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An Impact Assessment of Investment in the APL Environment RD&E Program

FINAL Report
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Executive Summary

As part of its Statutory Funding Agreement with the Commonwealth Government, Australian Pork Ltd (APL) is required to prepare and maintain an Evaluation Framework in line with APL's Research, Development and Extension (RD&E) Program Framework. Under the Evaluation Framework, APL has been conducting an ongoing evaluation process whereby, over time, each of APL's RD&E Programs is evaluated. In 2019, Agtrans Research was contracted to examine the economic, environmental and social benefits of APL's investment in the Environment RD&E Program.

The impact assessment followed general evaluation guidelines that are now well entrenched within the Australian primary industry research sector including Research and Development Corporations, Cooperative Research Centres, State Departments of Agriculture, and some Universities. The approach includes both qualitative and quantitative descriptions that are in accord with the impact assessment guidelines of the Council of Rural Research and Development Corporations.

The evaluation process involved identifying and describing the objectives, activities, outputs and outcomes, and actual and potential impacts for 21 projects in the evaluation population. The total investment (cash and in-kind) in each project by APL and others was reported by contributor and by financial year. The principal economic, environmental and social impacts associated with each project's outputs and outcomes then were summarised in a triple bottom line framework. To address the diversity of component projects and associated outcomes and impacts, the impacts from each project were categorised based on their contribution to key impact types. Once identified and described, some of the impact types then were valued in monetary terms to estimate the aggregate benefit for each of the impact types. The estimated value of the benefits from each impact type then were aggregated to form an overall aggregate value of benefits derived from the component projects in the APL Environment RD&E Program that were identified as having contributed to the impacts valued. This aggregate value was deemed to represent the principal benefits from the total Program investment.

Across the 21 projects evaluated as part of the APL Environment RD&E Program there was a wide range of impacts and/or potential impacts identified. Principal impacts of the Program investment included:

- Increased productivity/ profitability for the Australian pork industry,
- Improved efficiency of RD&E resource allocation, and
- Enhanced social licence to operate for Australian pork producers.

These three principal impacts were valued in monetary terms. Two sets of analyses and corresponding investment criteria were reported for the investment in the APL Environment RD&E Program. One analysis refers to the 18 projects that contributed to the impacts that were valued. Total funding for the 18 projects where impacts were valued totalled approximately \$4.82 million (present value terms) and produced aggregate total expected benefits of \$23.14 million (present value terms). This gave an estimated net present value (NPV) of \$18.32 million, a benefit-cost ratio (BCR) of 4.8 to 1, an internal rate of return (IRR) of 23.3% and a MIRR of 8.4%. The investment in the 18 projects valued represented approximately 96.5% of total Program funding (present value terms) for the 21 projects in the evaluation population.

When the benefits for the impacts valued were compared to the total investment in all 21 projects in the population, this slightly lowered slightly the investment criteria. Funding for all projects in the

population totalled approximately \$5.00 million (present value terms). When compared to the same value of benefits from the 18 projects (\$23.14 million PVB), the investment produced an estimated NPV of \$18.15 million (present value terms), a BCR of approximately 4.6 to 1, an IRR of 22.8%, and a MIRR of 8.3%.

The upper bound investment criteria for the total investment in the APL Environment RD&E Program (e.g. BCR of 4.8) were only slightly higher than the lower bound investment criteria (e.g. BCR of 4.6). This was because such a large number of projects (18 projects), representing approximately 96.5% of the total investment (present value terms) in the APL Environment RD&E Program evaluation population, contributed to the principal impacts valued. Thus, the difference between the upper and lower bound investment criteria is driven by only the investment costs of the three projects that did not contribute to the total estimated benefits. Assuming that some benefits existed in the projects not valued in monetary terms, the BCR for the total investment in all 21 projects could lie somewhere between 4.6 and 4.8.

The analysis suggests that the APL Environment RD&E Program has delivered positive benefits to the Australian pork industry and other industry stakeholders. Further, a pessimistic/ optimistic scenario analysis demonstrated that, under a worst-case scenario with key assumptions set to half their base values, investment criteria for the APL Environment RD&E Program were still positive with an estimated BCR of 1.2 to 1. Also, as not all of the impacts for the Environment RD&E Program were able to be valued within the scope of the current assessment, the investment criteria reported are likely to represent an underestimate of the performance of the APL Environment RD&E Program investment.

The results should be viewed positively by APL, the Australian pork industry and other APL funding partners, as well as policy personnel responsible for allocation of public funds.

