, but the result is still substantially positive.

Base case, proportion of costs and benefits

The base case was created around the concept that, in the absence of the GWRDC's investment in these AWRI capabilities, Australian winemakers would seek alternative forms of assistance. In the analysis, a delay in the development of a capability, at a reduced capacity was modelled. The proportion of capacity developed is a predicted figure, and therefore a sensitivity analysis was undertaken with a range of a lower than expected (15 per cent lower) and a higher than expected (10 per cent higher) value. The results are presented in Table 11–6.

Table 11–6 Results of sensitivity analysis on the base case, proportion of costs and benefits

Base case, proportion of costs & benefits	NPV ($m)
Low value	78.35
Expected value	**58.61**
High value	45.46

Source: EconSearch analysis.

The results of the sensitivity analysis show significant variation in the NPV, but the result is still substantially positive.

12. SUMMARY AND CONCLUSIONS

Based on the data and assumptions utilised in this analysis it is apparent that there are substantially positive returns to GWRDC and collaborator investment in projects grouped within the 'Yeasts' project cluster. Whilst it was assumed that the research findings would eventually have been developed without GWRDC investment, by bringing forward their development the GWRDC and collaborator investment will generate significant net benefits to the Australian economy (NPV of $488.56m over 30 years in and BCR of 7.4 in Table 12–1). Returns to total investment in individual projects within the cluster range from an NPV of $0.15m for project number AWRI 1.3.2 to $142.03m for project number AWRI 1.3.4 (Table 12–1).

It is important to note that there is a range of spill over benefits of the research findings which are difficult to quantify in monetary terms and have been excluded from the CBA calculations. For example, adoption of the research findings or technology from several of the projects within the cluster could generate net environmental benefits through a reduction in waste from less microbial spoilage of wine. Also, many of the research findings could be used as a basis for further research. In interview, a number of the smaller wineries indicated that access to microbial technology has provided the opportunity to create and sustain brand reputations, which has ensured their business viability and continued presence in rural communities through harsh market conditions. These benefits have not been quantified in this analysis and are therefore not reflected in the results presented in Table 12–1.

Table 12–1 Returns to investment in the 'Yeasts' project cluster and component projects

Project name	Project number	NPV ($m) [a]						BCR
		Year 0	Year 5	Year 10	Year 15	Year 20	Year 30	Year 30
Better wine through novel and better informed application of microbiology	UA 05/01	-0.33	0.00	2.57	2.57	2.57	2.57	9.9
Flavour enhancing yeast	AWRI 1.3.1	36.71	74.18	85.65	90.41	94.13	99.33	7.5
Generating wine yeast that make reduced levels of ethanol during wine fermentation	AWRI 1.3.2	-1.75	-0.47	-0.28	-0.13	-0.02	0.15	1.0
Interspecies hybrid yeast to provide flavour diversity to Australian wines	AWRI 1.3.3	41.63	90.28	105.58	111.54	116.21	122.74	8.4
Managing fermentation nutrients to meet wine composition and sensory specification	AWRI 1.3.4	44.23	103.21	122.04	128.99	134.43	142.03	8.4
Successor to AWRI projects 1.3.4 and 2.1.1	AWRI 1.3.6	16.41	44.86	55.01	57.83	60.04	63.12	7.1
Improving stress-tolerance in wine yeast to reduce the incidence of suboptimal fermentation	AWRI 2.1.1	10.26	39.40	49.26	52.51	55.05	58.61	7.5
Yeasts		147.15	351.45	419.83	443.71	462.41	488.56	7.4

[a] NPVs are in 2012 dollars and relate to aggregate investment in the project.

Source: EconSearch analysis.

REFERENCES

ACIL Tasman 2009, *Guidelines for Evaluation*, a report prepared for the Council of Rural Research and Development Corporation Chairs, April.

Australian Bureau of Statistics (ABS) 2013, *Consumer Price Index*, *Australia*, ABS Cat. No. 6401.0, Canberra.

Chudleigh, P., Simpson, S. and Schofield, N. 2007, *A Methodology for Evaluating Return on Investment from Natural Resource Management Research and Development*, a report prepared for Land and Water Australia, March.

Department of Finance and Administration 2006a, *Introduction to Cost-Benefit Analysis and Alternative Evaluation Methodologies*, Financial Management Reference Material No. 5, January.

Department of Finance and Administration 2006b, *Handbook of Cost-Benefit Analysis*, Financial Management Reference Material No. 6, January.

EconSearch 2007, *Cost Benefit Analysis of a GWRDC Hero Project*, a report prepared for GWRDC, October.

EconSearch 2008a, *Cost Benefit Analysis of a GWRDC Project Cluster: Vine Physiology - Flowering*, a report prepared for GWRDC, May.

EconSearch 2008b, *Cost Benefit Analysis of a GWRDC Project Cluster: Control of Measurable Grape Characteristics*, a report prepared for GWRDC, August.

EconSearch 2009, *Cost Benefit Analysis of a GWRDC Project Cluster: Vine Physiology - Water*, a report prepared for GWRDC, September.

EconSearch 2010a, *Cost Benefit Analysis of a GWRDC Project Cluster: Vine Physiology – Nutrient Management*, a report prepared for GWRDC, April.

EconSearch 2010b, *Cost Benefit Analysis of a GWRDC Project Cluster: Vine Physiology – Other Diseases*, a report prepared for GWRDC, July.

EconSearch 2013, *Economic Analysis of AWRI Projects and Activities: Microbiology*, report prepared for the AWRI, August.

Jiranek V 2011, *Better wine through novel and better informed application of microbiology*, Final Report to the GWRDC, Project Number UA 05/01.

McBryde C, Gardner J, de Barros Lopes M and Jiranek V 2006, Generation of novel wine yeast strains by adaptive evolution, *American Journal of Enology and Viticulture*, 57:4 423-430

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REVIEW
AUGUST 2012

Australian Government
Grape and Wine Research and Development Corporation

gwrdc
GRAPE AND WINE RESEARCH AND DEVELOPMENT CORPORATION

Rootstock breeding and associated R&D in the viticulture and wine industry

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Executive Summary

Rootstocks are widely used around the world and some regions in Australia are planted entirely on rootstocks. This demonstrates that their use is not a barrier to commercial vineyard viability.

Grapevine rootstocks have been an essential component of grape growing for over 130 years as rootstocks can impart desirable characteristics for grapevine growth. This review examined Australian and international literature on rootstocks, focusing on key issues including updates on tolerance to phylloxera and nematodes. Other related issues include the performance of major selection traits associated with salinity, low water supply, potassium uptake, vegetative growth, grape and wine quality and the propagation of grafted vines. National and international researchers were consulted and a cross-section of growers and nursery operators were surveyed on their perceptions about rootstocks.

Rootstocks are widely used around the world and some regions in Australia are planted entirely on rootstocks. This demonstrates that their use is not a barrier to commercial vineyard viability. However, winegrape growers in many other Australian regions only considered rootstocks as useful for pest-related problems and could not justify paying the additional cost for grafted vines. In more recent times attitudes have begun to change, with many growers identifying the advantages of rootstocks for non pest-related issues and being prepared to pay the cost for good quality grafted vines. It takes about one extra year to pay back the additional investment in rootstocks without factoring in potential improvements in yield and quality.

Many within the wine industry believe future plantings will include progressive replanting of existing vineyards, rather than planting new green-field sites. Replanting will be driven by the build-up of nematodes, the removal of under-performing blocks, changes to scion varieties and clones, and generational change through improvements in irrigation, trellises and production techniques.

The knowledge of rootstock traits used to select against has substantially increased in some situations. There has been quite a focus on salinity, to the extent of identifying the uptake mechanisms into the plant and the potential to identify genetic markers for chloride exclusion in breeding programs. Similarly, the potassium uptake mechanism has been well characterised. Rapid screening techniques have been developed for sodium, chloride and potassium. Whilst a number of techniques have been used to determine water use efficiency (WUE), the scion plays a major role in the plant response and rapid screening has yet to be developed. Likewise, drought tolerance involves a number of different mechanisms that contribute to survival, and the relative importance of these has yet to be determined or developed into rapid screening techniques.

This review examines six main components of rootstock use, covering aspects of germplasm, nursery production, selection and management, research and development, breeding and information management.

Germplasm and source blocks. The cornerstone of any vineyard is good quality, disease-free vines. Elite rootstock plantings need to be declared true to type and tested for virus and disease and maintained in a healthy state. Multiplication source blocks should be derived from elite plantings. The cutting material supplied to the nursery industry must be of high health status, true to type and verified through an agreed system of quality assurance. An Australian Grapevine Foundation Planting Scheme has been proposed in the past but has not progressed. A cohesive approach across relevant industry bodies to maintaining and providing elite planting material to the industry is essential.

Nursery industry. This is another important component of rootstock use in Australia, with many of those surveyed indicating they place a lot of faith in this sector for providing high quality planting material and as a source of information when selecting rootstocks. Constraints on the nurseries include the provision of potentially diseased cutting material from source blocks, the need to work

It takes about one extra year to pay back the additional investment in rootstocks without factoring in potential improvements in yield and quality.

with differing quarantine regulations between Australian states, the inability to supply particular variety/rootstock combinations and issues with incompatibility and graftability that add to the cost of grafted vines. Growers are concerned there are no agreed standards for grafted vines and scion/rootstock combinations are often limited to what works best for the nursery.

Selecting and managing rootstocks in the field. Most growers indicated that local experience with rootstocks would be a prime factor in the selection process, although specific information is quite limited in some regions. Many look for rootstocks with more consistent vigour between the variability of seasons, with vigour management linked to an expectation of more consistent fruit quality. Many indicated they could adequately manage rootstocks but there are some exceptional circumstances that prove difficult to manage.

Research and development aspects. Respondents indicated there were enough rootstock varieties available; however, a more thorough evaluation of each variety was required. This is likely to be a short-term view and confined to individual circumstances. Most surveyed growers identified issues with practically all rootstocks, suggesting ongoing research is required to address these issues. Furthermore, some respondents recognised breeding may be necessary to fill particular gaps in rootstock capabilities. The drought during the 2000s has prompted a strong interest in rootstocks with increased WUE and drought tolerance, but there are no clear guidelines for industry on what rootstock to use that will consistently produce a balanced vine across highly variable seasonal climatic conditions.

Breeding and commercialisation of rootstocks. Many respondents took some interest in the CSIRO breeding program, although many noted the lengthy duration of the evaluation and release of rootstocks. New techniques within the breeding program have resulted in the rapid screening of some traits which can be used for assessing current rootstocks and new hybrids. The CSIRO 'Breeding and Strategy Plan' is based around industry consultation in 2002 and review of the plan would be beneficial to ensure a tight focus is held on breeding objectives. Lessons have been learnt from the initial endeavours to commercialise the release of rootstocks that will expedite the process in the future.

Information and knowledge management. Growers believe there is generally plenty of information available, but consider it is not in the best format for them to access and understand. Given the current market cycle of the industry and limited planting of grafted vines, there is not a high demand for information, so putting effort into developing packages of information and disseminating it may not result in increased adoption of rootstocks at this stage. But industry needs to be ready to respond with targeted information when the need arises. Information on rootstocks should be provided at a steady rate through existing channels and consideration given to testing new forms of presentation to meet the needs of those actively seeking information.

Recommendations. Future investment in rootstocks in Australia for evaluation, breeding and commercialisation should be directed towards the following aspects:

1. maintaining rootstock (and scion) source vines as 'high health status' and ensuring that the status is maintained through to the purchaser of the planting material
2. ensuring relevant field evaluation information is available to assist in the selection of rootstocks for vineyard plantings
3. developing rapid screening techniques to select rootstocks with appropriate characteristics and, where gaps in rootstock performance are identified, undertake introductions or targeted breeding to address those gaps.

1. Background

In the past 15 years, the Australian wine industry has experienced exponential growth in export sales followed by a period of reduced sales. During the growth phase, expectations about the potential of the wine industry were high, which resulted in a planting frenzy placing unprecedented demand on planting material, including rootstocks. This has led to excessive planted area, overproduction of grapes, depressed grape prices, low returns to growers and an exodus of growers from the industry. The current economic conditions restrict growers to short-term decision making, and while some may have longer term plans to replant with rootstocks, many are unable to progress with those plans. In addition, climatic conditions have ranged from an extended drought period to the wettest season on record for many wine regions. This has resulted in many growers reconsidering their vineyard management and their vine selection for future plantings. The industry situation is primed for change but economic conditions are restrictive.

Rootstocks are essential in some regions, primarily where soil pests preclude using ungrafted Vitis vinifera vines. Other regions have anticipated that the risk of getting such pests is low and have, at least initially, planted ungrafted vines. Some growers see rootstocks as a risk avoidance strategy and are interested in using rootstocks for a range of abiotic issues, while still ensuring they have pest resistance. Rootstocks were one of the first long-term biological control strategies and remain very effective. Australia has a low adoption of rootstocks compared to around 70% of vineyards worldwide planted on rootstock. Nevertheless, many growers interviewed for this review indicated they were very interested in rootstocks for future plantings, albeit with some degree of uncertainty about when this might happen. The recent drought period has demonstrated that some rootstocks and ungrafted vines did not tolerate the extended dry period and growers continue to seek vines with less variability in growth and yield between seasons.

The Grape and Wine Research and Development Corporation (GWRDC) commissioned a review of research and development (R&D) issues related to grapevine rootstocks and breeding, along with an assessment of industry attitudes to rootstocks according to the Terms of Reference set out in Appendix A. This review considers developments in grapevine rootstocks since the last comprehensive review (May 1994), in consultation with a cross-section of industry representatives and researchers, both domestically and internationally. The aims of the review were to:

- provide a summary of the current use of rootstocks
- identify major gaps in research and development
- evaluate the relevance and significance of the current CSIRO Plant Industry rootstock breeding program
- identify the most effective future investment for GWRDC in relation to breeding, evaluation and commercialisation of rootstocks in Australia.

In South Australia in 2011, 20.8% of the state's vineyards were planted on rootstock (PGIBSA, pers. comm.). The zones with the highest proportions were Lower Murray (43.1%) and Barossa (23.4%). Coonawarra (3.3%), Clare Valley (4.0%), Adelaide Hills (5.0%) and McLaren Vale (9.9%) had relatively low proportions on rootstock.

2. The use of Rootstocks in Australia and historical drivers

Information on the commercial plantings of grafted vines in Australia is quite variable between states. The Phylloxera and Grape Industry Board of South Australia (PGIBSA) conducts an annual survey of South Australian vineyards to identify the area planted on rootstocks. Irregular surveys of rootstock use are undertaken in the Murray Darling region (Victoria and New South Wales) by Sunrise 21. Other Australian wine regions are not routinely surveyed.

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Rootstock cutting sales from vine improvement associations was routinely published but the reporting has been inconsistent in recent years. The downturn in grapevine plantings since the boom period has resulted in some vine improvement associations struggling to survive and maintain rootstock source areas. Total annual rootstock cutting sales through the major vine improvement associations was around 2.1m units in 1989 and 1990. In 1998 and 1999, 6.0m units were produced and this declined to 2.4m units by 2007 and 2008 (Walker and Clingeleffer, 2009). Due to the long lead time, it is difficult for the vine improvement associations to upscale and downscale source blocks in response to such rapid changes in the demand for rootstock cuttings. These cutting sales have been supplemented by commercial nursery grown cuttings, which currently comprise around 50% of all rootstock cuttings grafted.

Over the past 20 years, the mix of rootstock varieties has also changed markedly. During a five year period (1989–1993), May (1994) collated and reported the rootstock cutting sales through Australian Vine Improvement Association (AVIA) members. That data compared with recent information (Table 1) shows substantial changes in the proportions of each rootstock variety sold. In the early 1990s Ramsey, Schwarzmann and 5BB Kober made up nearly 80% of the sales and by the late 2000s, Ramsey and Schwarzmann sales had markedly declined. In more recent years, 101–14, 140 Ruggeri and 1103 Paulsen have become popular and now make up over 70% of the sales. These trends are also reflected in recent industry commentary on rootstock trends (Arbuckle 2011).

Table 1: *Cuttings distributed from vine improvement associations by rootstock variety, as a percentage of the total over two five year periods, comparing 1989–93 and 2007–11.*

Rootstock	1989–1993 [1]	2007–2011 [2]
Ramsey	54.3	15.2
Schwarzmann	17.6	2.3
K51–40	5.4	0
K51–32	2.6	*
5BB Kober/5A Teleki	7.0	2.1
140 Ruggeri	1.6	16.2
101–14	1.2	10.2
Dog Ridge	1.2	1.7
SO4	1.9	*
99 Richter	3.2	*
5C Teleki	1.7	1.4
1103 Paulsen	*	43.0
110 Richter	*	6.6
Other	2.3	1.3
Mean number of cuttings per year	2,269,400	2,689,292

[1] May (1994). [2] Production from MIAVIS not included. * Production <1% included in other.

May (1994) considered the lack of information on vineyard rootstock plantings for forward planning by the industry as regrettable, and that a vineyard registration scheme may help with planning. The Vine Industry Nursery Association (VINA) encompasses the majority of nurseries supplying grafted grapevines but do not provide information on aggregated sales to guide industry planning. VINA members also have their own rootstock source blocks and there does not appear to be coordination between VINA and AVIA to rationalise source areas or respond to different industry dynamics. The decline in vineyard plantings after the boom has challenged the ability of rootstock source block owners to carry rootstock varieties in low demand. May (1994) suggested a single repository for rootstocks, particularly those not currently being utilised commercially. Currently, there is no central repository and various individual state and federal repositories have been removed, down-sized or public access denied. AVIA maintain a relatively small number of rootstock varieties for public access.

The major reasons for using rootstocks described by May (1994) still remain but the focus has changed. Earlier on the industry focused on nematode and phylloxera tolerance and relied on parentage to match the general soil and climate conditions. More recently, following the drought, the focus has changed to increased WUE, drought tolerance and salt tolerance, Furthermore, the surplus in grape production has increased the focus on better grape and wine quality. The main reasons for using rootstocks will continue to change over time in response to conditions prevailing in the industry. In California, a cessation of rootstock R&D contributed to the replanting problems after phylloxera biotype B became wide-spread (Whiting 1993). Australia needs to ensure it maintains a capability to respond to changing industry circumstances.

Earlier on the industry focused on nematode and phylloxera tolerance and relied on parentage to match the general soil and climate conditions. More recently, following the drought, the focus has changed to increased WUE, drought tolerance and salt tolerance, Furthermore, the surplus in grape production has increased the focus on better grape and wine quality.

May (1994, p9) lists a number of reasons why ungrafted vines may be preferred over rootstocks. Many of the reasons are still valid but some issues and perceptions have changed:

- The higher cost of grafted vines compared with ungrafted vines remains. When the cost of grafted vines is amortised over the life of the vineyard, the difference is not significant and many growers are now prepared to pay the higher price for good quality planting material.
- The availability of grafted material was an issue during the planting boom (late 1990s–mid 2000s) but during more measured rates of planting, grafted vines should be accessible. Specific scion/rootstock combinations may not always be readily available and additional lead time would be required.
- The lower cost of training ungrafted vines is valid in some instances (potted vines), but some nurseries are producing more advanced (taller) grafted vines to speed up vine establishment.
- The introduction of systemic diseases through grafting is still a potential problem, although the risk is reduced. Nurseries are more aware of the issues and are attempting to manage their operations more assiduously. When cutting sales are high, the income can cover the cost of virus and disease screening of mother vine blocks, but a reduction in revenue, due to less industry planting, limits the ability to adequately test under-used mother blocks.
- The perceived greater longevity of ungrafted vines is a characteristic that has not been adequately assessed. The wine industry is dynamic, with regular changing of varieties, clones and management systems with an expected vineyard lifespan of 25–30 years. For example, in the Sunraysia district in 1979, the top wine varieties were Sultana, Muscat Gordo Blanco and Grenache. Thirty years later in 2009, the top varieties are Chardonnay, Shiraz and Cabernet Sauvignon.
- In some cases, there is uncertainty about the most suitable rootstock for a given site but, in most situations, a range of rootstocks are available that would be appropriate.
- The undesirable effects of enhanced vine vigour have largely been addressed by a better understanding of managing grafted vines.

Since the May review, phylloxera has continued to spread and more virulent nematodes have been detected—these remain important determinants of rootstock use. In addition, the drought period of the 2000s has focused the industry's attention on drought and salinity tolerant rootstocks.

May (1994) made reference to the desirability of calculating the economics of using rootstocks in non-phylloxera situations. The economics of using rootstocks have not been specifically addressed, but much more agronomic data is available to assess the economics of planting rootstocks in a range of situations. These include saline soils, better WUE, drought tolerance, improved grape quality and vineyard reconstruction. As a guide, substituting grafted vines into the economic analysis of a model vineyard (Dakis et al., 2001), without factoring in any change in yield or quality, delayed the break-even period by one year and reduced profitability by 1%. In eastern Washington State, Folwell et al. (2001) modelled payback time and internal rate of return over 20 years for Chardonnay and Merlot, comparing ungrafted and grafted vineyards with no conferred benefit in yield and quality from grafted vines. They determined the payback period was 0.7 years longer and the modified internal rate of return was 1.3% less with rootstocks for both varieties. Factoring in yield and quality benefits to economic models would demonstrate the profitability of using rootstocks. The impact of a phylloxera infestation on a regional basis has been calculated up to $49.2m per region for South Australia, over 10 years after infestation (PGIBSA 2002).

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Australia is a relatively low user of rootstocks, although a greater proportion of grafted vines are being included in new plantings, with around 40% of recent South Australian plantings grafted vines.

The rootstock varieties chosen for planting change with time, making it difficult for the management of source blocks to meet specific demands. This is compounded by the limited availability or removal of various repositories of elite material. While some of the reasons described by May (1994) for growers aversion to rootstocks remain valid, R&D has mitigated many of the perceived preferences towards ungrafted vines. The current issues relating to rootstock choice are covered in the section below.

3. Factors Affecting Current Rootstock Choice

This section (and the next) provides more recent information than provided by May (1994), but does not attempt to be a complete review of the subject. Some topics covered by May (loc. cit.) are not included here because they are not particularly relevant or minimal further information is available.

3.1 Phylloxera

The continued existence of phylloxera in Australia, and the regular new infestations since 1987, shows that phylloxera susceptibility must be considered in any selection of a rootstock .

Following the discovery of phylloxera in Australia in 1877, rootstocks were introduced in 1900 as the only means to combat its effects and produce viable vineyards, as occurred in Europe and elsewhere. The continued existence of phylloxera in Australia, and the regular new infestations since 1987, shows that phylloxera susceptibility must be considered in any selection of a rootstock . While new infestations have occurred, efforts to upgrade phylloxera management zones have continued in areas where phylloxera is believed to be absent, but has not been checked (Phylloxera Risk Zone [PRZ]). In recent years a large proportion of the PRZ in Victoria, and one area of Queensland, have been inspected and found free of phylloxera and upgraded to Phylloxera Exclusion Zone (PEZ) status. While this process reduces the risk of spread, many growers want to ensure they have phylloxera resistance in any rootstock they choose to plant. The term 'resistance' used here includes 'tolerance' where phylloxera reproduces on the roots but the vine is not debilitated. Interaction between rootstocks and phylloxera is a complex area and a brief overview is given here.

The identification of biotypes (biotypes is used here to cover terminology used elsewhere, such as clone, race or strain—see Granett et al., 2001) were not reported in Australia in the review by May (1994). Since then, the understanding of phylloxera biotypes has increased greatly. The existence of different biotypes in North America was speculated in 1870 (Riley, 1872, cited in Granett et al., 2001), and subsequent observations of phylloxera populations damaging some rootstocks, but not others, confirmed the proposition. The early classification of biotypes used differential feeding and reproductive behaviour (King and Rilling, 1985), but the use of techniques assessing insect DNA has enabled phylloxera to be categorised more accurately. The replanting of ARG1 (also called AXR1), commenced in 1983 in California due to the spread of a more virulent biotype of phylloxera. It was estimated to cost the industry $750–$1,250 million (Sullivan 1996) and demonstrates how costly the emergence of a more virulent biotype of phylloxera can be. In Europe, 5C Teleki has been reported to display root galling from an aggressive phylloxera biotype and, in combination with water stress, vines were seen to be suffering in the field (Walker et al., 1998).

Corrie et al. (1998) demonstrated that phylloxera from different sources grew differently on Schwarzmann rootstock, and they subsequently used DNA typing to establish phylloxera biotypes in Australia, some of which were geographically distinct (Corrie et al., 2001). Additional work described up to 83 biotypes. Given no evidence of sexual reproduction has been found in Australia, it is speculated that these biotypes were either brought into Australia or mutations have occurred (Corrie et al., 2002b). Similar results have been documented in Europe where one report identified 103 biotypes, that sexual reproduction was rare (possibly before the introduction to Europe), and migration rates between populations were low (Vorwerk and Forneck, 2006). Some biotypes in Australia live exclusively on the leaves (e.g. G52, G54), some exclusively on the roots (e.g. G1, G4, G39, G51) and others live on both roots and leaves (e.g. G2, G3, G35, G53, G56) (Corrie and Hoffmann, 2004).

Subsequent work in the field found some phylloxera biotypes were only associated with particular rootstocks (Corrie et al., 2002a; Corrie et al., 2003). These differences have been further explored using assays conducted in the laboratory and glasshouse. For example, a phylloxera biotype sourced from the King Valley (now classified as G4) did not feed and reproduce on Schwarzmann in laboratory assays. Corrie et al. (loc. cit.) suggested growers should select rootstocks resistant to the phylloxera biotype present in their vineyard, in order to reduce the population density of the pest and reduce the likelihood of resistance to the rootstock. However, rootstock selection may also be guided by other required attributes. For example, in areas where biotype G4 is present, Schwarzmann would not be suited to any drought conditions, and a drought tolerant rootstock that supports low populations of G4 would perform better.

'Resistant' rootstocks that show some root galling in laboratory studies rarely show above ground damage in the field, unless the vines are particularly stressed. Excised root and dual culture studies tend to overemphasize susceptibility, and in the field rootstocks are capable of surviving with low populations of phylloxera on the roots (Grzegorczyk and Walker, 1998). Glasshouse and excised root bioassay studies showed G1 could establish on Ramsey (Korosi et al., 2007, 2011), but in the field G1 was not observed on Ramsey rootstock (Trethowan and Powell, 2007). The reasons for the different reactions between field and controlled environment studies have yet to be elucidated.

Biotypes also differ in their ability to reproduce and influence vine growth of Vitis vinifera (Forneck et al., 2001; Herbert et al., 2010), with G1 and G4 appearing more virulent than six other biotypes tested in Australia. Field sampling of rootstock trials revealed different phylloxera biotypes appearing in different seasons on some rootstocks and variation in numbers between seasons (Powell, 2006). Phylloxera may also adapt to monoculture rootstocks, as demonstrated in Germany, where phylloxera sourced from 5C Teleki roots reproduced better on 5C Teleki roots than on Cabernet Sauvignon roots (Ritter et al., 2007).

A rootstock bred in Germany, Börner, has been touted as immune to phylloxera. In Australia, phylloxera have been observed feeding on Börner resulting in a rapid hypersensitive-like response and in situ death of crawlers (Kellow et al., 2000). In excised root assays, Börner was noted to support limited phylloxera survival to adulthood and egg production for the G7 and G30 biotypes, but not G1, G4, G19 or G20 (Korosi et al., 2011). In potted vines in a glasshouse, none of the six phylloxera biotypes used were able to colonise Börner roots. Electrical Penetration Graph (EPG) results showed adult insects displayed feeding activity on Börner roots, whereas first instar insects, commonly used to test phylloxera resistance, did not feed (Kingston and Powell, 2006). The EPG technique can give an indication of feeding responses within about eight hours and is currently underutilised. Börner rootstock has grown and yielded well in three phylloxera infested field sites in Victoria; however, phylloxera has been found feeding on the roots. This is consistent with other experiences in Europe where Börner is not immune to phylloxera as it was originally touted (Kevin Powell, pers. comm.). Two field trials in the Clare Valley and Adelaide Hills indicate that vines grafted to Börner have low vigour and yield compared to those on other standard rootstocks, such as 5C Teleki, 110 Richter and SO4 (PGIBSA 2011). A summary of the provisional resistance ratings based on excised root and potted vine assays is shown in Table 2.

Table 2: *Provisional resistance ratings of rootstocks to phylloxera biotypes (from Powell 2009).*

Rootstock	Phylloxera Biotype					
	G1	G4	G7	G19	G20	G30
V. Vinifera	S/S	S/S	S/S	S/S	S/S	S/S
Ramsey	T/T	T/T	T/T	T/T	T/T	T/T
Schwarzmann	R/R	R/R	T/T	T/T	T/T	T/T
Börner	R/R	R/R	T/R	R/R	R/R	T/R
110 Richter	T/T	T/T	T/R	R/R	R/R	T/R
1103 Paulsen	T/T	T/T	R/nd	T/T	R/nd	R/T
140 Ruggeri	T/T	T/T	R/R	R/R	R/nd	R/R
5BB Kober	R/R	R/R	T/T	T/T	T/T	T/T

S=susceptible, T=tolerant, R=resistant, nd=not determined (first letter=excised root assay/second letter=potted vine assay)

phylloxera resistance ratings of rootstocks depend on the biotype of phylloxera used in the tests. This means resistance results from overseas are unlikely to provide a definitive result for phylloxera populations in Australia and further testing needs to occur with Australian biotypes .

The variation in ratings of resistance among rootstocks summarised by May (1994), may be due to different biotypes of phylloxera being used in the testing. Rootstock management and response to drier soil conditions may also influence phylloxera-rootstock interactions (Kevin Powell pers. comm.). Overseas ratings of rootstock resistance must be used with caution, as rootstocks grown in Australia should be assessed against the common biotypes found locally. Research has determined that in genetic populations derived from V. cinerea x V. vinifera, resistance behaves as a single dominant gene (Zhang et al., 2009, cited in Clingeleffer and Smith, 2011). This could lead to molecular markers for resistance.

In summary, phylloxera resistance ratings of rootstocks depend on the biotype of phylloxera used in the tests. This means resistance results from overseas are unlikely to provide a definitive result for phylloxera populations in Australia and further testing needs to occur with Australian biotypes . It is not clear whether phylloxera feeding and damage on excised roots or potted vines translates to potential problems in the field. Some rootstock/biotype combinations allow phylloxera to reproduce without significant impact on grapevine performance. This is not desirable as it may create increased opportunities for phylloxera to spread or allow the rootstock to succumb to other environmental stress. A better way forward is to consider using rootstocks that are immune, or reduce the population of the particular phylloxera biotype, but still have the desirable agronomic characteristics.

3.2 Nematodes

Nematodes have been found widely dispersed in sandy soils but the distribution of species is variable. Many regions in Australia have sandy soils, and any replanting of vineyards will generally be on nematode resistant rootstock as predatory nematodes build up during the life of a vineyard. Prior to replanting, a soil nematode test is desirable to confirm the presence, species and concentration of nematodes. Rootstocks are currently the only viable answer to nematodes; however, the continuous use of the same rootstock may lead to the development of more aggressive biotypes of nematodes . Chemical and many biological controls often do not effectively disperse in the soil to reduce and sustain low populations. The potential negative impact of chemicals on other soil biota is also an issue. Soil amendments in the form of organic composts and manures (Akhtar and Mahmood, 1996), and glucosinolates from brassica crops (Rahman and Somers, 2005), can stimulate predatory and free-living nematodes and reduce the populations of plant parasitic nematodes.

Rootstocks are currently the only viable answer to nematodes; however, the continuous use of the same rootstock may lead to the development of more aggressive biotypes of nematodes .

Nicol et al. (1999) provided an extensive review of nematodes in Australian viticulture, including information on the resistance, tolerance and susceptibility for a wide range of rootstocks. However, resistance or tolerance ratings for nematode rootstock combinations can be different depending on the source of information (Walker, 2009). The variation may be due to the species of nematode being incorrect, the presence of aggressive strains, rootstock mis-identification, the method of classifying resistance and ambient conditions of the study. The rating process needs to be standardised for Australian conditions. Virulent populations of nematodes are more common in California where a number of previously resistant rootstocks (Ramsey, Harmony, Freedom and 1613C) were damaged by virulent nematodes. A breeding program has now produced rootstocks capable of growing in the presence of those virulent nematodes. Furthermore, DNA typing is available to assist with the identification of nematodes to species level, but cannot identify virulent biotypes.

Some rootstocks allow nematodes to reproduce without vines being debilitated; hence they are classed 'tolerant'. However, this may allow virulent nematodes to build up and ultimately have a detrimental effect on the plant. In Australia, virulent populations of root-knot nematode Meloidogyne incognita, and a population of M. arenaria, have been found to be relatively aggressive to Ramsey rootstock (Walker, 1997, Walker and Cox, 2011a). 1103 Paulsen also supports high populations of aggressive biotypes of M. arenaria and M. javanica, along with a less aggressive population of M. javanica (Walker and Cox, 2011a). The rootstocks RS–2 and RS–9, developed at the University of California Davis, have shown high resistance towards three root-knot nematode populations in Australia, including an aggressive population of M. arenaria (Walker and Cox, 2011b). However, these two rootstocks are susceptible to root lesion nematode and possibly ring and citrus nematode. A nematode 'resistant' rootstock is not necessarily resistant to all species or biotypes of nematode, and there is a need for multiple nematode resistance in rootstocks . Resistance to M. incognita has been proposed to be a single dominant gene, but rootstocks resistant to other species of Meloidogyne may well have different genes or alleles associated with the resistance. Resistance to M. javanica McLaren Vale strain appears to be a single dominant gene (Clingeleffer and Smith, 2011).

Resistance to Dagger nematode (Xiphinema index) is a prime focus of breeding overseas due to its association with the spread of fan leaf virus, which has significant consequences for grapevines. In Australia, X. index is thought to be limited to a small area in north eastern Victoria. This area is located within a Phylloxera Infested Zone (PIZ), which is expected to restrict movement out of the PIZ, although it may spread within the zone. Early rootstocks developed in California for resistance to X. index using Muscadinia rotundifolia x V. vinifera (e.g. O39–16) are not particularly resistant to phylloxera or root-knot nematode. Further work is proceeding to produce better rootstocks. Muscadinia rotundifolia is resistant to a wide range of pests and diseases (Olmo, 1986). However, it is difficult to work within breeding programs and progress developing M. rotundifolia hybrids has been slow.

A nematode 'resistant' rootstock is not necessarily resistant to all species or biotypes of nematode, and there is a need for multiple nematode resistance in rootstocks .

A rapid screening method has been used for screening rootstocks, with a range of nematode races and rootstocks only deemed resistant if no egg masses are observed in the roots (Clingeleffer and Smith, 2011). Vines are classed as tolerant if there is less than one egg mass per gram of dry weight root. Vines with more than one egg mass per gram dry weight of roots are classed susceptible (Table 3). Their studies have shown that 30 of the recognised 69 rootstock varieties in Australia allow reproduction of an aggressive strain of M. javanica in the glasshouse. The more virulent nematodes can only be recognised at this stage by culturing the nematode and inoculating potted plants.

Table 3: *Rootstocks screened with a virulent strain of Meloidogyne javanica from McLaren Vale (selected rootstocks from Clingeleffer and Smith, 2011).*

Resistant	Tolerant	Susceptible
101–14 Mgt	1616 C	1103 Paulsen
140 Ruggeri	'5A Teleki'	1202 C
1613 C	Riparia Gloire	5BB Kober
3306 C	Merbein 6262	Merbein 5489
420 A Mgt	Merbein 5512	SO4
99 Richter		Rupestris du Lot
Dog Ridge		5C Teleki
Fercal		
Freedom		
Harmony		
K51–40		
Ramsey		
Schwarzmann		

Techniques for the rapid screening of rootstocks, using known species and biotypes of nematode, have streamlined the assessment of rootstocks and enabled existing rootstocks to be rapidly assessed. Continued collaboration is required with overseas researchers working on resistance markers to ensure Australia can adopt the markers without duplication of research. There is potential for more aggressive races of nematodes to arise, given experiences in California and Australia's reliance on one predominant rootstock, Ramsey, in sandy soils.

3.3 Incompatibility

Issues associated with perceived incompatibility have not been adequately addressed since the review by May (1994). Nurseries have difficulty with grafting particular combinations of rootstock and scion, and some combinations have failed after one or two years in the field. Incompatibility is believed to be largely associated with the presence of virus or viroids and fungal pathogens. A number of trunk disease-related fungi have been described and isolated from some combinations. The hygiene practices of some nurseries have been questioned (Waite, 2006) and poor sanitation of rootstock and scion material used in grafting can introduce many diseases and viruses into grafted vines (see section 4.6).

In grafting an extensive range of rootstock hybrids, there has been no mention of incompatibilities (Clingeleffer, 2000; Clingeleffer, 2007; Clingeleffer and Smith, 2011). Large differences in the diameter of the rootstock and the scion have been reported but were not associated with any observations of incompatibilities (Clingeleffer and Emmanuelli, 2006). The density of wood above and below the graft union indicated that the rootstock and scion grow at different rates (Clingeleffer and Smith, 2011), but no further use of this relationship was investigated in relation to compatibility.

Graft-scion incompatibility continues to be an issue and understanding needs to be improved. Incompatible combinations can be costly for nurseries and replacing young vines in the field that have declined is expensive. Unfortunately, there is little published definitive information on these issues.

3.4 Soils

May (1994) lamented the lack of attention to soil in Australia when deciding on a suitable rootstock. Since then, an Australian Soil Classification has been produced which combines many of the features of the previously used Northcote system (Maschmedt et al., 2002). This system was used to determine categories of soils for Australian vineyards in 'Viticulture Volume 1—Resources, 2nd Edition' (Maschmedt, 2004). While addressing many of the issues raised by May (1994), the chapter in the textbook is probably not as readily usable as envisaged. There is still room to provide a stand-alone publication of soils for Australian vineyards, which includes information related to rootstock selection.