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Acronyms & Abbreviations

ABARES	Australian Bureau of Agriculture and Resource Economics and Sciences
ACCU	Australian Carbon Credit Unit
ADG	Average Daily Liveweight Gain
APIQ	Australian Pork Industry Quality Assurance Program
APL	Australian Pork Limited
AWMC	Advanced Water Management Centre
BCE	Bubble Column Evaporator
BCR	Benefit Cost Ratio
BMP	Best Management Practice
CAD	Computer Aided Design
CAP	Covered Anaerobic Pond
CBA	Cost-Benefit Analysis
CBM	Compartmental Based Model
CFD	Computational Fluid Dynamics
CFI	Carbon Farming Initiative
CO ₂	Carbon Dioxide
CO ₂ -e	Carbon Dioxide Equivalent
COD	Chemical Oxygen Demand
CRC	Cooperative Research Centre
CRRDC	Council of Rural Research and Development Corporations
cwt	Carcase Weight
DAF	Department of Agriculture and Fisheries (Queensland)
DAFF	Department of Agriculture, Fisheries and Forestry (Queensland)
DAMO	Nitrite-Dependent Anaerobic Methane Oxidation
demo	Demonstration
DTM	Digital Terrain Model
EC	Electrical Conductivity
EMP	Environmental Management Plan
FCR	Feed Conversion Ratio
FNLI	Farm Nutrient Loss Index
FS	Fixed Solids
GHG	Greenhouse Gas
GPS	Global Positioning System
GRDC	Grains Research and Development Corporation
HBPP	Hot Bubble Pilot Plant
HRT	Hydraulic Retention Time
HSCW	Hot Standard Carcase Weight
IPCC	Intergovernmental Panel on Climate Change
IRR	Internal Rate of Return
K	Potassium
LCA	Life Cycle Assessment
LPG	Liquid Petroleum Gas
lwt	Liveweight
MAP	Mono Ammonium Phosphate
MIRR	Modified Internal Rate of Return
N	Nitrogen
NEGIP	National Environmental Guidelines for Indoor Piggeries

NEGP	National Environmental Guidelines for Piggeries
NEGROP	National Environmental Guidelines for Rotational Outdoor Piggeries
NH ₄ -N	Ammonium Nitrogen
NPV	Net Present Value
NRM	Natural Resource Management
NSP	Non-Starch Polysaccharides
NSW	New South Wales
NZ	New Zealand
P	Phosphorus
PNLI	Piggery Nutrient Loss Index
PO ₄ -P	Phosphate Phosphorus
PV	Photovoltaic
PVB	Present Value of Benefits
QLD	Queensland
R&D	Research and Development
R&I	Research and Innovation
RD&E	Research, Development and Extension
RDC	Research and Development Corporation
RIRDC	Rural Industries Research and Development Corporation
S	Sulphur
SA	South Australia
sCOD	Soluble Chemical Oxygen Demand
SEPS	Sedimentation and Evaporation Pond System
SFA	Statutory Funding Agreement
STC	Standard Test Conditions
tCOD	Total Chemical Oxygen Demand
TKN	Total Kjeldahl Nitrogen
TKP	Total Kjeldahl Phosphorus
TS	Total Solids
tVFA	Total Volatile Fatty Acids
UNE	University of New England
UNSW	University of New South Wales
UQ	University of Queensland
VFA	Volatile Fatty Acids
VIC	Victoria
VS	Volatile Solids
WA	Western Australia
WHS	Workplace Health and Safety

I. Background & Rationale

As part of its Statutory Funding Agreement (SFA) with the Commonwealth Government, Australian Pork Ltd (APL) is required to prepare and maintain an Evaluation Framework in line with APL's Research, Development and Extension (RD&E) Program Framework. This Framework is included in the APL Strategic Plan 2015-2020 (as amended in July 2018) (APL, 2018).

Under the evaluation framework, APL has been conducting an ongoing evaluation process whereby, over time, each of APL's RD&E Programs is evaluated. The evaluation of the impact of APL's investments in RD&E is required to understand and demonstrate APL's effectiveness in delivering desired outcomes to its key stakeholders, informing investment decisions, its annual reporting to the Australian Government, reporting to industry stakeholders and contributing to the performance assessment of Research and Development Corporations (RDCs) compiled by the Council of Rural Research and Development Corporations (CRRDC). However, some past Program evaluations have not met all of APL's internal and external reporting requirements. Thus, APL sought to improve its impact assessment process for the next evaluation of one of APL's RD&E Programs for 2018/19.

In 2019, Agtrans Research was contracted to examine the economic, environmental and social benefits of APL's investment in its Environment RD&E Program. The impact assessment was to be conducted according to the CRRDC's impact assessment guidelines (CRRDC, 2018).

2. Objectives

The impact assessment of investment in APL's Environment RD&E Program aims to identify, describe and evaluate the actual and potential impacts of a cluster of APL's project investments. The primary purpose of this report is to provide input to APL's Evaluation Framework.

Specific objectives of the project were to:

1. Conduct the impact assessment according to the CRRDC Guidelines (2018).
2. Provide a comprehensive impact assessment report for one of APL's RD&E Program investments.

3. Methodology

3.1 Population Definition

After discussions with APL personnel, it was decided that the population of projects to be included in the Environment RD&E Program evaluation would be defined according to the following criteria:

- The project was completed (final deliverable submitted and subsequently accepted by APL) in the five-year period from 1 July 2014 to 30 June 2019,
- Total APL expenditure in the project was greater than, or equal to, \$20,000, and
- The project would not be subject to other evaluation reporting requirements (for example, projects funded through the Australian Government's Rural Research and Development for Profit Program that are required to have an independent evaluation completed for end-of-project reporting).