An attempt to link rootstock trial results with soil descriptions was made in the GWRDC-funded project CRS 95/1. Rootstock trials were predominantly planted on six groups of soils. Other groups of soils, for which there were no rootstock trials, are normally unsuitable for planting (Cass et al., 2002). The trials included a range of sites with low water availability, but no correlation with rootstock performance was attempted. While rootstock performance data was provided by various collaborators, the data was never thoroughly examined for any relationships with soil physical and chemical properties. Perhaps the complexity of the data was too great for the biometric analyses available at the time, but it would certainly be worth investigating the potential for analysing the data set. An initial attempt to relate rootstocks with soil attributes was provided in Whiting (2004), but a more comprehensive guideline should be produced.

"…there is a wealth of useful information still to be extracted from the Australian rootstock trials".

Cass et al. (2002)

3.5 Potassium

The issue of high potassium soils in Australia compared with overseas is described by May (1994), and subsequently reviewed by Mpelasoka et al. (2003). Basically, the uptake of potassium, which is exacerbated by some rootstock/scion combinations, increases the pH of the juice and wine, particularly if skins are included in the ferment. If left untreated, the higher pH can lead to poorer quality wines, so most wineries add tartaric acid to adjust the pH down to an acceptable level. This is an added expense to winemaking, but is not deemed a significant issue due to the range of grape juice pH accepted by wineries. There are relative differences between grape rootstocks in the uptake of potassium and the juice pH (Ruhl, 1990a,b). Potassium uptake and translocation may be influenced by vine vigour and canopy shading, which are characteristics of some rootstocks. Root uptake, xylem loading and translocation are steps where rootstocks can have an influence.

Since high potassium has been identified as a characteristic feature of Australian vineyards, there has been some degree of focus on potassium uptake in breeding and selecting rootstocks. Ungrafted rootlings of various rootstocks were shown to differ in their growth, water use and ability to accumulate potassium (Kodur et al., 2010). A screening technique for rootstock breeding programs has been developed using flood tanks with a high potassium solution and measuring petiole potassium in small ungrafted rootstock vines. There was a good correlation between rootstock petiole potassium and results for juice pH of vines grafted to the same rootstock in the field (Clingeleffer and Smith, 2011).

Improved management of Ramsey rootstock has, to some extent, mitigated the high uptake of potassium and high pH in juice. Where the vine vigour of Ramsey is not appropriately controlled (such as wet seasons and soils with high water availability), problems with high juice pH persist; hence, alternative rootstocks are sought. Three low potassium uptake rootstock hybrids have been released by CSIRO and preliminary results show juice pH is lower, but the results are confounded by earlier harvesting of the hybrids at lower sugar concentrations. Some winemakers would prefer not to process red grapes from rootstocks with high potassium uptake, such as Ramsey and Schwarzmann. The challenge for breeding programs is to address the issue from both the grower (yield) and winemaker (quality) perspectives.

Rapid screening techniques are available to select for lower potassium uptake in rootstocks and several rootstocks have been released by CSIRO with low potassium uptake characteristics.

Overall, excess potassium in the juice is recognised by many winemakers as having a negative impact on wine quality, however, few wineries penalise growers based on potassium levels in grapes. Rapid screening techniques are available to select for lower potassium uptake in rootstocks and several rootstocks have been released by CSIRO with low potassium uptake characteristics.

3.6 Salinity

Salinity is another issue which is largely a feature of Australian soils and irrigation water. Vines are able to take up sodium and chloride and transfer them to the grapes. There are international guidelines on levels of sodium and chloride accepted in wine, which can have implications for the trade of wine. There has been a reasonable amount of work on the role of rootstocks on this issue in GWRDC-supported projects since the review of May (1994). The work has looked at the mechanisms of salt uptake, various glasshouse-based methods of assessing uptake, response to salinity in the field, salinity and wine and the breeding of hybrids.

Some rootstocks, grafted with a range of grapevine cultivars, have significantly less petiole and juice concentrations of sodium and chloride under saline soil conditions, or when irrigated with saline water. Rootstocks that generally perform well under saline conditions include Ramsey, 140 Ruggeri, 1103 Paulsen, Fercal and SO4 (Walker et al., 1997; Walker et al., 2002; Walker at al., 2010; Stevens et al., 2011). The high vigour of some rootstocks assists with the tolerance to salinity (Walker et al., 2002).

In one trial, the ability of some rootstocks to exclude salt from the juice diminished over time at one site but not another (Tregeagle et al., 2006). While 140 Ruggeri and 1103 Paulsen grew and yielded well in a saline site, 1103 Paulsen excluded sodium and chloride less (Richards et al., 2010). Shiraz tends to accumulate more chloride than Chardonnay, irrespective of rootstock (Walker et al., 2010). The grape berry skin is a significant repository of chloride and sodium. This means the fermentation of grapes including skins exacerbates sodium and chloride release into the wine (Gong et al., 2010). Juice chloride and sodium concentrations correlate well with wine values across a range of rootstocks.

The distribution of salt within a grapevine suggests salt exclusion is occurring at the cellular level. Reduced loading of chloride into the xylem in the roots, and reduced root-to-shoot transport, were considered the differences between a chloride excluding (140 Ruggeri) and non-excluding (K51–40) rootstock (Tregeagle et al., 2010). Chloride transporters across cell membranes have been identified and there is potential for genetic markers to be developed and used for screening. The transport of sodium into cells is less well elucidated. Further understanding of the mechanisms of salt exclusion may come from studies of wild Vitis genotypes collected from arid and saline areas in North America. These collections contain many genotypes with lower chloride uptake than Ramsey (Heinitz and Walker, 2011). V. cinerea var. helleri (V. berlandieri) may provide a dominant, single and fixed allele for chloride exclusion and genetic markers will be pursued (Fort and Walker, 2011).

A flood tank process has been developed to rapidly screen rootstocks for the ability to exclude chloride (Clingeleffer and Smith, 2011), although further replication of the method is required. Under these conditions, 140 Ruggeri excluded of chloride well, consistent with field trial results. Whilst 1103 Paulsen was considered a good chloride excluder in short-term field trials, there is doubt about its ability to exclude chloride in long-term studies, and this was matched by high chloride uptake in glasshouse studies.

Significant progress has been made towards identifying rootstocks that exclude salt and are more appropriate for longer term salinity problems. The identification of the cellular mechanisms will assist progress towards markers for salt exclusion. Collaboration with researchers at the University of California on their genetic work would also allow for further progression.

Significant progress has been made towards identifying rootstocks that exclude salt and are more appropriate for longer term salinity problems. The identification of the cellular mechanisms will assist progress towards markers for salt exclusion.

3.7 Chlorosis

While chlorosis is an important consideration overseas, it is much less of a problem in Australia. It primarily occurs on soils with an alkaline subsoil (sandy and loamy calcareous soils) when spring seasonal conditions are cold and wet. Improved methods of irrigation and soil management, along with an extended period of drought, have diminished this problem in recent years. If wet soil conditions in spring become more regular, then chlorosis may become an issue in some locations. The low prevalence of this issue does not justify Australian breeding programs for iron chlorosis tolerant rootstocks. Rather, the Australian sector should rely on work from overseas. Part of the field evaluation process could include planting potential new rootstocks on highly alkaline soils to assess their tolerance to lime chlorosis. Fercal, a specifically bred lime tolerant rootstock, has only had limited assessment in Australia.

3.8 Soil acidity

The general recommendation that acid soils be ameliorated by incorporating lime prior to planting (May 1994) still applies. Some variation in the tolerance to low soil pH exists between rootstocks, although few can tolerate very low soil pH. Gravesac is a rootstock that has been selected for acid soils; however, testing in Australia has been limited. In soil of pH 5.0–5.5 (near Lake Erie, New York State, USA) Gravesac had higher pruning weights, higher petiole potassium and phosphorous, and higher yield and berry weight than ungrafted vines across four scion varieties (Bates, 2008). Developing rootstocks for this issue is low priority.

3.9 Water supply

Much greater attention has been paid to this issue since the review of May (1994). A series of drier-than-average seasons (some substantially so) has fostered a number of trials supplying grapevines with reduced amounts of water and monitoring responses. Plants can respond to drought by either dehydration avoidance or by dehydration tolerance through mechanisms such as:

1. reducing transpiration
2. developing extensive root systems
3. improving water conductivity within the plant
4. increasing solutes within the plant to increase the water potential
5. producing more biomass per unit of water.

The geographic origin of V. vinifera from the Mediterranean and Middle East is likely to confer a reasonable amount of drought tolerance, while many American species, traditionally used in rootstock breeding, are found in wetter areas of northern and eastern North America or along stream beds in their native habitat—thus, they have only adapted to short drought periods.

Water use efficiency (WUE) is mainly driven by characteristics of the scion, although interactions between the scion and the rootstock can have an influence. Following is a general discussion on WUE and drought tolerance in grapevines, and the specific role played by the rootstock in these aspects.

The definition of WUE can vary and it is often erroneously interchanged with drought tolerance. Improved WUE can be achieved by various mechanisms relating to increasing the biomass production (photosynthesis, yield) and/or decreasing the water use (transpiration, irrigation)—the latter mechanism being the most common. High WUE is largely a function of reduced water use rather than a net improvement in plant production. Plant water use is commonly regulated by moderated leaf function, reduced leaf area and short growth duration.

WUE can be expressed on a whole crop basis (the ratio of the amount of carbon gained in the plant to the water application, including plant consumption, drainage, runoff and evaporation), a whole plant basis (the ratio of carbon gained to water used by the plant) or on a yield basis (tonnes of crop per ML water applied) (Flexas et al., 2010). Whole plant WUE can be measured instantaneously, which does not account for environmental conditions over time or integrated over a longer term. WUE depends on many processes, such as plant photosynthesis, respiration, leaf area index, leaf angle, canopy structure, stomatal density, hydraulic conductivity and leaf transpiration (and other factors), which makes genetic selection and manipulation difficult. Efforts to improve WUE may not necessarily improve drought tolerance.

WUE depends on complex interactions between environmental factors and physiological mechanisms. Under water stress conditions, maintaining plant survival or productivity will come at a 'cost', such that high WUE may not be the ideal compromise between drought tolerance and economic return (Schultz and Stoll, 2010). Reducing transpiration improves WUE, but results in reduced photosynthesis and yield. Specific targets for genetic manipulation and selection include stomatal physiology, plant respiration, mesophyll conductance to CO2 and the Rubisco enzyme specificity for CO2 (Flexas et al., 2010). However, these relate specifically to aspects of the scion and not the root system. For rootstocks to have an influence, signals from the roots are required to mediate these processes. Of more relevance to rootstocks is the observation that improved WUE can be associated with abscisic acid synthesis and signalling, as well as modified aquaporins.

Transpiration efficiency, expressed as dry matter/water transpired, is negatively related to carbon-isotope discrimination (a measure of photosynthetic efficiency), thus the latter may be a useful technique to assess WUE (Gibberd et al., 2001). However, transpiration efficiency was only closely related to WUE of vines in the field under certain circumstances (Walker, 2004). The variation in transpiration efficiency between grape varieties was greater than the variation between rootstocks with well watered vines, although under reduced irrigation and salinity, greater differences emerged between rootstocks (Walker, 2004). Smith (2004) also found that the differences in transpiration efficiency between scion genotypes were substantially greater than between rootstocks under non-saline and non-water stressed conditions.

Williams (2010) calculated tonnes of crop per megalitre of applied water as a measure of WUE. Values ranged from 15.8 (at 25% irrigation) to 4.4 (at 125% irrigation), and while the high WUE value looks impressive, it was associated with very low yield. Depending on the relative cost of irrigation water and returns for grapes, it may not be economically viable to pursue a particularly high WUE figure.

Grafted Shiraz vines that underwent water deficit in pots had reduced the root growth of Schwarzmann and reduced the shoot growth of vines grafted onto 110 Richter, 140 Ruggeri and Ramsey (Collins and Edwards, pers. comm.). All rootstocks had reduced stomatal conductance and increased instantaneous WUE. This response was associated with increased xylem sap abscisic acid concentration and decreased root hydraulic conductivity. This suggests that canopy size, yield and root-to-shoot ratios may not be the only factors affecting WUE with rootstocks. Any drought tolerant response is likely to be derived from the rootstock and scion combination, and not the rootstock alone.

Various field trials have studied the responses of grafted vines to water deficit. In a field trial at Urrbrae, South Australia, rootstocks had a significant impact on scion gas exchange, water status, canopy growth and yield (Soar et al., 2006). An inverse relationship between relative xylem sap abscisic acid and relative stomatal conductance was also observed. While abscisic acid may be an indicator for water use physiology, the trial proposed using instantaneous leaf gas exchange and leaf water potential to identify drought tolerant vines. Shiraz grafted on 5C Teleki and Ramsey were the least sensitive to water deficit, thus conferring more drought tolerance. Speirs et al. (2010) also demonstrated that the root system provided most of the signal regulating stomatal conductance and, under water deficit conditions, rootstocks produced a greater concentration of abscisic acid (ABA) than own-rooted Shiraz. Loveys (2004) also showed stomatal conductance was inversely correlated with petiolar abscisic acid concentration across a range of rootstocks, confirming the potential for using ABA to distinguish high and low water use rootstocks under water stress in the field.

rootstocks that are regarded as more consistently conferring drought tolerance include Ramsey, 140 Ruggeri, 110 Richter and 1103 Paulsen; whereas poorer drought tolerance are exhibited by Schwarzmann, 420A, K51–40 and 101–14

Further field trials of various scions grafted to rootstocks have demonstrated differences between the scion/rootstock combinations in WUE, carbon assimilation, transpiration rates, leaf loss, vegetative growth and yield potential (Loveys, 2004; Stevens et al., 2008; Stevens et al., 2010; Sommer et al., 2010; Stevens et al., 2011). However, some responses have been inconsistent between trial sites. McCarthy et al. (1997) demonstrated, in a shallow sandy soil in the Barossa Valley, non-uniform yield reductions occurred between grafted rootstocks and own-rooted Shiraz with and without irrigation. Stevens et al. (2008, 2010) showed, in deep well drained soils, no change in relative performance of grafted rootstocks where irrigation was reduced by 30–35%. The latter result implies there is no drought specific adaptation being demonstrated within the range of water deficits applied. Furthermore, a high yielding scion/rootstock combination in well watered conditions will also yield higher under reduced water supply. Vigorous rootstocks appear to confer advantages where there are prolonged water deficits, through their ability to develop roots deeper in the soil (Stevens et al., 2008).

As a general summary, rootstocks that are regarded as more consistently conferring drought tolerance include Ramsey, 140 Ruggeri, 110 Richter and 1103 Paulsen; whereas poorer drought tolerance are exhibited by Schwarzmann, 420A, K51–40 and 101–14.

Within the breeding program conducted by CSIRO Plant Industries, various drought-related attributes are being studied. Assessing crop water use index has shown one of the new CSIRO rootstocks, Merbein 5489, has a higher WUE than 1103 Paulsen (less water use, lower pruning weight and lower yield) (Walker and Clingeleffer, 2009). Ungrafted rootstocks in a nursery situation have been monitored for leaf loss and decrease in vigour under drought conditions, but the ability to confer drought tolerance to grafted scions is yet to be proven (Clingeleffer et al., 2011b). While the ratio of yield to pruning weight (Ravaz index) has been suggested as a surrogate for crop water use index (yield/water transpired), new CSIRO rootstocks with a high Ravaz index were less robust than standard rootstocks under deficit irrigation (Clingeleffer et al., 2011a).

Drought tolerance of rootstocks is foremost in many grape growers' minds given the many recent seasons of below average rainfall. There is no clear screening method for drought tolerance as there are many ways drought tolerance can be generated, and WUE is not a robust indicator of drought tolerance.

Rooting pattern, either through finer roots with greater surface area for water uptake or deeper roots to access water, may provide additional strategies to cope with drought. However, the root architecture of nursery vines across 310 genotypes did not show a consistent association between an overall root architecture rating and a reduction in pruning weight following withholding of irrigation (Clingeleffer and Smith, 2011). The deeper rooting strategy may not always be possible with impenetrable soil layers and the authors concluded that drought tolerance is a complex trait that will require greater investigation. Clingeleffer and Smith (2011) reported several potential attributes for assessing drought tolerance (pruning weight reduction, rooting angles, root thickness, carbon isotope discrimination) on 310 experimental genotypes, but 'standard' rootstocks of known drought tolerance were not included to verify which attributes could be useful indicators of drought tolerance. The difficulty in determining suitable traits for drought tolerance is illustrated by the inconclusive results from over more than 10 years of research (Clingeleffer, 2007; Clingeleffer and Smith, 2011).

Drought tolerance of rootstocks is foremost in many grape growers' minds given the many recent seasons of below average rainfall. There is no clear screening method for drought tolerance as there are many ways drought tolerance can be generated, and WUE is not a robust indicator of drought tolerance. Field trial results have been mixed with moderate to high water deficits in hot 'irrigated' areas, not producing any differentiation between rootstocks compared with full irrigation. Where water deficits have been high in cooler areas and in heavier soils, rootstocks may react differently, such that some appear more drought tolerant than others. Although ABA production has been suggested as a possible marker for responses to water deficit conditions, it remains to be adopted as a standard method. This topic requires much further development and clarification if the breeding and selection of rootstocks are to provide answers.

4. Rootstock Physiology and Propagation-Related Issues

4.1 Root system

Some research projects on rootstocks have included studies of the root system. Different rooting patterns in a sandy loam soils have been described for rootstocks, with 1103 Paulsen and 140 Ruggeri having relatively more roots in the upper 40cm of soil (around 70%) compared with Ramsey and Dog Ridge (around 60% in upper 40cm) and Freedom (50% in upper 40cm) (Walker and Clingeleffer, 2009). In potted vines and some field trials, grafted Ramsey has a lower root-to-shoot ratio than other combinations, implying Ramsey is more efficient at supplying nutrients and water to the scion (Smith, 2004). Root physiology is an aspect that could benefit from more research and should contribute to improved understanding on WUE and drought tolerance.

4.2 Nutrition

Rootstocks can influence the nutrient levels within the grafted plant; hence, influencing grapevine performance. The leaf nitrate-nitrogen at flowering, and the yield of Shiraz grafted onto Schwarzmann and 5C Teleki rootstocks, increased in the season following a post-harvest application of nitrogen, but there was no such response with Ramsey rootstock (Holzapfel and Treeby, 2007). There were also differences in grape juice assimilable free amino-nitrogen in vines grafted to the rootstocks 5A Teleki and Ramsey. Where nitrogen applications were limited to the post-harvest period, the minimum value of assimilable free amino-nitrogen, regarded as necessary to ferment musts through to dryness, was not achieved. The authors suggested the typical uptake/storage model for grapevines was not applicable to Schwarzmann grafted grapevines. This was due to a difference in their seasonal pattern of uptake from the soil and/or a difference in the mobilisation of nitrogen within the vine. Therefore, nitrogen fertilisation may need to be modified for different rootstocks. Differences in nitrogen uptake led to differences in fermentation rate and anthocyanin concentration in the wine, but no significant differences in wine aroma, palate or wine total score (Treeby et al., 1996; Treeby et al., 2000).

In Australian soils low in phosphorous, more attention could be paid to the uptake of phosphorous and the uptake of nitrogen to reduce the liberation of nitrous oxide—a greenhouse gas emission consideration.

The accumulation of whole plant biomass in Cabernet Sauvignon grafted to five rootstocks was highly responsive to increasing nitrogen supply, but the rootstock effect on biomass was less pronounced than the impact of nitrogen supply (Zerihun and Treeby, 2002). Keller et al. (2001a) noted 5BB Kober had significantly higher glutamine, organic nitrogen and total nitrogen in the xylem sap than five other rootstocks, but with nitrate it was only higher than two other rootstocks. They found no interaction between scion and rootstock in contrast to other reports, but cautioned against extrapolating their results to other situations. Early vine growth relies on stored carbohydrate and it is possible rootstocks can have an influence on that, but studies are limited. In Australian soils low in phosphorous, more attention could be paid to the uptake of phosphorous and the uptake of nitrogen to reduce the liberation of nitrous oxide—a greenhouse gas emission consideration.

Growers have questioned whether nutrient standards developed with own-rooted vines apply to grafted vines. In one instance, Stevens et al. (2011a) reported that the petiole standard for sodium (>0.5%) determined by Robinson (1986) was applicable to Colombard grafted to Ramsey rootstock. Keller et al. (2001b) reported no impact of rootstock on inflorescence or bunch stem necrosis, conditions sometimes associated with nutrient imbalances. Any differences in nutrient uptake between grafted rootstocks appear to be manageable, provided the relevant petiole and juice concentrations are monitored and adjusted accordingly.

4.3 Vegetative and reproductive growth

Rootstocks can influence vine growth, but results are often contradictory depending on the conditions and location of the experiment and the scion variety. Differences are more apparent in infertile soils or where vines are under stress. Biomass partitioning between the root, shoot, trunk and fruit of potted vines can be influenced by rootstock. Higher fruit-to-shoot ratios reduced the ability of some rootstocks to ripen the fruit, based on sugar concentration (Smith, 2004). However, there were no differences in total plant biomass; hence, the main influence of rootstock was on partitioning rather than net production of assimilate. The scion had a larger impact on shoot development in young vines than the rootstock, and root development of rootstocks can be strongly impacted by scion type (Tandonnet et al., 2010). Rootstocks also affect the intensity and duration of shoot growth, leaf area, trunk size, pruning weight, bud fertility, yield and phenology, with many cases of interactions between scions and rootstocks being observed (Tandonnet et al., 2010 and references therein). These results could explain the unexpected responses with some scion/rootstock experiments.

While many trials show that rootstocks can impact on growth and reproductive development, it is also apparent that the scion and management practices may have more effect than the rootstock.

In a humid environment, root restriction (approximately 15L) within vine row cover cropping had more impact on reducing vine size, shoot vigour and elements of canopy density than did rootstock (Hatch et al., 2011). Cabernet Sauvignon grapevines grafted to Riparia Gloire produced less growth than grafted 101–14 and 420A. Shiraz grafted to three rootstocks developed by CSIRO Plant Industries had a lower leaf area index during a wet season, compared with grafted Ramsey and 1103 Paulsen rootstocks (Clingeleffer et al., 2011a). Starch and soluble sugar reserves can be influenced by rootstocks (Smith, 2004). For example, Shiraz grafted to Ramsey had high pruning weights but a low root-to-shoot ratio and low carbohydrate reserves, which may have impacted on growth in a subsequent season. Rootstocks also influenced the reproductive development of grafted Shiraz scion under similar light, temperature and nutritional conditions (Smith, 2004). In potted vines, Ramsey increased the bunch number and inflorescence development, while 140 Ruggeri reduced flower numbers and was the lowest yielding rootstock. Zeatin type cytokinin concentrations were different between rootstocks at budburst, but not at fruit set (Smith, 2004).

While many trials show that rootstocks can impact on growth and reproductive development, it is also apparent that the scion and management practices may have more effect than the rootstock. Therefore, it is difficult to extrapolate grafted vine behaviour from that of the ungrafted rootstock, and in any assessment of rootstock behaviour it is necessary to evaluate grafted vines.

4.4 Budburst and bud fruitfulness

Some differences in budburst of up to 11 days were described by Smith (2004) with potted vines of Shiraz grafted on different rootstocks. Budburst date correlated with total vine weight from the preceding winter in year two of the trial, but not year three. In year two, earlier budburst also correlated with higher concentrations of cytokinin in the plant sap. Ramsey rootstock displayed earlier budburst in the potted vines and was also observed in the field in grafted Shiraz, but not with Chardonnay or Cabernet Sauvignon scions (Krstic and Hannah, 2003). Other issues, such as increased salinity, may have more impact on budburst. Thus, it is difficult to ascribe consistent effects of rootstock on budburst when it can also be markedly influenced by scion variety and season.

Vigorous Sultana grafted to Ramsey rootstock has decreased bud fruitfulness, indirectly associated with shading on buds, compared to lower vigour own-rooted Sultana. Reducing the vigour of grafted Ramsey vines through judicious irrigation, and exposing buds to greater amounts of light through re-trellising, improves bud fruitfulness. It appears bud fruitfulness can be greater influenced by cultural and environmental conditions than with rootstock selection.

It appears bud fruitfulness can be greater influenced by cultural and environmental conditions than with rootstock selection.

4.5 Yield and fruit quality

It is difficult to quantify a direct rootstock effect on yield, due to the multiple contributors to yield. In most cases, increased yield is due to increased growth and the ability to retain more buds per vine (e.g. on Ramsey and Dog Ridge). Where soil pests exist, grafted rootstocks out yield ungrafted V. vinifera vines. Where there is abiotic stress alone, rootstocks do not always yield better than ungrafted vines.

The inclusion of some basic grape maturity data has become more common in rootstock trials (e.g. Whiting, 2003). Grape berry composition measurements (sugar, acid, pH, potassium, sodium, chloride, nitrogen, anthocyanins and phenols) were made in a series of trials by Krstic and Hannah (2003) and integrated into an overall assessment of rootstocks for three wine grape cultivars (Shiraz, Chardonnay and Cabernet Sauvignon). As alternatives to Ramsey, the rootstock 101–14 (induces earlier ripening) was one of the best performers for all three cultivars. 1103 Paulsen was well rated for Shiraz and Chardonnay, 116–60 Lider performed well with Chardonnay, and 5C Teleki and 140 Ruggeri performed well with Cabernet Sauvignon. The use of 101–14 as a rootstock under conditions of limited water availability would need to be carefully considered. Earlier ripening and higher colour were attributed to vines grafted to 101–14 in an un-replicated trial planting, compared with Schwarzmann, 5C Teleki and six clones of own-rooted Pinot Noir (Henschke, 2006).

There has been more emphasis on wine composition and sensory assessment since the review of May (1994). Gawel et al. (2000) reported differences in wine composition and spectral measures when Cabernet Sauvignon grapes on different rootstocks were harvested on the one day (in some years there were differences in total soluble solids concentration at harvest). Ramsey and 110 Richter rootstocks produced wines with colour density and phenolics in the lower range and 5C Teleki and Schwarzmann in the higher range. Aroma and flavour intensity were greater with 5C Teleki, Schwarzmann and ungrafted vines, compared with Ramsey and 110 Richter. Clingeleffer et al. (2011a) showed higher colour density and total phenolics in wines from two CSIRO hybrid rootstocks grafted to Shiraz, compared with wines from Ramsey and 1103 Paulsen.

Botrytis infection of grapes can affect wine quality. Keller et al. (2001b) found no significant differences between rootstocks for bunch rot, although severity was correlated with berries per bunch and berry weight. Whiting (2002) found greater proportions of bunch rot on more vigorous rootstocks such as 161–49 and 5BB Kober, associated with larger bunches and greater vine vigour—creating more favourable conditions for disease within the bunch. Rootstocks can influence yield, but higher yielding rootstocks do not always have a negative impact on wine quality, as long as vegetative and reproductive growth of the vine is balanced.

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4.6 Propagation and disease issues

Healthy vine planting material is fundamental to successful grape growing, but in periods of high demand, some growers compromise by using material of uncertain sanitary condition. The boom in plantings during the late 1990s resulted in significant strain on nurseries to meet demand and has exposed issues about the quality of planting material. There have been cases of the failure of vines to establish, young vine decline and longer term poor performance of vines. In California, 36.3% of bench-grafted and rootling rootstocks did not meet the California Department of Food and Agriculture regulations for No. 1 grade grapevines (Weber et al., 1996; Stamp, 2001). No equivalent standards are applied in Australia, nor have rigorous surveys of planting material been conducted. It has been anecdotally reported that a substantial amount of planting material distributed during the planting boom in Australia would not have met the Californian standard.

Nursery practices involving source block management, hot water treatment, hydration, nursery sanitation and cold storage all contribute to the production of high quality planting material (Waite and Morton, 2007). Steps to improve nursery practices have been outlined (Waite, 2006), including ensuring the nursery industry is involved in industry planning, vine propagation practices are improved, good planting material is valued by industry and research and education is ongoing.

A number of trunk diseases, such as black-foot disease (Cylindrocarpon spp.), Petri disease (Phaeomoniella chlamydospora) and bot canker (Botryosphaeria spp.), have been associated with young vine decline (Gramaje and Armengol, 2011; Weckert, 2011). These diseases block the xylem vessels and vines suffer under periods of high water demand. Water stress of vines significantly increased the number of diseased plants nine months after inoculation with Petri disease and planting out (Ferreira et al., 1999). Young vines can be infected before they reach the field and contamination can occur in the mother vines or during the propagation process (Weckert, 2011). Surveys of scion and rootstock mother blocks have detected the presence of the diseases. In rootstock blocks, the diseases are symptomless and latent until the vine is stressed. Liminana et al. (2009) reported the mean necrotic area (typical of esca) in 16-year-old rootstock trunks ranged from 33% in 1103 Paulsen to 71% in 101–14, sampled over 11 rootstocks. These diseases have been isolated from soil and it is suggested rain or irrigation splash can infect pruning wounds. Trunk-related diseases have become more prevalent in California since the replanting of ARG1, which is more resistant to these fungi, with new phylloxera resistant rootstock (Gubler 2003). In some countries, rootstock source vines are trellised so that their shoots are off the ground to avoid potential contamination.

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Nursery operations, such as soaking cuttings in water, disbudding, grafting, callusing and planting in field nurseries, have been associated with spread of these diseases, although often at levels not considered to be pathogenic (Gramaje and Armengol, 2011; Weckert, 2011). Other issues, such as poor graft unions, lifting and trimming of young vine roots, poor cold storage and poor transport conditions, provide opportunities for these diseases to establish. Some chemicals will reduce inoculum levels but do not entirely kill infected tissue within the cuttings. The feasibility of treating pruning cuts on rootstock source vines to prevent the entry of disease or, if infected, to suppress the fungus (e.g. phosphorous acid has been demonstrated to have some activity) need to be investigated.

Hot water treatment is claimed to lower the inoculum level of trunk diseases, but work specifically on Phaeomoniella chlamydospora and Phaeoacremonium inflatipes infused into V. vinifera cuttings found hot water treatment did not reduce the inoculum (Rooney and Gubler, 2001). The climatic source of cutting material may influence responses and biological control has shown promising results. Experiments investigating susceptibility periods at different pruning times has produced inconsistent results; however, research indicates the potential infection period after pruning is quite long—up to several months. There is variation in susceptibility between rootstock cultivars.

A recent report (Weckert, 2011) demonstrated there is an ongoing issue with diseased planting material during a period of relatively low demand, where the focus should be on producing high quality vines. The issue needs urgent attention to ensure that future vineyards are disease-free and will be viable for the long-term.

In one study with Pa chlamydospora (and other root fungal pathogens), 161–49 Couderc was less susceptible than 110 Richter and 140 Ruggeri (Gramaje and Armengol, 2011). While in another study with Pa chlamydospora, 3309 Couderc, 420A, Rupestris du Lot, 110 Richter, 5C Teleki, Schwarzmann and Ramsey were less susceptible than 99 Richter, Freedom, Riparia Gloire, 140 Ruggeri and 1103 Paulsen (Eskalen et al., 2001).

Research in this area has progressed markedly and general guidelines for producing healthy young grafted vines are available. However, there is a need for ongoing investigations into minimising the impacts from these diseases. A recent report (Weckert, 2011) demonstrated there is an ongoing issue with diseased planting material during a period of relatively low demand, where the focus should be on producing high quality vines. The issue needs urgent attention to ensure that future vineyards are disease-free and will be viable for the long-term.

4.7 Virus issues

Leaf roll virus has been largely eliminated from plantings in Australia, although several hotspots in Western Australia and South Australia were recently reported. In Western Australia, it has been found in clones deemed clean in the eastern states (Habili and Randles, 2011). This result is disappointing given earlier work to produce clean planting material. It indicates some degree of laxness in monitoring and preservation of clean source vines, or the virus is being transmitted in another way. Rugose wood associated viruses are responsible for graft failures and vine decline after planting, where it is believed combinations of virus from the scion and rootstock induce the stem pitting and grooving symptoms (Bonfiglioli et al., 1998). The change from ARG1 to other rootstocks in California exposed substantially more virus issues, as ARG1 was a symptomless carrier of many viruses. Monitoring for virus content needs regular consideration in Australia as rootstock cultivars change with time (NVHSC and GWRDC, 2002). Rapid PCR testing methods are available, and regular testing is required to ensure the germplam and mother blocks of scion and rootstock varieties remain free of virus.

4.8 Germplasm, industry source blocks and provision of rootstock information

Issues related to germplasm collections were addressed at a workshop in 2002 (NVHSC and GWRDC, 2002). The first resolution in the report requested the National Vine Health Steering Committee (NVHSC) (at the time) to establish a Vine Improvement Reference Group to develop standards for certified planting material to the industry. This is still being addressed under the Australian Grapevine Standards Scheme project. The New Zealand Winegrowers body has already developed standards for certified grafted planting material in New Zealand (New Zealand Grapegrowers, 2011). The second resolution was for the NVHSC to facilitate the development of a national nuclear collection of high health status that would be the foundation of state and regional vine improvement schemes. This resource would need to be supported through boom and bust times and GWRDC indicated its funding support at the time if there was broad industry support. Issues between vine improvement groups at the time have precluded the establishment of a national high health facility with support of all groups.

Constable and Drew (2004) produced a comprehensive review of the health parameters and capabilities for vine improvement groups and accredited nurseries, involving extensive consultation across the industry. A number of recommendations were proposed based on an Australian Grapevine Foundation Planting Scheme to ensure planting material of the required health status and provenance was available to meet the grape and vine nursery needs. Many of the recommendations are yet to be implemented.

The Vine Industry Nursery Association (VINA) represents the interests of leading nurseries in the industry, and has an established accreditation scheme where nurseries follow quality assurance protocols established by VINA, which are audited annually

The Vine Industry Nursery Association (VINA) represents the interests of leading nurseries in the industry, and has an established accreditation scheme where nurseries follow quality assurance protocols established by VINA, which are audited annually. This scheme is further being strengthened by the development of the Australian Grapevine Standards Scheme, to improve variety identification protocols and establish an Australian grapevine standard based around sound propagules for industry.

Several major sources of information have been produced since the review of May (1994), including a revised chapter in a major textbook (Whiting, 2004); a revised publication on rootstock use in South Australia (Dry 2007); the Yalumba Nursery website (www.yalumbanursery.com) and several project reports relating to rootstocks on the GWRDC website (www.gwrdc.com.au). Another example of information sharing is the review of rootstock performance by the Alpine Valleys region in Victoria some 10–15 years after they first started using rootstocks (Wigg, 2006)—it is suggested this exercise could be conducted in other regions.

5. International Situation

The current situation with rootstock breeding, evaluation and commercialisation in a cross-section of other countries was reviewed and a summary is presented here. Most of the rootstocks in use today were developed in the late 1800s and early 1900s by European breeders in response to phylloxera spreading throughout Europe. Much of the early breeding in North America focused on direct producers, bred from local vine species that produced crops and tolerated the local conditions (primarily the harsh winters and phylloxera). It did not focus on rootstocks since Vitis vinifera cultivars were not widely planted, apart from the west coast of USA and New York State. There have been relatively few recently released rootstocks that have gained the popularity of those earlier releases.

5.1 Geisenheim Research Centre, Germany (Dr Ernst Ruhl, pers. comm.; Geisenheim website)

The Geisenheim rootstock breeding program aims for complete resistance to leaf and root galling phylloxera, combined with high affinity between the rootstock and scion, good adaptation to different soil types (particularly high lime content and drought tolerance) and positive effects on grape quality. The majority of the rootstocks used in Germany are crosses of V. cinerea var. helleri x V. riparia, with SO4 being widely used. However, recent warmer and drier summers have moved attention to more drought tolerant rootstocks in the V. cinerea var. helleri x V. rupestris group. Börner is a V. riparia x V. cinerea cross with a high level of resistance to phylloxera but low tolerance of lime ($CaCO_3$), and is one of the more recent releases in Germany. V. cinerea, along with Rici and Cina, has been used extensively in breeding over the last 20 years because of its high phylloxera resistance. The preference in Germany is to have 20 years' experience with new hybrids, including evaluation on grower properties, before official release and the expectation of industry taking them into the commercialisation phase.

The research station at Geisenheim also supervises bud wood production from 160-ha of rootstock mother blocks. Researchers continue to collect and evaluate native American Vitis species, with one project focusing on V. cinerea var. helleri for improving lime tolerance. Biotypes of phylloxera are less of a focus, but secondary pathogens associated with phylloxera damage, particularly Roesleria subterranean (grape root rot), is viewed as an emerging issue. There is also quite a focus on rooting, grafting and wood production, to ensure the material has good nursery characteristics (Dry, 2005). This includes re-selecting within rootstock cultivars for clones of rootstocks. Nurseries need to be registered to propagate and distribute material and must use certified material. Most growers rely on the nurseries for rootstock selection.

Only three rootstocks have been registered and released in France in the last 45 years—viz. Gravesac (1967), Fercal (1978) and Nemadex Alain Bouquet (2010).

5.2 Institut National de la Researche Agronomique (INRA), France (Dr Nathalie Ollat pers. comm. ; INRA website)

Around 10 rootstocks cover 90% of the wine industry in France, with rootstock SO4 widely planted and viewed as a 'safe choice' (much like the initial use of Schwarzmann in cooler areas of Australia), but it does not overcome all the issues. The breeding programs in France were stagnant in the 1990s (Dry 2005), but have since been revived to address grapevine fanleaf virus and the vector nematode Xiphinema index using Muscadinia rotundifolia in breeding programs. Lime tolerance, low vigour, phylloxera resistance, high fertility (fruitset), drought tolerance and grape and wine quality are also important issues to be addressed. The future direction of the program is to develop molecular assisted selection for biotic stress. However, breeding V. vinifera varieties for disease resistance has higher priority with industry and government than rootstock breeding. Transgenic rootstocks produced to resist X. index and fanleaf virus were produced and planted in a trial plot for evaluation, but was destroyed by vandals in 2010. The process for developing and planting out the trial vines involved considerable community consultation, and cost taxpayers €1m.