Based on the above criteria, a population of 21 Environment RD&E Program RD&E project investments were identified for evaluation. Table I shows the list of projects included in the evaluation population.

Table I: Population of APL Environment RD&E Program RD&E Investments for Evaluation

No.	Project No.	Project Title	Start Date	End Date	Total APL Investment (nominal \$)	Total Project Investment (nominal \$)
1	2013/034	Innovative Methane Treatment - Alternative Waste Management Systems	1/10/2013	30/07/2014	47,500	47,500
2	2013/032	Upgrade and Development of Environmental Management Plans (EMP's) for Conventional and Outdoor Production Systems	1/07/2013	15/08/2014	50,000	50,000
3	2013/031	Demonstrations of How to Achieve Best Management Practices - Environmental Management	1/07/2013	31/03/2015	50,000	50,000
4	2013/027	National PigGas Extension	16/05/2013	30/07/2015	60,000	508,520
5	2015/018	National Environmental Guidelines for Piggeries (NEGP) Update	17/05/2015	12/04/2016	30,000	30,000
6	2015/021	Promoting the Utilisation of Spent Pig Bedding in Broadacre Cropping Systems	15/05/2015	30/08/2016	48,620	48,620
7	2015/010	Effect of feed wastage on piggery manure characteristics and methane potential	1/05/2015	15/09/2016	66,655	202,254
8	2014/488	Energy Audit Program	13/10/2014	15/01/2017	268,000	268,000
9	2015/051	Establishment of a soluble and insoluble NSP database by University of New England for all feed ingredients commonly fed in the pig and poultry	21/09/2015	22/03/2017	80,000	373,500

		industry to replace crude fibre values in feed formulation.				
10	2016/2207	Review of a new water purification technology - bubble column evaporator	1/12/2016	7/04/2017	30,000	30,000
11	2016/083	Strategic evaluation of opportunities and R&D needs for water management in piggeries	2/01/2017	15/09/2017	20,000	57,000
12	2015/2221	NEGP Update - Consultation with Industry and Regulators and Finalisation of Content for 3rd Edition	13/04/2016	22/12/2017	58,000	58,000
13	2017/006	Planning for Piggery Developments	7/08/2017	30/04/2018	30,000	30,000
14	2016/093	Explainer Videos: Piggery Planning Requirements	17/10/2016	23/05/2018	42,137	42,137
15	2014/446	CIC - Fertilisers from piggery liquid effluent and solids via nutrient extraction and solid formulations	1/07/2014	24/06/2018	370,597	848,424
16	2016/099	Soil Sustainability Indicator extension material	1/09/2016	30/06/2018	107,294	107,294
17	2016/2250	The bubble column evaporator feasibility study via a demo unit	22/05/2017	31/12/2018	145,000	145,000
18	2017/2212	Trends in environmental impacts from the pork industry	8/09/2017	23/01/2019	100,000	100,000
19	2018/0003	Pork water balance model development	27/08/2018	30/04/2019	23,930	32,948
20	2016/085	Anaerobic pond sludge profiling and trigger point determination	13/02/2017	7/05/2019	204,074	413,726
21	2017/2203	Pathogens and Piggery Effluent - An Updated Review	1/03/2018	29/05/2019	20,000	50,054

3.2 Evaluation Method

The impact assessments followed general evaluation guidelines that are now well entrenched within the Australian primary industry research sector including RDCs, Cooperative Research Centres (CRCs), State Departments of Agriculture, and some Universities. The approach includes both qualitative and quantitative descriptions that are in accord with the impact assessment guidelines of the Council of Rural Research and Development Corporations (CRRDC) (CRRDC, 2018).

The evaluation process involved identifying and describing the objectives, activities, outputs and outcomes, and actual and potential impacts for each project in the evaluation population. The total investment (cash and in-kind) in each project by APL and others was reported by contributor and by

financial year. The principal economic, environmental and social impacts associated with each project's outputs and outcomes then were summarised in a triple bottom line framework.

To address the diversity of component projects and associated outcomes and impacts, the impacts from each project were categorised based on their contribution to key impact types for the APL Environment Program as a whole. Once identified and described, some of the Program level impact types then were valued in monetary terms to estimate the benefit for each of the impact types. The estimated value of the benefits from each impact type then were aggregated to form an overall aggregate value of benefits derived from the component projects in the APL Environment RD&E Program that were identified as having contributed to the impacts valued. This aggregate value was deemed to represent the principal benefits from the total Program investment.

For example, after qualitatively describing all 21 projects in the APL Environment RD&E Program evaluation population, three key impact types were identified for valuation. From the 21 projects, 18 projects were deemed to contribute to the three primary impact types. The valuation of each of the three impacts was then the basis for estimating the aggregate benefits for the 18 projects that were identified as contributing to the benefits derived from the three impact types.

This process then enabled two sets of aggregate investment criteria to be estimated:

1. The costs and benefits for the contributing projects only are aggregated to form a set of investment criteria for this subset of projects. The results represent an upper bound for the economic impact of the Program when the benefits from the contributing projects are compared with only the costs of those projects.
2. The benefits for the contributing projects are aggregated as in 1 above and compared with the costs of all 21 projects in the evaluation population, to provide a lower bound for the Program's investment criteria.

3.3 Other Evaluation Considerations

Defining the 'without RD&E' scenario (the counterfactual) to assist with defining and quantifying impacts is often one of the more difficult assumptions to make in investment analyses. The 'without' scenario usually lies somewhere between the status quo or business as usual case and the more extreme positions that the research would have happened anyway but at a later time; or the impact would have been delivered anyway through another mechanism. The important issue is that the definition of the 'without' scenario is made as consistently as possible between analyses.

The counterfactual scenario for the APL Environment RD&E Program impact assessment was defined for each impact valued and described as part of the valuation process (see Section 6.2.6).

4. Project Descriptions

4.1 Logical Frameworks

Each project in the evaluation population (see Table 1) was described in a logical framework. Within each framework the objectives, activities, outputs and outcomes, and actual and potential impacts for each project were identified and briefly described. The logical frameworks for each project are shown in Table 2 to Table 22 below.

Table 2: Logical Framework for APL Project 2013/027

Code and Title	Project 2013/027: National PigGas Extension.
Project Details	Organisation: Ian Kruger Consulting. Period: October 2013 to July 2015. Principal Investigator: Ian Kruger (<i>Principal Consultant</i>).
Rationale	<p>The Australian pork industry accounts for approximately 0.4% of the nation's GHG emissions. Most GHG emissions associated with pork production relate to emissions from effluent ponds. The Australian pork industry has set itself a goal to reduce emissions on farm to 1 kg carbon dioxide equivalent (CO₂-e) per kg of pork produced (Australian Pork Ltd, 2020).</p> <p>The Pork Industry Greenhouse Gas (PigGas) Calculator was developed as a tool for producers to calculate their piggery enterprise emissions and identify ways to reduce them. Project 2013/027 was funded to provide carbon emissions education and mitigation extension to the Australian pork industry. The project aimed to deliver information that was clear, consistent and current for farmers, land managers and their key influencers to assist them to reduce GHG emissions and to participate in the Australian Government's Carbon Farming Initiative (CFI).</p>
Objectives	<ol style="list-style-type: none"> 1. Expert Users of PigGas Calculator are trained to provide high quality information and support to producers about piggery greenhouse gas emissions management and the PigGas Calculator. 2. Ian Kruger and project delivery consultants (see objective above) are skilled to provide high quality information and support about greenhouse gas emissions management and the CFI. 3. Educate pork producers on the National Carbon Accounts, the CFI and the PigGas Calculator. 4. Provide one-on-one piggery emissions modelling using the PigGas Calculator to accurately calculate producers' farm-business greenhouse gas emissions profiles and provide future mitigation options. 5. Enable other pork producers to use PigGas, model their emissions and make emissions management decisions by communicating to the pork industry and the Commonwealth about: <ul style="list-style-type: none"> - Pig Gas Calculator, - CFI, - National PigGas Extension project updates, - PigGas modelling results.
Activities	<ul style="list-style-type: none"> • Three 'Expert User' workshops were conducted to train users in PigGas and upskill them to help producers model their GHG emissions. At least six key pork industry consulting and extension personnel participated in each workshop. • From the workshop attendees, at least two Expert Users were selected as project delivery consultants. • Project leader Ian Kruger and the selected project delivery consultants completed the CFI eLearning course and then attended two face-to-face CFI sessions and two CFI webinars each financial year for the duration of the project. • Eleven PigGas producer training workshops were conducted across NSW, WA, SA, QLD, VIC and Tasmania.

	<ul style="list-style-type: none"> • 55 piggeries, representing approximately 24% of Australian pork production, were modelled and farm-business GHG emissions accurately calculated. Emissions abatement strategies also were modelled for each piggery. • Project findings were published and extended through: <ul style="list-style-type: none"> - Australia pork press extension articles/papers, - Direct mail pork industry newsletter updates, - General project media releases, and - Several conference papers.
Outputs	<ul style="list-style-type: none"> • 55 reports describing piggery GHG emissions modelling and abatement strategies were produced and are available for download at: https://australianpork.com.au/industry-focus/environment/greenhouse-gases/ • Total on-farm emissions calculated for pork production from the 55 piggeries was 260,480 t CO₂-e per year with potential abatement of 54% (141,230 t CO₂-e per year). • On a whole of industry basis, the maximum potential abatement was estimated to be 588,500 t CO₂-e per year. • Baseline on-farm emissions intensities averaged 3.9 (0.3-16.7) kg CO₂-e per kg hot standard carcass weight (HSCW) with average potential abatement of 51% (0-84%) for all piggeries. • Applying emissions abatement strategies may also lead to cost savings in feed or energy, improved manure management and/or new income streams from trading Australian Carbon Credit Units (ACCUs) and electricity (renewables).
Outcomes	<ul style="list-style-type: none"> • Increased use of the PigGas Calculator by producers across the Australian pork industry leading to increased adoption of GHG abatement strategies. • Also, the PigGas calculator currently is being licenced to New Zealand (NZ) Pork for use in the NZ pork industry (Gemma Wyburn, pers. comm., 2020). • Increased understanding of potential GHG abatement strategies and the potential benefits of reducing emissions on-farm.
Impacts	<ul style="list-style-type: none"> • Reduced GHG emissions for the Australian pork industry through increased adoption of GHG abatement strategies. • Potentially, reduced production costs for some pork producers through feed/energy efficiencies and/or improved manure management. • Potentially, increased incomes for some Australian pork producers through realisation of alternative income streams (e.g. ACCUs and electricity). • Enhanced social licence to operate for the Australian pork industry. • Increased regional community wellbeing through spillover benefits from more profitable pork production enterprises.