Only three rootstocks have been registered and released in France in the last 45 years—viz. Gravesac (1967), Fercal (1978) and Nemadex Alain Bouquet (2010). INRA are also interested in evaluating rootstocks from other countries, primarily for drought tolerance. INRA seek a minimum of 10 years for evaluation after selections are made, with the recently released Nemadex Alain Bouquet being bred in 1987 (20+ year process). The Etablissement National Technique pour l'Amelioration de la Viticulture (ENTAV) is a non-government organisation responsible for the conservation and sanitary status of vine material and the distribution of base material to nurseries. INRA release all their material through ENTAV for commercialisation, and like to track the performance of their releases in commercial plantings to learn more about rootstock performance.

5.3 University of California Davis (UCD), USA (Dr Andy Walker; UCD website)

Part of the breeding program in California has focussed on nematode resistant rootstocks for the sandy soils of the Central Valley. Following the development of Ramsey and Dog Ridge, the rootstocks Freedom, Harmony and O39–16 were produced. In other USA wine regions, traditional European rootstocks assessed although ARG1 appeared best suited. The failure of ARG1 in the 1980s and 1990s necessitated a return to European-bred rootstocks, and the popular rootstocks currently are Freedom, 1103 Paulsen and 101–14. Rootstock preference may change in the future as more vineyard replanting is expected than new plantings. Industry recognised there were gaps in the performance of current rootstocks, but was unwilling or unable to fund the expanding breeding programs in the past. The University of California Davis (UCD) are developing rootstocks with more manageable vigour, broader nematode resistance, salt and drought tolerance, virus and Pierce's Disease tolerance and fungal resistance. Although the USA economy is down and there is a reduced demand for rootstocks, the wine industry views the breeding programs as high priority and the current breeding programs are well supported.

One of the major projects involves breeding for, and identifying, the genes conferring resistance to Xiphinema index nematode. Markers that can expedite the screening of hybrid rootstocks have been identified. Seeds supplied as M. rotundifolia x V. rupestris by Prof. H P Olmo actually turned out to be a mixture of unintended outcrosses, and it was discovered that V. arizonica and its hybrids with V. candicans had high resistance to Pierce's disease and dagger nematode. The pathway to release began in 1993–4 when 75 crosses were made, resulting in 5,000 seedlings. In 1996, 1,000 of those were tested for rooting ability and the best 100 were selected for nematode testing. Several stages of nematode testing reduced the number to 33 then 14, and finally five hybrids (listed as UCD GRN 1 to 5; GRN = Grape Rootstock for Nematode) were released in 2008 to University of California licensed nurseries for further field testing (Walker and Ferris, 2009).

UCD have used rapid screening systems for a number of key issues to be addressed. For example, salinity tolerance was examined by testing hybrids of tolerant and sensitive species to determine the genetics associated with sodium and chloride exclusion and to identify the potential markers. Using these techniques, UCD have sped up the basic evaluation process enabling progression to field evaluation sooner. The commercialisation process occurs through the Foundation Plant Services, with most of the promotion of the new rootstocks done by Dr Walker.

The focus is on root-knot nematodes (Meloidogyne spp), particularly with the emergence of aggressive populations that feed on and damage previously well regarded nematode resistant rootstocks (e.g. Harmony and Freedom).

5.4 United States Department of Agriculture (USDA), Geneva USA (Dr Peter Cousins)

The United States Department of Agriculture (USDA) work is conducted collaboratively with a number of other groups in the USA. The focus is on root-knot nematodes (Meloidogyne spp), particularly with the emergence of aggressive populations that feed on and damage previously well regarded nematode resistant rootstocks (e.g. Harmony and Freedom). USDA have developed methods for the rapid screening of germinated seedlings inoculated with nematodes, and are able to screen over 5,000 seedlings in one season. Around 1% of seedlings show resistance to aggressive root-knot nematodes, and material from promising selections are bulked up and made available to industry for further evaluation. Three improved nematode resistant rootstocks bred in 2000 (Matador, Minotaur and Kingfisher) were released in 2010 and a further 20 rootstock hybrids have been grafted and planted in 2010 for field evaluation.

The work has also characterised additional sources of resistance above that found in V. champinii rootstocks, and that these new sources of resistance offer protection against a broader range of nematodes. They have been unable to develop molecular markers associated with resistance to root-knot nematode. An evaluation of rootstocks in southern Texas, where Pierce's disease is prevalent, revealed that Dog Ridge rootstock showed fewer disease symptoms and greater pruning weights than four other rootstocks. In north Florida, Ramsey had the highest survival against Pierce's disease (Lu et al., 2008). There is an extensive fraternity of grape breeders across North America who share information and vine material, but most of the focus is on fruiting varieties, not rootstocks (see www.ibiblio.org/grapebreeders).

5.5 Washington State University, USA (Markus Keller; WSU Prosser website)

The grape industry in Washington State has very few issues that require rootstocks, apart from some lime chlorosis in high pH soils and, consequently, more than 99% of the grapes are ungrafted. There are some rootstock evaluation trials in place, in the event of further phylloxera infestations or if nematode populations increase. This work includes monitoring growth, yield and its components, fruit composition and wine quality. In one trial at Prosser, in the absence of phylloxera or nematodes, results were primarily influenced by annual climate, spatial differences across the vineyard and the scion varieties. The rootstocks induced few and often minor differences in performance and scion varieties modified the rootstock impact. Rootstock evaluation has a low priority and no breeding is undertaken; however, the high health status of source material is maintained for industry use, even though current demand for rootstocks is low.

5.6 Marlborough Wine Research Centre, Blenheim, New Zealand (Dr Mike Trought)

Phylloxera spread throughout New Zealand over a period of about 30 years and growers rely on the traditional suite of European rootstocks. Demand for rootstocks has been high at times, with some

International research centres currently undertaking breeding programs in similar research areas, could increase collaboration, which may provide mutual benefits

less than desirable planting material (contaminated with virus and disease) used. This includes 101–14, which was widely planted and some plantings have succumbed to Cylindrocarpon root rot. While the industry has managed with the rootstocks available, there have been some issues that require more careful selection of rootstocks in the future, such as irrigated vineyards with fertile soils and high potassium levels. The spread of leaf-roll virus through infected propagation material and insect vectors is also of serious concern in New Zealand (Hoskins et al., 2011). A breeding program does not exist and industry relies heavily on nurseries for source blocks and information on performance, with little government intervention.

5.7 Summary

International research centres currently undertaking breeding programs in similar research areas, could increase collaboration, which may provide mutual benefits, (e.g. field trials in opposite hemispheres would produce two crops a year which may speed up evaluation). Advances in rapid screening techniques need to be monitored and adopted where relevant in Australia. Progress towards molecular or genetic markers is often slow or uncertain and requires long-term investment. Other international centres plant material into the field soon after laboratory evaluation, thus providing more information to growers when material is finally released. Some counties have strong control over industry, ensuring wide-spread use of certified planting material.

6. Grape Rootstock Breeding in Australia

The rootstocks available in Australia are largely those bred and selected over 100 years ago in Europe. Worldwide, the bulk of the grape industry relies on relatively few rootstock species (de Andres et al., 2007), which limits the adaptability of the grapevine across a broad range of climates and soils. The CSIRO commenced breeding rootstocks over 40 years ago and it has made a concerted effort in the past 20 years to evaluate hybrids and use that information to conduct targeted crosses to address particular issues in Australian vineyards. Research since the late 1980s focused on rootstocks with reduced potassium uptake to address high juice pH issues, combined with evaluating the rootstocks for phylloxera and nematode resistance, ease of grafting and propagation and restricting the uptake of ions, such as sodium and chloride (Wheal et al., 2002). The work now includes assessing vigour potential, WUE and the impact on wine quality.

The rootstocks available in Australia are largely those bred and selected over 100 years ago in Europe. Worldwide, the bulk of the grape industry relies on relatively few rootstock species (de Andres et al., 2007), which limits the adaptability of the grapevine across a broad range of climates and soils.

The process of developing rootstocks for lower potassium uptake commenced with the selection of 55 promising rootstocks in 1987, and the establishment of a field trial in 1989 (Ruhl, 1990a). A small number of promising selections were identified for further evaluation (Clingeleffer, 2000). Four of the rootstocks underwent evaluation for Plant Breeders Rights (PBR) purposes and testing against a wider range of phylloxera biotypes (Clingeleffer, 2007). Three rootstocks were released for industry evaluation in 2008, originally derived from crosses conducted in 1967. In Sunraysia, Shiraz grafted onto the new hybrids had lower pruning weight, yield, juice Brix and pH, higher wine colour density and total phenolics, compared with Ramsey (Clingeleffer et al., 2011a; Clingeleffer and Smith, 2011). The new rootstocks showed tolerance to some common strains of phylloxera and nematodes, but were less robust under water deficit conditions.

The most recent research project report (Clingeleffer and Smith, 2011) included several recommendations for future work. These included maintaining a germplasm of rootstock material of old and newly developed hybrids, further research on the evaluation of rootstocks, the development of rapid screening techniques and building knowledge on key rootstock traits. The general direction for grapevine breeding in Australia has been supported by industry through consultation meetings such as 'Future Rootstocks' (28 November, 2002) and 'Grapes for Growth' (1 June, 2005), along with National Rootstock Forums (2005 and 2008). There is a great opportunity for industry to be more directly engaged through an industry project reference group or similar consultative group.

The focus should be on selection, based on the predominant traits required and assessing pest resistance and other important attributes. A rootstock breeding program must have some specific endpoints and not become a never-ending program.

Development of rapid screening methods of large numbers of hybrids for traits, including phylloxera and nematode resistance and potassium, chloride and sodium uptake, will reduce the initial selection and evaluation process and enable a quicker transition into field studies. With the use of faster screening techniques, it is anticipated the screening process would be reduced to two or three years after the initial crosses were made.

Producing a universal rootstock through selective breeding, including all the traits the industry may need, is unlikely in the short-term. The focus should be on selection, based on the predominant traits required and assessing pest resistance and other important attributes. A rootstock breeding program must have some specific endpoints and not become a never-ending program.

Cost benefit analysis was performed on several rootstock projects funded by GWRDC and was based around improved rootstocks from trial work and breeding (although there were other components relating to improved irrigation efficiency in some projects) (McLeod, 2001). At the time, analysis showed a relatively high return on investment of around 10:1. It would be useful to revisit the topic using known benefits and adoption rates to reassess the conclusions.

6.1 Rootstock screening

In Australia, it has taken a period of around 20 years from the beginning of screening to release the first specifically selected rootstocks based on hybrids created in 1967. These rootstocks have only been evaluated in a limited number of sites and broader commercial evaluation is required. The initial screening to measure petiole potassium concentrations of potential rootstocks was completed quickly. The subsequent field evaluation and screening for other traits was a much longer process. Similar durations from commencement of the selection process to release of rootstocks for commercial evaluation have been experienced in other countries.

Development of rapid screening methods of large numbers of hybrids for traits, including phylloxera and nematode resistance and potassium, chloride and sodium uptake, will reduce the initial selection and evaluation process and enable a quicker transition into field studies. With the use of faster screening techniques, it is anticipated the screening process would be reduced to two or three years after the initial crosses were made. After that time, initial field testing could be undertaken for five to six years to identify the best performing selections. If PBR are to be pursued, it is suggested broader field evaluation in commercial situations could be undertaken during the period when PBR information is being collected.

6.2 Field trials

The three rootstocks selected and released through the rootstock breeding program by CSIRO were first established in a field trial in 1989. Assessments at other sites are in the early stages (first harvest 2010). Site, season and scion variety interact with rootstock performance, so it is likely different management strategies will be required to maximise performance of any particular combination. Field trials enable growers to more readily assess the performance of a rootstock under conditions similar to their own vineyard. Once a series of trials is conducted, the recommendations may not last forever as was demonstrated by ARG1 being found to be susceptible to a different biotype of phylloxera in California. In this case, there was little information available to growers on alternative rootstocks, because rootstock evaluation had ceased some years earlier (Whiting, 1996).

Trials can be at various levels to match the information required. Small replicated plots allow limited amounts of available material to be assessed and can be used to screen a range of rootstocks for site suitability. In this case, tailored vineyard management for individual rootstocks is difficult on a small number of vines. Larger scale trials can then follow with greater numbers of fewer rootstocks. Whole row treatments enable precision viticulture to be used, including yield monitors on harvesters and individual management of rootstocks. Larger trials would allow consistent vine management and may supply enough fruit for commercial size ferments, but statistical comparison is limited unless some replication is included. There are opportunities to integrate small trials with whole row or block plots by embedding the small trial within a larger block (Dry, 2005).

Field trials enable growers to more readily assess the performance of a rootstock under conditions similar to their own vineyard.

6.3 Commercialisation

Some countries use industry bodies to maintain the sanitation of rootstocks and supply 'certified' material to nurseries for subsequent bulking up and propagation (e.g. ENTAV in France, regional institutes in Germany and FPS in the USA). Generally, the adoption of new rootstocks is slow and relies on promotion by the researchers and the nurseries. For example, Gravesac (for acid soils) released in 1967 is currently the seventh most popular rootstock in France, and Fercal (for limey soils) released in 1978 is currently the fourth most popular. Adoption of a rootstock is restricted to the sites for which it is suitable, so some rootstocks will have a limit to their demand.

The CSIRO Plant Industry 'Future Rootstocks—Breeding and Strategy Plan' (revised October 2011) is based on consultation with industry, primarily in 2002. The commercialisation process proposed several key outcomes, including rapid multiplication of source blocks established on properties under test agreements, selection and licencing of nurseries to produce grafted vines for commercial sale under non-propagation agreements with PBR protection, collection of royalties and the provision of information to industry and nurseries through a variety of means. Three nurseries are currently licenced to propagate and distribute grafted vines using the three new rootstocks released in 2008.

The commercialisation model proposed by industry is similar to what occurs internationally. The main difference is that some other countries have more clearly defined groups responsible for the maintenance of the health status of candidate material (e.g. ENTAV, FPS, Geisenheim Institute). Rootstocks are then released to nurseries for the propagation of grafted vines for interested growers.

The breeding of rootstocks to suit Australian conditions commenced in 1967, with the CSIRO using introduced seeds from specified crosses in the USA. Serious consideration of rootstocks for lower potassium uptake in 1987 provided impetus for further breeding and selection. While evaluation periods in Australia have been similar to those in other countries, new procedures should speed up the process. Where the process has been quite targeted overseas, rootstocks have been released 10 years after the initial crosses were made. Developing rapid screening techniques and moving field trials into semi-commercial stages earlier will enhance the rate of commercialisation.

While evaluation periods in Australia have been similar to those in other countries, new procedures should speed up the process. Where the process has been quite targeted overseas, rootstocks have been released 10 years after the initial crosses were made. Developing rapid screening techniques and moving field trials into semi-commercial stages earlier will enhance the rate of commercialisation.

7. Industry Involvement and Feedback from Industry

Industry involvement in setting the future directions for rootstocks has occurred at several stages. Early discussions between interested groups were held on a regular basis through the Vine Improvement Research Committee, hosted by the CSIRO (e.g. Anonymous 2000). More specific consultation has occurred through a 'Future Rootstocks' meeting in November 2002, followed up by industry consultation through the 'Grapes for Growth' workshop in June 2005. The latter focused on vine genetics and concluded Australia needed to maintain an investment in vine genetics and improvement, which included breeding new rootstocks, developing markers for rapid screening and the evaluation of new varieties. Some of the more pertinent discussion points on future projects suggested there should be focus on particular issues, support for the longer term (10–15 years), targeted outcomes, use of regional sites to fast track evaluation and strong industry involvement. In addition, progress with rootstock breeding was presented at two National Rootstock Forums (2005 and 2008) sponsored by the PGIBSA. A third forum in 2011 was renamed as a 'Below the Ground' seminar sponsored jointly by the Australian Society of Viticulture and Oenology and the PGIBSA.

The Second National Rootstock Forum in 2008 produced a model for the coordination and cooperation of various groups involved in rootstocks through a Rootstock Advisory Group; however, this model has yet to gain traction. The forum also determined priorities for RD&E which were (in order) national coordination, improved information, industry standards, regional trials, rootstock improvement and rootstock physiology.

7.1 Attitudes to rootstocks

The Phylloxera and Grape Industry Board of South Australia (PGIBSA) conducted a comprehensive survey of growers and winemakers in 2000 in that state. The survey focused on their attitudes and behaviour towards rootstocks (Hathaway, 2001). At the time, PGIBSA considered (and still does) using vines grafted to phylloxera resistant rootstocks was the preferred way to deal with the threat. In 2000, around 15% of the vines in the state were grafted. The report identified the greatest barriers to planting grafted vines were the extra cost and perceived low risk of a phylloxera outbreak. While some growers recognised excess vigour and reduced wine quality as negatives for rootstock use, the majority of growers acknowledged the positive aspects and believed the negative aspects could be managed. Around one third indicated phylloxera was a reason for planting rootstocks, but two thirds indicated other reasons for planting rootstocks. More information on the choice and performance of rootstocks was identified by the survey respondents, but the author concluded better communication of existing information was also required. Since the survey, the total area of rootstocks in South Australia has increased by around 8,000-ha, taking the proportion of total plantings on rootstock to about 20%.

While some growers recognised excess vigour and reduced wine quality as negatives for rootstock use, the majority of growers acknowledged the positive aspects and believed the negative aspects could be managed.

7.2 Current industry perceptions

Twenty five wine industry personnel (Appendix B), representing a cross-section of the industry, were contacted to discuss their perceptions on current rootstock use and their needs into the future. The feedback received from industry has been pooled and condensed into six main themes (Figure 1). Note these are views of a small cross-section of the wine industry and are not necessarily the views of the author, nor should they be taken to represent the collective view of the industry because of the small sample size. Many of the views expressed were similar to the discussions recorded at the Second National Rootstock Forum in 2008 and gives a high degree of confidence that an appropriate cross-section of the industry was interviewed.

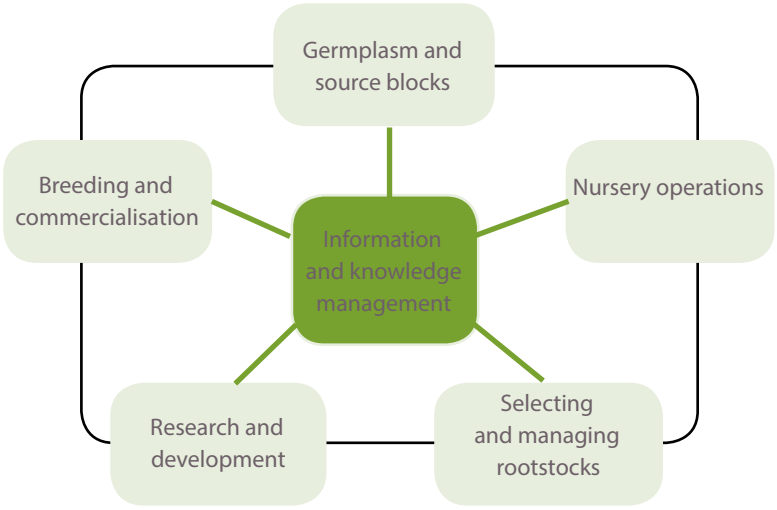

Figure 1: *Six main themes for rootstocks identified by a cross-section of the wine industry.*

Respondents took a long-term view that rootstock germplasm, while not used every year, needs to be maintained to meet new phases of grape industry planting.

7.2.1 Germplasm and source blocks

There was strong feedback about how rootstock use has changed over the years and will continue to change. Respondents took a long-term view that rootstock germplasm, while not used every year, needs to be maintained to meet new phases of grape industry planting. In the future this will primarily be replanting existing vineyards, and rootstocks are regarded as essential in most cases. Replacement of existing vineyards is ongoing to meet the needs of new consumer preferences and to replace old, under-performing vines. If all Australian vineyards were replaced after 30 years, this equates to around nine million vines required for replanting annually. Given that the majority of plantings are less than 20-years-old, the current rate of replanting is less, with rates of replanting expected to increase in the future.

The maintenance of high quality germplasm material from which multiplication blocks can be propagated, was raised by many of those consulted. The germplasm needs to be true to type, pest, virus and disease-free and maintained in such condition. A central accessible database providing relevant information was also desired by some. An Australian Grapevine Foundation Planting Scheme has been proposed (Constable and Drew, 2004) but has not been fully developed by industry, and further consideration should be given on how it may be implemented. Elite germplasm blocks are not commercial operations, as they serve to hold the repository material which is only accessed infrequently for establishing multiplication source blocks. However, their existence is vital as they form the foundation of all vineyards and their maintenance needs to be supported by industry across the board.

If all Australian vineyards were replaced after 30 years, this equates to around nine million vines required for replanting annually.

The coordination and production of planting material across the various states and agencies could be improved. The decline in new vineyard plantings has reduced the sales of cuttings. This has caused financial strain on vine improvement groups, agencies and nurseries who maintain source blocks of rootstocks, which are currently in low demand but with potential increased demand in the future (Nitschke, 2011). Some nurseries use their own rootstock source block plantings to service their ongoing requirements, and purchase additional planting material from state vine improvement groups only as required. Another issue raised by industry was the splintering of vine improvement groups through political and personal differences. The small size of the Australian grapevine industry cannot sustain a fractured approach to vine improvement and yet remain efficient. This requires strong leadership from the national industry bodies to get vine improvement working more effectively.

7.2.2 Nursery industry

The grower segment of the industry rely quite heavily on the nurseries for assistance in selecting and supplying high quality rootstocks. Most growers will pay the higher price of a grafted vine providing it is of high quality. Nurseries have had issues with viruses and diseases in grafted vines with resultant failures in the field in the past. Some viruses (e.g. stem pitting viruses) and diseases (e.g. Phaeoacromonium spp, Botryosphaeria spp, Cylindrocarpin spp, etc.) are relatively new to grapevines and infected source blocks and/or poor nursery practices have resulted in substantial issues for growers. Greater attention to germplasm and source blocks will address some of the problems. Nursery practices, such as hot water treatment, may assist with reducing some of these diseases (but not the viruses), and further research would help nurseries identify and control other sources of contamination.

A quality standard for grafted vines was also raised by interviewees, and many were disappointed with the great variation in quality of planting material during the planting boom. With a significantly lower demand, growers expect nurseries to produce consistent high quality material. There is an expectation that the Australian Grapevine Standard Scheme project will address these concerns.

Problems with incompatibility between various rootstocks and varieties or clones were regularly raised in the interviews. Individual nurseries (and growers) identified specific incompatible combinations, but there was no central registry of this information. VINA was identified as a suitable repository for this information. Little research has been undertaken to identify the causes of incompatibility and provide remedies or recommendations. The cost of grafted vines, which is an issue for some growers, relates largely to the success rate of the grafting of rootstocks and scions, and while there is a large degree of variation in graftability between rootstocks, little research is undertaken to improve the low success rate of some rootstocks. While hot water treatment has proved useful in reducing agrobacterium problems, it is not as effective against other diseases. Hot water treatment can also affect the viability of cuttings. Other nursery-related issues raised included: the lack of harmonisation of quarantine regulations between states complicating the transfer of cutting material; concern about the lack of maintenance of vine improvement source blocks; the limited availability of some rootstocks and growers having to use second rate combinations for their site.

The small size of the Australian grapevine industry cannot sustain a fractured approach to vine improvement and yet remain efficient. This requires strong leadership from the national industry bodies to get vine improvement working more effectively.

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7.2.3 Selecting and managing rootstocks in the field

Most of the interviewees were using rootstocks or had some experience with them. Of those that had little or no experience, most said they would use rootstocks for any new plantings. Around two thirds indicated that the extra cost of a grafted vine was not an issue provided they got quality vines. The predominant reasons for using rootstocks were phylloxera (control and protection), vigour control, drought tolerance, nematode tolerance, improved grape quality and salinity tolerance. Rootstocks were considered essential for replant situations, but there was some uncertainty about the performance of rootstocks in drought conditions.

There was an overwhelming response for increased regional evaluation of rootstocks, as many thought results from other regions with different soils, climate and management were unreliable. Most wanted the information to be local and in commercial scale blocks to help them decide on the rootstocks appropriate to their conditions. For combined vineyard/winery operations, there was a greater emphasis on grape and wine quality rather than yield alone. Growers were not particularly concerned about high potassium uptake or the negative impact on juice pH. This may be because there are not many penalties associated with these factors, although several winemakers indicated some rootstocks, in red varieties in particular, had caused problems.

Getting the right rootstock to match vine vigour to the site was also highlighted by many growers. In some cases high vigour was required, particularly for white grapes, where fruit exposure was not desirable (e.g. Chardonnay on Ramsey is a preferred combination in hot, irrigated areas). However, growers sought a rootstock with vigour that matches that of ungrafted vines for red varieties. A comment occasionally made by growers was a rootstock with the vigour of 101–14 or Schwarzmann was desired, but not with the high potassium uptake and low drought tolerance attributes. Other issues mentioned for more work included: rootstocks to cope with rising temperatures; stabilisation of yield and vigour fluctuations; new varieties and clones and reduction of sunburn.

The management of rootstocks was considered by many to be much improved after negative experiences early, although growers would like to see more documentation of any alternative approaches. It was also recognised that management of some rootstocks was difficult on some sites (e.g. Ramsey with red grapes in some regions), and it was better to select a rootstock that would produce less vigour. Where growers had reliable water supply, they were happy to use Schwarzmann, but Schwarzmann suffered badly in droughted areas where irrigation was limited. Most used irrigation to manipulate vigour and many just managed grafted blocks according to vine growth. The general process for rootstock selection was to look at the market requirements and determine variety and clone, then consider their site attributes (soil, climate, salinity, pests and disease, risk of issues developing) to determine a range of potential rootstocks, and then approach nurseries to ascertain availability and quality of material available. Growers often mentioned that their selection was compromised due to their optimum scion/rootstock combinations not being available.

The predominant reasons for using rootstocks were phylloxera (control and protection), vigour control, drought tolerance, nematode tolerance, improved grape quality and salinity tolerance.

7.2.4 Research and development aspects

A predominant view of the interviewees was that there were sufficient rootstocks in Australia and there was a need for more thorough evaluation of these rootstocks. Growers tended to concentrate on their own situation and think in the short-term (i.e. what are the issues affecting them now and into the immediate future). Hence, many think about selection of currently available rootstocks suited to their current conditions and do not consider future conditions and suitable characteristics. Across all those interviewed, around two thirds of the growers using rootstocks indicated they had issues with the rootstocks they were using, and on aggregating individual information, it was apparent there were deficiencies with all rootstocks.

Most wanted the information to be local and in commercial scale blocks to help them decide on the rootstocks appropriate to their conditions.

As mentioned earlier, respondents wanted to see more regional testing of rootstocks to provide information pertinent to their local conditions. Longevity of grafted vines was raised a few times, and it was proposed that some of the older rootstock trials established 30–40 years ago may be available for reassessment. Also, the issue of how many regional situations are needed to cover likely soil/climate variations when evaluating rootstocks was raised, as well as consideration to re-examining results from all available trials to see if some benchmark sites can be identified. For example, an earlier GWRDC-funded project on soils and rootstock trials (Cass et al., 2002) contained rootstock performance and soil data available for analysis, which was not fully undertaken at the time. Climate data could also be integrated into such an analysis. Greater collaboration with overseas colleagues was also mooted as a way of advancing our understanding of rootstocks.

Interviewees provided feedback on where they thought there were gaps in the information available, and the more commonly raised points included rootstock issues related to incompatibilities, uneven growth between wet and dry years, rising temperatures, excess vigour, drought tolerance, inconsistent grape and wine quality, phylloxera biotypes, aggressive nematode strains, salinity, producing 'fine' wines, colour stability, high potassium and juice pH, cooler and wetter regions, improving phosphorous uptake, better utilisation of nitrogen, drought predisposing vines to pests and disease and scion to rootstock signals.

7.2.5 Breeding and commercialisation of rootstocks

A predominant view of the interviewees was that there were sufficient rootstocks in Australia and there was a need for more thorough evaluation of these rootstocks.

Around half of the interviewees had taken some degree of interest in rootstock breeding and supported the CSIRO program. However, they were concerned about the slow pace of evaluating and releasing rootstocks and identified a perceived gap between the amount of funds invested and the outputs. The CSIRO have been following a 'Breeding and Strategy Plan' developed from an industry meeting in November 2002. The plan considered the market for rootstocks, breeding objectives, breeding vs importing, breeding strategies, intellectual property and the commercialisation plan. Commercialisation primarily involves obtaining PBR protection on promising rootstocks, establishing multiplication blocks, selecting and licencing nurseries, purchasers signing non-propagation/distribution agreements and royalties going back to investors (CSIRO, GWRDC and HAL) to contribute to ongoing research.

A number of production-related issues have been described in the earlier sections of this report, towards which breeding may provide answers. These issues are principally the ones outlined in the 'Breeding and Strategy Plan', but tolerance to heat and rootstocks for cooler and wetter regions were also mentioned by interviewees. Of interest to the interviewees would be the development of more rapid screening techniques which would speed up the selection process. Some interviewees questioned the lack of independent evaluation of potential new rootstocks. They cited it was a constraint to adoption, since the perception was that plant breeding organisations, in general, have a self-interest in promoting their own products. Opportunities to import rootstock material should also be considered.

7.2.6 Information and knowledge management

Many of the interviewees indicated there was plenty of information available, but it was either not readily available or not presented in the right context to encourage the adoption of rootstocks. Some indicated the information was hard to keep up with and there were mixed messages about some rootstocks. For example, different tests had been used to determine drought tolerance and results varied between the tests and field experience. The terminology surrounding drought tolerance and WUE also needs further explanation.

Many of the interviewees indicated there was plenty of information available, but it was either not readily available or not presented in the right context to encourage the adoption of rootstocks.

There was a general belief that there will be another growth phase and interviewees wanted to be prepared. The most common sources of information were publications, local trials (where available), Yalumba nursery website, discussion with nurseries, general internet searches, consultants, PGIBSA rootstock book (Dry, 2007) and other growers. With the latter, there can be a disconnect between what the growers want (yield) and what the wineries want (quality). There were several mentions of updating the PGIBSA book, which is focused on South Australian regions, and expanding it to include other Australia wine regions. An individual grower may only need to refer to information on rootstocks for a short period when making a decision on rootstock selection and may not need information until replanting 20–30 years later. However, replanting is likely to be spread over many years to minimise fluctuations in income while blocks are out of production.

A few of the interviewees indicated there is resistance to the adoption of rootstocks from some winemakers (mainly related to excess vigour and poor grape quality), and some growers who do not see any particular benefit in a rootstock (e.g. in the MIA water supply is assured and salinity is not an issue). Continuation of the (currently) triennial rootstock forums was also seen as essential and that the PGIBSA is the appropriate lead agency for that event.

The growers interviewed generally fitted into one of five groups. The groups were those that:

1. did not need rootstocks
2. did not have rootstocks but would consider rootstock use in the future
3. had some rootstocks and would consider planting again in the future
4. needed rootstocks for replant situations in all future plantings
5. always required rootstocks due to existing issues.

It is likely each group will have different information needs and this should be considered in any extension activities.

Attention to all six themes will be required for the efficient development of the wine industry. If there is insufficient or no progress in one or more of these themes, the full potential for rootstock use within the wine industry will be inhibited. The industry seeks good quality planting material, rootstocks suited to their site, a breeding and selection program that can address any deficiencies in the current rootstocks and improved access to information presented in a context suited to their needs. Growers and winemakers know there may be unknown issues in the future and that the industry must be ready to adapt. Rootstocks will be part of that adaption process.

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8. Conclusions

The present use of rootstocks in Australia is relatively low compared with most other countries. Historically, there has not been a great need to use rootstocks, due to many new areas being planted on previously unplanted soil, and the absence of soil pests and diseases from many wine growing areas. Recent drought conditions have encouraged the industry to consider rootstocks and many replant situations required rootstocks to overcome nematodes. Current economic conditions in the industry preclude wide-spread replanting but replacement replanting will be required over the next 10 or more years. As replanting increases, industry needs to be ready with an appropriate selection of rootstocks with high quality, healthy planting material. Industry also needs to be in a position to respond to a critical need for rootstocks if that arises (e.g. new phylloxera outbreaks).

Techniques developed in breeding programs to understand the genetic basis of traits, and the development of associated rapid screening techniques, have beneficial application for the current suite of rootstocks, also. Any new rootstocks need to have points of difference from the existing range and need to instil a competitive advantage in the market place. The three recently released CSIRO rootstocks appear to fulfil this requirement. The information required by growers and nurseries are variable, with only those seriously considering planting on rootstocks actively seeking information. The industry would suffer in the longer-term if R&D on rootstocks did not continue.

A number of factors influence the use of rootstocks by the wine grape industry, and market failure in any one of these areas would lead to a reduction in competitive advantage or industry resilience. Some of these facets may not require significant investment from GWRDC, but may require GWRDC's input into facilitating progress and working with other grape industry bodies. Under present circumstances, the rate of rootstock planting is slow. However, there has been strong interest in replanting with rootstocks, as some existing vines need replanting due to their condition, change in market demand or poor adaptation to their current site. Most in the industry were optimistic about the future and would focus on replanting once profitability returned. While there is a lull in vineyard redevelopment and planting, now is an opportune time to ensure the industry has suitable infrastructure and systems for rootstocks in the future.

Future investment in rootstocks in Australia for evaluation, breeding and commercialisation should be directed toward the following:

8.1.0 Evaluation of rootstocks

8.1.1

A high standard of cleanliness of elite planting material needs to be maintained from which multiplication source blocks can be established as required. This necessitates regular virus and disease testing and maintenance, the cost of which should be borne across the grape industry, so there are opportunities for co-investment. Practical techniques need to be investigated and implemented to reduce or prevent the infection of source blocks. There are issues about where such plantings should be located. The various vine improvement groups need to work closely with each other and with industry, and the GWRDC may play a facilitation role with other industry bodies to improve the functioning of the system. Industry feedback noted this as a high priority issue.

Recent drought conditions have encouraged the industry to consider rootstocks and many replant situations required rootstocks to overcome nematodes. Current economic conditions in the industry preclude wide-spread replanting but replacement replanting will be required over the next 10 or more years. As replanting increases, industry needs to be ready with an appropriate selection of rootstocks with high quality, healthy planting material. Industry also needs to be in a position to respond to a critical need for rootstocks if that arises (e.g. new phylloxera outbreaks).

8.1.2

Producing high quality planting material through nurseries is an integral part of the wine industry. Industry feedback indicated the need for high quality planting material free of diseases and incompatibility issues. Some funds need to be allocated to ensure this occurs, preferably as co-investment with the nursery industry. Some independent, random sampling of nursery material may be necessary to ascertain the extent of the problem. The nursery costs arising from incompatibilities, disease in multiplication blocks, poor nursery hygiene and poor graftability, get passed on to the buyers and there is an opportunity to reduce the cost of planting material—one of the barriers to the use of rootstocks. Research into incompatibilities, diseases in propagation material and improving graftability of some scion/rootstock combinations is warranted.

8.1.3

There is very strong interest from industry in drought tolerance and improved WUE, which are not necessarily the same thing. However, there needs to be a clearer understanding of the differences between the two by industry, along with what criteria should be used to determine appropriate rootstocks for particular situations. The current GWRDC project CSP 09/01 is addressing these issues. It needs a firm focus on tools that can be used to rapidly assess drought tolerance and WUE that can be translated into screening existing rootstocks, so industry has some firm guidelines to go on with. While the mechanisms for WUE are reasonably well understood, it appears premature to conduct breeding and selection for drought tolerance until the key underlying traits are determined and screening tools developed. A comprehensive review of drought tolerance mechanisms may provide clearer direction for progress on this issue.

8.1.4

The location and duration of field testing of rootstocks was an issue mainly raised by the researchers. There is an expansive range of rootstock trials in the country that have been analysed individually, but not across the board. The broad-acre cropping industry has used its extensive range of breeding evaluation sites to refine the number of locations they need. It would be worth engaging some biometric expertise to firstly determine the feasibility of analysing the range of rootstocks trial data available along with an analysis of soil (GWRDC project CRS 95/1) and climate data. And secondly, to conduct an analysis to determine such things as optimum length of time of data collection, the influence of soil and climate characteristics, trial design and the feasibility of determining benchmark sites to which most growers can relate. At the least, there needs to be some basic soil, climate and water availability information that growers need to collect that can be matched to an appropriate rootstock selection.

8.1.5

Most growers said they wanted to see how rootstocks performed locally to be more confident in making a choice. A first step would be to collate and analyse the current performance of rootstocks in a region (for example: Wigg, 2006) with GWRDC support. Such a summary may identify some significant gaps in knowledge which could be further explored through trials or block plantings. Not many growers initiate their own experimentation, but they are happy to participate in trials if offered to them. GWRDC may be able to facilitate a package where small trials are propagated through a cooperating nursery and are offered to regional groups pending co-investment. Small plots using Latin square single vine plots were effectively used in Sunraysia for the initial evaluation of nematode rootstocks.

Any new rootstocks need to have points of difference from the existing range and need to instil a competitive advantage in the market place.

8.1.6

The Phylloxera and Grape Industry Board of South Australia publication on 'Grapevine Rootstocks' (Dry, 2007) was well recognised as a good source of information. Those in other states commented that it would be good to have such a book on a national basis, particularly providing recommendations for all regions. Consideration should be given to printing a similar publication, or adapting it to the internet, in conjunction with the PGIBSA and other grape industry bodies.