Table 3: Logical Framework for APL Project 2013/031

Code and Title	Project 2013/031: Demonstrations of How to Achieve Best Management Practices - Environmental Management.
Project Details	<p>Organisation: FSA Consulting.</p> <p>Period: September 2013 to August 2014.</p> <p>Principal Investigator: Robyn Tucker (<i>Principal Consultant</i>).</p>
Rationale	Over the past several years, APL has funded a large body of industry environmental research. However, most of the knowledge generated by past research investments is stored in detailed research reports that are not readily accessible for producers. There was a need to transfer information related to pork industry best management practices (BMPs) to a form that would appeal to industry and provide practical information to facilitate increased adoption of BMP technologies by industry stakeholders (one of APL's 2013/14 RD&E priorities). The expanded, summarised, and integrated BMP information would highlight to producers the options for BMPs and demonstrate the industry's sustainability to external stakeholders.
Objectives	<ol style="list-style-type: none"> 1. To develop text, photographs and diagrams for a set of 5-6 descriptive and visual booklets that showcase environmental BMPs through case studies by 30 April 2014. 2. To promote the BMP booklets in the FSA Update newsletter on the FSA Consulting website by 10 May 2014.

Activities	<ul style="list-style-type: none"> • A list of potential BMPs to be covered by the booklets was prepared by the project team. • Six topics were selected: <ol style="list-style-type: none"> 1. New design guidelines for anaerobic ponds, 2. Getting the best value from manure nutrients, 3. Minimising odour and dust from piggeries, 4. Rotational outdoor piggeries and the environment, 5. Reducing energy costs for piggeries, and 6. SEPS¹. • Research data from the available literature for each selected BMP were collated and summarised. • The project team visited a number of industry participants to collect further information including photos and quotes from producers. • Six BMP booklets/ factsheets were developed and reviewed by APL. • The six BMP booklets were promoted in the FSA Update newsletter and were uploaded on the FSA Consulting website.
Outputs	<ul style="list-style-type: none"> • Six BMP booklets for Australian pig producers: <ol style="list-style-type: none"> 1. New design guidelines for anaerobic ponds, 2. Getting the best value from manure nutrients, 3. Minimising odour and dust from piggeries, 4. Rotational outdoor piggeries and the environment, 5. Reducing energy costs for piggeries, and 6. SEPS.
Outcomes	<ul style="list-style-type: none"> • Increased knowledge of BMPs by Australian pig producers. • Increased adoption by Australian pig producers of each of the six BMPs promoted by the FSA consulting/APL booklets. • Demonstration of the sustainability of the Australian pork industry to the wider community.
Impacts	<ul style="list-style-type: none"> • Potentially, reduced operating costs for some Australian farms through increased adoption of the BMPs. • Potentially, improved environmental outcome as a result of increased adoption of the BMPs. • Potential contribution to enhanced social licence to operate for the Australian pork industry because of potentially improved environmental outcomes.

Table 4: Logical Framework for APL Project 2013/032

Code and Title	Project 2013/032: Upgrade and Development of Environmental Management Plans (EMPs) for Conventional and Outdoor Production Systems.
Project Details	<p>Organisation: FSA Consulting.</p> <p>Period: September 2013 to August 2014.</p> <p>Principal Investigator: Robyn Tucker (<i>Principal Consultant</i>).</p>
Rationale	<p>EMPs focus on the general management at a whole of farm level, taking into account the environment and associated risks. EMPs document design features and management practices, identify risks and mitigation strategies, and document monitoring plans to ensure impacts are minimised. EMPs. Further, piggery planning requirements vary from state to state and, although EMPs are optional, they can be useful to help producers assess their individual enterprise and meet the National Environmental Guidelines for Indoor Piggeries (NEGIP) or the National Environmental Guidelines for Rotational Outdoor Piggeries (NEGROP).</p> <p>APL's existing EMP template was out of date and was inconsistent with the second edition of the National Environmental Guidelines for Piggeries (NEGP) including risk assessment. Also, the existing template was not designed for application to outdoor piggeries and was not compatible with new environmental guidelines for outdoor piggeries. Project 2013/032 was</p>

¹ SEPS: Sedimentation and Evaporation Pond System – a least cost system that uses settling of solids, anaerobic and facultative digestion, and evaporation of liquid to treat effluent.