8.2 Rootstock breeding

8.2.1

The CSIRO Plant Industries 'Breeding and Strategy Plan' was based around an industry consultation meeting in 2002. It is timely to revisit the plan and check whether the intervening period has changed industry perceptions of breeding rootstocks and the commercialisation process. A number of lessons have been learnt during the process of releasing the first batch of rootstocks and the process needs reviewing. While the National Rootstock Forums provide an overview of the program, industry and CSIRO would benefit from more regular and closer review of the breeding and commercialisation program.

The industry would suffer in the longer-term if R&D on rootstocks did not continue.

8.2.2

Useful rapid screening approaches have been developed for some issues relating to rootstock performance (e.g. nematodes, phylloxera, potassium, sodium and chloride). The capability to undertake screening needs to be maintained (e.g. screening current and emerging rootstocks against virulent nematodes that emerge), and expanded to other attributes required of rootstocks, such as phosphorous and nitrogen uptake.

8.2.3

Under present circumstances, the rate of rootstock planting is slow. However, there has been strong interest in replanting with rootstocks, as some existing vines need replanting due to their condition, change in market demand or poor adaptation to their current site.

Breeding for traits that provide the Australian industry with a competitive advantage should continue. The largest part of the industry produces quality wine with low production costs, so this is one area to focus on. Those producing premium wines are looking more for consistency of vine growth and quality in a variable climate.

8.2.4

Collaboration with overseas breeding institutes should continue and be strengthened to cooperatively develop genetic, biochemical, physiological and molecular markers. The process is quite involved and greater progress could be made by sharing resources. This may involve segregation of the work on the development phase and cooperation on the evaluation phase. This is higher risk research, as evidenced by inconclusive results for developing markers for resistance to root-knot nematode (Cousins pers. comm.). Some promising results appear to be coming out of the salinity research and it would be valuable to see that through and evaluate its usefulness in screening rootstocks.

8.2.5

An aspect of evaluating new rootstock hybrids that does take time is the field assessment. Industry should look at ways of speeding up the process of assessment by rapid propagation techniques, earlier establishment of the initial field trial, quicker transition to regional evaluation and the use of semi-commercial evaluation, as done with new V. vinifera cultivars.

While there is a lull in vineyard redevelopment and planting, now is an opportune time to ensure the industry has suitable infrastructure and systems for rootstocks in the future.

8.2.6

Most breeding programs in the past have had timeframes of around 20 years to commercial release, but this period should be able to be reduced to around 10–15 years. Projects could be funded in five year periods—with the breeding, screening and selection occurring in the first period, initial field evaluation and preparation for semi-commercial release in the second period, and broader field evaluation and monitoring in the third period. If projects don't meet the targets at the end of anyperiod, then they can be halted at that stage.

8.3 Commercialisation

8.3.1

Since GWRDC has an investment in new rootstocks, it is in its interest to ensure the commercialisation process is expedited. There are issues with quarantine regulation between states, including the treatment of planting material that diminish the viability of cuttings and grafted vines. Some investment in these aspects, and points raised in 8.1 above, is warranted to ensure sales of new rootstocks are not compromised.

8.3.2

Growers and winemakers often do not make decisions based just on published information, but they like to observe the vines performing in the field and see and taste the wines from different treatments. There are opportunities to use this process with the current field plots with the new CSIRO rootstocks. Such activities could be funded through regional viticulture technical groups, state extension officers, wine company Grower Liaison Officers and Industry Development Officers. Funds may be required to assist with small scale winemaking if commercial wines are not available.

8.3.3

Growers tend to consult the nurseries as a major source of information, so the information needs of nurseries need to be addressed .

There is a need to continue the provision of information in a range of formats. While the availability of the new CSIRO rootstocks has been mentioned in industry publications for several years, many growers interviewed were not aware of them—primarily because they were not in the process of planting on rootstock and had no need for that information. When they decide to plant with rootstocks is when the information will attract their attention. Growers tend to consult the nurseries as a major source of information, so the information needs of nurseries need to be addressed . Consideration should also be given to formulating information so it appears readily on internet searches, perhaps with a regional focus. For example, the grains industry provides the results of variety trials on the internet using an interactive map (see www.nvtonline.com.au). Other means, such as applications for smart phones, should also be considered. In the event of a rapid increase in interest in rootstocks due to a critical situation (e.g. a new phylloxera outbreak), information should be ready to go into targeted packages. Since it is difficult to predict what situation might stimulate a sudden increase in rootstock planting, it is difficult to justify preparing information packages in advance.

9. Recommendations for GWRDC Action

The main issues facing the wine grape industry, with regard to rootstocks, are:

1. maintaining rootstock (and scion) source vines as 'high health status' and ensuring that the status is maintained through to the purchaser of the planting material
2. ensuring relevant field evaluation information is available to assist in the selection of rootstocks for vineyard plantings
3. developing rapid screening techniques to select rootstocks with appropriate characteristics and, where gaps are identified, undertake introductions or targeted breeding to address those gaps.

A number of activities may be funded by GWRDC alone or in partnership with other grape and nursery industry organisations, or the GWRDC may act as a facilitator to ensure appropriate outcomes are met. The following recommendations address the key issues identified in the review.

1. Nuclear germplasm material, from which multiplication blocks are derived, need to be monitored and maintained in a true to type and high health status. This activity is not a commercial proposition due to the need to maintain infrequently used material. Industry needs to support it financially, whether that be through GWRDC and other grape and nursery bodies, or a funding model to be determined. The establishment of an Australian Grapevine Foundation Planting Scheme was proposed in 2004 and GWRDC should pursue the establishment of this group. The downstream use of planting material through multiplication blocks and nurseries should also be monitored to maintain the high health status through to customers. GWRDC and other grape industries need to co-invest with vine improvement bodies and nurseries to address issues related to maintaining high health status planting material to the industry.
2. An assessment of the potential to extract improved guidelines for the selection of rootstocks for field plantings, should be initiated using available trial information—largely based on the work on soils and rootstocks conducted by Cass et al. (2002)— also including climatological and other relevant information. If the above appears feasible, analysis of the data should be conducted with the aim to provide better and easily measurable guidelines for industry on the selection of rootstocks for their particular site. At the very least, rootstock trial data could be made more accessible on the internet through an interactive map, as the grains industry has done. GWRDC should also support a process whereby regional groups can review the performance of rootstocks locally (such as in the Ovens Valley, Wigg, 2006). If significant gaps are identified, GWRDC would facilitate the implementation of local trials. Given the importance of wine quality to the industry, GWRDC should provide funding to assist the making of wines from new rootstocks for demonstration purposes to growers and winemakers.
3. Funding support for the strategic introduction of rootstocks for public benefit should be considered, in conjunction with other beneficiaries. Rapid screening techniques should continue to be developed with the support of GWRDC, and other grape industry groups, to assess current and prospective rootstocks, initially with a focus on drought tolerance and WUE in conjunction with GWRDC project CSP 0901. Where there are gaps in the ability of current rootstocks to address particular issues, or where a particular market advantage can be identified, breeding and selection for targeted outcomes should be supported. Inherent in such a project is the need to:

- establish and have regular contact with an industry consultation group for grapevine breeding
- have an industry consultative group conduct a review of the 'Future Rootstocks – Breeding and Strategy Plan', developed with industry in 2002
- develop a staged process for rootstock breeding and evaluation, broadly encompassing a breeding and screening stage, an initial field evaluation stage and a broader field evaluation/ semi-commercialisation phase, with a comprehensive review against outcomes before proceeding to a subsequent stage
- develop rapid field evaluation procedures to speed up the process
- continue with and broaden contacts with potential collaborators.

References

Akhtar, M., and Mahmood, I., (1996), Control of plant-parasitic nematodes with organic and inorganic amendments in agricultural soil. App. Soil Ecol. 4:243-247.

de Andres, MT., Cabezas, JA., Cervera, MT., Borrego, J., Martinez-Zapater, JM., and Jouve, N., (2007), Molecular characterisation of grapevine rootstocks maintained in germplasm collections. Am. J. Enol. Vitic. 58(1):75-86.

Anonymous, (2000), National Vine Improvement Research Forum. CSIRO Plant Industry, Merbein, 30 August, 2000.

Arbuckle, K., (2011), Rootstock trends highlight industry priorities. Aust. NZ Grapegrower Winemaker 569:35–36.

Bates, T., (2008), Improving wine grape production in acid soils with rootstocks and soil management. Report on 2007 research. http://lergp.cce.cornell.edu/Bates/Reports/2008%28c%29Bates WinegrapeProgress.pdf

Bonfiglioli, RG., Habili, N., Green, M., Schliefert, LF., and Symons, RH., (1998), The hidden problem—Rugose wood associated viruses in Australian viticulture. Aust. Grapegrower Winemaker 420:9–13.

Cass, A., Fitzpatrick, R., Maschmedt, D., Thomson, K., Dowley, A., and van Goor, S., (2002), Soils of the Australian rootstock trials. Aust. NZ Grapegrower Winemaker 461a:40–42, 44–45, 47, 49.

Clingeleffer, P., (2000), Field assessment of selected rootstock hybrids for quality wine production. Final report to the Grape and Wine Research and Development Corporation. Project No. CSH 94/3.

Clingeleffer, P., (2007), A systematic and smarter approach to breeding and developing grapevine rootstocks adapted to Australian conditions. Final report to the Grape and Wine Research and Development Corporation. Project No. CSP 99/2.

Clingeleffer, PR., and Emmanuelli, DR., (2006), An assessment of rootstocks for Sunmuscat (Vitis Vinifera L.): a new drying variety. Aust. J. Grape Wine Res. 12:135–140.

Clingeleffer, P., and Smith, B., (2011), Rootstock breeding and development for Australian wine grapes. Final report to the Grape and Wine Research and Development Corporation. Project number CSP 05/03.

Clingeleffer, P., Smith, B., Edwards, E., Collins, M., Morales, N., Davis, H., Sykes, S., and Walker, RR., (2011a), Industry puts low-medium vigour rootstocks to the test. Wine and Viticulture Journal 26(3):72, 74–76.

Clingeleffer, PR., Smith, BP., Davis, HP., Edwards, EJ., Collins, MJ., Morales, NB., Boettcher, A., Singh, DP., and Walker, RR., (2011b), Rootstock breeding and development for Australian conditions: Update on current work. Proceedings of Australian Society of Viticulture and Oenology Above Ground Seminar, Mildura, July 2011 (in press).

Constable, F., and Drew, C., (2004), Review of vine health parameters, implementation priorities and capabilities for vine improvement groups and accredited nurseries. Final report to Grape and Wine Research & Development Corporation. Project Number NVH 03/01.

Corrie, AM., and Hoffmann, AA., (2004), Fine-scale genetic structure of grape phylloxera from the roots and leaves of Vitis. Heredity 92:118–127.

Corrie, AM., Kellow, A., Buchanan, G., and van Heeswijck, R., (1998), Phylloxera biotypes in Australia. Aust. Grapegrower Winemaker 417:32–36.

Corrie, AM., van Heeswijck, R., and Hoffmann, A., (2001), Life cycle of grape phylloxera: management implications. Aust. Grapegrower Winemaker 450:13–16.

Corrie, A., van Heeswijck, R., and Hoffmann, A., (2002a), Can phylloxera grow on your rootstocks? Aust. Grapegrower Winemaker 461a:116–119.

Corrie AM, Crozier RH, van Heeswijck R and Hoffmann AA (2002b) Clonal reproduction and population genetic structure of grape phylloxera, Daktulosphaira vitifoliae, in Australia. Heredity 88:203-211.

Corrie, AM., van Heeswijck, R., and Hoffmann, AA., (2003), Evidence for host-associated clones of grape phylloxera Daktulosphaira vitifoliae (Hemiptera: Phylloxeridae) in Australia. Bull. Entomol. Res. 93:193–201.

Dakis, P., Hayes, P., Noon, D., Whiting, J., and Everett, M., (2001), The profitability of investing in a small vineyard and winery. Department of Natural Resources and Environment.

Dry, N., (2005), Grapevine rootstock evaluation and breeding in Germany, France and California. Final report to the Grape and Wine Research and Development Corporation. Project No. PGI 05/01.

Dry, N., (2007), Grapevine rootstocks. Selection and management for South Australian vineyards. Lythrum Press, Adelaide.

Eskalen, A., Gubler, WD., and Khan, A ., (2001), Rootstock susceptibility to Phaeomoniella chlamydospora and Phaeoacromonium spp. Phytopathol. Mediterr. 40:S433–S438.

Ferreira, JHS., van Wyk, PS., and Calitz, FJ., (1999), Slow dieback of grapevine in South Africa: stress-related predisposition of young vines for infection by Phaeoacremonium chlamydosporum. S. Afr. J. Enol. Vitic. 20(2):43–46.

Flexas, J., Galmes, J., Galle, A., Gulias, J.,Pou, A., Ribas-Carbo, M., Tomas, M., and Medrano, H., (2010), Improving water use efficiency in grapevines: potential physiological targets for biotechnological improvement. Aust. J. Grape Wine Res. 16:106–121.

Folwell, RJ., Cifarelli, V., and Hinman, H., (2001), Economic consequences of phylloxera in cool climate wine grape production areas of eastern Washington. Small Fruits Review 1(4):3–15.

Forneck, A., Walker, MA., and Blaich, R., (2001), Ecological and genetic aspects of grape phylloxera Daktulosphaira vitifoliae (Hemiptera: Phylloxeridae) performance on rootstock hosts. Bull. Entomol. Res. 91:445–451.

Fort, K., and Walker, MA., (2011), Chloride exclusion patterns in six grapevine populations. Abstract from ASEV 62nd National Conference, 22–23 June 2011, Monterey, California. Am. J. Enol. Vitic. 62(3):400A.

Gawel, R., Ewart, A., and Cirami, R., (2000), Effect of rootstock on must and wine composition and the sensory properties of Cabernet Sauvignon grown at Langhorne Creek, South Australia. Wine Industry Journal 15(1):67–73.

Gibberd, MR., Walker, RR., Blackmore, DH., and Gordon, AG., (2001), Transpiration efficiency and carbon-isotope discrimination of grapevines grown under well-watered conditions in either glasshouse or vineyard. Aust. J. Grape Wine Res. 7(3):110–117.

Gong, H., Blackmore, DH., and Walker, RR., (2010), Organic and inorganic anions in Shiraz and Chardonnay grape berries and wine as affected by rootstock under saline conditions. Aust. J. Grape Wine Res. 16(1):227–236.

Gramaje, D., and Armengol, J., (2011), Fungal trunk pathogens in the grapevine propagation process: Potential inoculum sources, detection, identification and management strategies. Plant Disease 95(9):1040–1055.

Granett, J., Walker, MA., Kocsis, L., and Omer, AD., (2001), Biology and management of grape phylloxera. Ann. Rev. Entomol. 46:387–412.

Grzegorczyk, W., and Walker, MA., (1998), Evaluating resistance to grape phylloxera in Vitis species with an in vitro dual culture assay. Am. J. Enol. Vitic. 49(1):17–22.

Gubler, WD., (2003), Young vine decline and black measles: new research results. Wines and Vines June:48, 50–52, 5455.

Habili, N., and Randles, J., (2011), Leafroll hotspots confirmed in Australia. Aust. NZ Grapegrower Winemaker 571:22.

Hatch, TA., Hickey, CC., and Wolfe, TK., (2011), Cover crop, rootstock, and root restriction regulate vegetative growth of Cabernet Sauvignon in a humid environment. Am. J. Enol. Vitic. 62(3):298–311.

Hathaway, S., (2001), Rootstock survey report. Attitude and behaviour of South Australian grapegrowers and winemakers regarding rootstocks. Phylloxera and Grape Industry Board of South Australia.

Heinitz, C., and Walker, MA., (2011), Germplasm screen for chloride exclusion in wild grapevines. Abstract from ASEV 62nd national Conference, 22–23 June 2011, Monterey, California. Am. J. Enol. Vitic. 62(3):400A.

Henschke, P., (2006), The influence of three rootstocks on vine performance and the composition and sensory properties of wine from early, mid and late maturing clones of Pinot Noir. Final report to the Grape and Wine Research and Development Corporation. Project No. RT 04/11-3.

Herbert, KS., Umina, PA., Mitrivski, PJ., Powell, KS., Viduka, K., and Hoffmann, AA., (2010), Clone lineages of grape phylloxera differ in their performance on Vitis Vinifera. Bull. Entomol. Res. 100:671–678.

Holzapfel, BP., and Treeby, MT., (2007), Effects of timing and rate of N supply on leaf nitrogen status, grape yield and juice composition from Shiraz grapevines grafted to one of three different rootstocks. Aust. J. Grape Wine Res. 13(1):14–22.
Hoskins, N., Thompson, C., and Andrew, R., (2011), NZ winegrowers working hard to eliminate Leafroll. Aust. NZ Grapegrower Winemaker 569:23–25.

Keller, M., Kummer, M., and Vasconcelos, MC., (2001a), Soil nitrogen utilisation for growth and gas exchange by grapevines in response to nitrogen supply and rootstock. Aust. J. Grape Wine Res. 7:2–11.

Keller, M., Kummer, M., and Vasconcelos, MC., (2001b), Reproductive growth of grapevines in response to nitrogen supply and rootstock. Aust. J. Grape Wine Res. 7:12–18.

Kellow, AV., Sedgley, M., McDonald, G., and van Heeswijck, R., (2000), Analysis of the interaction of phylloxera with susceptible and resistant grapevines using in vitro bioassays, microscopy and molecular biology. In: Powell KS and Whiting J (Eds) Proceedings of the international symposium on grapevine phylloxera management. 21 January 2000, Melbourne, Australia. Dept. Natural Resources and Environment.

King, PD.,and Rilling, G., (1985), Variations in the galling reaction of grapevines: evidence of different phylloxera biotypes and clonal reaction to phylloxera. Vitis 24:32–42.

Kingston, K., and Powell, K., (2006), Understanding the fundamental interactions between grapevine phylloxera and Vitis species. Final report to the Grape and Wine Research and Development Corporation. Project No. DNR 01/3.

Kodur, S., Tisdall, JM., Tang, C., and Walker, RR., (2010), Accumulation of potassium in grapevine rootstocks (Vitis) as affected by dry matter partitioning, root traits and transpiration. Aust. J. Grape Wine Res. 16(2):273–282.

Korosi, GA., Trethowan, CJ., and Powell, KS., (2007), Screening for rootstock resistance to grapevine phylloxera genotypes from Australian vineyards under controlled conditions. Acta Hort. 733:159–165.

Korosi, GA., Carmody, BM., and Powell, KS., (2011), Rootstock screening for phylloxera resistance under controlled conditions using selected phylloxera clonal lineages. Acta Hort. 904:33–39.

Krstic, M., and Hannah, R., (2003), Matching rootstock and scion combinations in Sunraysia. Final report to Grape and Wine Research and Development Corporation. Project No. RT 02/19–3.

Liminana, J-M., Pacreau, G., Boureau, F., Menard, E., David, S., Himonnet, C., Fermaud, M., Goutouly, J-T., Lecomte, P., and Dumot, V., (2009), Inner necrosis in grapevine rootstock mother plants in the Cognac area (Charentes, France). Phytopathol. Mediterr. 48:92–100.

Loveys, B., (2004), Improving water use efficiency, canopy structure and grape quality by better matching rootstock and scion physiology to irrigation practice. Final report to Grape and Wine Research and Development Corporation. Project No. CRV 99/8.

Lu, J., Ren, Z., and Cousins, P., (2008), Evaluation of grape rootstocks for resistance to Pierce's disease and adaptation to north Florida environment. Acta Hortic. 772:257–261 (abstract only).

Maschmedt, DJ., (2004), Soils and Australian viticulture. In: Dry PR and Coombe BG (Eds) Viticulture Volume 1 – Resources, 2nd Edition. Winetitles, Adelaide.
Maschmedt, D., Fitzpatrick, R., and Cass, A., (2002), Key for identifying categories of vineyard soils in Australia. CSIRO Land and Water. Technical Report 30/02, August 2002.

May, P., (1994), Using grapevine rootstocks: the Australian perspective. Winetitles, Adelaide.

McCarthy, M., Cirami, R., and Furkaliev, D., (1997), Rootstock response of Shiraz (Vitis vinifera) grapevines to dry and drip-irrigated conditions. Aust. J. Grape Wine Res. 3:95–98.

McLeod, R., (2001), Ex-anti and ex-post cost benefit analysis of the GWRDCs project portfolio. Final report to Grape and Wine Research and Development Corporation. Project No. GWR 01/02.

Mpelasoka, BS., Schachtman, DP., Treeby, MT., and Thomas, MR., (2003), A review of potassium nutrition in grapevines with special emphasis on berry accumulation. Aust. J. Grape Wine Res. 9(3):154–168.

National Vine Health Steering Committee and Grape and Wine Research and Development Corporation, (2002), Proceedings of the clean planting material workshop, March 2002. Final report to Grape and Wine Research and Development Corporation Project No. GWR 01/04.

New Zealand Grapegrowers, (2011), Grafted grapevine standard. New Zealand Grapegrowers, Auckland, p 25.

Nichol, JM., Stirling, GR., Rose, BJ., May, P., and van Heeswijck, R., (1999), Impact of nematodes on grapevine growth and productivity: current knowledge and future directions, with special reference to Australian viticulture. Aust. J. Grape Wine Res. 5:109–127.

Nitschke, D., (2011), Grapevine material collections— How to access them and the current status of Vine Improvement Association collections across the industry. In: Petrie PR (Ed.) 'Think global: Plant local alternative varieties'. Proceedings ASVO and AAVWS seminar, 5 November 2010, Mildura. Australian Society of Viticulture and Oenology Inc. 2011. pp 18—21.

Olmo, HP., (1986), The potential role of (vinifera x rotundifolia) hybrids in grape variety improvement. Experientia 42:921–926.

Phylloxera and Grape Industry Board of South Australia, (2002), The risk and economic impact of phylloxera in South Australia's viticultural regions. Volume 1, Main report.

Phylloxera and Grape Industry Board of South Australia, (2011), Annual Report 2010–2011.

Powell, K., (2006), Sustainable long term strategies for phylloxera management under Australian conditions. Final report to the Grape and Wine Research and Development Corporation. Project No. DNR 03/3.

Powell, K., (2009), Sustainable phylloxera management – Phase II. Final report to Grape and Wine Research and Development Corporation. Project number DPI 06/02.

Rahman, L., and Somers, T., (2005), Suppression of rootknot nematode (Meloidogyne javanica) after incorporation of Indian mustard cv Nemfix as green manure and seed meal in vineyards. Australasian Plant Pathology 34:77–83.

Richards, AL., Ayliffe, KA., and Aworth, DE., (2010), Assessing the impact of rootstocks on yield, vigour and juice ion concentration on Cabernet Sauvignon in Langhorne Creek, South Australia. Poster at the 14th Australian Wine Industry Technical Conference, 3–8 July 2010, Adelaide South Australia.

Ritter, A., Vorwerk, S., Blaich, R., and Forneck, A., (2007), Adaptational potential of grape phylloxera (Daktulosphaira vitifoliae) clonal lineages. Mitteilungen Klosterneuburg 57:116–122.

Robinson, JB., (1986), Fruits, vines and nuts. In: Plant analysis: an interpretation manual. Eds. DJ Reuter and JB Robinson (Inkata Press: Melbourne) p 131.

Rooney, SN., and Gubler, WD., (2001), Effect of hot water treatments on eradication of Phaeomoniella chlamydospora and Phaeoacremonium inflatipes from dormant grapevine wood. Phytopathol. Mediterr. 40:S467-S472.

Ruhl, EH., (1990a), Evaluation of rootstocks for wine grapes. Final report to the Grape and Wine Research and Development Corporation. Project No. CS 2V.

Ruhl, EH., (1990b), Better rootstocks for wine grape production. Aust. Grapegrower Winemaker 316:113–115.

Schultz, HR., and Stoll ,M .,(2010), Some critical issues in environmental physiology of grapevines: future challenges and current limitations. Aust. J. grape Wine Res. 16:4–24.

Sheng, Y., Gray, EM., Mullen, JD., and Davidson, A., (2011), Public investment in agricultural R&D and extension: an analysis of the static and dynamic effects on Australian broadacre productivity. ABARES research report 11.7. Australian Bureau of Agricultural and Resource Economics and Sciences, Canberra, September.

Smith, JP., (2004), Investigations into the mechanisms underlying grapevine rootstock effects on scion growth and yield. PhD Thesis, Charles Sturt University, Wagga Wagga, Australia.

Soar, CJ., Dry, PR., and Loveys, BR., (2006), Scion photosynthesis and leaf gas exchange in Vitis Vinifera L. cv. Shiraz: Mediation of rootstock effects via xylem sap ABA. Aust. J. Grape Wine Res. 12(2):82–96.

Sommer, KJ., Hancock, F., and Downey, MO., (2010), Resilience of Sultana (Vitis Vinifera) to drought and subsequent recovery: field evaluation of nine rootstock scion combinations. S. Afr. J. Enol. Vitic. 31:181–185.

Speirs, J., Lovey, B., and Binney, A., (2010), Optimizing irrigation and response to abiotic stress through development of biochemical, physiological and molecular markers of vine performance. Final report to Grape and Wine Research and Development Corporation. Project number CSP 06/03.

Stamp, JA., (2001), The contribution of imperfections in nursery stock to the decline of young vines in California. Phytopathol. Mediterr. 40 :S369–S375.

Stevens, RM., Pech, JM., Gibberd, MR., Walker, RR., Jones, JA., Taylor, J., and Nicholas, PR., (2008), Effect of reduced irrigation on growth, yield, ripening rates and water relations of Chardonnay vines grafted to five rootstocks. Aust. J. Grape Wine Res. 14:177–190.
Stevens, RM., Pech, JM., Gibberd, MR., Walker, RR., and Nicholas., PR, (2010), Reduced irrigation and rootstock effects on vegetative growth, yield and its components, and leaf physiological responses of Shiraz. Aust. J. Grape Wine Res. 16(3):413–425.

Stevens, RM., Pitt, TR., Dyson, C., Pech, JM., and Skewes, M., (2011), Salt tolerant rootstocks for long term sustainability in the Limestone Coast. Final report to the Grape and Wine Research and Development Corporation. Project number SAR 09/03.

Sullivan, V., (1996), New rootstocks stop vineyard pest for now. Calif. Agric. 50(4):7–8.

Tandonnet, J-P., Cookson, SJ., Vivin, P., and Ollat, N., (2010), Scion genotype controls biomass allocation and root development in grafted grapevine. Aust. J. Grape Wine Res. 16(2):290–300.

Treeby, MT., Holzapfel, BP., and Walker, RR., (1996), Optimizing nitrogen supply to grafted Shiraz. In: Stockley et al. (Eds) Proceedings of the ninth Australian wine industry technical conference. Winetitles, Adelaide. pp 132–137.

Treeby, MT., Holzapfel, BP., Pickering, GJ., and Friedrich, CJ., (2000), Vineyard nitrogen supply and Shiraz grape and wine quality. Acta Hort. 512:77–92.

Tregeagle, JM., Tisdall, JM., Blackmore, DH., and Walker, RR., (2006), A diminished capacity for chloride exclusion by grapevine rootstocks following long-term saline irrigation in an inland versus a coastal region of Australia. Aust. J. Grape Wine Res. 12:178–191.

Tregeagle, JM., Tisdall, JM., Tester, M., and Walker, RR., (2010), Cl^- uptake, transport and accumulation in grapevine rootstocks of differing capacity for Cl^--exclusion. Functional Plant Biology 37:665–673.

Trethowan, CJ., and Powell, KS., (2007), Rootstock-phylloxera interactions under Australian field conditions. Acta Hort. 733:115–121.

Vorwerk, S., and Forneck, A., (2006), Reproductive mode of grape phylloxera (Daktulosphaira vitifoliae, Homoptera: Phylloxeridae) in Europe: molecular evidence for predominantly asexual populations and a lack of gene flow between them. Genome 49:678–688.

Waite, H., (2006), Who is responsible for the quality of planting material in Australian vineyards? Looking to the future. Aust. Grapegrower Winemaker 507:40–42.

Waite, H., and Morton, L., (2007), Hot water treatment, trunk diseases and other critical factors in the production of high quality grapevine planting material. Phytopathol. Mediterr. 46:5–17.

Walker, A., Granett, J., Omer, A., Lin, H., Kocsis, L., Forneck, A., and Porten, M., (1998), Are phylloxera feeding on 5C rootstock in Europe. Practical Winery Vineyard Mar/Apr, 21–22, 25–26.

Walker, A., and Ferris, H., (2009), Nematode-resistant rootstocks released to nurseries. Practical Winery Vineyard Jan/Feb.

Walker, GE., (1997), Ramsey is not resistant to all local populations of rootknot nematodes. Aust. Grapegrower Winemaker. 402a:113–115.

Walker, GE., (2009), Resistance of some commonly used rootstocks to root-knot nematode: the problem of rootstock selection. Aust. NZ Grapegrower Winemaker 547:16, 18, 20, 22.
Walker, G., and Cox, C., (2011a), Resistance of rootstocks depends on the vineyard populations of Root-knot Nematode. Aust. NZ Grapegrower Winemaker 566:37–39.

Walker, G., and Cox, C., (2011b), Resistance of RS–3 and RS–9 rootstocks depends to local nematode populations. Aust. NZ Grapegrower Winemaker 567:35–36.

Walker, R., (2004), Application of carbon isotope discrimination technology to understanding and managing wine grape water use efficiency. Final report to Grape and Wine Research and Development Corporation. Project No. CRV 99/10.

Walker, R., and Clingeleffer, P., (2009), Rootstock attributes and selection for Australian conditions. Australian Viticulture 13(4):70–76.

Walker, RR., Blackmore, DH., Clingeleffer, PR., and Iacono, F., (1997), Effect of salinity and Ramsey rootstock on ion concentrations and carbon dioxide assimilation in leaves of drip-irrigated, field-grown grapevines (Vitis Vinifera L. cv. Sultana). Aust. J. Grape Wine Res. 3:66–74.

Walker, RR., Blackmore, DH., Clingeleffer, PR., and Correll, RL., (2002), Rootstock effects on salt tolerance of irrigated field-grown grapevines (Vitis Vinifera L. cv. Sultana). 1. Yield and vigour inter-relationships. Aust. J. Grape Wine Res. 8:3-14.

Walker, RR., Blackmore, DH., and Clingeleffer, PR., (2010), Impact of rootstock on yield and ion concentrations in petioles, juice and wine of Shiraz and Chardonnay in different viticultural environments with different irrigation water salinity. Aust. J. Grape Wine Res. 16:243¬–257.

Weber, E., Walker, A., Steinhauer, B., Ledbetter, J., Stoller, G., and Freese, P., (1996), Standards for grapevine nursery materials and guidelines for planting. 1996 Unified Symposium, 22 February 1996, Sacramento, CA.

Weckert, M., (2011), Young vine decline in the Riverina: a riddle solved. In: Hacket S and Somers T (Eds) Grapevine management guide 2011–12. Dept. Primary Industries, NSW, pp 16–18, 20.

Wheal, M., Clingeleffer, P., and Sykes, S., (2002), Grapevine rootstocks for Australian conditions. In: McComb JA (Ed) proceedings of the 12th Australasian Plant Breeding Conference, Perth, Western Australia, 15–20 September 2002, pp 161–166.

Whiting, J., (1993), Contrasting attitudes to phylloxera and rootstocks: conclusions from an overseas tour. Aust. NZ Wine Industry Journal 8(3):220–222.

Whiting, J., (1996), Fourth International Symposium on Cool Climate Viticulture and Enology and tour of North America research and extension facilities. Final report to the Grape and Wine Research and Development Corporation. Project No. DAV 96/3.

Whiting, J., (2002), Influence of rootstock on bunch rot. Viticare News 3(10):1-2.

Whiting, J., (2003), Selection of grapevine rootstocks and clones for Greater Victoria. Department of Primary Industries, East Melbourne, Victoria.

Whiting, JR., (2004), Grapevine rootstocks. In: Dry PR and Coombe BG (Eds) Viticulture Volume 1 – Resources 2nd Edition. Winetitles, 2004. pp 167–188.

Wigg, F., (2006), Rootstock review for the Alpine Valleys region, Victoria. Final report to Grape and Wine Research and Development Corporation. Project No. RT 05/03-4.

Williams, LE., (2010), Interaction of rootstock and applied water amounts at various fractions of estimated evapotranspiration (ETc) on productivity of Cabernet Sauvignon. Aust. J. Grape Wine Res. 16(3):434–444.

Zerihun, A., and Treeby, MT., (2002), Biomass distribution and nitrate assimilation in response to N supply for Vitis Vinifera L. cv. Cabernet Sauvignon on five Vitis rootstock genotypes. Aust. J. Grape Wine Res. 8(3):150–156.

Appendix A

GWRDC Rootstock Review —Terms of Reference

Overview:

GWRDC is currently reviewing its investment into rootstock breeding and other associated rootstock research and development (the Review). The Review will summarise relevant literature and document the current state of play and the major gaps in research and development for wine-related viticulture. The Review will be conducted with a view to guiding GWRDC's future investments in this area. GWRDC is seeking recommendations on where the most effective future investments can be made to add value to the considerable body of rootstock-related research and development already in the public and commercial domain. The Review will evaluate the current CSIRO Plant Industry rootstock breeding program, briefly document activities and progress in other international grapevine rootstock breeding programs and provide recommendations to GWRDC on the usefulness to the Australian wine sector of future investments.

Consultation with:

1. a cross-section of industry representatives (nursery operators, growers, consultants, Phylloxera and Grape Industry Board of South Australia [PGIBSA], grower liaison officers, winemakers and marketers—a minimum of 20 selected in consultation with GWRDC), to better understand what industry demand there is for new and existing rootstock varieties in Australia, and what information gaps exist in relation to the use and management of the current suite of rootstocks available both in Australian and overseas.
2. the research community, both domestically and internationally (10 Australian and at least five international representatives), about the current status of active rootstock breeding programs internationally, that focuses particularly on those rootstock breeding programs linked to improving the performance of wine-related outcomes. This should include investigating the timelines from initiation to commercialisation of particular rootstock selections, the resourcing input levels and the commercialisation models used within industry.

Consideration of:

1. viticulture-related rootstock research and development funded by GWRDC and other international research and development partners, including but not limited to Prof. Andrew Walker, UC Davis, CA; Dr Peter Cousins, USDA, Geneva, NY, and Dr Ernst Ruhl, Geisenheim Research Institute, Germany.
2. GWRDC's initiated review—May, P., (1994), Using Grapevine Rootstocks - The Australian Perspective. Grape and Wine Research Corporation, Adelaide.
3. PGIBSA coordinated rootstock forums and the outcomes of the meetings held in Mildura in 2005 and 2008.
4. Dry, N., (2007), Grapevine Rootstocks: Selection and Management for South Australian Vineyards, Lythrum Press in association with Phylloxera and Grape Industry Board of South Australia.

Expectation to:

1. work with GWRDC staff with respect to methodology, external participants and project outputs.

2. conduct one-on-one interviews that will engage the key scientific and industry representatives actively working on in the area of rootstocks within viticulture both in Australia and internationally.

3. review relevant project reports, scientific literature and reviews conducted within the broader viticultural sector (wine, dried and table grape).

4. make recommendations to GWRDC on future research in relation to the management of existing rootstocks and the need/demand for a rootstock breeding program within Australia.

5. identify, prioritise and detail areas for future research in relation to the breeding, evaluation, commercialisation and management of rootstocks in the Australian wine sector.

Deliverable:

A report on the priorities identified by the Australian wine industry representatives and the national and international research representatives that includes:

1. an evaluation on the relevance and significance of the current CSIRO Plant Industry rootstock breeding program in relation to other international grapevine breeding programs.

2. an assessment on the Australian wine sector access to outputs from the current rootstock breeding program.

3. recommendations on the most effective future investment for GWRDC in relation to breeding, evaluation and commercialisation of rootstocks for use in the Australian wine sector (Report).

Appendix B

Guidelines for Industry Interviews and People Interviewed

Guidelines for Industry Interviews

1. Do you currently use rootstocks or see a need for rootstocks? If not, why not?
2. In your vineyard/region what are the reasons you currently require rootstocks? (Phylloxera, nematodes, drought, salinity, vigour management.)
3. Where have you obtained information from to determine what rootstock to use? (Consultants, books, industry journals, field days, internet, Yalumba website, R&D reports, government agencies, soil tests.)
4. What things do you consider when selecting a rootstock and do you rate them high, medium or low importance? (Yield, vigour, berry size, wine quality, longevity, environmental impact, juice pH, grape colour, royalties, compatibility, cost, nursery quality.)
5. Do you think that rootstocks need to be managed differently to ungrafted vines and what sort of things do you do differently? (Nutrition, trellis, canopy management, irrigation, P&D control.)
6. Have the rootstocks used in your vineyard/region changed over the years? Why? (New information, local trials, new issues developed in vineyard, more drought conditions, better material available, winemakers wanted something different.)
7. Thinking about the future, do you think the current rootstocks that are available will be adequate for your future needs? Why? (Climate change, new P&Ds might appear, increasing salinity in region.)
8. What are the shortcomings with the current rootstocks? (Too vigorous, too costly, my site conditions are extreme, not drought tolerant.)
9. What needs to happen to address any shortcomings in current rootstocks? (More basic R&D, more applied R&D, more imports from overseas, better transfer of information we already have, more field demonstrations, case studies, more local breeding.)
10. Can we rely on overseas countries to provide the rootstocks we need? Why?
11. Do you follow what's happening with breeding rootstocks in Australia? Why?
12. What process would you go through that results in you changing rootstocks? (A rootstock fails, identify a need, collect information, consult others, trial different ones on my vineyard, final decision.) What are the most difficult stages?
13. What are the priority areas for the future of rootstocks in Australia?
14. Any other comments on where the Australian industry should be heading in regard to the breeding, use and evaluation of rootstocks?

List of Industry People Interviewed

John Beresford, Mitchelton Wines, Nagambie, Victoria

Malcolm Campbell, Campbells Wines, Rutherglen, Victoria

Jim Campbell-Clause, AHA Viticulture, Western Australia

Brian Currie, Westend Estate, Griffith, New South Wales

Paul Dahlenburg, Treasury Wines, Glenrowan, Victoria

Nick Dry, Yalumba Nursery, Nuriootpa, South Australia

Andy Gordon, KC Vine Nursery, Trentham Cliffs, New South Wales

Paul Greblo, Sandhurst Ridge Wines, Marong, Victoria

Russell Johnstone, Consultant, McLaren Vale, South Australia

Stephen Lowe, Stony Creek Vineyard, Edi Upper, Victoria

Kym Ludvigsen, Fox Hat Vineyard, Ararat, Victoria; Chair, Australian Vine Improvement Association

Geoff McCorkelle, McWilliams Wines, Griffith, New South Wales

Bret McLenn, Brown Brothers Wines, Milawa, Victoria

Jeff Milne, Zilzie Wines, Karadoc, Victoria

John Monteath, Balgownie Estate, Maiden Gully, Victoria

Alan Nankivell, Phylloxera and Grape Industry Board of South Australia

David Oag, Department of Employment, Economic Development and Innovation, Queensland

Stephen Partridge, Agribusiness Research and Management, Busselton, Western Australia

Ken Pollock, Blackjack Wines, Harcourt, Victoria

Liz Riley, Vitibit, Hunter Valley, New South Wales

Nathan Scarlet, Rathbone Wine Group, Port Melbourne, Victoria

Liz Singh, Murray Valley Wine Growers, Mildura, Victoria

Tim Smythe, Riverland Winegrape Growers Association, Loxton, South Australia

Mark Walpole, Aquila Audax Enterprises, Whorouly South

Paul Wright, Vinewright, Mt Pleasant, South Australia, Chairman, Vine Industry Nursery Association

Appendix C

List of Scientists and Others Contacted

Mr Peter Clingeleffer, CSIRO Plant Industry, Adelaide, South Australia

Dr Marissa Collins, CSIRO Plant Industry, Adelaide, South Australia

Dr Peter Cousins, USDA, Geneva, New York, United States of America

Mr Andrew Downs, PGIBSA, Adelaide, South Australia

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Dr Greg Dunn, NWGIC, Wagga Wagga, New South Wales

Prof Jim Hardie, CSU, Wagga Wagga, New South Wales

Dr Markus Keller, Washington State University, Prosser, Western Australia

Dr Michael McCarthy, SARDI, Nuriootpa, South Australia

Dr Nathalie Ollat, INRA, Bordeaux. France

Dr Kevin Powell, DPI Victoria

Prof Dr Ernst Ruhl, Forschungsanstalt Geisenheim, Germany

Dr Brady Smith, CSIRO Plant Industry, Adelaide, South Australia

Dr Rob Stevens, SARDI, Adelaide, South Australia

Dr Mike Trought, Marlborough Wine Research Centre, Blenheim, New Zealand

Prof Andrew Walker, University of California, Davis, California

Dr Rob Walker, CSIRO Plant Industry, Adelaide, South Australia

Scholefield Robinson
HORTICULTURAL SERVICES

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GRAPE AND WINE RESEARCH AND DEVELOPMENT CORPORATION

SUMMARY OF A REVIEW OF GRAPEVINE GERMPLASM COLLECTIONS IN AUSTRALIA

SUMMARY REPORT to

GRAPE AND WINE RESEARCH & DEVELOPMENT CORPORATION

Project Number: **GWR 1112**

Principal Investigator: **PRUE McMICHAEL**

Research Organisation: **SCHOLEFIELD ROBINSON HORTICULTURAL SERVICES PTY LTD**

Date: full report prepared **26 February 2013**, edited **22 July 2013**

GWR 1112
Review of Grapevine Germplasm Collections in Australia

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[1] This summary report is based on the final report prepared by Scholefield Robinson Horticultural Services with detailed confidential material on the collections removed after consultation with the collection custodians and the authors

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ACRONYMS

ACIAR	Australian Centre for International Agricultural Research
AGRF	Australian Genome Research Facility
AHVII	Adelaide Hills Vine Improvement Inc.
APFIP	Australian Pome Fruit Improvement Program
ARM	Agribusiness Research and Management
AVIA	Australian Vine Improvement Association
CDFA	California Department of Food and Agriculture
CEV	Citrus exocortis viroid
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CTV	Citrus tristeza virus
DAFWA	Department of Agriculture and Food, Western Australia
DPI	Department of Primary Industries
DUS	Distinctive, Uniform, Stable (tests for Plant Breeder's Rights)
ELISA	Enzyme-linked immune sorbent assay
EMAI	Elizabeth Macarthur Agricultural Institute
ENTAV	Etablissement National Technique pour l'Amelioration de la viticulture
FPS	Foundation Plant Services (California)
FVF	Fruit Variety Foundation
FSAC	Fragmented shoot apex culture
GFKV	Grapevine fleck virus
GWRDC	Grape and Wine Research and Development Corporation
HAL	Horticulture Australia Limited
IAREC	Irrigated Agriculture Research and Extension Center (USA)
IFV	Institut Français de la Vigne et du Vin (France)
INRA	Institut National de la Recherche Agronomique (France)
Kapunda-AGFPS	Australian Grapevine Foundation Planting Scheme (in Kapunda)
MIAVIS	Murrumbidgee Irrigation Area Vine Improvement Society
NGR	National Grape Registry (USA)
NSW DPI	Department of Primary Industries, New South Wales
PCR	Polymerase chain reaction
PIRSA	Primary Industry and Resources South Australia (Department of Agriculture, South Australia)
PORVID	Associação Portuguesa Para A Diversidade Da Videira (Portugal)
PRC	Plant Research Centre (South Australia)
RSPaV	Rupestris stem-pitting associated virus
RVIC	Riverland Vine Improvement Committee Inc.
SA	South Australia
SARDI	South Australian Research and Development Institute
SAVIC	South Australian Vine Improvement Committee
STBA	Southern Tree Breeding Association
UCD, UC Davis	University of California, Davis
UMT	Unité Mixte Technologique Géno-Vigne (France)
USDA	US Department of Agriculture
VAMVVIA	Victoria and Murray Valley Vine Improvement Association
VI	Vine Improvement
Vic DPI	Department of Primary Industries, Victoria
WA	Western Australia

EXECUTIVE SUMMARY

This report has addressed the four main tasks in the Brief and presents the following findings.

Review the status of existing grapevine collections

The project team has collated all available data in current Australian viticultural germplasm collections. This also involved a review and update of the existing germplasm register (not available for public access)[2]. Through this process, the industry's genetic resources were elucidated.

The register has revealed that Australia holds valuable genetic resources of wine, table and dried grape varieties and clones, heritage and alternative varieties, and rootstocks. The total number of different varieties and clones held within Australia's grapevine collections is estimated at close to 900, with multiple clones of some varieties. The project revealed that there is considerable duplication in collections, variation in naming practices, traceability evidence, identity verification and health status.

Resolution of the following data issues would refine the exact quantum of genetic diversity:

- Capture details of all private imports.
- National agreement on accepted synonyms.
- Removal of duplication of varietal and clonal names.
- Accepted methodology for identity verification.
- Agreed guidelines on evidence of traceability.
- Consistent reporting of imposed treatments, eg. hot water, virus elimination.

Deliver information on 'best practice' management of genetic resources

The review of international grapevine repositories and of other perennial repositories in Australia, has provided perspective on various practices undertaken to maintain germplasm resources. All large grapevine collections in Europe and USA are funded by governments at levels ranging from 40-100%. Strong alliances with research institutions are common.

Income earned is derived from sales of cuttings but also specialist services are offered. On entry to most international germplasm repositories, grapevine identity is verified against a reference. However, it should be noted that there is no international agreement of plant type reference standards for grapevine varieties or an agreed method of determination. Many germplasm collections were actually established before standardised visual verification or cross-referencing procedures existed. The level of health status maintenance in international collections often reflects the purpose of the collection and material released.

The Australian citrus industry has always required full testing for endemic and exotic pathogens in post-entry quarantine. It is the leading example of integrated germplasm management and supply amongst perennial crops in Australia, with its germplasm arboreta; breeding and evaluation collections; foundation, high health repositories; and budwood multiplication scheme.

In Australia, less than 7% of grapevine accessions have had their DNA tested. Few have been referenced against international reference databases, however, as noted above, there is no agreed standard. Ampelographers have historically been used for variety identification.

At present the large CSIRO and SARDI germplasm repositories are closed to industry. Several other collections may be financially unstable and the lack of resilience of collections during

[2] The register is not available publically due to confidentiality agreements with the collection custodians.

periods of low demand for planting material has been highly evident in recent years. Total reliance on the sale of cuttings for collection viability is a serious weakness in Australian grapevine collections. There is no requirement for vineyards to be established with specified quality material, and therefore the cost of high health material has contributed further to its low demand. High health collections are expensive to maintain. With the exception of Western Australia's on-going commitment to germplasm and vine improvement activities, government funding of repositories and the provision of specialist services, has declined. The WA industry has benefited from their superior biosecurity and ready access to relevant vine material.

Make recommendations on priority collections

The priority purposes of collections have been ranked in this report, with the highest rankings being:

- Industry supply – high health, for industry development.
- Industry supply – for industry development.
- Germplasm repository – biodiversity, research and breeding.

The perceived collection capabilities have also been ranked. The weightings assigned revealed that the AVIA, CSIRO, RVIC and SARDI collections have the capability to provide the priority services to the Australian industry, at present. As noted previously, not all these collections are currently open to the public.

The project team strongly recommends that the register be maintained, investment in germplasm-related R&D is continued, and that national guidelines on naming, health testing and identity verification, be developed. It should be noted that at the time of preparation of the project report, an Australian Standard for grapevine identity determination is being formulated.

The practical options for germplasm collection management in Australia are limited. There is general agreement that government priorities do not support the funding of germplasm collections. The options presented are to:

Option 1. Do nothing,

Option 2. Secure some government funding to support some collections, or

Option 3. Rationalise the number of collections.

The project team recommends Option 3 be pursued, after completion of a risk assessment, development of a Strategic Plan and formation of a Board of Management.

Discuss potential business models

The business of germplasm management is complex. Until some firm directions for the Australian germplasm collections have been formulated in the Strategic Plan that is recommended by the project team, any work on the development of a formal business plan is premature.

Several other industries are managing their genetic resource 'businesses' successfully and they are models for consideration by the grape industry.

The citrus industry germplasm structure and management are the most advanced of the horticultural industries in Australia. The citrus industry now manages arboreta, high health mother stock in screen houses, some breeding and evaluation collections and a multiplication scheme. Their systems ensure all planting material is managed with skilled oversight of protocols and audits.

The forestry industry has the most commercial germplasm improvement system, but they are working with a small number of tree species and superior lines and have a relatively small number of clients, mainly corporates, across Australia.

Options for future funding of collections could include activation of a biosecurity levy, which would require industry agreement; raising a nursery levy, or expanding the levy payer base of the existing nursery pot levy (to include field nurseries). Biosecurity funding needs to be secured with an industry commitment, as industry members are identified as the major beneficiaries.

1 INTRODUCTION

The nature of genetic resources in the form of *in situ* plantings nationally and internationally, is diverse. The nature of formal collections of plant material is usually an indication of the original purpose of collecting the plants and the value perceived in having the plants maintained in a specific location under particular conditions and operating plans.

The project team was asked to conduct a review of Australia's main grapevine collections. The Brief outlined four main tasks:

- Review the status of existing grapevine collections.
- Deliver information on 'best practice' management of genetic resources.
- Make recommendations on priority collections.
- Discuss potential business models.

A revised and expanded register of grapevine germplasm was produced. To update the previous edition of the National Register (Nicholas, 2006), the team has collated confidential information received from public and private collection managers. It has also reviewed available information on other perennial (grape and non-grape) genetic collections in Australia and overseas. The functions and resources of these collections have been considered in identifying options for Australia and recommended approaches for Australia's future management of grapevine genetic material.

2 REVIEW OF COLLECTIONS

Collection curators provided the data that enabled the update of the 2006 National Register (Nicholas, 2006) by the project team. The composition of collections, number of varieties and clones in each collection, their health status and potential traceability has been documented, and the location of unique varieties has been determined. This information was provided on the basis that it would remain confidential, hence the details are not included in this summary.

2.1 Collection summary

2.1.1 Size of collections

Grapevine collections in Australia include government-supported collections that maintain a large number of accessions, mid-sized vine improvement (VI) collections, and smaller private collections. The government-supported collections analysed for this report included those of CSIRO in Sunraysia, Victoria and SARDI in Nuriootpa, South Australia. The Tasmanian collection has been abandoned. Table grape accessions were removed from the Queensland collection in 2009 and the surviving rootstocks and wine grapes have not been actively managed in the last three years. The number of accessions in these government-supported collections range from about 70 to up to almost 1000.

The Kapunda-AGFPS, RVIC, the Victoria and Murray Valley Vine Improvement (VAMVVIA) and the Adelaide Hills Vine Improvement site were the VI-focussed collections analysed by the project team. The number of accessions in these collections ranges from around 10 to up to 450.

The number of accessions in the private collections of ARM, Brown Brothers, Chalmers[3], Viticlone and Yalumba, ranged from around 10 to up to 120.

The total number of different varieties and clones held within Australia's collections at present cannot be precisely determined. Double entries, spelling variation, name changes and synonyms suggest that the total number in the updated register may be overstated.

[3] This collection is no longer maintained at the original Chalmers site, but has been transferred and most entries retained.

2.1.2 Composition of collections

The majority of rootstock, multi-use and table grape accessions are held within the larger collections. Table grape material is concentrated within the CSIRO and SARDI collections. Private and VI collections have traditionally held wine grape and rootstock material. VAMVVIA however also holds some table grape accessions.

The collections collectively include:

- Common clones of major varieties.
- Old varieties of R&D interest or not in demand.
- Little known varieties never commercialised.
- Major varieties from other countries[4].
- Minor and 'alternative' promising varieties - either recent imports, or old material with identified potential for the future.
- Pre-phylloxera material possibly unique to Australia.

2.1.3 Health status

The data on health status assessed by the review team is that provided by curators. No independent validation has been undertaken. Details are not provided here due to the confidential nature of this information.

The extent of virus testing is variable and appears to reflect a collection's age, size and primary purpose. The samples submitted, frequency of testing, and methodology of testing influence the extent to which virus test results may be relied upon as an indicator of a whole collection's health status. Given the nature of viruses present in Australia and the means by which they are spread, it is our opinion that testing within a year is an indicator of the vine's health only in that year. Past test results are however valuable and should be retained. Positive results usually trigger action within a collection (eg removal, isolation), depending on the nature of the collection. Negative results however indicate that the virus is either not present or at a level too low for detection.

Changes in a collection's schedule or extent of virus testing have occurred for many of the collections reviewed. This is due to questionable result reliability as well as current understanding of the economic impact of several viruses on vine production and growth. Interpretation and reliability of results, as well as cost, were noted as concerns by several custodians. There is no requirement for growers to plant high health vineyards and therefore collections with significant virus testing programmes are unlikely to enjoy financial security if the only income stream is the sale of cuttings.

2.1.4 Identification verification

The data on identification verification are those provided by curators. No independent validation has been undertaken, and, as noted above, there are no agreed international plant type reference standards.

No collection has a specific commitment to the verification of identification (trueness-to-type) of all its entries. This reflects the availability of technology at the time many collections were established. Prior to the development and accessibility of DNA technology, importers and custodians relied heavily on the word of their suppliers. Objective DNA testing is replacing expert, ampelographic examination of collections. The shortage of qualified ampelographers is such that none is employed for 'mass' verifications, but they are often utilised when a specific

[4] Old varieties of unknown identity or value are within the large public collections. Some have their origin listed as old vineyards

varietal identity is in question. Yalumba's ENTAV material is still inspected every second year, by the French ampelographer, Laurent Audeguin.

There are no requirements for DNA identity validation for material held in Australian collections, nor guidelines on what may constitute type reference material. Commercial facilities for DNA identification are the IFV, UMT Geno Vigne (in Montpellier) and the Australian Genome Research Facility (AGRF). The Europeans utilise the European *Vitis* database, a common reference point for DNA identification of some varieties. This is the most referenced database available, but as noted above, there is not international agreement that this is the definitive collection for plant type reference standards.

The collections reporting DNA identification in this review have either used the French database or a combination of the French and the Australian databases. The AGRF profile database developed by CSIRO is the basis of the Australian commercial DNA testing service, offered by AGRF.

Less than 7% of grapevine accessions in Australian collections have been verified by DNA testing. CSIRO has DNA profiled many varieties from the old CSIRO collection, but they are yet to be referenced against an agreed international variety type reference database. In collaboration with WA, a DNA-based verification project was undertaken on SARDI and WA material (Tassie *et al.*, 2012). The Kapunda-AGFPS and RVIC collections have a long term plan to verify the identity of all entries and they have utilised AGRF and IFV services.

Despite the difficulty in definitive identification, it appears there are about 900 different varieties and clones held within collection in Australia.

2.1.5 Unique material in collections

A unique accession is defined as a single variety and/or clone contained within only one collection in Australia[5]. Of the approximately 900 different varieties and clones within the collections, 470 are unique. Most of the collections contain at least one unique accession. The largest and oldest collections (CSIRO and SARDI) house the majority of the material identified as unique; about 75% of the unique varieties are held at CSIRO. Of these, 60% are wine grapes and about 25% are table grape accessions.

The limitations of the database for the detection of unique material need to be noted. Incorrect spelling and synonym use may result in classification of the material as unique, eg Peverella and Verdiccio Bianco are potentially synonyms, as are Trincadeira and Tinta Amarella. Clonal naming is inconsistent and the addition/omission of prefixes and suffixes has potentially resulted in the incorrect determination of some material as unique.

2.1.6 Access to material in collections

Australia's two largest collections, CSIRO and SARDI, are closed to the industry at present. This amounts to approximately 50% of germplasm and accessions, and more significantly, up to 80% of unique material being unavailable to industry. Prior to complete closure, clients/applicants could access material from these collections after virus testing had been completed. This was undertaken on the basis of full recovery of the costs of virus testing and packaging and handling. CSIRO also licensed its DNA typing technology to service providers, which was available on request.

There is an increasing local and international interest in a range of material:

- Heritage.

[5] This terminology does not infer that the variety or clone is globally unique.

- Australia's old Riesling and Shiraz clones (by France and Germany – to increase clonal diversity).
- Alternative varieties.
- Varieties bred for drought tolerance to address climate change.

Over the last twenty years, there has been a steady increase of sales of 'alternatives'. The supply of public alternative varieties to nurseries and VI groups (for multiplication) has been affected by the closure of the large collections.

To address shortages, and gain some time advantage, 'private' importers have brought in alternative varieties in recent years. Chalmers, ARM, RVIC and Kapunda-AGFPS have been active importers of interesting proprietary material, but access to it once in their collections, is restricted. The Adelaide Hills Vine Improvement (AHVII) group and private vineyards have collaborated to import new clones, bulk them up and evaluate them in trials on a range of sites.

2.2 Current status and observations of collections

The review of specific collection data has resulted in the revised register of inventory. In addition, some observations have been made and noted below. A questionnaire on management practices and resources in the collections sought a broader view of local activities.

Of the original six governments' state and national collections, Tasmania has been abandoned, Queensland has been mothballed, and two are closed to industry. The trend for collections is a reduction of government involvement.

- It appears that the sustainability of Australia's vine improvement collections is tied to the demand for cuttings, as few have other income streams. VAMVVIA and AVIA are VI plantings on government land (planted in the early 2000s) and AVIA's long term viability is uncertain.
- Partnerships of government and VI groups and/or some private groups have increased in response to financial difficulties. Some remain cost effective.
- Common varieties and clones occupy too many collections.
- High health collections that are too large and house material not in current demand are very expensive to maintain. AVIA, Kapunda-AGFPS and VAMMVIA were reportedly established as high health nuclear collections, but may not be able to be maintained as such.
- Industry has historically not been the driver of collection establishment. The on-going support of industry is needed, but not assured with the current pricing structures for high health material.
- Leadership in germplasm advancement and maintenance has been fragmented in the last 10 years. Progressive private importers and several VI groups are the current leaders, but large collections with government involvement remain the main resource.
- Naming practices have resulted in the loss of traceability for some material and confusion with registered clonal names.
- A national approach to clonal naming and registration is needed.
- Label integrity requirements are expected to increase evidence requirements for traceability.
- National guidelines are needed for vine health testing, traceability and identification verification, and clonal registration.

- Australia has no native, or 'autochthonous' *V. vinifera* and is dependent on international sources for genetic resources. Australia cannot assume it will always be granted access to this material.
- A national body that serves as the agent importing on the Australian industry's behalf, may increase our access to some European material.
- Alternative varieties are of increasing interest and may remain by default in the private import arena, if SARDI and CSIRO are not re-opened to industry.
- International interest has been expressed in our heritage varieties.
- Biodiversity increase and conservation, is the driver behind some international interest in Australia's older material.

3 REVISED REGISTER

3.1 The database

The primary output of this project was to review and update the existing 2006 National Register (Nicholas, 2006). The process revealed new material, material lost from collections, missing entries of older material and name changes. It is the author's view that this is the most current record of germplasm inventory in Australia and is a valuable resource to industry that should be maintained.

The updated register[6] (not available for public access) has confirmed that Australia holds valuable genetic resources of wine, table and dried grape varieties and clones, heritage and alternative varieties, and rootstocks. The total number of different varieties and clones held within Australia's grapevine collections is estimated at close to 900, with multiple clones of some varieties. About half of this material is present in more than one collection: there is in built redundancy.

The database extends beyond varietal, clone and accession details, and also includes product identify, origin, location, end-use and health status.

3.2 Knowledge gaps and data limitations

The updated register reflects current information, however, there is variation in naming practices, traceability evidence, identity verification and health status.

Resolution of the following data issues would refine the exact quantum of genetic diversity:

- Capture details of all private imports.
- Naming guidelines
- National agreement on accepted synonyms.
- Removal of duplication of varietal and clonal names.
- Accepted methodology for identity verification.
- Agreed guidelines on evidence of traceability.
- Consistent reporting of imposed treatments, eg. hot water, virus elimination.

[6] The register is not available publically due to confidentiality agreements with the collection custodians.

4 LOCAL GRAPE GERMPLASM MANAGEMENT AND RESOURCES

Australia has grapevine collections established with different original purposes. Each is maintained by different practices, with differing levels of financial support. Historically, resources supporting germplasm activities have been significant in ensuring on-going industry development. The scope of the review did not extend to the details of the operation or management status of any current collection, but it is evident that today's resources are limited and for several collections, insufficient to ensure on-going viability.

4.1 Background - establishment of collections

The grapevine germplasm collections in Australia were established through three resource bases. The early collections were established by governments recognising the public good in maintaining germplasm. State and Commonwealth governments were active in establishing such resources in the 1960s and 1970s. Other collections were established as integral components of VI organisation activities. They were generally planted in the 1970s and are of variable size. The third basis of current 'collections', is that of private interest and benefit. Individuals and some wineries have seen an opportunity for investment and the potential to gain advantage from importing and housing a small number of specific selections.

Table 1 shows the original basis of a collection's establishment which also reflects the primary funders of each. It is noted that seven of the 16 collections investigated in this review were initially resourced by governments. VI organisations initiated 4 of the 16 collections. VAMVVIA evolved from the Victorian government collection under funding pressure. The remaining 5 collections were established with private funding. The RVIC collection is currently resourced through accumulated funds from its VI activities together with entrepreneurial projects designed to keep each operation solvent.

Table 1 : Collection establishment and original funding

Collection	Code	Government	Vine Improvement	Private
AVIA	A			
AHVII	AH			
WA, ARM	Ar			
Browns	BB			
CSIRO	C			
Chalmers	Ch			
Kapunda	K			
NSW	N			
Queensland	Q			
RVIC	R			
SARDI	S			
Tas	T			
VAMVVIA	V			
Viticlone	Vs			
WA	W			
Yalumba	Y			

KEY			
	National	National	Private entities
	State	Regional	
	Funding pressure	Mothballed	Destroyed

4.1.1 Changes in collection resourcing

Government

In the late 1980s, financial pressures on governments initiated broad review of funding needs and priorities in all forms of agriculture, and horticulture in particular. The pressure on horticulture and germplasm collections has not ceased and some collections have been closed; others have changed to new funding arrangements. As shown in Table 1, the Tasmanian collection is now closed and the Queensland collection has been "mothballed". The Queensland table grape entries have been removed and the number of accessions remaining has been reduced.

The insecurity of funding for the Victorian collection was relieved through a partnership with the VAMVVIA. The VAMVVIA plantings occupy NSW government land at Dareton, but the commercial operation is that of the vine improvement organisation. The MIAVIS collection at Griffith (not reviewed) is a collection established from mother vines in the NSW government site.

Changes in resourcing have affected germplasm collections. In Victoria and South Australia, over a period of 25 years the Full Time Equivalent (FTE) resources have decreased from about 25 FTEs in 1986 to between 4 and 5 in 2011. The current FTE level is 3.5. In 1986, the two relevant state Departments of Agriculture and the CSIRO were driving forces for all vine improvement activities. Their activities were focussed on maintenance of germplasm collections, clonal and rootstock importation, viticultural comparative trials, vine breeding and vine health, especially virology.

Since 1986, the Northfield facilities that supported these activities have closed although the Plant Research Centre (PRC) in Adelaide was initially intended as its replacement. Today, neither the PRC nor the Loxton Research Centre, has permanent staff formally assisting germplasm maintenance. The Victorian DPI no longer supports vine improvement activities.

The situation is similar in Tasmania and Queensland, with the state Departments of Agriculture withdrawing all funding for state vine collections. The Western Australian government is the exception. It has continued to support the maintenance of germplasm and vine improvement activity, and in so-doing WA has established itself as a state with superior biosecurity and ready access to vine material of relevance to their industry. In part, WA's particular quarantine restrictions (based initially in downy mildew absence to 1998), have underpinned the commitment of such resources to ensure WA nurseries and growers are not disadvantaged by having no access or delayed access, to material imported through another state. As in other states, private groups like ARM have seen the maintenance of their own collection as a commercial opportunity and benefit.

The CSIRO station at Merbein was supported by the Australian government. It has been closed and CSIRO's significant collection of germplasm has been replanted at CSIRO's Sunraysia site, Victoria. Although funding is still provided, the human resources to support germplasm maintenance and research in related areas, has been reduced.

Vine Improvement

The formation of the AVIA in 1988 followed the success of the South Australian Vine Improvement Committee (SAVIC) which was initiated in 1985. SAVIC was an initiative of the SA Department of Agriculture and chairpersons of the six existing regional vine improvement committees. The funding was achieved through levies on cuttings. AVIA was established with the same model, with the chairs of the state vine improvement organisations representing their members. At the time, state bodies and AVIA benefitted from the considerable support of volunteers, the state departments and CSIRO. While the volunteer ethos continues, supporting resources and income streams are too limited to sustain most bodies through any prolonged planting downturn. The downturn since early 2000 has curbed expenditure on management and development activities and some collections have not been maintained to the level, or kept as relevant, as many desire. Several bodies are not financially viable. The RVIC collection however has addressed the problems more strategically, and remains a dynamic collection that has recently expanded. It has added an income stream by establishing a nursery.

Private funding

In this report on current collections and their future, private collections must be acknowledged despite them not serving as assured resources for industry at-large. Private imports account now for 98% of wine grape entries to Australia, and this is likely to be the same for table grape accessions. Of concern, has been the industry's failure to engage and corral private importers into a national system that accommodates inventory data from all sources, and under agreed industry guidelines that protect privacy, but allow relevant inventory details to be shared.

The essentially private funding and management of collections like those at Yalumba and ARM, demonstrate that proactive importation and responsiveness to industry are worthwhile commercially and apparently viable financially. Neither group functions in isolation. Each has the technical and financial support of a larger organisation underpinning its activities.

4.2 Resources and operations

Australia's current grapevine collections have variable levels of commercial utility. The demand for grapevine material from collections directly affects the maintenance practices and specific testing conducted on the collection entries. At present low demand for material, financial insecurity and/or restrictions on access, are compromising the management of most collections.

4.2.1 Summary of practices and management

- The reported approximate costs of grape collection management ranged from $18,000 to $160,000. It is presumed the latter cost estimate included costs of cutting propagation material which is a commercial, rather than maintenance operation.
- The purpose of the majority of open collections is germplasm maintenance, with some also identifying biodiversity/heritage relevance. 'Industry supply' is the primary purpose of the VI collections with 'high health' also considered important.
- The collections can normally be accessed by public, industry nurseries, growers, corporate and private clients, however the larger collections (CSIRO and SARDI) are at present not accessible to the industry. CSIRO researchers may access CSIRO material.
- Of the collection curators that responded, none reported it was fully meeting the expectations of the intended users, i.e. nurseries and growers.
- The main drivers of success for each collection are similar. All agreed that funding security, industry support, and international recognition would increase their success.
- Insecure funding was the most frequently identified limitation on collection success.
- The supply of cuttings is the only identified source of income noted for collections, but AVIA also acknowledged the voluntary levy paid by VI associations.
- Conditions of entry to collections reflect the primary purpose of the collection.
- Some collections have reported utilising DNA-based verification on some material. All collections have used ampelography at times, especially at time of initial entry. CSIRO profiled a cross section of accessions in their collection to create an initial DNA profiling database. It has not yet been verified against type reference standards because there is no international agreement on what collections hold plant type reference standards for grapevine varieties from which DNA could be obtained for comparative verification purposes.
- Collections generally have accepted material with detectable Grapevine fleck virus (GFKV) and Rupestris stem-pitting associated virus (RSPaV). Such material has not been isolated within any collection.
- Traceability appears to extend to the maintenance of the supplier number, not necessarily the accession number. Individual paper and/or electronic registers exist for most collections.

- Pathogen testing after collection entry is inconsistently undertaken by collections.
- Loss of traceability and identity doubts are given as reasons for vine removal from some collections. Lack of demand for material and duplication of entries do not necessarily result in removal from any collection, which suggests internal collection rationalisation is not occurring.
- Risk management to-date has been achieved through partial or total (AVIA, VAMVIA) duplication of the collections. All collections are planted on 'own roots' so as not to mask pathogens or pests such as phylloxera.
- Collections have different capacities to respond to risk exposure associated with change. Costs rather than expertise limited their capacity in this area.
- Proprietary material is protected in practice (restricted access, coded labels etc.) or legally through the plant breeder's rights (PBR), when included in collections.

5 GERMPLASM MANAGEMENT IN OTHER PERENNIAL HORTICULTURE COLLECTIONS

Task 2 of this project's Brief required a review of several international grape collections and local collections of other (non-grape) perennial, horticultural plant material. Managers of international grape collections and local citrus, almond and grape collections were asked to complete a questionnaire on their management and operational activities and resources.

'Best practices' associated with germplasm collections are neither universally similar nor universally relevant. The best practices appropriate for any collection are those that maximise the potential of the collection to achieve its purpose and to minimise its risk factors. It has been possible to gauge through discussions and questionnaire responses, details of collection purpose, funding and management, if expectations are being met and the relative capacities in addressing challenges in the climate of change. The practices and parameters that underlie the operations of several different collections locally and internationally are discussed below.

5.1 Australia – perennial horticulture collections

Most collections have been established for the purpose of maintaining genetic material in a location that is deemed suitable for the plants' normal growth and maintenance. It is apparent that most of the larger genetic collections in Australia were at one time, located and maintained by governments or institutions that had a relevant research mission and/or industry responsibility.

Specific information on the Australian citrus and almond germplasm collections was provided by Graeme Sanderson, Pat Barkley and Ben Brown. These industry experts have working knowledge of their industry's germplasm collections. Information from the pome and forestry industries was provided through discussions with Garry Langford, Dr. David Boomsma and Peter Cunningham.

5.1.1 Primary function of collections

The main purpose/s and funders of several local perennial plant collections is shown in Table 2.

The primary function and expectations of collections vary. Elite, nuclear or 'high health' collections usually include foundation material (or material with traceability to foundation material) and plants tested routinely for the presence of pathogens. Entries in 'high health' collections are expected to have a known health status (in the year they are tested). The operating costs of these collections are high, and therefore their composition is usually limited to small quantities of in-demand (or promising) material.

Table 2 : Primary function identified - local collections

Commodity	Primary functions	Funding
Grapes	Germplasm repository	Government
	High health elite	Industry – grape grower levies and sales levy
	Supply for industry	Industry - sales of cuttings
Citrus	Germplasm repositories at Auscitrus (Dareton) and EMAI (NSW-DPI, Menangle) + services (health and horticultural testing)	Australian government and Industry (grower levies)
	Arboreta at Dareton and DAFF-Qld Bundaberg	NSW and Qld governments
	Budwood and seed, multiplication	Industry (Auscitrus) - sale of budwood, seed
Almonds	Scion germplasm repository - defined health status	Government + industry – (grower levies)
	Budwood; multiplication	Industry – sale of budwood
Pome Fruit	Germplasm improvement; restricted supply	Government, industry and private
Forestry	Germplasm improvement – breeding and conservation	Industry

5.1.2 Management factors in local perennial collections (other than grapes)

The questionnaire responses of other local perennial germplasm managers are summarised below.

- The majority of other (non-grape) perennial collections are funded by industry funds and government contributions through matched industry levy funds, research grants and in-kind support (land, labour).
- The main drivers of success in the local almond, citrus and pome germplasm schemes/collections were identified as matched funding (from Horticulture Australia Limited – HAL) and industry support through levies and purchase of material.
- Most collection managers suggested government (Australian and/or state) funds were essential to the collection's viability and cost effectiveness.
- The industry demand for planting material influences collection viability because supply of budwood is the only income stream for most. The Dareton citrus arboretum has no identified income stream.
- The limitations on collections were identified as funding (citrus and almond), space (citrus arboretum), and technology to underpin desired collection entry criteria (almonds).
- Conditions of entry to collections reflect the primary purpose of each collection. The citrus germplasm repository requires a defined health status, but the arboretum does not. Almond material may enter the collection if free of exotic pathogens and four endemic viruses.
- Post-entry pathogen testing reflects the primary purpose of the collection, but the testing levels in high health collections have been compromised by the funds available. The almond repository requires 50% of trees to be tested annually for four endemic viruses. The citrus arboretum trees are not tested, but low health trees (visually assessed) are removed. The citrus germplasm collection is tested annually for citrus tristeza virus (CTV) and every three years for specific viroids.
- Each germplasm collection has listed pathogens that trigger removal from a collection if detected.

- Lack of demand for material or duplication of entries does not necessarily result in automatic removal from any collection.
- Risk management to-date in local collections has been achieved through partial duplication of the collection at another location. Proprietary material has been protected generally through restricted access and non-propagation agreements but the citrus industry through Auscitrus, has legal agreements with variety managers that provide greater protection.
- The managers of collections have not clearly identified their perceived risk exposure to changing conditions – regulations, demand for material, disease pressure, climate change, heritage or biodiversity protection, staffing changes. Most collections that carry out health testing believe 'disease pressure' is a manageable risk, but the capacity to respond quickly to exotic or difficult endemic citrus diseases, is noted as 'weak' by arboretum personnel.
- Germplasm collections usually accept visual identity verification but the citrus germplasm repository and pome fruit collection requires confirmed identity (but not through molecular testing) and traceability. The almond repository does not require identity verification but identity doubts may result in removal from the collection.
- Managers of the local citrus, almond and pome collections responded that their collections were meeting expectations of owners and users.

5.1.3 Australian Citrus collections

The Australian citrus industry (through Auscitrus) maintains plant material collections with different purposes – two high health repositories maintained in screenhouses, germplasm conservation sites as arboreta, and sites for horticultural evaluation and budwood and seed multiplication. Auscitrus produces material available to all growers (public scion varieties and rootstock seed) and proprietary line owners, under legal agreement. Private varieties are however held separately to public varieties and are maintained on a cost recovery basis.

The citrus industry believes there should only be one source of high health status (foundation) budwood in Australia (Auscitrus). It manages risk by having two sites where such material is located. The citrus collections are an integral component in a system intended to maintain across industry at all levels, agreed standards for planting material health and horticultural performance. The scheme is maintained with funding contributed by industry (through grower levy funds) and the Australian government (through HAL).

The citrus industry is unique in requiring full testing of commercial and ornamental citrus relatives for endemic and exotic pathogens while in post-entry quarantine (PEQ). The use of a range of biological indicators in PEQ enables the detection of a large complement of graft-transmissible pathogens. The released material therefore has a known health status and is eligible for entry to specific industry collections – foundation repository and budwood scheme. Locally-selected material is tested for graft-transmissible citrus pathogens and undergoes shoot tip grafting *in vitro* before a mother tree is placed in a repository. The testing costs are borne by the importers, but the beneficiaries are the citrus industry members and nurseries, collectively.

Foundation trees are maintained in insect proof screenhouses. They are the "insurance policy" for the citrus industry. Should there be an outbreak of an exotic disease, these would be the source of budwood for the establishment of new budwood multiplication trees. One tree of each variety is held in two locations for 'insurance' purposes. The repositories at Dareton and EMAI include 162 'virus free' clones, some of which are proprietary material. The virus free repository at EMAI fills two screenhouses and fruit from all trees is photographed, with images stored in a database. The repository of more than 80 CTV pre-immunised clones at EMAI is within a controlled environment greenhouse. Dareton houses the larger mother tree repository in an insect-proof screenhouse. The associated nurseries at the two locations are NIASA accredited and the Citrus Pathology and Soil Health technical teams that provide technical and scientific support to Auscitrus for pathogen testing, are ISO 9001:2008 certified.