	funded to update and upgrade the APL EMP template for indoor piggeries and to develop a template for rotational outdoor piggeries.
Objectives	<ol style="list-style-type: none"> 1. To develop an easy-to-use, electronic EMP template for use by indoor piggeries by 30 May 2014. 2. To develop an easy-to-use, electronic EMP template for use by rotational outdoor piggeries by 30 May 2014.
Activities	<ul style="list-style-type: none"> • The existing EMP template was compared to the NEGP, the manure and effluent guidelines (then under development), and pollution incident response plan requirements to identify items that could be retained and items that needed to be upgraded or added in a revised template for indoor piggeries. • A draft template for indoor piggeries then was developed that included a risk assessment, pollution incident response plan and duty of care information for offsite users of piggery by-products. • The project team also prepared a report summarising the changes made (and rationale for changes) to the indoor piggery EMP template and developed a completed example EMP for publication. • For outdoor rotational piggeries, a draft EMP template was developed and compared to the NEGROP to determine any changes that needed to be made. • The new EMP for outdoor rotational piggeries also included a risk assessment, pollution incident response plan and duty of care information for offsite users of piggery by-products. • The new and improved EMP templates were reviewed by APL, edited, and then electronic versions were developed and submitted. • The electronic versions of the new EMP templates then were tested with a conventional indoor piggery and a rotational outdoor piggery.
Outputs	<ul style="list-style-type: none"> • An upgraded and up-to-date electronic EMP template for indoor piggeries and a new electronic EMP template for rotational outdoor piggeries were developed and now are available on the APL website (http://australianpork.com.au/industry-focus/environment/planning-and-development/) • A final report, detailing all aspects of the new EMP templates, and a PowerPoint presentation summarising the project and key findings were submitted to APL.
Outcomes	<ul style="list-style-type: none"> • Australian pork producers now are able to access up-to-date EMPs for planning and development.
Impacts	<ul style="list-style-type: none"> • Improved compliance of some Australian pork enterprises with the NEGP and various state planning requirements. • Potentially, reduced negative environmental impacts from pork production activities through improved identification of environmental risks and associated mitigation strategies to minimise impacts. • Potentially, some contribution to maintained or enhanced social licence to operate for some Australian pork producers.

Table 5: Logical Framework for APL Project 2013/034

Code and Title	Project 2013/034: Innovative Methane Treatment - Alternative Waste Management Systems.
Project Details	<p>Organisation: GHD.</p> <p>Period: October 2013 to May 2014.</p> <p>Principal Investigator: Anthony Allan (<i>Senior Process Engineer</i>).</p>
Rationale	<p>The Australian pork industry contributes significantly to greenhouse gas (GHG) emissions. To reduce GHG emissions associated with the pork industry there has been a drive to improve piggery waste management practices through the implementation of suitable treatment technologies, such as anaerobic digestion systems (lagoons). However, these systems reduce the organic load of the waste but produce methane, which has a significantly higher global warming potential than other greenhouse gasses. Some previous RD&E associated with methane recovery had been undertaken (e.g. research project PRJ-005672 'Methane recovery and use at a piggery' funded by the Rural Industries Research</p>

	and Development Corporation (RIRDC, now AgriFutures Australia). However, APL project 2013/034 was funded to look beyond conventional waste treatment methods and investigate alternative technologies to improve waste and wastewater management practices for Australian piggeries to further reduce GHG emissions.
Objectives	<ol style="list-style-type: none"> 1. To determine what innovative waste technologies have been recently applied to piggery waste treatment. 2. To apply recently developed technologies and research to piggery waste treatment. 3. To develop a process flowsheet that integrates a range of treatment processes to achieve the process objectives (minimise GHG emissions, beneficial nutrient management). 4. To evaluate and compare these technologies, based on a range of assessment criteria. 5. To determine what laboratory or pilot testing could be undertaken based on the findings of the literature review and technology evaluation.
Activities	<ul style="list-style-type: none"> • A project inception meeting was held in 2013. The meeting was attended by GHD and APL personnel. The meeting allowed the project team to gain a deeper understanding of APL's requirements, review the project objectives, methodology and deliverables, and to obtain relevant research/ documentation available from APL. • A literature review was undertaken. The review covered: <ol style="list-style-type: none"> i) The current status and recent development in piggery waste treatment technology, ii) The new emerging technologies not yet necessarily applied to piggery waste management, such as chemical oxygen demand (COD) conversion to hydrogen (as opposed to methane) and the DAMO (Nitrite-dependent anaerobic methane oxidation) process. • The literature review was submitted in a Technical Memorandum to APL. • Based on a short-list of potential technologies identified through the literature review, a technology review was undertaken to comprehensively assess the prospective technologies that used high-level mass and energy balances. Evaluation criteria included: <ul style="list-style-type: none"> - Greenhouse gas emissions (fugitive, process, residuals emissions), - Energy (heat and electricity) utilisation and production, - Residual / sludge production, - Nutrient management / recovery, - Impacts related to the national carbon farming initiative (including nutrient based emissions), - Simplicity of operation, - Process robustness, - Process scalability (suitability for small or large-scale operations), and - Current status of technology development. • A report summarising the technology review findings was submitted to APL Including advantages/disadvantages of the short-listed technologies and key recommendations.
Outputs	<ul style="list-style-type: none"> • A literature review report identifying technologies potentially capable of improving the waste and wastewater management practices of Australian piggeries. • A technology evaluation report that identified and assessed seven potential technologies (identified and short-listed through the literature review) against a range of criteria such as energy benefits, nutrient recovery, GHG reduction potential, technology maturity, and simplicity of operation. • A number of recommendations associated with the short-listed technologies were made. Priority technologies flagged for further analysis included: <ol style="list-style-type: none"> i. Pyrolysis, ii. Dry fermentation, iii. Plug flow anaerobic digesters, • A number of conference papers and/or presentations to APL were completed throughout the project. • The findings of this project formed a basis for recommendations to APL regarding potential laboratory or/and pilot testing requirements.
Outcomes	<ul style="list-style-type: none"> • This research has been used to prioritise and inform additional RD&E for new waste management technologies in the Australian pork industry.

Impacts	<ul style="list-style-type: none"> • Potential contribution to future generation of renewable energies for use on farms through capturing the produced GHG emissions resulting in reduced energy cost for farmers. • Potential contribution to future reduction in GHG emissions generated by the Australian pork industry through the implementation of more effective and efficient waste management technologies. • Potential contribution to future economic and environmental sustainability improvement for intensive piggery operations. • Potential contribution to strengthening the future social licence for the pork industry with less GHG emissions.
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Table 6: Logical Framework for APL Project 2014/446

Code and Title	Project 2014/446: Fertilisers from piggery liquid effluent and solids via nutrient extraction and solid formulations.
Project Details	<p>Organisation: DAF QLD. Period: Oct 2014 to May 2018. Principal Investigator: Matt Redding (<i>Principal Scientist</i>).</p>
Rationale	<p>Piggery liquid effluent and solids have nutrient value for crop production. However, these materials are not economically attractive due to the costs associated with transportation. Further, localised use of piggery manure and sludge may lead to issues with nutrient load management and land-based emissions as well as on-going maintenance issues for piggeries related to struvite-scale ($\text{NH}_4\text{MgPO}_4\cdot 6\text{H}_2\text{O}$; magnesium ammonium phosphate) build-up in effluent pipework.</p> <p>A potential solution to address such issues was to use a struvite crystallization process to extract nutrients (mostly nitrogen and phosphorous) from piggery effluents on-farm to produce a nutrient dense, cost-effective fertiliser product. Project 2014/446 was funded to conduct a trial pilot-scale extraction of struvite from piggery effluents to validate their economic and environmental effectiveness compared with commercial fertiliser sources.</p>
Objectives	<ol style="list-style-type: none"> 1. Incorporate the most recent advances in: <ol style="list-style-type: none"> a) plant nutrient supply science, and b) fertiliser formulation science to produce high value products from piggery materials. 2. Test the effectiveness of struvite precipitation as a key nutrient extraction technology at the pilot scale. 3. Pilot scale application of three technologies for fertiliser formulation and testing versus plant uptake, nutrient transport loss, gaseous loss, and volatilisation (including greenhouse gas emission), and carbon benchmarks.
Activities	<p><u>Experiment 1: Struvite extraction pilot trial</u></p> <ul style="list-style-type: none"> • A pilot scale crystallizer was constructed with a total working volume of 100L. • Piggery wastewater from an anaerobic pond was fed into the crystallizer's storage tanks and processed. • The solids (struvite) were captured in the crystallizer and collected once a week. • A separate 'bench scale' system also was trialled to improve nutrient recovery compared to the pilot scale trial. • Three soils then were selected for investigation in a laboratory and in growth accelerator pot trials. • Soils, piggery sludge, and trial struvite were subjected to a range of analyses. • Collaborators from the University of Queensland (UQ) prepared a range of encapsulated nitrification inhibitor formulations that were passed onto the DAF project team for investigation in laboratory and growth trials. <p><u>Experiment 2: Phosphorus pot trial</u></p> <ul style="list-style-type: none"> • 120 pots of black clay soil were prepared for testing. • Treatments applied included several contrasting Phosphorus (P) sources. Experimental treatments included combinations of the following: <ol style="list-style-type: none"> i) an acidifier, +/- sulphur,

- ii) a range of P sources (laboratory struvite, piggery waste derived struvite, piggery pond sludge, and mono ammonium phosphate (MAP)), and
- iii) addition of a layered double hydroxide P sorbent at a range of rates.
- Pot management was comparable to that applied in the Nitrogen (N) pot trial described in Experiment 3 below.

Experiment 3: Nitrogen pot trial

- 288 pots of black clay soil were prepared.
- Treatments applied included several contrasting N sources and formulations designed to inhibit nitrification.
- The N source treatments corresponded to constant N additions in the form of analytical reagent grade urea, struvite plus urea, or sludge plus urea.
- Pots were maintained in a randomised and blocked row-column design.
- Various nutrients were applied to all pots after plant establishment and subsequent to each plant cut.
- Leaching was conducted on each pot from the point of plant establishment and then every two weeks throughout the trial.
- Five cuts were completed for each pot at about four weekly intervals over a total experimental period of 152 days.
- Dry matter was determined for all plant samples and analysis for total N content was conducted.
- Microbial community meta-genomics was conducted on the soil from all of the inhibitor/N source/inhibitor rate combination trials.