No DNA testing is undertaken to ensure the validity of varietal names, but annual inspections occur to ensure "trueness to type" and the absence of bud sports. On-going health testing is specifically planned to minimise risk of an undetected infection or contamination through mechanical transmission (eg of viroids) or entry of aphids (eg CTV) and therefore the implemented scientific methodology and testing frequency reflect the identified risk. Since 2010 all viroid re-testing has been undertaken using molecular techniques. High health and pre-immunised repository trees are tested every three years for citrus exocortis viroid (CEV) infection using biological (woody) indexing. Every tree in the high health repositories is tested annually using serological techniques, for CTV – its presence in pre-immunized and its absence in virus-free clones. In the multiplication phase there is recognition that some rootstocks may mask symptoms of citrus tatterleaf virus and therefore some trees on specific rootstocks are tested.

The annual cost of managing the high health repositories at Dareton and EMAI, including annual pathogen indexing of repository trees is approximately $55,000. It is funded through matched industry contributions and secured in 5-year periods through HAL. The project addresses in part, industry protection against its most serious threat, being incursion by an exotic pathogen, eg huanglongbing, citrus canker. The citrus industry has recognised that further action is also needed to minimise the threat, and mandatory certification and nursery registration schemes have been identified as necessary biosecurity actions.

The citrus arboretum at Dareton is one of two industry arboreta. It occupies two hectares with two trees per species/variety on different rootstocks. Its purpose is germplasm conservation. It is a resource of historical significance. Although the trees are visually examined for obvious virus/viroid symptoms and general health status of the source tree, arboretum trees (and therefore budwood) do not have their health status specifically maintained or tested and therefore no budwood from the arboretum is made available to citrus growers, groups or private individuals.

The survival of this arboretum has largely been the result of local interest and the long-term commitment of the present research officer, and his predecessors at the original arboreta sites. Its future may become more secure if it is agreed to be a suitable site for establishment of mother trees for promising citrus rootstocks obtained from China and Vietnam (under an ACIAR project).

Records are incomplete but those that exist include accession numbers supplied from NSW DPI and CSIRO, PEQ and the old Fruit Variety Foundation (FVF) databases. A card system held at Dareton holds early collection records, varietal names and the date and source of the material in the collection. An old database provides information on source, propagation records etc. Some past records of locally selected variants include only the date and location of where the collection occurred. More recent information is held in Excel spreadsheets and field plans.

Although not the subject of this report, it is interesting to note the citrus industry's activity in multiplication and evaluation. The evaluation of newly imported or locally-selected varieties and clones, is undertaken at Dareton under HAL grower levy funding. The Auscitrus self-funded multiplication of scion varieties as budwood and rootstock seed occurs at two sites. Some rapid nursery multiplication is undertaken by Auscitrus, for newly imported varieties (mostly private) and for public varieties in short supply. Trees are inspected annually by NSW DPI and routinely indexed. The scheme has been operating since 1924 and while NSW DPI has supported it over a long period, it is now operated and owned by Auscitrus.

5.1.4 Australian Almond collection – Monash SA

The most important resource of Australia's almond industry is its germplasm repository and multiplication block at Monash, a property owned and managed by RVIC. A private mother block established with budwood cuttings from Monash (not foundation material), in a cooler, isolated area of central Victoria, has been important at times of high demand, and in 2012 as a

virus-tested alternative source of budwood. A detailed description of the almond repositories is included in McMichael and Barkley (2008).

The almond industry scheme is funded as a 'research' program and it therefore legitimately attracts both industry and government funds. Site management by the Industry Development Officer is funded by HAL as is pathogen testing, but labour (eg budwood cutting) is a commercial operation and at present is unfunded. It is the manager's view that the scheme would become unviable if government funding was removed, unless high volume sales of budwood returned reliably. The annual estimated cost of managing the almond scheme at Monash is given as $40,000. It is unlikely this includes virus testing costs that are a component of the breeding project with University of Adelaide.

The primary aim of the Monash repository is to procure, secure and maintain pathogen-tested public clones of industry-relevant propagation material and to make them available on a basis equitable and advantageous to the national industry. In times of low demand for planting material, the scheme is financially stressed as the operating costs and required maintenance do not decline commensurately. The sale of budwood is the only source of income.

The almond scheme does not include a protected foundation collection, although first generation trees are included within the collection at Monash. The inclusion of imported proprietary clones, other than for breeding purposes, is limited. The collection does not provide a service of horticultural evaluation but regional trials are being initiated by the industry. Collection entries may be rejected on the basis of health status (exotics, four endemic viruses). Similarly, annual testing results of 50% of the collection (as single tree samples) may result in removal from the collection. Identity confirmation is not formally undertaken (DNA) and relies largely on trust in the supplier/exporter.

Almond rootstocks are propagated from seed (local and imported) or cuttings and the rootstock supply to industry is largely outside the almond germplasm scheme and industry control. As a result almond trees in the past have not qualified for certification, especially as it relates to graft-transmissible organisms. Industry is therefore at risk and their scheme is compromised if 'dirty' rootstocks are used.

5.1.5 Australian Pome fruit scheme

The Australian Pome Fruit Improvement Program (APFIP) accommodates and encourages the submission of public- and privately-imported clones that are in the interests of national industry development. The scheme's focus is fruit *improvement* (through attainment of high health status) of a small number (approximately 30) of promising and in-demand cultivars, rather than general maintenance of germplasm or industry supply.

In Tasmania APFIP operates a repository for its certified rootstocks and budwood. The scheme can accommodate privately-imported planting material but there is no obligation for importers to utilise the services of the APFIP repository. The scheme aims to be self-supporting by 2015 with income received from industry through royalty payments on APFIP trademarked material.

The approximate operating cost of the pome fruit improvement scheme is $120,000 annually and funding is received from the government, industry and commercial sources in approximately equal proportions. 'Approved users' of clean cultivars undertake formal evaluation of material according to set guidelines. The data are entered, collated and reported to industry. More information on APFIP material is available at: www.apfip.com.au. See HAL final report AF10000 for more information on APFIP certification and evaluation of pome fruit in Australia.

There is also an example of a privately-owned collection of 850 heritage pome varieties in Tasmania. For more information see http://www.oak.org.au/our-businesses/grove-heritage-nursery/.

5.1.6 Forestry improvement scheme

Two organisations based in Mt Gambier, SA, provide plant *improvement* services to the Australian and NZ forestry industries. The National Genetic Resource Centre manages breeding and conservation of genetic material. The Southern Tree Breeding Association (STBA) was formed in 1983 and consolidated the genetic resources developed by private companies, state and federal governments, resulting in more cost effective breeding and improvement programs. Improved growth rates and superior wood quality are the targets of the improvement program.

STBA manages the improvement programs for Radiata pine (750,000ha) and Blue Gum (450,000ha), the major plantation forestry species in Australia. The STBA also manages evaluation trials across Australia. Their system of genetic evaluation (TREEPLAN®) identifies elite material for mass propagation and release of "mother" material to member companies and Seed Energy Pty Ltd. (Seed Energy). Non-members may also access material subject to payment of royalties to industry. TREEPLAN® is an integrated solution to managing data, and informing industry on breeding values relevant to improved profitability.

Seed Energy was established in 2001 when acquired from STBA. It manages seed orchards to produce commercial quantities of genetically-superior seed for plantation forestry. It is licensed to produce seed from the STBA genetic material, especially Radiata pine, Blue Gum, Shining Gum, Maritime Pine and Dunn's Whit Gum. Seed Energy is committed to sustainable production forestry and more information on its key clients is available from their website at www.seedenergy.com, or from STBA at www.stba.com.au.

5.1.7 Avocado industry plant health scheme

In some other industries, risk management has focussed on curbing the *distribution* of major pathogen threats, rather than maintaining a high health germplasm collection. The avocado industry for example recognises the threat associated with the distribution of trees with avocado sunblotch viroid or roots infected by *Phytophthora* sp. Through third party inspections of nurseries, and tree testing, nurseries earn accreditation and the right to sell 'certified' trees "*free of Phytophthora root rot* and *avocado sunblotch*". The certification in this case is very specific and provides no guarantee of horticultural performance, identity or traceability.

For information on the avocado collection and selections, in California, see http://www.avocadosource.com/Journals/AUSNZ/AUSNZ_2005/WitneyGuy2005.pdf

5.2 International grapevine collections and schemes

Several researchers have previously reviewed the features of international horticultural and viticultural germplasm and high health schemes (Whiting, 2012; McMichael and Barkley, 2008; Dry, 2005; Constable and Drew, 2004; Nicholas, 2003). Multiplication, certification and distribution components of international schemes are not the subject of this review but comparison of schemes with these purposes was included in Constable and Drew (2004) and McMichael and Barkley (2008) reports.

Key personnel at the main grape collections in Europe (France, Germany and Portugal) and the United States (Washington State and California) were consulted. Private, international collection owners were not consulted. Questionnaire responses have allowed assessment of the current purpose and nature of several international grapevine repositories and of the management resources and practices that underpin them.

Comparative collection information is discussed below.

5.2.1 Purpose

Collection curators were asked to identify their collection's primary purpose. This information is summarized in Table 3. It is noted that the main European and American collections are one of

several in the country; each may have a different purpose. Other collections of note in Italy and Chile were not investigated in this review.

Table 3: Primary purpose of international grapevine collections

Country	Primary functions	Primary funder
Germany - Siebeldingen	Germplasm	Government
Germany - Geisenheim	Germplasm	Government
France – INRA Montpellier	Germplasm, supply, biodiversity, high health; evaluation	Government
France – IFV Vassal	Germplasm, heritage, biodiversity	Government
United States – Washington State	Germplasm, high health	Government
United States – California UC Davis	Germplasm, high health	Government
Portugal – Dois Portos	Germplasm breeding, R&D	Government
Portugal - PORVID	Biodiversity	Industry

5.2.2 Composition of international grapevine germplasm collections - 2012

The composition of collections gained from questionnaire responses and direct contact with some collection managers, is tabulated below.

The size of collections as indicated by the number of accessions range from over 7,500 at Vassal (France), 3,000 table grape, wine grape and/or rootstocks at FPS (California) and at Siebeldingen (Germany), to a total of 323 clones under management at the Clean Plant Center-Northwest (for grapes) in Washington state, USA. Respondents reported a range of 5-100% of material within their collections as being 'unique' to their repository, in their country.

GERMANY

These collections are two of the largest in the country. Regional collections exist and also contain other relevant material.

Julius Kühn-Institut, Institut für Rebenzüchtung Geilweilerhof - 76833 Siebeldingen, Germany

Material within main collection	Wine grapes		Rootstocks		Table grapes	
	Varieties	Clones	Varieties	Clones	Varieties	Clones
Total number of accessions[a]	Ca. 2300		Ca. 225		Ca. 850	
Replicates- eg #vines/clone	3		3		3	

[a] Accessions without indication of use = 888.

Hochschule Geisenheim Inst., Von-Lade-Str. 1 Geisenheim, Germany

Material within main collection	Wine grapes		Rootstocks		Table grapes	
	Varieties	Clones	Varieties	Clones	Varieties	Clones
Total number of accessions	Ca. 500	Ca. 1200	Ca. 200	Ca. 40		
Replicates- eg #vines/clone						

PORTUGAL

There are a number of government collections in Portugal, and smaller regional collections. The PORVID collection is a recent development and good example of a productive and efficient public/private partnership.

Portuguese Ampelografic Collection (PRT051) - Quinta de Almoínha, 2565-191 Dois Portos, Portugal

Material within main collection	Wine grapes		Rootstocks		Table grapes	
	Varieties	Clones	Varieties	Clones	Varieties	Clones
Total number of accessions	Ca. 675		Ca. 25			
Replicates-eg #vines/clone	7 plants/ accession					
Secondary collection/s	Regional collections					

* The PORVID 'collection' is more correctly a 'set of populations' under collective management.

For more information, see
http://www.ecpgr.cgiar.org/fileadmin/bioversity/publications/pdfs/1293_Report_of_a_Working_group_on_vitis_.pdf#page=101

Associação Portuguesa Para A Diversidade Da Videira – PORVID –Tapada da ajuda, 1349-017 Lisboa, Portugal

Material within main collection	Wine grapes		Rootstocks		Table grapes	
	Varieties	Clones	Varieties	Clones	Varieties	Clones
Total number of accessions	Ca. 60	15,000*	Ca. 25			
Replicates-eg #vines/clone		5 x 3 = 15 plants				
Secondary collection	Yes	Yes				

* Another 5,000 clones are kept in pots pending field grafting.

UNITED STATES OF AMERICA (USA)

The Clean Plant Center Northwest for Grapes - Washington State University (Washington State), and Foundation Plant Services, University of California, Davis California (UC Davis-FPS), are both public grape collections. UC Davis-FPS, with the University of California Agriculture and Natural Resource, and the National Clonal Germplasm Repository of the USDA Agriculture Research Services, coordinates the National Grape Registry (NGR), a comprehensive and impressive database of germplasm available in the USA (ngr.ucdavis.edu/).

For more information on the National Grape Registry, see
http://ngr.ucdavis.edu/publicnurserylist.cfm?setdisclaimer=yes

Foundation Plant Services One Shields Ave, University of California, Davis CA 95618 USA

The response from UC Davis-FPS was not provided in direct response to the questionnaire, but the details given have been noted. The collection has over 700 varieties of grapes and over 3,000 total clones. A register, categorised by 'end purpose', is not maintained but collection entries include table, wine, and raisin grape scions, rootstocks, and juice and concentrate varieties. Some have multiple uses.

For more information, see http://nationalcleanplantnetwork.org/files/63869.pdf

Clean Plant Center Northwest for Grapes - Washington State University – IAREC, 24106 N Bunn Road, Prosser, Washington 99350 USA

Material within main collection	Wine grapes		Rootstocks		Table grapes	
	Varieties	Clones	Varieties	Clones	Varieties	Clones
Total number of accessions	Ca. 80	Ca. 150	Ca. 10	Ca. 20	Ca. 30	Ca. 30
Replicates-screenhouse	1	1	1	1	1	1
Secondary collection	5	5	5	5	5	5

For more information, see http://wine.wsu.edu/research-extension/nwgfs/info/ and

http://ucanr.edu/sites/NCPNGrapes/Grape_Centers/Prosser/

The **Centre for Viticulture and Small Fruit Research, Florida A&M University** may also have information of value to the industry, but it has not been reviewed in this project.
For more information, see http://ucanr.edu/sites/NCPNGrapes/Grape_Centers/Florida_A-M_University/.

FRANCE

The two main collections in France are the collection at Domaine de Vassal INRA, Montpellier (Vassal) and the collection of Domaine de l'Espiguette IFV (l'Espiguette). Vassal includes internationally-sourced and diverse inter-varietal species, hybrids, rootstocks and *V. vinifera*. L'Espiguette maintains clonal French material (and some foreign cultivars) suitable for propagation. A third tier of repositories in the regions hold specific clonal material, directly relevant to the region.

All French grapevine material is released through, and evaluated by, the Institut Français de la Vigne et du Vin (IFV), previously the Etablissement National Technique pour l'Amelioration de la viticulture (ENTAV). Ten rootstocks service 90% of the wine industry in France.

Domaine de Vassal INRA, Montpellier, France

Material within main collection	Wine grapes		Rootstocks		Table grapes	
	Varieties	Clones	Varieties	Clones	Varieties	Clones
Total number of accessions	Ca. 2,600	Ca. 5,500	Ca. 210	Ca. 480		
Replicates- eg #vines/clone	3					

Plus 60 species of Vitaceae family and 250 accessions

200 *lambrusca V. vinifera* subsp *sylvestris*

400 experimental new varieties, hybrids, rootstocks, breeding lines (populations of segregation)

For more information, see http://www.brg.prd.fr/brg/pages/les_rg_en_france/rgv_vigne_an.php and http://www.ecpgr.cgiar.org/fileadmin/www.ecpgr.cgiar.org/NW_and_WG_UPLOADS/VITIS_2_2012/FRANCE.pdf

Domaine de l'Espiguette IFV, France

Material within main collection	Wine grapes		Rootstocks		Table grapes	
	Varieties	Clones	Varieties	Clones	Varieties	Clones
Total number of accessions	Ca. 400	Ca. 3500	Ca. 40	Ca. 200	Ca. 100	Ca. 500
Replicates- eg #vines/clone		10		5		10
Secondary collections	Vassal and/or local collections	Nurseries	Vassal	Nurseries	Vassal and/or local collections	Nurseries

5.3 International collection comparisons

5.3.1 Purpose

All curators reported their collection was meeting the expectations of owners and industry.

The PORVID 'collection' is more correctly a 'set of populations' built from 30+ years of selection and study. This Portuguese scheme collectively manages close to 100 sites that include 50-100 clones of 260 native varieties. There is a current effort to re-locate all material to one site.

In France the two main collections have distinct purpose and utility that differ from, but support, many regional repositories. They are responsible for germplasm maintenance, biodiversity, research and development, high health attainment, and supply to nurseries and smaller collections where multiplication and regional R&D are carried out. UC Davis operates similarly. The Washington State scheme has an additional role as an importer of public and private material, in response to industry requests.

5.3.2 Entry and rejection criteria

Known identity, health status and traceability are collection entry criteria in international collections. The presence of quarantineable pathogens is a rejection criterion in all collections. Other pathogens may be accepted if they do not pose an economic threat (eg PORVID).

Health status does not restrict entry to the Geisenheim and Dois Portos collections. The PORVID collection accepts pathogen presence if it is not expected to cause economic loss. Other collections screen candidate material for viroids, viruses and phytoplasmas. Washington State requires all selections (public and private) to satisfy the Foundation certification requirements. Viroid presence may be accepted but elimination of specific viruses is required to gain entry to the collection. The cost of therapy and treatments to eliminate viruses and screen for diseases is US $3,500 at Washington State. UC Davis-FPS and Washington State accept material that carries grapevine fleck and RSPaV, but the infected material is isolated until a virus free clone is available. Infected plant material in the Dois Portos collection, is not isolated from higher health accessions.

5.3.3 Funding

Collections in Germany (Siebeldingen), France (Vassal) and Portugal (Dois Portos) appear to be entirely government-funded with annual management cost estimates given as AUD 400,000-450,000 (Siebeldingen), AUD 625,000-650,000 (Vassal). The UC Davis-FPS operations are the most costly, at close to AUD1.5m/pa. The l'Espiguette and UC Davis-FPS collections receive 60% and 40% of their funding from government, respectively. The Washington State collection acknowledges 90% of its funding is from the government and 10% from industry. Only l'Espiguette and UC Davis-FPS reported private sources of funding.

Conservation genetic resource collections have historically had the least secure funding. The ampelographic collection in Portugal however has indicated it runs on a very small annual budget (ca AUD 4,000).

Most international collections have an income stream that results from activity at the collection site. The sale of cuttings is the primary income stream reported. The other income earning activities reported by collection curators include diagnostic, identification, and viticultural acceptability screening; proprietary line care; and distinctness, uniformity and stability (DUS) testing to support plant breeders' rights. It is noted that for several collections these 'services' are in fact costs of management. Income may also be derived from royalty payments, research grants. No collection reported that oenological testing was a source of income (or cost), but several undertake such activity.

Washington State, as an importer of industry-requested material, recovers costs on public selections through sales, grants and nursery assessments. Proprietary material may be imported on behalf of individual 'sponsors' with sponsors responsible for all importing and related operational costs.

5.3.4 Health testing, ampelography and traceability - data management

Most international collections are planted on rootstocks, but the US collections are planted on own roots. In the Pacific north-west, 99% of vineyards are planted on own roots but in high pH soils rootstocks are occasionally used to overcome lime chlorosis (Whiting, 2012).

After acceptance into a collection, health testing may cease or be on-going. Post-entry health testing reflects a collection's primary purpose. At UC Davis-FPS, 20% of the collection is tested each year, thereby achieving a whole collection health status check every five years. The practice is similar at l'Espiguette. The range of tests conducted post-entry usually includes regulated viruses, phytoplasmas, strains of leafroll virus and grapevine fleck (in rootstocks). On-going maintenance of material at Washington State is estimated to be USD150/pa/accession.

To ensure correct identity, the USA and European collections utilise internationally-recognised ampelographers. The European database[7] includes ampelographic descriptors, and has EU agreement on microsatellite markers to be used for verification. It needs be reemphasized, however, that there is no international agreement on which collection or collections holds agreed plant type reference standards for grapevine varieties from which DNA could be obtained for variety verification purposes with the agreed number of microsatelite markers. Australia's use of the European Vitis collection is unknown, but recommended.

The basis of naming/re-naming entries and traceability standards are variable. In some collections the original accession numbers and or donor numbers and breeding codes are retained. In others a unique naming system is applied to material on entry, either as a local name or identification number linked into a national database. UC Davis-FPS and Washington State assign a unique identification number which is linked to the National Grape Register. Recent work has linked this to the original name of the imported clone.

Many European countries have a clonal registration system that ensures some continuity in nomenclature, and maintenance of traceability. At Siebeldingen the accession number and donor number are maintained and breeding codes are kept as synonyms. PORVID has a unique naming system that identifies the original vineyard and mother vine. It is linked to a central database that includes information on the origin, region, and all practices/treatments applied to the vine before entry.

5.3.5 Collection limitations and risk management

Most curators identified money as the limiting factor in operations. The financial status of a collection has an impact on all management activities – expansion, health testing, register/data maintenance, technical staff, long-term planning and technology development etc. The limitations of technology are most pronounced in timeliness and management efficiency. Washington State identified that virus elimination, despite significant advancement in practices, in combination with changing regulations on imports, had delayed access to new clones by interested parties (as for shoot tip grafting as practised by some Australian industries).

Space in which to expand was identified as a limiting factor at one Portuguese collection (Dois Portos). Space is expected to be a limitation at Washington State in the future.

Questions about the resilience of collections and their capacity to adapt to changing circumstances revealed risk exposures in those areas not aligned with a collection's primary purpose. PORVID for example, rated its potential to satisfy heritage and biodiversity demands as 'excellent', whereas Washington State rated their capacity in this area as 'poor'. Washington State however is well-prepared to respond to changing disease pressures. Few collections can reasonably predict their adaptation capacity in a changing climate. Collections with income earning potential beyond the sale of cuttings, are more resilient.

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[7] For more information on the European *Vitis* database, see:
http://www.eu-vitis.de/index.php
http://open-pub.iasma.it/bitstream/10449/20980/1/2012%20Vitis%20Maul%20et%20al.pdf
http://www.cabdirect.org/abstracts/20083299039.html;jsessionid=2E23DE5BDFBEE985AFD1BC7BA2D78E9D?gitCommit=4.13.20-5-ga6ad01a
http://cwrsg.org/ECPGR/workgroups/vitis/Vitis1_WEB.pdf#page=173

5.3.6 Scheme drivers

Managers of international collections identified the drivers of success of their collection. All suggested that funding was a key driver (and also a limitation), while most also suggested industry support was essential to their viability. The UC Davis-FPS curator suggests that expansion will underpin their further success while the authority at PORVID in Portugal believes its international reputation (and consequent demand for heritage material) will continue to contribute to its success. Their reputation for high phytosanitary standards has underpinned Washington State's successful scheme and is expected to drive increased usage.

5.3.7 Summary: International grape collections –resources and management factors

- The international collections are primarily multi-purpose, government-supported resources.
- Most international viticultural collections include wine, table grape and multi-purpose scion material, and rootstocks.
- Most collections identify national government ownership. In the USA, state governments are the acknowledged owners (eg California Department of Food and Agriculture (CDFA) but support is also received from the US Department of Agriculture (USDA), and relevant universities (UC Davis, Washington State University).
- In several European countries, including France and Germany, there is more than one government-owned national collection. Most international collections are partially duplicated in another collection within the same country.
- The collection funding received from governments ranges from 40 -100% of operational costs. Estimated management costs per annum for Vassal, Montpellier is between AUD 625,000-650,000, and Siebeldingen and Washington State both estimate their management costs exceed AUD 400,000. The UC Davis-FPS collection costs are cloes to AUD1.5m/annum.
- Internationally, the multi-purpose repositories list the maintenance of genetic resources as the primary purpose. Portugal's PORVID 'collection' is a scheme of collective clone management, rather than a repository.
- The maintenance of heritage cultivars and increasing/conserving biodiversity are purposes increasingly valued.
- Other identified 'purpose': PORVID's stated purpose is evaluation of inter-varietal diversity, and they do not provide material to growers.
- Washington State, FPS, and France's l'Espiguette collection identify their collections as having high health purpose. The Vassal collection in Montpellier and Germany's Siebeldingen collections are important in supporting research.
- Respondents reported a range of 5-100% of material within their collections as being 'unique' (not in another collection within the country).
- The international schemes generally allow broad access to material by nurseries, growers, and public, private and/or corporate entities. The 'private' access is likely to be for owners of proprietary lines of wine grapes, table grapes and/or rootstocks. Access may reflect obligations of government ownership rather than the stated repository 'purpose'.
- Respondents stated their collection was 'meeting the expectations' of government owners and industry users.
- Reported income streams other than contributed funds, are diverse. The collections that sell cuttings also report other income stream/s from services provided. These include: diagnostics, identification, viticultural acceptability screening, nursery evaluation etc.

- Most collection managers identified funding and industry support as the key drivers of their collection's 'success'. The success of the Geisenheim and l'Espiguette collections however was also attributed to legislation. Several collections recognised their success was due to international recognition of the collection as a global resource.
- The limitations of the majority of collections were identified as funding, space and regulations. Regulatory imposts may reflect changing government priorities on entry criteria and/or quarantine requirements.
- The 'number of entries' is a limiting factor in collections that maintain too many cultivars not in demand.
- No collection accepts material with regulated/quarantineable pathogens. Other than this level of assurance, infected planting material may be accepted by collections depending on the collection purpose and the specific pathogen detected.
- Post-entry vine health testing varies with collection purpose. At Geisenheim and Dois Portos, testing occurs only on entry, but high health collections conduct an array of tests, regularly.
- In high health collections, vines are removed on the basis of specific pathogen presence. In other collections, vines are rarely removed on the basis of health status - unless there is an economic consequence of the disease, or it involves an exotic pathogen.
- European schemes rely on the management and technical expertise of highly qualified virologists/plant pathologists, ampelographers, and molecular scientists and are part of a larger organisation Similarly, the UC Davis-FPS and Washington State collections, are strongly linked to university researchers, technology and equipment.
- The practices applied to maintain traceability through identity integrity and records of origin and treatments, are varied but ideally would be uniform within a country.
- The international collections undertake ampelography and DNA testing to confirm trueness-to-type of new entries.
- Most respondents identified 'duplication' as the primary reason for vine removal from collections, but this was qualified by some with perceived heritage and biodiversity value. Loss of traceability and identity doubts were also reasons for removal.
- The collections, other than the two consulted in USA, are planted on rootstocks due mainly to the presence of phylloxera.
- Restriction on access is the main means of protecting private material, although some legal arrangements are also reported.
- Considerable variation exists in the reported capacity of a collection to adapt to/respond to changing situations. Some responses were predictable on the basis of the collection's purpose and composition, with Vassal at Montpellier being most confident in their capacity to sustain or respond to changing regulations, demand, disease pressure, climate change, and to heritage and biodiversity priorities. Washington State predictably rated their capacity in heritage and biodiversity maintenance as 'poor', while PORVID's rating in the same categories, was "excellent".

6 RELEVANCE OF OTHER GERMPLASM SCHEMES TO AUSTRALIAN VITICULTURE

The characteristics of, and influences on, international germplasm collections, warrant consideration by the Australian viticulture industries and those with authority to develop strategies for germplasm research, maintenance and usage that benefits industry.

Australia's main collections cannot at present satisfy industry needs *and* government priorities.

Germplasm repositories require government support.

There is no national coordination of inventory knowledge, management practices, or agreed national standards for testing, health status or identity verification. There is no collaborative resolve that is driving the maintenance of germplasm collections in Australia, to an agreed standard.

High health collections have a different purpose than germplasm collections, and the expected demand for material from each, is different. In practice, and for financial reasons, high health collections need to be smaller and dynamic, maintaining only high health material in-demand (>90% of material demanded[8]). Depending on the resources available, promising alternative varieties (including privately-sponsored imports maintained at full cost recovery) could be accommodated. Successful high health collections should have greater direct use by industry members, than a general germplasm collection.

An informative, formal register/central database of inventory in Australian collections (and all imported material[9]) should be maintained as an industry resource. Entries should adhere to agreed:

- Reporting of private entries.
- Proof of identity and name[10].
- Reporting of imposed treatments - in post-entry quarantine (and health certificate).
- Reporting of treatments on entry to repositories (hot water, virus elimination).
- Registered location of mother vines (potential for an insect proof repository?).

Risk management and collection resilience requires more than simple duplication. Australia cannot rely on any autochthonous varieties as a future resource.

Income streams are too limited for funding Australian grapevine repositories. Services that ensure income in times of industry downturn, need to be offered. Regional, viticultural evaluations could be funded by competitive grants. Central DUS testing (as required by PBR) testing would be welcomed by private importers. Table grapes could derive some income from retail nurseries.

A lack of resilience of several collections during periods of low demand for planting material has been highly visible in Australia. Since 2008, demand for planting material has fallen significantly and no public collection has proven to be self-sustaining, nor sufficiently-funded to allow continued activity at the desired level. Sole reliance on the sale of cuttings (for collection viability) is a serious weakness in Australian vine collections.

Importation by a national body, in response to industry requests and international agency acceptance, is an activity and service Australia has neglected. With efforts to build knowledge of alternative varieties, international agency relationships, and legal protection for proprietary lines, this importing role by a national body, should be resurrected. The potential to create a scheme like that of Washington State exists.

Criteria of entry to collections must be defined. They should reflect the primary purpose of the collection. High health repositories should adhere to agreed testing protocols.

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[8] In 2012, the total of 589,000 cutting sales comprised 48 varieties. In 2010, 90% of the total crush comprised 15 varieties; 80% from eight varieties. In 2002, 20 varieties made up the 590,000 sales. While the interest in and planting of alternative varieties is increasing, they remain a very small percentage of the current vineyard area and crush.

[9] FVF held mother stock of approved virus-tested varieties associated with certain state departments of agriculture until 1991.

[10] Currently new clones may be named in Australia with no frame of reference as to uniqueness or eligibility for clonal (rather than selection), status. The Australian system compares poorly with the European registry system and will continue to suffer inefficiencies due to unnecessary duplication and loss of inventory knowledge.

Technical services are more freely available in Europe, due to proximity, industry structure, funding priorities, and training priorities. The case for a central testing facility for Australian perennial crops is warranted and would allow for the development and more affordable provision of specialist services and technology. Decline in services by most state departments has made this option more viable.

Standards for health status and testing, specifications of wine grape and table grape planting material and labelling are needed. Unlike the citrus industry, viticultural industries have not demanded testing for endemic pathogens in quarantine. Unless further testing before entry to collections is required, there is risk that endemic pathogens will spread within collections and subsequently through the distribution of propagation material.

Access to material and technical services will be critical in the future. There are strong indications that Australia may not have ready access to several overseas collections in the future. The Australian grapevine industry is notably fragmented in its importing efforts. With several European collections limiting their export of heritage material and reluctance to work through individual rather than national bodies, the Australian industry is at risk of having limited access to material at a time when alternative varieties are underpinning most vineyard activity[11].

The response capacity of local collections to an exotic disease outbreak is highly variable. The vulnerability of vine germplasm resources to eradication during an incursion by an exotic pest should not be discounted[12].

Traceback and forward knowledge from nurseries during an incursion would be incomplete in the absence of inventory records, and an up-to-date vineyard registry and nursery registration scheme. Accuracy of the industry data is important for industry biosecurity and for future planning, resource use and market access decisions. At present it is lacking due to the limited ability of the industry to undertake rigorous data gathering under agreed guidelines.

It is essential to have a process, supported by legislation, that ensures the addresses and contact details of those involved in vineyard and nursery industries, are known and accurate.

Australia's inventory of grapevine accessions has not been systematically reviewed – either as a database, or in terms of identity confirmation against European collections. Industry is currently unable to access the main collections due to unconfirmed identity and health status of entries.

7 COMPARISON OF COLLECTIONS WITH RESPECT TO FUTURE PRIORITIES

7.1 Collection types

There are several types of collections that have the potential to serve the different priorities and needs of the various components of the viticulture industry. They are briefly described in Table 4. The features, beneficiaries and ownership of different collections are noted, as are the barriers to meeting their intended industry objectives.

[11] Germany is reluctant to export to a party other than a national body for vine improvement; current restrictions on wine from Australia due to naming, eg Prosecco, Montepulciano varieties; access to ampelographic expertise is limited due to demands on such services within Europe.

[12] The 2005 experiences in Florida with huanglongbing and canker serve as a reminder that healthy perennial sources may be removed in eradication efforts. The challenge for the nursery industry in Florida was to overcome critical shortages of citrus budwood after the loss of two budwood repositories. The extensive Citrus Variety Collection at UC Riverside is at risk as hunaglongbing moves westerly in the USA. CVC has two trees each of more than 1000 different citrus types, and is one of the premier citrus germplasm collections in the world and a valuable university resource. For information on US citrus certification programs and repositories see (from p 26): http://www.citrusresearch.org/wp-content/uploads/CitrographMay-June.pdf

Decisions on the collection types needed for the future must include consideration of risk, inventory knowledge, biosecurity and climate change. To achieve biosecurity Australia needs to have a genetic resource from which material in demand can be readily accessed and multiplied. A source of high health material that is true to type is needed to protect the Australian industry from exotic and endemic graft-transmissible diseases. Only with the availability and use of pest and disease-free nursery stock will biosecurity in nurseries and vineyards be manageable. An industry repository with favoured, promising and clean varieties can best serve this purpose. In the event of a large scale replanting, duplicated resources may be beneficial and these may be in vine improvement or regional plantings.

Germplasm resources are useful to the industry and researchers engaged in breeding and climate change adaptation. Rather than being undefined plantings, germplasm collections are irreplaceable gene banks and are particularly valuable if associated with an up-to-date database. Climate change researchers are evaluating grapevine material for its suitability to warming environments. Researchers have continued access to the large germplasm repositories and are likely to retain this access even if the SARDI and CSIRO repositories do not open up to the industry.

Table 4 : The features of different genetic collection types

Collection type	Main features	Beneficiaries/benefits	Preferable ownership	Barriers to meeting expectations
Germplasm repository General industry access to public material	Library of varieties of unknown health (until released) and often unverified identity, but traceable. Unlikely duplication of content or site. Basis of industry inventory records and knowledge.	Diversity of germplasm – for industry; researchers, breeders. International resource esp. if native material, heritage, biodiversity value established. Research institutions benefit from close proximity to collections. Industry - naming, traceability, maintained. Source of material for international requests.	National – government; or government/industry.	Funds to maintain - size, too many entries; rarely rationalised once established. Limited income potential. Lack of perceived value - by industry or government. Low 'public good' value. Risk of disease spread. Legal implications of material released.
Industry repository Relevant in-demand and promising clones Core, heritage, alternatives Clients - nurseries; VI groups	Dynamic, high percentage relevant and promising clones. High health - optional or obligatory. National importer - on behalf of industry. Potential to isolate incoming material of unknown health. R&D potential - evaluation trials – tolerance, resistance, regional suitability. Income potential – cuttings, R&D, member services – trials, performance records, proprietary line care.	Nurseries and VI groups Industry – through good quality material for nurseries and VI groups Industry - more responsive to industry than germplasm repository. Industry can drive entry and removal - to keep relevant Added value for members. Industry as a whole – a means of engaging private importers.	Industry – membership rewarded with access. Partnerships with government (encouraged).	Funding. Incomplete record keeping. Private importers outside system – imports, naming, record keeping etc. Size - too many clones; high health clones maintained without commensurate demand. Lack of facilities – testing, trials, isolation etc. Private importers with import rights that preclude industry at-large importing, restricted access to international clones of interest.
Scientific resource Addressing R&D	Utilised for R&D - by researchers, breeders eg climate change, disease, drought, salinity, compatibility etc.	Same as for germplasm repository.	Government + institution. Should not duplicate germplasm repository.	Unnecessary cost if overlap with germplasm repository in purpose and composition.
Multi-purpose repository Any combination of the above	Germplasm collection with potential to value-add, house incoming material, utilise collection for R&D; and/or supply nurseries etc.	Industry as a whole.	Partnership- industry and government.	Funds. Loss of relevance; mixed objectives. Record-keeping.
Vine integrity collection	Entries have identity verified by DNA testing (noting current lack of	Industry, researchers, peak marketing bodies (label integrity	Government with support from	Few entries likely to be suitable for

Collection type	Main features	Beneficiaries/benefits	Preferable ownership	Barriers to meeting expectations
Addressing biosecurity, traceability	international agreement on plant type reference standards for grapevine varieties). 1-3 vines confirmed against international reference + complete origin and identity history. Potential storage alternatives, eg *in vitro* collection - cryopreservation.	program managers).	industry (eg marketing components).	entry (30 to-date). *In vitro* storage potentially not sufficiently explored. No established national standards, guidelines. Cost to industry. (if DNA identity required on imports, cost transferred to importer/exporter) Technology important, expensive.
High health repository Addressing biosecurity, industry response	Repository for vines with defined health status – field and/or screen house (mother vines). Virus elimination services Addresses some biosecurity threats. Records of all treatments – linked to database. Adheres to naming protocols.	Nurseries, VI groups doing multiplication. Industry – but at growers cost unless mandated/contracted use of high health clones and endemic and exotic testing in post-entry quarantine. Potential for certification scheme	Industry – with technical support in-kind from eg a national facility for perennial vine /plant testing (proposed).	Funds. Lack of nursery contributions Keeping too many clones in high health state (especially if demand is low). Purchase price doesn't cover testing/treatment costs and grower resistance to pay. Absence of leadership in directing the planting of high health material.
Private repositories	Small, dynamic, relevant. Restricted access to material. Exclusive rights. Legal protection.	Private owners and importers – early adoption benefits Industry – if proprietary line inventory added into central database.	Private- but merit in partnerships – eg other perennials, VI groups.	Costs/risk not shared. Private entries can 'tie-up' agency agreements that deny access for national industry (to import). Hidden inventory – loss of national inventory knowledge.

* The larger the collection, the greater the cost is a constant across all categories

7.2 Comparison of collections with respect to future priorities

The review team have made a subjective assessment and ranking of the collections and their organisation's capacity to meet the needs of the grape industry. The ranking was based on much of the confidential data gathered in this project, and thus the details cannot be provided in this summary report.

Eight priority purposes (or needs) for the collections of grape germplasm were identified:

- A germplasm repository for biodiversity, research and breeding.
- Planting material superior to the existing standard for industry development.
- Planting material of the highest health standard.
- A supply to industry of new or alternative varieties.
- A germplasm repository for heritage varieties that warrant preservation.
- A germplasm repository of unique varieties that may not be found elsewhere in the world.
- A germplasm collection that includes wine grapes but also table and dried grape varieties.
- A supply of appropriate rootstock material for current and future industry needs.

The ranking for the purpose of the collections was assigned by the consultant team taking into account our view of industry priorities combined with a broader view of what we considered to be best for the industry.

Each of the nine collections[13] was given a ranking for their capacity to satisfy the priority purposes. It should be noted that the CSIRO and SARDI collections are currently not available to supply germplasm material to industry but our ranking has presumed that this position will not be permanent. The ranking of the capacity of these two collections was made on the basis of them being available to service industry's needs in the future. The Western Australian collection provides high level service to the WA industry, but does not at present provide material to other parts of the national industry.

Some of the priority purposes are covered by a high proportion of collections; for example, industry rootstock supply and alternative varieties. However other priority purposes are covered by a low proportion of collections; for example, germplasm repository, unique and heritage collections. Within the collections covering any one priority purpose there is also a very wide range of capability of the collections to satisfy the priority purpose.

Given the assigned priorities, the outcome of the subjective weightings show that AVIA, CSIRO, RVIC and SARDI are the collections with the highest weighting for capability to meet the priority purposes. These collections/organisations are those that have played leading roles in providing varietal resources to the industry in various ways in the past.

The top priority purposes are the core purposes of repositories for research/breeding, high health status, availability of quality scion and rootstock varieties for industry and new alternative varieties.

Some of the lower priority purposes are still very important to industry but they cannot compete with the higher priority purposes, and an industry cannot sustain itself on these priorities.

For example:

- Table and dried grape germplasm is critical to these industries. Table grape varieties are well supplied with varieties from overseas breeders and CSIRO. Dried grape varieties are

[13] Main public collections. Despite its supply limitations, the NSW collection rather than MIAVIS was included because it houses the mother vines.

also supplied from overseas breeders and CSIRO, albeit to a very small market. The R&D funding of the table grape and dried grape industries is through Horticulture Australia Limited and not within the responsibility of GWRDC.

- Unique and heritage germplasm repositories are very important and must be included in at least one collection. However because of the low numbers of these varieties, they have been given a low weighting compared with the other priority areas. Nevertheless, Australia has a responsibility to maintain these varieties, which may only be present in Australia, on behalf of the international grape industry as they are a key global resource to provide genes for future breeding programs.

The rankings and weightings used for this assessment were subjective and present the collective view of the consultant team, even though we did not individually rank or weight things exactly the same. Readers of this summary report may use their own rankings and weightings to compare our view with theirs. We anticipate that there will still be a range of very different views within the complex grape collections and vine improvement sectors of the grape industry.

8 FUTURE OPTIONS

In providing options for future grape genetic resources and future investment in germplasm research, the project team recognises a full risk assessment has not been undertaken, that their review of other schemes has been extensive but not exhaustive, and that our view of the priorities for the wine grape industry are likely to differ from those of the table grape industry.

Ultimately the industry will identify the value they place on genetic resources through their demand for material and support for collections, but industry leadership at the national level must allow time and provide resources for the development of risk-based guidelines that ensure the industry in times of low demand, do not relinquish/abandon resources that will be required to underpin subsequent growth in demand.

The project team has considered the 'ideal' genetic resource/s for Australian viticulture. The ideal scenarios assume no encumbrances.

8.1 Some ideal scenarios for germplasm management

The ideal genetic material resource for Australian viticulture serves two purposes, and is best provided as two separate collections. One is a resource to serve national viticultural interests; the other primarily serves the grape growing industry.

The ideal genetic resource for *national viticultural interests* is a collection comprised of.

- Accessions with confirmed identity (DNA tested against agreed international standards).
- Accessions of known health status, subject to on-going testing that meets industry-agreed standards.
- Accessions from environmentally-diverse regions.
- Mainstream varieties and clones.
- Promising varieties and alternative varieties, be they of heritage or unique interest.

The collection ideally would have:

- An enviable international reputation.
- A system by which the database of inventory of vine material was maintained, was accessible (nationally and internationally) and was considered a valuable global resource.
- A close association with a research and development facility, that housed professional resources in plant pathology (virology, mycology, bacteriology), entomology, molecular biology, and ampelography.
- Government ownership.
- Industry support through demand for material at fair prices, and demand for services (eg. central coordination of imports and exports).

The ideal genetic resource for the Australian *wine grape industry* would include:

- Accessions with verified identity.
- Accessions in-demand, improved and/or identified as having demand in the near future.
- Accessions with high health status.
- A database that includes health status, and follows nationally-agreed nomenclature conventions.
- Dynamic and responsive links to industry and international intelligence on trends.
- Accredited nurseries (including approved VI bodies) as clients.

- Co-operation with the national repository on import requests on behalf of industry (private and public) material, to reduce duplication and loss of traceability.
- Industry support and fees for service that provide an income stream.

Australia is unlikely to achieve the 'ideal' situation for its genetic resources, but the team recognises that two complementary repositories can serve the Australian viticultural industries well. They should have most of the features of the 'ideal' scenario. Some are considered 'essential'; others 'beneficial' for the Australian germplasm context. The essential components are:

- Accessions with confirmed identity (DNA tested on entry).
- Accessions of high health status (known prior to release for propagation).
- An appropriate range of varieties and clones.
- To be resourced to allow regular database maintenance.
- Associated with a professional support facility.
- Resourced effectively to provide stability and maintain cash flow with government partnerships.

In addition to the above, the 'beneficial' features in the Australian repositories are:

- Coordination of industry importing.
- Potential for self-sufficiency.

9 WHAT ACTION IS NEEDED?

Three options are presented for consideration by industry. Ultimately the industry will have to conduct a full risk assessment in order to justify the chosen course of action. A strategic plan will also be necessary to guide decision-making on genetic resources.

The options are:

1. No action

Leave collections in the current state. Allow market forces to dictate the survival of VI resources, and government to dictate the future of their resources without industry engagement or consideration. It appears it will not be possible to maintain the *status quo* because the reported financial constraints are such that industry could anticipate:

- The closure of several collections.
- A decline in health and number of genetic resources the industry can access.
- An increase in private importations (legal and illegal) outside any industry system.
- The loss of inventory details and intelligence on existing and in-coming plant material.

The potential outcomes of this option are that:

- Industry will not advance. It will lose pace against respected international industries.
- Industry will not be responsive to new trends.
- Planting of clones with unknown confirmed health and identity will increase.
- Response to new trends for varieties and clones will be slow.
- Industry will not be assured adequate supply of good quality rootstocks or mainstream scion material when vineyard development again becomes popular.
- R&D and germplasm development will decline and industry is unlikely to see appropriate returns on their investment of $500,000 per annum of levy funds for the past 20 years.

2. Provide funding

It is not expected that funding to rescue or maintain all collections is either likely or warranted. However the injection of some funds, directly or with the assistance of a levy activation or levy base increase, would allow time to develop, with an engaged industry, a process for the management of grape genetic resources and adjustment for the future. In the absence of financial support, Option 1 is likely the only real option.

With the provision of industry funds, collection managers and a guiding management body would have the opportunity to conduct a risk assessment, and develop a strategic plan that should direct decision making. Some industry funds may be warranted now to maintain key resources in the short term, but would be contingent on some effort to investigate alliance and re-structuring potential.

With the provision of government funding, the CSIRO and SARDI collections have the potential to return as active, accessible collections with more identity-verified accessions. In the absence of this, it is likely these collections will become research collections only. This has industry-wide consequences as these two collections hold a significant number of accessions held nowhere else in Australia.

Potential outcomes of this option:

- The CSIRO and SARDI collections remain as industry resources (if vine identity investment resolves outstanding issues).
- VI partnerships may be strengthened.
- AVIA, RVIC and VAMVVIA survive[14].
- WA collection remains active as a WA industry resource.
- NSW collection may be able to remove virus-infected material and increase its use by industry.
- Private collections are unaffected.

3. Rationalise collections

This review has confirmed that Australia has valuable grapevine genetic resources. It has also confirmed that different segments of the industry may have different priorities, and no collection meets all industry priority purposes. There is significant duplication in the composition of collections, and few non-government collections are financially viable and stable.

To retain necessary industry germplasm resources, there is justification for rationalisation of collections, primarily between similarly funded bodies, eg between the two government-owned germplasm repositories, and between the leading VI groups.

Government funds may increase the partnership potential for the advanced VI groups that house valuable plant material; allow them to rationalise and reduce the duplication across collections to become more relevant and dynamic industry resources.

Potential outcomes of this option are budget dependent, but include:

- CSIRO and SARDI collections maintained, as a risk management strategy.
- Amalgamation of the CSIRO and SARDI collections to one site (new or existing), minimising duplication.
- Consolidation of viable VI groups, to ensure states are effectively served, and biosecurity is considered, by

[14] RVIC and VAMVVIA are the most viable, industry-relevant collections at present amongst the VI groups. Both have income streams in addition to sales of cuttings. RVIC has a commercial nursery and initiatives with other horticultural crop germplasm programs.

either *Selecting two physical collections*, eg. SA – rationalise RVIC and Kapunda; Victoria – rationalise AVIA and VAMVVIA,

or *Uniting to form one collection* that has assured industry and professional support (near a university or other research facility) or best complements the government repository and close working relationship.

These alternatives would each benefit from an association with a government program, directly (eg in partnership with funding) or indirectly (with R&D institution and/or university). Comparable arrangements internationally all have some government support.

Rationalisation of collections will require time and some immediate resourcing. A timeframe for review of progress should be a requirement, if this option is pursued.

4. Recommendations

The project team's assessment of the options:

Option 1 is not an option that is acceptable to industry.

Option 2 with government funding is preferred, but full government underwriting of germplasm repositories is unlikely, when the public good is unclear.

Option 3 has most potential to satisfy industry needs in the future. This is supported by the analysis conducted on priority purposes and collection capabilities.

The project team recommends that Option 3 be pursued.

To progress the further assessment of Options 2 or 3, the industry will require a Risk Assessment, Strategic Plan and the formation of a skilled management committee.

10 OTHER RELATED MATTERS

In order to progress the broader issues identified for vine collections, there is a need for a Risk Assessment, the development of a Strategic Plan, and for appointment of a Board of Management. Further requirements are the forming of alliances with more institutions, other perennial industries, and vine improvement groups, and to combine these elements into a strategy for vine collections.

10.1 Risk Assessment

A risk assessment that identifies perceived threats to the industry related to the future of planting material is essential. The threats are likely to be at both the organisational level and vineyard level. A thorough risk evaluation would clearly identify risk, its potential impact, and the necessary actions to avoid, transfer or eliminate both risk and impact.

It may reasonably be predicted that a risk assessment on Australian vine germplasm resources would identify risks associated with: financial viability of collections, material access, diagnostic standards and inconsistency, loss of traceability, loss of professional specialist services, loss of germplasm inventory knowledge, and loss of international access to material. Of particular importance in determining future options is the likely impact of each threat: loss of access to genetic material for example, may trigger a damaging industry response, eg increase in illegal importations, planting of diseased material, poor industry stakeholder relations etc. The distribution and planting of mis-identified germplasm has been experienced and in the absence of national protocols and plant standards, variable database referencing, and industry supply and acceptance of variable quality planting material, we can assume the potential remains for this to occur again.

In the event of an incursion of exotic disease, subsequent re-planting needs must not be met with common stock. Collections therefore are essential industry assets and the impact of threats to their existence must be identified and factored into decisions on germplasm resources.

It is important that the risks to the Australian germplasm resources are know and the responses required are identified and understood.

10.2 Strategic plan

WFA and WGGA have agreed in principle that germplasm resources are important for the future performance of the wine sector. An agreed strategic plan is required to determine industry priorities and on-going funding. It may incorporate a biosecurity plan. Essential to the development of these plans, is industry engagement and commitment to the agreed outcome.

A strategic plan for the industry may identify the most advantageous balance of purpose priority and size of collections, against available funds and the returns to industry. The strategic plan would also recognise that not all collections provide a financial return to industry (eg. germplasm repository) and would therefore guide a strategy for securing government support and re-structuring of collections, together with a vision for self-sufficiency in the longer term.

The absence of funding from nurseries (and nursery registration) is a barrier that should be addressed. Nurseries are a beneficiary of collections and the associated best practice activities, but they do not contribute to the funding of them, other than in the price paid for cuttings. Nursery levies are relevant to potted plants, rather than field nurseries. The pot levies are paid into HAL and table grapes and dried grapes may be a potential beneficiary of them, but it is unlikely. The strategic plan may identify a means by which nursery industry contributions could be directed to collection maintenance, or a nursery levy could be raised and collected on field plantings.

10.3 Management Board

A Management Board to oversee the Australian vine germplasm resources will require a strong independent chair to ensure that the core organisations (CSIRO, SARDI, AVIA, and the relevant VI groups) complete a strategic plan and commence its implementation in an agreed timeframe. The management board may also guide the process by which CSIRO and SARDI germplasm collections can meet the industry priorities in the strategic plan.

10.4 Alliances with other perennial crop industries

Alliance with other organisations to reduce net costs for collection maintenance and servicing would be a useful strategy. In preparing this review it is apparent that other Australian horticultural collections are having similar problems with funding and maintenance of collections and there is a requirement to establish partnerships in this environment. However, with so many common interests, the sharing of ideas and resources really need to be seriously explored.

Detailed examples from other industries are presented in Section 5 of this report and are the basis of the following comments.

The citrus industry's management of the health and quality of their collections and the supply of superior planting material to their growers is the most developed of the horticultural/viticultural industries in Australia. Their practices and funding arrangements should be further investigated for their relevance to the grape industry.

Some cooperation between the citrus and grape collections occurred when Auscitrus, NSW DPI and VAMVVIA were partners in the development of the resource block at Dareton, NSW in 2010.

The pome fruit group is well-organised. It limits its activities to cleaning up varieties in demand, or those that are newly imported. They add value for members, by providing exclusive access initially and coordinating evaluation trials.

The almond collection has been actively maintained at Monash in the SA Riverland under arrangement with RVIC. The almond industry plans to review its activities and biosecurity and is likely to establish a new mother block in the near future.

Several perennial, horticultural industries have expressed support for a central facility for professional support services (pathology, molecular biology, indexing) relevant to germplasm maintenance and industry development. The economies of scale and the assurance of on-going specialist services would be valuable to all industries. Other cross-industry activities that may deliver cost reductions through alliances include: a nursery registration scheme, development of national guidelines for germplasm database management, legal protection agreements for proprietary material, and investigation of joint *in vitro* repositories, eg. cryopreservation.

In the forestry industries, the Southern Tree Breeding Association has managed an improvement program since 1983. It is recommended that the Management Board examine this program for elements that may be applied to a vine improvement model that also addresses germplasm maintenance in the long term.

The other important alliances that are often taken for granted are those with universities and research institutions that have the capacity to provide specialist pathology and DNA testing services, and germplasm evaluation. Without access to these specialist services, the monitoring and quality control essential for the guarantee of germplasm quality will not be possible.

11 POTENTIAL BUSINESS MODELS

The business of germplasm management is complex. Until some firm directions for the Australian germplasm collections have been formulated in the Strategic Plan, any work on the development of a formal business plan is premature.

The examples in Section 5 of this report explain how other industries are managing their genetic resource "businesses" and they are models for consideration by the grape industry.

The citrus industry germplasm structure and management are the most advanced of the horticultural industries in Australia. The citrus industry manages arboreta, high health mother stock in screen houses, breeding and evaluation collections and multiplication schemes. Their systems ensure all planting material is managed with skilled oversight of protocols and audits. They accommodate proprietary lines imported by commercial variety managers, who pay a fee to gain access to the valued Auscitrus label and horticultural evaluation.

The forestry industry has the most commercial germplasm management system, but they are working with a small number of tree species and superior lines and have a relatively small number of clients, mainly corporates, across Australia.

The international germplasm resource schemes in Europe and California are supporting larger industries than those in Australia and they appear to have a strong government funding base and access to associated technical expertise from research and university agencies.

None of the examples will exactly fit the requirements and politics of the complex collection arrangements found in the Australian grape industry.

11.1 Current funding

The viability of commercial collections at present relies on sale of cuttings. This is not sustainable in times of low demand and any business model must include consideration of income streams. The different skills and focus of some VI groups suggest this is already being

considered. Some VI groups do not maintain collections but source their material from other VI bodies and focus activity on multiplication in source blocks. Some VI groups maintain collections beyond the needs of industry. The specialisation of VI groups through rationalisation will likely present some cost mitigation opportunities and reduce the non-competitive pricing for high health material, and competition for the same income stream. It is also expected that VI groups will consider a fee structure for sales to nurseries, especially retail nurseries (eg for table grapes) in times of low vineyard demand.

Government funding at present is restricted to the government collections, and research stations. Indirectly they are supporting some non-government collections through the sharing of space and some services.

11.2 Other avenues for funding

The viticulture industry has several options to economically advance the status of their genetic resources beyond those dependent on collection management and funding. If DNA-based identity evidence were required on entry to Australia, it would relieve the industry and collection managers of this cost. Registration in the database could be immediate. Similarly, it is incumbent on the industry and especially private importers, to ensure that endemic pathogens do not enter the vine collections so the industry should increase alliances with private importers and quarantine services within DAFF to increase post-entry quarantine indexing for endemic as well as exotic pathogens (as for citrus and citrus relatives). Importers rather than the industry would incur the additional cost, but material released would have a known health status, and be immediately suitable for propagation or entry into a foundation mother block.

Options for funding may include activation of a biosecurity levy, which would require industry agreement; raising a nursery levy, or expanding the levy payer base of the existing nursery pot levy (to include field nurseries). Biosecurity funding needs to be secured with an industry commitment, as industry members are identified as the major beneficiaries. The EPPR (Biosecurity) levy has been set at zero for the grape industries that are signatories to the Deed. Under the biosecurity requirements this may be activated in the event of an incursion, or set at a positive rate to build up a fund. It is the latter option that may be used to support the industry plan for the germplasm collections, in the interest of biosecurity.

12 SUMMARY AND RECOMMENDATIONS

This review recommends actions to be taken to optimize Australia's germplasm resources, their management and usefulness to the viticulture industries and allied interests. This will assist the Australian wine industry to reach an international, competitive standard with respect to knowledge of, and access to extensive genetic resources that can provide options to address future environmental and marketplace challenges.

The project has resulted in a revised register of germplasm in Australian grapevine collections. The project team strongly recommends that the register be maintained, regularly updated, and refined, in association with the development of national guidelines on naming, health testing and identity verification. A focus on identification verification against international reference databases, is recommended.

The project team recommends that investment in germplasm-related R&D continue and that some funds be directed to management of the register and collection management, as inventory knowledge and the germplasm plantings underpin much of the relevant R&D.

The practical options for germplasm collection management in Australia, are limited. The options presented are to:

Option 1. Do nothing,

Option 2. Secure some government funding to support some collections, or

Option 3. Rationalise the number of collections.

The project team recognizes that government priorities do not generally support the funding of germplasm collections, and therefore it recommends Option 3 be pursued. It is recommended that support be provided to first undertake a risk assessment, develop a Strategic Plan and form a Board of Management.

It is recommended that the Management Board examine the activities, funding and business structures of other perennial industries (eg. citrus, forestry) to identify elements that may be applied to germplasm management and/or vine improvement models, requiring long term relevance.

It is recommended the industry pursue closer alliances with other perennial industries and with authorities in post-entry quarantine services.

13 REFERENCES

Constable, F. and C. Drew. 2004. Review of vine health parameters, implementation priorities and capabilities for vine improvement groups and accredited nurseries. Final Report GWRDC NVH03/01.

Dry, N. 2005. *Grapevine Rootstock evaluation and breeding in Germany, France and California.* PGIBSA Final Report to GWRDC. PGI 05/01.

McMichael, P. and P. Barkley. 2008. *Review of Almond Budwood and Seed Multiplication and Recommendations for Accreditation Scheme.* HAL Final Report AL06006.

Nicholas, P. 2003. *Standardised protocols for conducting grapevine improvement trials in Australia.* Final Report GWRDC Project SAR99-6. 26 pp.

Nicholas, P.(ed). 2006. *National Register of Grapevine Varieties and Clones.* AVIA, Irymple, Australia.

Nitschke, D. 2013. *Alternative varieties, planting material and RVIC approach.* in Central Region Alternative Varieties Workshop – Successes, Opportunities and Cautions. Feb 2013. GWRDC Grassroots funding.

Tassie, E., Henschke, P. and D. Coleman. 2012. *Ensuring Trueness to Type of some Alternative Varieties.* GWRDC Project GWR IN1007.

Walker, R., Thomas, M., Clingeleffer, P., Davis, H and M. McCarthy 2009 *The future of Dual purpose Grapevine Germplasm Collections in Australia.* (component of Project GWR 1112 Brief).

Whiting, J. 2012. *Rootstock Breeding and associated R&D in viticulture and wine industry.* GWRDC Review – Final Report GWR 1009. August 2012.

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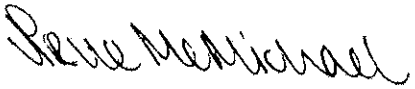

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GRAPE AND WINE RESEARCH AND DEVELOPMENT CORPORATION

INDEPENDENT REVIEW: INNOVATION AND ADOPTION ACTIVITIES

Strictly Private and Confidential

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Executive summary and recommendations

The Grape and Wine Research and Development Corporation (GWRDC) invests in research, development and extension to support a competitive Australian wine sector. The GWRDC's funding for R&D investment comes from levies on the annual winegrape harvest, with the Australian Government matching these funds up to 0.5 per cent of industry GVP.

The GWRDC invests in R&D from existing providers (such as CSIRO, state agencies, universities and the Australian Wine Research Institute (AWRI)) on behalf of the Australian wine industry. The investments are guided by the strategic research priorities of the Australian Government and the Australian grape and wine sector, through the GWRDC 5-year Strategic Plan.

The GWRDC also invests in innovation and adoption. These extension activities are overseen by the Innovation and Adoption Committee whose activities are guided by an Innovation and Adoption Strategy.

The aim of the strategy is to increase the rate of adoption of the R&D outcomes in the Australian wine sector. In line with this goal, GWRDC invests in activities and projects that encourage the use of R&D outcomes, technologies and practices and that develop industry capability to adopt and innovate. These activities and projects are delivered through networks and programs and by working with key enablers.

This review was commissioned to review GWRDC's innovation and adoption activities and evaluate their effectiveness in encouraging and facilitating the use of the research and development outcomes in order to make recommendations for maximising value in the future and to guide any potential changes to these activities. The scope and objectives of the review, as defined by the Terms of Reference, were as follows:

- To understand the effectiveness of the innovation and adoption activities funded by GWRDC; including an analysis of the scope and outcomes of the activities against both the intended scope and outcomes and Innovation and Adoption Strategic Objective.
- To understand the value of the innovation and adoption activities to the Australian wine sector; including an analysis of the cost of each activity (allowing accurate comparison) and an analysis of the effectiveness of the activity against the aims of the Innovation and Adoption Strategic plan.
- To recommend changes to GWRDC support of current innovation and adoption activities (if necessary).

The review was undertaken by an independent third party consultant. The main approach used by the independent consultant was face-to-face or teleconference interviews with AWRI, key industry stakeholders and other grape and wine researchers. Key GWRDC documents were also reviewed including the Innovation and Adoption Strategy, Regional Program Strategy and Annual Operating Plans and AWRI final reports and funding documents.

The majority of respondents interviewed pointed out that the most effective way to convey new information to grapegrowers and small winemakers is through face-to-face contact. Many suggested

that field trials and other 'hands-on' activities were the key ways to ensure that new techniques would be adopted but they also pointed out that adoption would depend on the financial circumstances at the time. Those who are in financial difficulties are more likely to be candidates for structural adjustment and financial and other assistance rather than seeking extension advice.

In light of the information gathered during interviews and from analysis of relevant documents, the review makes the following recommendations.

Grape and Wine Workshops provided by GWRDC-funded extension providers (including AWRI Roadshows, Workshops and Seminars)

Recommendation 1: That for future years GWRDC considers the following:

- setting strict KPIs against which to measure the value for money from workshops, seminars and roadshows and related activities including participant feedback surveys with data provided to GWRDC and setting target participant numbers; and
- determine topics jointly with AWRI and the relevant regional body, select the topics that are most relevant to the particular region and limit the number of topics to ensure that presenters are properly focussed on the event; and
- make funding for each activity contingent on the relevant regional body making a contribution to the cost of the function – this could be an in-kind contribution – to help ensure that significant local effort is made to encourage as many participant to attend as possible.

Recommendation 2: That GWRDC considers the future workshop and seminar program in parallel with the proposed roadshow program to ensure that topic coverage is coordinated and that regional coverage is at least partially consistent with levy contributions. At the same time attention should be paid to ensuring that funding is available in establishing regions particularly as growers adapt to any climate change.

Recommendation 3: That GWRDC considers increasing funding of extension activities that are directly targeted at grapegrowers.

GWRDC Regional Program

Recommendation 4: That, in order to ensure effective use of the Regional Program funds, GWRDC considers stipulating that the relevant regional body contribute $1 for every $4 contributed by GWRDC for program activities. The contribution from the regional body could be 'in-kind' at the discretion of GWRDC. Emphasis should be placed on organised field days and field trials as a means of extending information but there will need to be an on-going commitment to field trials if these are to be successful.

GWRDC Media and Communications

Recommendation 5: That as a part of the redevelopment of the GWRDC website, GWRDC considers establishing its website as the central industry web portal for the distribution of wine and grape growing research and extension information.

AWRI nodes

Recommendation 6: That GWRDC maintain funding to the Victoria node on the current basis and enter into discussions with state departments and other organisations as relevant to establish other 'extension' partnerships. Such partnerships should be jointly funded by the relevant state department and others (if applicable) where the primary focus is extension and the partnership performs an identifiable extension function. Support for the Riverina, Hunter and Tasmania nodes should be discontinued from 2014-15 unless they can be re-configured on the recommended basis.

Technical Reviews and Factsheets

Recommendation 7: That technical reviews and factsheets be edited by authors with appropriate written communication training and that all such material be available on the industry web portal (Recommendation 5).

AWRI social media and electronic extension products

Recommendation 8: That careful consideration be given to the level and type of support for the development of electronic extension products and in particular that:

- any organisation funded to produce electronic extension products be required to provide training in written communications skills for authors of those products; and
- no financial support be provided to third parties for activities that are largely aimed at 'branding' such as Twitter.

John Fornachon Memorial Library

Recommendation 9: That the funding for the John Fornachon Memorial Library be maintained and that AWRI be requested to better inform industry participants of the services available from the library and actively promote its use.

Background and introduction

The Grape and Wine Research and Development Corporation's (GWRDC) key role is to efficiently invest in research, development and extension for both the industry's and Australia's benefit. This review was commissioned to examine the effectiveness of the innovation and adoption activities flowing from the R&D funded by GWRDC.

The Innovation and Adoption activities stem from the R&D program and its findings and include the following:

- GWRDC workshops and seminars – including Innovators' Network and Regional Program Modules;
- GWRDC-funded workshops and seminars – including AWRI, NWGIC, Regional Program;
- GWRDC website;
- Webinars – including Wine Communicators' Australia and AWRI;
- Factsheets, journal and magazine articles;
- Innovators' Network newsletter; and
- Pilot field studies - including Regional Program field trials and direct extension by GWRDC-funded researchers.

The scope and objectives of the review were as follows (Appendix 1):

- Understand the effectiveness of the innovation and adoption activities funded by GWRDC; including an analysis of the scope and outcomes of the activities against both the intended scope and outcomes and Innovation and Adoption Strategic Objective.
- Understand the value of the innovation and adoption activities to the Australian wine sector; including an analysis of the cost of each activity (allowing accurate comparison) and an analysis of the effectiveness of the activity against the aims of the Innovation and Adoption Strategic plan.
- Recommend changes to GWRDC support of current innovation and adoption activities (if necessary).

Method

The review was undertaken by an independent third party consultant. The consultant was selected by the GWRDC Board based on his track record and standing, his experience in reviewing R&D outcomes with a focus on impact for industry and on his expertise within the grape and wine sector and within grape and wine research.

A brief synopsis of the independent third party consultant's credentials is provided below:

Independent consultant	Dr Brian Fisher	Director and Chair BAEconomics, and formerly CEO Concept Economics, Vice-President, CRA International, Executive Director ABARE, Dean of Agriculture and Professor of Agricultural Economics, University of Sydney.

The review involved identifying the value of, and comparing, innovation and adoption activities, as defined by the Terms of Reference (Appendix 1), delivered by:

- Grape and Wine roadshows (including former AWRI Roadshows).
- Grape and Wine workshops (including NWGIC Spring Vine Health Field Days).
- GWRDC Regional Program.
- GWRDC Media and Communications – including Twitter, Innovators' Network newsletter, R&D@Work and GWRDC website.
- AWRI Nodes.
- AWRI Technical Review and factsheets.
- AWRI social media and electronic extension products (including applications and simulators).
- John Fornachon Memorial Library.
- Current R&D projects that may have included an adoption and/or adaption process.

These activities were analysed against GWRDC's Innovation and Adoption Strategy (Appendix 2).

The main instrument used by the independent consultant was face-to-face or teleconference interviews with key innovation and adoption stakeholders, including:

- third party providers;
- regional Program Partners;
- regional associations; and
- grapegrowers and winemakers.

Details of the interviewees, including their roles, can be found in Appendix 3. The topics raised and questions asked during the interview period were formulated to address the Terms of Reference and are listed in Appendix 4. In addition to interviews, the reviewer examined relevant documents including fact sheets, websites and written documentation supplied by various extension providers.

Explanation of extension and adoption

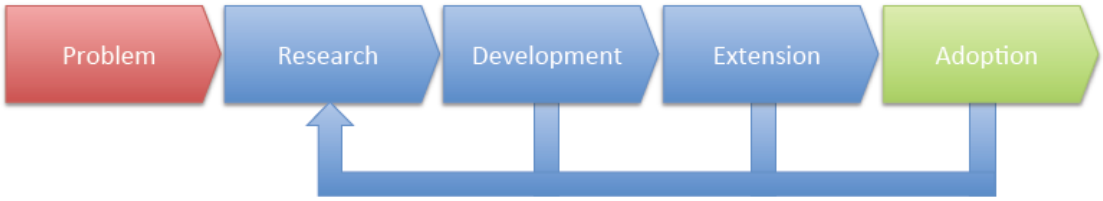
In agriculture, formal research activities commence in research stations or laboratories, away from farms where the new techniques are actually required. Consequently, there is a need to extend the research and advice to the target audience in order to influence farmers to alter their practices and increase productivity (Jennings and Pukula 2011).

Theories, which form the basis of agriculture's research, development, extension and adoption (RDEA) strategies, explain the stages of the process in the following way (Jennings and Pukula 2011):

- research is identified and undertaken in alignment with priorities established by the industry;
- development is undertaken in order to adapt the research into a commercial form;
- extension is the promotion of the innovation via the implementation of various activities; and
- adoption is considered accomplished when the target audience deems the innovation to be useful.

Although it may appear as though each stage flows to the next, the research, development, extension and adoption process is not always linear, as shown in the diagram below. At any stage of the process, further questions or problems can arise, which can lead to the need for further research (Jennings and Pukula 2011).

This fits in with the idea that successful models of RDEA begin and end with the farmer, rather than agricultural research being undertaken in the research station in isolation. Reviews of RDEA processes have shown that involving the beneficiaries in the research process results in the best extension and adoption outcomes as it leads to greater understanding of the results and creates stewardship (Fisheries and Aquaculture Extension and Adoption Working Group 2012).



Adapting the solutions created by research and development to a problem in a particular region can involve the following activities (Jennings and Pukula 2011):

- local trials;
- demonstrations;
- field days;
- on-site visits; and
- workshops.

Summary of GWRDC's extension activities

GWRDC managed extension activities

1. Workshops

2013 Example Workshop

An example of a GWRDC workshop series is the spray application workshops that were provided at no cost to participants in 15 locations around the country in October and November 2013. These workshops attracted 480 participants who were provided with a factsheet, a USB containing information from the presenters and a trial sample of new technologies. The factsheet and video footage of the Q&A session was then made available on the GWRDC website. The average cost per participant of this workshop series was a little under $175.

	01/07/12 – 28/11/13
Funding	$83,717.77
Average cost per participant	$174.41

Consumer Insights Workshop

This workshop aimed to share the latest research with the industry and demonstrate how it can be applied in a business context. The first series of workshops in this program was 'China Insights' that extended R&D findings about the Chinese wine market and consumer values. This series was held for free in five wine regions and was attended by 139 participants. These regions were determined based on the number of businesses exporting to China. Of the 60 per cent of participants who completed the survey, 97 per cent of respondents said they would use the information in their business and would share with their colleagues and industry.

	China Insights
Funding	$25,113
Average cost per participant	$180.67

2. Media and Communications – including Twitter, Innovators' Network newsletter, R&D@Work and GWRDC website

GWRDC website and Twitter

The GWRDC website had 24,000 unique visitors in 2012-13. At December 2013, GWRDC had 548 followers on Twitter. The Twitter account tweets information about industry activities as well as links to information relevant to the industry such as the Agriculture White Paper and how to improve business skills.

	01/07/12 – 28/11/13
Funding	$30,103.54

Innovators' Network and R&D@Work newsletters

The monthly Innovators' Network newsletter aims to disseminate information from grapegrowers and winemakers across the regions, as well as provide information about GWRDC's research outcomes and upcoming events. Membership for this network grew by 208 in 2012-13, to 1068 subscribers. This growth can partly be attributed to the mobile-enabled signup.

Approximately 89 per cent of subscribers said that the Innovators' Network Newsletter provided timely information, approximately 72 per cent said that the information was useful, approximately 52 per cent said that they wanted more detailed articles, 59 per cent said they wanted different topics and only approximately 20 per cent said they wanted the newsletter to be published more frequently.

R&D@Work newsletters

R&D@Work is a bi-monthly 4-page publication disseminated through Australia and New Zealand Grapegrower and Winemaker magazine. The activity aims to extend the latest R&D findings.

	01/07/12 – 28/11/13
Funding (development and publication)	$61,719

AWRI-managed extension activities

1. AWRI Nodes

The AWRI Nodes were established with the aim of developing research outputs into knowledge, methods and tools applicable to the industry and then promoting the adoption of this knowledge. Priorities identified by each region determine which research outputs will be developed and these are then assessed on their potential to improve production. Project staff work with grapegrowers and winemakers to ensure adoption of the resulting technologies.

Funding (original funding requested from GWRDC):

	2013-14	2014-15	2015-16	2016-17
Tasmania	$176,889	$143,466	$146,067	$152,324
Riverina	$185,353	$205,114	$210,181	$219,002
Hunter Valley	$198,127	$165,554	$169,039	$176,214
Victoria	$34,382	$41,931	$46,891	$49,181
Total	**$594,751**	**$556,066**	**$572,178**	**$596,720**

Examples of Node Projects 2013-14

AWRI Hunter Valley Node

Projects in the Hunter Valley Node include:

- Investigating barriers to adoption of the AWRI Fermentation Simulator, which optimises fermentation management. As uptake has been slow, the project aims to encourage the use of the simulator, in conjunction with the Riverina Node.
- Development of a half-day workshop for grapegrowers titled 'Realising the potential of smart phones and tablets as tools for improving vineyard management and efficiency'. Aim is to improve management productivity and efficiency through a hands-on workshop, delivered to ten grapegrower groups in five regions in NSW and the ACT and two in Tasmania, as well as gatherings of grapegrowers organised by three major wine producers in South Australia.
- Increased extension delivery by staging additional workshops in five regions of NSW and the ACT. These workshops will use existing AWRI content in conjunction with information modified based on the technical issues each region wishes to address.

AWRI Tasmania Node

Projects in the Tasmania Node include:

- The creation of a winemaker panel in Tasmania to rate at least 30 Tasmanian Chardonnay wines for their stone-fruit characters.
- Examination of Chardonnay fruit from at least 20 Tasmanian vineyards for tropical thiol precursor concentrations.

The aim of these projects is to allow winemakers and grapegrowers to understand the concentrations of tropical thiols responsible for tropical fruit characters in Chardonnay grapes and as a consequence target commercially relevant grape and wine style attributes. The information gathered from these studies will then be made available in a report.

AWRI Riverina Node

Projects in the Riverina Node include:

- Winery refrigeration efficiency workshops accompanied by refrigeration efficiency benchmarking in at least two regions, from which case-studies will be created for inclusion in the workshops. The aim will be to provide wine producers with the information and skills necessary to benchmark and improve their own refrigeration systems and as a consequence lower electricity costs. These will be delivered to at least 56 wineries in at least 7 regions.
- Modelling refrigeration and develop a prototype monitoring software tool to assist producers in increasing their refrigeration efficiency.
- Investigating barriers to adoption of the AWRI Fermentation Simulator, in conjunction with the Hunter Valley Node, as described above.
- Expanding the Fermentation Simulator to include cool climate and indigenous yeast fermentations. Model will be expanded so it has broader applicability and functionality.

2. Grape and Wine roadshows (including former AWRI Roadshows)

Roadshows Seminar Program

This program aims to present seminars, regarding up-to-date research, in at least 15 regions to 450 Australian wine sector personnel per annum. Ten per cent of the content / presenters will come from external research organisations.

Roadshow Workshops

This program aims to hold workshops, providing practical hands-on-training in at least 10 regions to at least 300 wine sector personnel in 2014, increasing by 10 personnel per annum until 2017. Ten per cent of the content / presenters will come from external research organisations.
In terms of the former AWRI Roadshows, in 2012-13, 458 people across seven states and regions participated in 20 of these events.

Webinar Series

This series will see the presentation of 20 webinars per annum from 2014-17, using AWRI and external researchers, regarding winemaking issues. Forty per cent of the webinar content will come from external organisations.

Regional communication on topical issues

This element aims to disseminate information from the Roadshow Workshops and Seminars via AWRI Technical Review, the AWRI eNews, the GWRDC R&D@Work, GWRDC Innovators' Network newsletters, 'Ask the AWRI', AWRI eBulletins and via social media platforms.

Post the Seminars, Workshops and Webinars the attendees will be surveyed to determine how they rate the material and the likelihood of using it in their businesses.

	2013-14	2014-15	2015-16	2016-17	Total
Funding (requested from GWRDC ex GST)	$358,654	$363,118	$354,066	$364,199	$1,440,037

3. AWRI Technical Review, factsheets, social media, and general communications

Technical Review

The Technical Review is a summary of current technical articles and papers published on grape and wine production, as well as technical notes on AWRI's work. The Technical Review is published bi-monthly in hardcopy and electronic formats. From 2006-2013, 42 issues were produced and distributed to more than 3000 levy payers and other industry stakeholders.

Social media

The AWRI has Facebook, Twitter and LinkedIn accounts that are used to communicate their activities with the industry. Twitter is the AWRI's most important social media tool with 2065 followers in December 2013. As well as posting information about upcoming webinars, wine tastings and workshops, the AWRI also uses Twitter to encourage followers to complete surveys regarding AWRI extension activities.

As well as the Technical Review and social media, the cost of AWRI's communications will also include their website upkeep, publishing the AWRI report in the Wine and Viticulture Journal (6 times per year), publishing their column 'Ask the AWRI' in Australia & New Zealand Grapegrower and Winemaker (12 times per year), issuing their eNews publication (6 times per year), creating webinars and publishing other reports in industry and other non-refereed journals as opportunities arise.

	2013-14	2014-15	2015-16	2016-17	Total
Funding (requested from GWRDC ex GST)	$203,527	$204,832	$202,187	$205,148	$815,694

4. Electronic extension products (including applications and simulators)

Fermentation Simulator

As fermentation is a critical area of the winemaking process, there is a demand for tools that monitor fermentation, therefore the AWRI Fermentation Simulator was built in order to optimise performance by modelling fermentation using an excel based system. The simulator has undergone extensive field-testing, with input from industry in the Hunter and Riverina and has been developed over several vintages.

WineCloud

WineCloud is a web-based tool that allows industry to measure tannin, colour and other phenolic parameters in red grapes, fermentations and wine. The tool is simple to use and allows the user to gather data quickly in order to generate specific qualities in their wines. Data from the WineCloud demonstrates how parameters in red grapes are affected by adjusting the plantings, viticultural treatments and the vineyard site.

5. Library Service

The aim of this project is to develop a comprehensive library, both physical and online, comprised of technical information on grape and wine production, allowing easy access to information for the industry. The library will advance to include an eBook platform and for the library to be accessible on

a range of mobile devices. The collection will be reviewed and updated every six months as technology progresses.

	2013-14	2014-15	2015-16	2016-17	Total
Funding (ex GST)	$187,106	$188,916	$185,245	$189,354	$750,621

Extension activities managed by organisations other than AWRI

1. GWRDC Regional Program

The Regional Program aims to encourage regional adoption and adaption of the findings from research and development, invested in by the GWRDC, via methods such as practical trials. The 72 distinct GIs in Australia are grouped into 11 regional clusters. Each cluster develops a four-year strategic plan, identifying their own priorities. Each cluster is represented by a Regional Program Partner, whose role is to develop and implement the Regional Program. An annual operation plan is also submitted each year, by the Program Partner, containing the proposed activities for the region, which is then assessed by the GWRDC to determine whether the activities are eligible for funding. Eligible activities include, but are not limited to, in-field trials based on published on GWRDC-funded research results, workshops, demonstrations and development of extension materials such as factsheets, DVDs, flyers and electronic materials.

In 2012-13, 40 per cent of people that attended a Regional Program event said they changed their management practices as a result.

Funding (excluding GST):

Regional cluster	Regional Program Partner	2012-13 (payments made)	2013-14 (budget)
Queensland	Queensland Wine Industry Association	$12,000	$25,000
Riverland	Riverland Wine Industry Development Council	$125,890	$125,000
Greater Victoria	Wine Victoria Inc	$50,000	$46,600
Western Australia	Wine Industry Association of WA	$50,000	$50,000
Riverina	Wine Grapes Marketing Board	$62,500	$125,000
Tasmania	Wine Industry Tasmania Ltd	$23,047	$25,000
SA North	Barossa Gape Wine Association	$44,517	$44,420
Murray Valley	Murray Valley Winegrowers Inc	$126,450	$68,750
SA South / Limestone Coast	Limestone Coast Grape and Wine Council	$50,000	$50,000
SA Central	Langhorne Creek Grape and Wine	$50,000	$50,000
Great NSW and ACT	NSW Wine Industry Association	$31,737	$42,235
	Total	**$626,641**	**$652,005**

Examples of Regional Program Projects 2013-14

Riverland Regional Program

One of the projects that the Riverland cluster will undertake is Weed Control Technology Field Day. As part of this project, current weed control technology will be reviewed and machinery will be sourced to utilise in the field day. This will allow growers in the region to compare a range of technologies to determine which will be most suitable in their operations.

SA Central Regional Program

In 2014 the SA Central region plans to develop a Malbec trial, as growers in this region have expressed interest in this variety, especially in the Langhorne Creek wine region. Key growers in this region, with available land, want to take part in the trail. This project will involve performing research to establish Australia's Malbec clonal history, determining which types of clones are available and finally selecting the clones for trial and developing the trial plan.

SA South Regional Program

The SA South cluster plans to provide three tutored tasting to grapegrowers and winemakers in their region in order to allow them to benchmark their produce and operations against competitor regions. These tastings will also help growers understand how wines are judged in Australia. The people facilitating the tastings would include a wine critic and wine show judges, including local growers that are also judges.

2. NWGIC Spring Vine Health Field Days

Spring Vine Health Field Days

The Spring Vine Health Field Days were an initiative of the National Wine and Grape Industry Centre (NWGIC), with significant funding from GWRDC. Seven field days were held in four states and territories in 2012-13 regarding vine health and how it is affected by disease, weeds and pests. 183 people attended these field days.

In 2010, 11 field days were held and prior to the field days, six assessments were completed in five regions to determine their capacity to manage vine health. Of the topics presented in the 2010 field days, the attendees rated them an average approximately 7 out of 10 in terms of their importance.

Funding (2010)	Source
$19,717.53	GWRDC Grassroots Regional Program
$65,825.00	GWRDC project funds

3. Webinars by Wine Communicator's Australia

In 2013 three webinars were provided: 'Chardonnay Challenge', 'Online Communities' and 'China Insights'. These webinars attracted 97, 114 and 132 registrants respectively, who were provided with the webinar and corresponding powerpoint. This media was also made available on the GWRDC website. A survey of the participants showed that 97 per cent thought that the webinar information was appropriate, relevant and useful.

	Funding
Per webinar	$1,200
Per participant	$10.50

Interview findings

The following themes arose during the interviews with grapegrowers, winemakers, AWRI node employees and other industry members and leaders.

Processes used to disseminate information

From the interviews it was discovered that the industry uses the 'people network' to learn including - Grower Liaison Officers (although their independence is questioned), Industry Development Officers, Regional Associations, peer to peer, national bodies – AWRI, GWRDC, CSIRO and third parties – re-sellers, Elders.

Also used are a number of alternative mechanisms including e-based – web, email, workshops and seminars, factsheets, practical trials, Crop watch, shed meetings, simulators, the 'Dog Book' and the AWRI Library.

GWRDC as extension funders

In regard to the extension activities provided by GWRDC, very few interviewees were able to identify/name a specific extension activity that the organisation directly funded. Those GWRDC activities that were identified included the spray application workshop, Future Leaders and the Innovators' Network. However, these were identified by engaged members of industry. GWRDC is generally perceived to be funding the facilitation of extension activities (rather than providing extension services itself).

Some interviewees wondered whether there was a duplication of activities performed by the Regional Programs and the AWRI nodes, and whether this means that funding is not being used as effectively as possible. There was also concern about the clarity around where funding actually comes from and who information belongs to. For example, GWRDC will often use their brand on workshop information and factsheets etc., that is, activities that they have funded but not developed.

Some stakeholders suggested that there should be formal KPIs for extension contracts. This way GWRDC can ensure that funding is being used appropriately.

One interviewee believed that the GWRDC should better explain reasons for funding certain activities, such as those that have an overseas component. This is because many farmers have not been made aware of the benefits of this funding and are consequently disenchanted by what some construe to be support of overseas competitors.

The benefit of face-to-face extension activities

The large majority of interviewees contended that the best way to disseminate information to the industry is through face-to-face contact in seminars, workshop, and field trials from a source that is independent, trusted and can translate the theoretical information into practical actions. Some interviewees noted that many 'bench researchers' are not well suited to this communication task.

Multiple interviewees voluntarily offered that, as extension activities, they valued AWRI roadshows and workshops and these have improved over the past five years. People stated that, through the organisation of the workshops, there was interaction with the regions, which allowed the

participants to make better use of the information provided. Many people stated that they would like more roadshows. Although one comment, from an engaged member of the industry, highlighted the cost of the workshops and was concerned that there was presently no method to measure their value.

Field trials were also highly regarded and particpants found that the provision of research findings directly at the winery/vineyard was generally more useful than that provided in other forms. As with the roadshows, people are keen to see more field trials. However, some interviewees explained that experimental trials are only useful if they have been properly structured with a sound experimental design. One person stated that it was more effective to have farmer-run field days because participants are often more receptive to people with local understanding rather than to laboratory technicians who are perceived to be 'far removed from the field'.

Alternatives to face-to-face activities

Interviewees stressed that, while factsheets and webinars are useful they are not a substitute for workshops and field trials. However, some people stated that there is still more room for webinars but not as a replacement for the other activities. On the other hand, some participants believe that the travel costs associated with GWRDC or AWRI employees visiting the more remote wine regions to perform activities that could be easily performed via the internet is money wasted, and that this money could be spent on research instead. This comment was made in particular in relation to extension activities in grapegrowing regions where growers are widely spread such as in Queensland.

In relation to factsheets, some interviewees suggested that it was hard to locate good factsheets that were suitable for growers. It was contended that often the information is available but it is not in a form suitable for the end user.

Also it was suggested that information from field days and workshops needed to be disseminated more widely afterwards. This is where the non face-to-face extension methods, such as the factsheet, become critical.

Difficulties associated with encouraging involvement and adoption

Interviewees stated that in some regions it is becoming more difficult to encourage grapegrowers to participate in extension activities including roadshows, with estimates of approximately 10 per cent of the community being involved. One person stated that farmers are not adopting research because substantial information is not provided regarding the monetary benefits of the technology, which is the main driver for change. Some perceived that the GWRDC was more focused on technological information rather than financial. Also participants are less interested in how the research was done; they simply want to know how to apply it. Content should be created with this in mind.

On the other hand, one interviewee stated that low participation was a reflection of the state of the industry at present, rather than the quality of the material/services being provided.

The importance of grower liaison and other field staff

Although grower liaison officers can never formally be part of the extension process, interviewees expressed the need to ensure that those officers are properly trained and are equipped with the correct information, as many farmers see them as the first point of contact for solving a range of

production and financial problems. The officers also see the farmers on a more regular basis than other people involved with extension. One interviewee suggested that if the funding is not available to employ more officers, it is critical that the existing personnel are highly knowledgeable.

Networks and communication

Networks are key to information extension and the traditional ones are claimed by many interviewees to be crumbling. If there is a problem, instinct dictates asking someone who may know the answer – however, people generally ask someone with whom they have an existing relationship (as opposed to someone whose name they cannot 'put a face to').

Problems used to be solved, ideas exchanged, and information disseminated through state government departments, agriculture bureaus, extension officers, third parties with time to spend with growers and winemakers and researchers with time to spend out in the field. These networks either no longer exist, or exist in a form that is not as valuable (for example, operate on a less regular basis).

Interviewees suggested that mechanisms needed to be established to encourage growers to talk to each other and share their knowledge on a more regular basis. One participant stated that this was particularly important as some farmers are suffering from information overload and instead of turning to the regional and node programs they are relying more on support from their peers.

AWRI, general observations

A range of interviewees suggested that the reasons for the establishment of the AWRI nodes and their current role are not clear. There seems to be a different purpose for each node - some are pure extension and have taken on the traditional role of the Department of Primary Industries, whereas others perform what is more akin to a research development function and act as problem-solvers for the industry (Griffith node).

Despite the comments on confusion about the purpose of the AWRI nodes, most interviewees were positive about the contribution of the nodes and indicated that they are of value.

Review outcomes

A number of general observations are pertinent to this review and are important background to understanding the effectiveness (or otherwise) of the current innovation and adoption program.

First, state departments of agriculture have substantially withdrawn from the provision of free agricultural extension advice and in this reviewer's opinion are unlikely to put more effort into this activity in the future. While it is reasonable to argue that agricultural extension is a state government responsibility and that if other organisations partially replace support for the activity then state governments will have even less incentive to be involved, the reality is likely to be that state government sponsored extension on a large scale is a thing of the past. During the interviews it was reported by one respondent that in greater Victoria, for example, there is only one part time funded state viticulture extension officer. It follows that if the wine and grape growing industry values the agricultural extension function then it will need to find means other than the traditional state government sources to support it.

Second, significant parts of the grape growing industry appear to be in a parlous financial state. Analysis of on-farm incomes of grapegrowers and small winemakers was outside the scope of the present project but many interviewees indicated that financial circumstances in the industry had deteriorated in the past two years and that grape prices for the coming harvest were expected to be lower than those for last season. This seems to have been confirmed by media reports on expected grape prices in the bulk wine producing areas since the beginning of 2014. ABARES' most recent survey of the industry, released in December 2013, reports on estimated farm incomes in the industry for the 2011-12 year and does not attempt to project incomes for the current season. During the interviews a number of respondents pointed to low farm incomes and growers struggling to cope, together with the advancing average age of growers in the industry, as key reasons for non-involvement in learning activities. If the financial situation in the industry deteriorates further in 2014 it follows that encouraging many growers to engage in extension activities will become even more difficult. This needs to be considered in setting key performance indicators for such activities and in measuring 'success'.

Third, a large number of groups are involved in extension of knowledge, both directly and indirectly, in the grapegrowing and winemaking industry ranging from grower cooperatives, regional grower support groups, large wine producers, state government agencies, AWRI and GWRDC. Whilst each organisation has an important role to play, the present arrangements appear to have developed in the past largely independently from each other and because of that there may be some efficiencies that can be achieved through further cooperation.

The majority of respondents interviewed pointed out that the most effective way to convey new information to grapegrowers and small winemakers is through face-to-face contact. Many suggested that field trials and other 'hands on' activities were the key ways to ensure that new techniques would be adopted but they also pointed out that adoption would depend on the financial circumstances at the time. Those who are in financial difficulties are more likely to be candidates for structural adjustment and financial and other assistance rather than seeking extension advice.

In light of these observations and the information gathered during interviews and from analysis of relevant documents the review makes the following recommendations.

1. Grape and Wine Workshops provided by GWRDC-funded extension providers (including AWRI Roadshows, Workshops and Seminars)

All respondents interviewed were fully supportive of the roadshows. Many suggested that the roadshows covered important and relevant topics and that they were of high value. This reviewer observes that average attendance at these events is relatively low but that this is not inconsistent with the numbers of growers that attend similar meetings such as ABARES' regional OUTLOOK conferences where a single industry is targeted. In discussions with AWRI it was suggested that the topics covered at these events were chosen from a large menu by the regional partners and that this process was valued because it ensured relevance.

Assuming that a similar number of participants are reached in 2014-15 as attended these events in 2012-13 and taking the requested budget for this activity for 2014-15, the average cost per attendee of this activity will be around $1100 given the AWRI's budget request. While these events are popular according to interviewee feedback, this reviewer questions whether there are not more effective ways of delivering extension information.

Recommendation 1: That for future years GWRDC considers the following:

- setting strict KPIs against which to measure the value for money from workshops, seminars and roadshows and related activities including participant feedback surveys with data provided to GWRDC and setting target participant numbers; and
- determine topics jointly with AWRI and the relevant regional body, select the topics that are most relevant to the particular region and limit the number of topics to ensure that presenters are properly focussed on the event; and
- make funding for each activity contingent on the relevant regional body making a contribution to the cost of the function – this could be an in-kind contribution – to help ensure that significant local effort is made to encourage as many participant to attend as possible.

Grape and wine workshops should be clearly branded so the source of the information can be easily identified. Whilst most people found workshops to be beneficial, the remoteness of the region should be considered to determine whether it is worth the additional costs associated with organising a workshop in isolated locations, or whether other extension activities such as webinars could be used instead.

Most interviewees mentioned the recent Spray Workshop as a particularly popular and successful event. However, as with the roadshows, attendance at these events appears on average to be low. GWRDC should increase it efforts in attracting more participation in these events.

Recommendation 2: That GWRDC considers the future workshop and seminar program in parallel with the proposed roadshow program to ensure that topic coverage is coordinated and that regional coverage is at least partially consistent with levy contributions. At the same time attention should be paid to ensuring that funding is available in establishing regions particularly as growers adapt to any climate change.

At present the grape growing industry is under severe economic pressure and there is likely to be significant structural change over the coming years. At times such as these there is an increased need for relevant economic, production and other up-to-date technical data to be readily available for growers if the industry is to succeed in increasing productivity growth.

Recommendation 3: That GWRDC considers increasing funding of extension activities that are directly targeted at grapegrowers.

2. GWRDC Regional Program

Interviewees from regional bodies indicated that support from GWRDC was essential for their continued functioning as information providers. Many also indicated that participant numbers at their events were low. Regional organisations are more likely to put significant effort into organising extension functions if they have a financial commitment to the activity. Almost all interviewees emphasised the importance of field days and field trials as the most effective extension activity.

Recommendation 4: That, in order to ensure effective use of the Regional Program funds, GWRDC considers stipulating that the relevant regional body contribute $1 for every $4 contributed by GWRDC for program activities. The contribution from the regional body could be 'in-kind' at the discretion of GWRDC. Emphasis should be placed on organised field days and field trials as a means

of extending information but there will need to be an on-going commitment to field trials if these are to be successful.

3. GWRDC Media and Communications

In general, interviewees believed that the search function on the GWRDC website could be improved radically. Therefore, this function should be reviewed and updated. Some interviewees considered that tweets were a useful way to provide quick alerts about extension and adoption and new research information, so this strategy has a role to play but should not be considered as a substitute for more targeted face-to-face extension activity.

Some interviewees suggested that there should be one main web portal that either contained all relevant industry research and extension information or provided direct links to that information. One young winemaker with a small business, who in this reviewer's opinion appeared to be an innovator, suggested that he was 'inundated' by new information and had no effective way of shifting the useful from the less useful material.

Recommendation 5: That as a part of the redevelopment of the GWRDC website, GWRDC considers establishing its website as the central industry web portal for the distribution of wine and grape growing research and extension information.

4. AWRI nodes

All respondents were highly supportive of AWRI and a large majority were supportive of the concept of the AWRI nodes although some were unclear on what role the nodes performed. The AWRI believes that the nodes perform an important function in taking AWRI's information and skills directly to key regions.

It appears to the present reviewer that the nodes do not perform a consistent function. The Victoria node appears to perform, in conjunction with the relevant state department, an almost 'pure' extension role and is highly valued as such. The Riverina node appears to have performed a research development role in wineries and until recently was staffed by a process engineer. This function was also highly valued by the wineries but the functions performed were quite different from those performed by the Victorian node for example. Reports from interviewees about the performance of the Hunter node were mixed. This reviewer understands that at present there are no staff in either the Riverina or Tasmania nodes.

Given the recent staffing changes in two of the nodes and the disparate functions the nodes appear to have performed in the past it seems appropriate to reconsider the allocation of funds to the nodes in the overall context of the GWRDC innovation and adoption strategy and actions.

Recommendation 6: That GWRDC maintain funding to the Victoria node on the current basis and enter into discussions with state departments and other organisations as relevant to establish other 'extension' partnerships. Such partnerships should be jointly funded by the relevant state department and others (if applicable) where the primary focus is extension and the partnership performs an identifiable extension function. Support for the Riverina, Hunter and Tasmania nodes should be discontinued from 2014-15 unless they can be re-configured on the recommended basis.

5. Technical Reviews and Factsheets

Participants recognised how important and useful factsheets can be. The GWRDC/AWRI should ensure that factsheets contain information that can be easily processed by the end user in order to encourage higher rates of adoption. Factsheets should be distributed after workshops and roadshows so that the information can reach people unable to attend, or to encourage people to attend such events in the future.

Recommendation 7: That technical reviews and factsheets be edited by authors with appropriate written communication training and that all such material be available on the industry web portal (Recommendation 5).

6. AWRI social media and electronic extension products

Given the geographic spread of the grape and wine industry and the increasing use on farms of computers, electronic media is an important method of getting new information to growers. Many interviewees pointed to this as a cost effective way of conveying new information. However, electronic media is unlikely to be effective unless it meets a number of criteria and in particular:

- electronic fact sheets should be concise and clearly written by authors trained in written communication with further references provided should the reader wish to explore the topic more deeply; and
- websites should have efficient search engines and be organised in ways that facilitate easy searches and public information should be readily available and not 'protected' by unnecessary passwords and log-in procedures.

Some forms of modern communication, such as Twitter, are more effective as means of 'branding' an organisation or person rather than for conveying useful information.

Recommendation 8: That careful consideration be given to the level and type of support for the development of electronic extension products and in particular that:

- any organisation funded to produce electronic extension products be required to provide training in written communications skills for authors of those products; and
- no financial support be provided to third parties for activities that are largely aimed at 'branding' such as Twitter.

7. John Fornachon Memorial Library

The library is a beneficial way for grapegrowers and winemakers to do additional research independently. The library should be maintained and updated as new information arises and as new technologies become available. Many interviewees were not fully aware of the services available from the library but it is clear that it serves as important function for a significant group of well-informed industry participants.

Recommendation 9: That the funding for the John Fornachon Memorial Library be maintained and that AWRI be requested to better inform industry participants of the services available from the library and actively promote its use.

References

Fisheries and Aquaculture Extension and Adoption Working Group 2012, Extension and Adoption Strategy, viewed on 4 December 2013, http://frdc.com.au/research/Documents/Extension%20strategy%20-%20final%20-%201%20June%202012.pdf

Jennings J, Pakula B 2011, Understanding Extension and Adoption in the Fishing Industry.

Appendix 1. Review Terms of Reference for the review of GWRDC's Innovation and Adoption activities

Purpose and scope of the review

This is a review of all GWRDC innovation and adoption activities – both those managed directly by GWRDC and those for which funding is provided by GWRDC that are managed by third party organisations.

These activities will be measured against their effectiveness in encouraging and facilitating the use of research and development outcomes.
The review will include innovation and adoption activities delivered by:

- Grape and Wine roadshows (including former AWRI Roadshows)
- Grape and Wine workshops (including NWGIC Spring Vine Health Field Days)
- GWRDC Regional Program
- GWRDC Media and Communications – including Twitter, Innovators' Network newsletter, R&D@Work and GWRDC website
- AWRI Nodes
- AWRI Technical Review and factsheets
- AWRI social media and electronic extension products (including applications and simulators)
- John Fornachon Memorial Library, and
- Current R&D projects that may have included an adoption and/or adaption process

The purpose of the review is:

1. to understand the effectiveness of the innovation and adoption activities funded by GWRDC; this will include an analysis of the scope and outcomes of the activities against both the intended scope and outcomes and Innovation and Adoption Strategic Objective;
2. to understand the value of the innovation and adoption activities to the Australian wine sector; including an analysis of the cost of each activity (allowing accurate comparison) and an analysis of the effectiveness of the activity against the aims of the Innovation and Adoption Strategic plan; and
3. if necessary, to recommend changes to GWRDC support of current innovation and adoption activities.

The review will include consultation with key innovation and adoption stakeholders that include third party providers, Regional Program Partners and regional associations to ensure comprehensive industry engagement.

Who

The GWRDC Innovation and Adoption Committee will approve these Terms of Reference.

The review will be conducted by an independent third party consultant.

The findings of the report will be provided to the Innovation and Adoption Committee.

Deliverables

The review of innovation and adoption activities and recommendations will result in a report that addresses the review's purposes (abovementioned) delivered to the Innovation and Adoption Committee.

This report will be delivered by 31 January 2014.

Appendix 2. GWRDC Innovation and Adoption Strategy

The Grape and Wine Research and Development Corporation and Australian Wine Industry have committed to increasing the rate of adoption of R&D outcomes in the Australian wine sector by:

- **developing and packaging RD&E outcomes for stakeholders;**
- **using a range of delivery networks and programs to deliver GWRDC outputs and encourage adoption of new technologies and practices; and**
- **identifying and working with the key enablers to enhance the adoption of R&D outcomes within the Australian wine sector.**

Decisions by the Innovation & Adoption Committee in relation to innovation and adoption activities pursued through GWRDC, are guided by this overarching goal.

Strategic objective

The Innovation & Adoption Committee will **deliver value to levy payers by facilitating activities and projects that encourage the use of research and development outcomes.**

To this end, the Committee will **support the delivery of activities** that:

- increase the rate of adoption of GWRDC-funded R&D - where 'adoption' is the use and adaption of research findings by the target audience;
- encourage innovation based on this R&D - where 'innovation' is the introduction of new things or methods by the target audience;
- develop industry capability to adopt and innovate using R&D findings.

Activities will provide:

- both theoretical and practical information;
- in a format that is accessible and supports the development and communication of innovative business practices; and
- within a timeframe that encourages the making of informed choices that support sustainable business outcomes.

Barriers to adoption will be identified and, where consistent with GWRDC priorities, taken into account when providing theoretical and practical information.

Target audience

There are three distinct target audiences for the information:

1. Grapegrowing and winemaking levy-payers;
2. Levy payers who are thought leaders and early adopters; and
3. Key industry influencers including consultants, financial services and suppliers.

Identification of activities and mechanism for information provision

Innovation and adoption activities will be determined based on the sector's priorities and will extend GWRDC-funded research outcomes. However, GWRDC will also continue to develop its information broker role and extend relevant information that is not the product of GWRDC-funded R&D.

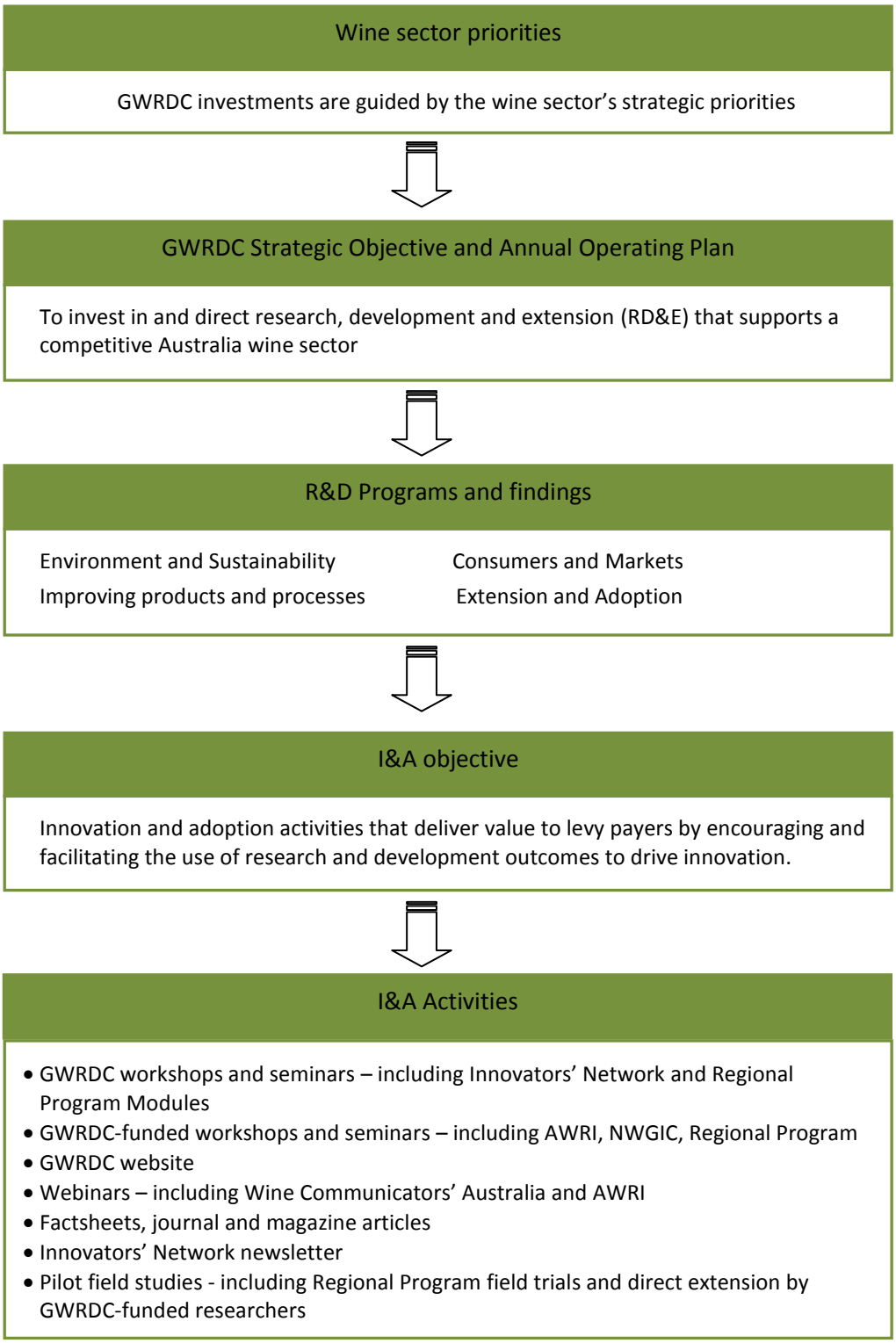
The information will be provided using a suite of communication tools (including written material, face-to-face workshops, social media, webinars and pilot plots) that will encourage innovation and adoption by the target audience.

Assuming the benefits in distinguishing between learning styles, the same information will be presented using multiple methods targeted to each of the three learning styles (auditory, visual, kinaesthetic)

Measurement of value

The Innovation & Adoption Committee will measure the value of activities to industry, and uptake by the Industry, of I&A activities using various mechanisms. These include but not limited to cost-benefit analyses of activity outcomes, the rate of adoption, the number of users or subscribers, participation rates and survey results and case studies indicating practice change.

Innovation and Adoption Activities - Flowchart



Appendix 3. List of proposed interviewees

I&A STRATEGIC GOAL: deliver value to levy payers by encouraging and facilitating use of research and development outcomes:

I&A activities will:

- Increase the rate of adoption of GWRDC-funded R&D
- Encourage innovation based on this R&D
- Develop industry capability to adopt and innovate using R&D findings

The value and effectiveness of I&A activities will be measured against this goal.

REVIEW TERMS OF REFERENCE

The purpose of the review is to:

- understand the effectiveness of the innovation and adoption activities funded by GWRDC; this will include an analysis of the scope and outcomes of the activities against both the intended scope and outcomes and Innovation and Adoption Strategic Objective;
- understand the value of the innovation and adoption activities to the Australian wine sector; including an analysis of the cost of each activity (allowing accurate comparison) and an analysis of the effectiveness of the activity against the aims of the Innovation and Adoption Strategic plan; and
- if necessary, recommend changes to GWRDC support of current and potential future innovation and adoption activities.

PARTICIPANTS

- One grapegrower and one winemaker from wine regions that represent the gamut of Australian winemaking (to include all regions with AWRI nodes).
- Representatives from top 8 companies (by volume)
- Thought leaders.

ORGANISATION / GI	NAME	ROLE
NEW SOUTH WALES		
Hunter	Bruce Tyrrell	Owner – Tyrrells Wines
Riverina	Kristy Bartrop	Industry Development Officer - Wine Grapes Marketing Board Riverina
	Allen Kennett (Casella – see below)	
NSW Industry Association	David Lowe	Owner, Lowe Wines Depty Chair, NSW Wine Industry Association
SOUTH AUSTRALIA		
Barossa	Nicki Robbins	Viticultural Development Officer – Barossa Grape and Wine Association
	Damien Tscharke	Winemaker/grapegrower Tscharke Wines
	Nigel Blieschke	Grower Liaison Officer – Peter Lehmann Wines
	Roger Maywald	Farm Manager – PIRSA Barossa Viticulture Technical Group
	Steve Schiller	Grape grower, NextCrop participant
Coonawarra	Dan Newson	Grower liaison officer – Yalumba, Coonawarra Wine
CCW	Jim Caddy (Riverland)	Chairman of Directors – CCW Co-operative
	Andrew Weeks	Senior Viticulturalist – CCW Co-operative
Riverland / Inland		
	Tim Smythe	PIRSA Regional Development Manager
	Peter Arnold	Treasury Wine Estates - Regional Manager
	Dave Liebich	Grape grower
	Chris Byrne	Executive Officer, Riverland Wine
VICTORIA		
TASMANIA		
	Jeremy Dineen	Chief Winemaker – Josef Chromy Wines
QUEENSLAND		
	Jim Barnes	Owner, Hidden Creek Wines,

		Deputy Chair QLD Wine Industry Association
WESTERN AUSTRALIA		
	Erl Happs	Owner/Winemaker – Happs Wines
COMPANIES		
	Brett McClen	Chief viticulturalist Vic /Tas
Casella	Alan Kennett	Chief Winemaker Riverina
De Bortoli	Rob Glastonbury	Operations Manager Riverina
Pernod Winemakers		
	Dr. Paul Petrie	National Viticulturist
Yalumba Wine Company	Andrew Murphy	Director of Production Barossa Valley
EXTENSION PARTNERS		
AWRI		
	Con Simos	Manager – Extension
	Peter Godden	Manager – Development
	Sam Connew	AWRI Node Manager – Hunter Valley
	Richard Mulack	AWRI Node Manager – Griffith
	Bob Dambergs	AWRI Node Manager – Tasmania
	Mark Krstic	AWRI Node Manager – Victoria

Appendix 4. Interview topics and questions

Desired outcomes of wine industry conversations (to support the desired outcome of review – Terms of Reference):

1. To understand what innovation and extension activities (funded by GWRDC) are seen as valuable to industry.
2. To understand the results of the current extension activities – have these activities led to practice change, if not, what other value they are providing.
3. To understand whether GWRDC is meeting industry needs in terms of *what* subject matter information is extended; and to understand whether GWRDC is meeting industry needs in terms of *how* the subject matter information is extended.
4. To understand gaps in either subject or mechanism that we are not covering that will encourage practice change.

Topics	Interview topics and questions for
Current valuable activities	• How do you obtain information about R&D outcomes and new innovation and technology? • Who / what do you rely on for information? • What was the last piece of research information that you discovered? • Did this information change the way that you do things? Was it hard or easy to adapt this information to your business? *OR (for practical thinkers):* • Can you give an example of how you change practices in your business: • How was example identified as needing to be changed, what information was relied on when looking at what to change to, from where / who was this information sourced? *If no GWRDC-funded activity has been identified – note and then prompt:* • Have you participated in a GWRDC-funded workshop e.g. AWRI roadshow or NWGIC Spring Vine Health Field Day or spray application workshop? • If yes – which one? Did you consider this an activity that provided useful information? • Have you used the AWRI library? If not, why not? • If yes – for what purpose did you use it? What was the outcome? • Are you a member of the GWRDC Innovators' Network? If not, why not? • Have you interacted with the AWRI nodes? • If yes: How? If yes, what specifically did you find useful – face to face contact, person who could visit the winery etc. What was the outcome of the contact? • If no: Why not?

Topics	Interview topics and questions for
Potential valuable activities	• How would you prefer to find out about R&D outcomes and new innovation and technology? • What elements of an extension activity make it useful – prompt: face-to-face, information that can be printed, practical demonstration, practical information, researchers in the field etc. • What would make you use the information that you accessed? *OR (for practical thinkers)* • Thinking about your business and a problem that you are currently faced with: • Take me though the steps that you would take to address the issue: where would you find information, who would you talk to, what information would you source, would you rely on one type of information more than another? If so – why?
Gaps	• What are the most/least useful extension activities in your opinion? • If we increase the money spent on extension activities what would you like to see the new money spent on? Are there activities that we should cease?
Stakeholder discussion on potential extension concepts	If more funding were made available for extension activities would you find any of the following valuable? • Access to experts who visit regions to discuss issues and potential solutions with industry practitioners; • The potential to participate in running trials to test experimental technology or new techniques; • Training for earlier adopters in regions (if yes, what type of training?)