Experiment 4 & 5: Plant establishment effects of piggery derived fertilisers – confirmatory plant establishment pot trial and root development and piggery sources nutrient pot trial

- Repeatability of results for sludge effects of plant production (from Experiment 3 above) were studied in a subsidiary pot trial with three N sources (urea, sludge, and a young sludge).
- Four replicates of each treatment at a fixed N rate using black clay soil were carried out.
- Dry matter was harvested at 16 days.
- Further, an experiment was conducted to examine plant shoot and root spatial responses to organic nutrients.
- Three piggery fertiliser sources plus a control were tested (spent piggery litter, piggery effluent pond sludge, and piggery effluent-derived struvite).
- Responses were assessed under depleted N as well as replete N conditions.
- A separate growth trial was performed to investigate the influence of the addition of sludge on the microbial community in the soil.

Experiment 6: Nitrogen delivery under challenging conditions: N pot trial 2

- A second N pot trial was conducted in order to better differentiate the performance of a range of formulations under conditions that promoted both leaching losses of nitrate and the decomposition of inhibitors.
- The second, 120 pot N trial involved the combination of a N source (urea or pond sludge plus urea), two soils, and six inhibitor formulations.
- Pots were leached at seven, 21, 44 and 60 days after establishment and analysed for N content.

Experiment 7 & 8: Formulation performance under simulated rainfall – P formulation performance and N formulation performance

- A rainfall simulator was built and stationed over a flume.
- For each treatment, a section of cut, homogenous kikuyu turf was spread in a tray and placed on the flume assembly. The apparatus enabled simultaneous evaluation of two turf sections and their treatments.
- A rainfall simulation trial was conducted with several formulations designed to supply P to identify if they were able to decrease losses of P to surface water.

	<ul style="list-style-type: none"> • Equal applications of P were applied to each turf in the form of piggery-derived struvite or MAP. • Samples of water run-off were analysed for molybdate reactive P and total P in soluble and particulate form. • A similar rainfall simulation trial also was conducted with several formulations designed to supply N to identify if they were able to decrease losses of N to surface water. • Equal applications of N were applied to each turf in the form of pond sludge or ammonium sulphate. • Run-off samples were analysed for mineral N and total N in dissolved and particulate forms.
Outputs	<ul style="list-style-type: none"> • The project developed approaches to the use of piggery-derived nutrient materials that delivered significant advantages relative to conventional fertilisers such as urea or MAP. • A combination of struvite plus urea was found to significantly increase late season N-uptake. • A formulation of combined sludge plus urea increased N uptake by 42% during plant establishment. This N source also increased residual total N stored in the soil profile. However, a small negative effect was observed in terms of N leaching ($\approx 6\%$ increase in losses), though this loss was small relative to the decreased overall loss potential associated with the increased rate of plant establishment. • Some piggery-derived struvite materials and piggery pond sludges demonstrated a plant stimulation effect that increased root and shoot development during plant establishment. • The application of piggery-derived pond sludge resulted in lower nitrate and total N losses. • Addition of elemental sulphur (an acidifier) to piggery-derived P sources in pot trials greatly increased plant P uptake, outperforming conventional fertilisers. • Some struvite forms outperformed MAP as a P source, particularly where the material was formulated with elemental sulphur (76 to 128% increased P uptake relative to conventional MAP without sulphur). The P uptake from these sources significantly exceeded uptake from sulphur formulated MAP. • Pelletising a piggery-derived P source (in this case struvite plus elemental sulphur) with a bentonite addition effectively eliminated run-off P. • Hydrotalcite additions to P sources also proved capable of effectively eliminating P run-off losses. • Un-modified struvite as a fertiliser was likely to result in lower P run-off losses than conventional MAP. • The study recommended that larger scale trials, including field trials, be conducted to complete economic viability assessments for piggery-derived fertiliser products. • The project identified a range of formulations of piggery-derived nutrients that significantly improved agronomic and environmental performance at the lab and pot scale. The formulations outperformed their conventional fertiliser equivalents. However, further work was required to translate the project findings to field-ready technologies and products.
Outcomes	<ul style="list-style-type: none"> • Additional RD&E was funded to undertake the recommended large-scale field trials and to complete the economic viability assessments for piggery-derived fertiliser products. • If the large-scale field trials are successful, project 2014/446 potentially has contributed to increased adoption/utilisation of fertilisers derived from piggery effluents.
Impacts	<ul style="list-style-type: none"> • Potentially, some contribution to improved profitability for some Australian crop producers as a result of a net reduction of fertiliser costs. • Potentially, some contribution to increased average crop performance as a result of utilisation of piggery-derived nutrients with better performance compared to commercial fertilisers. • Potentially, some contribution to decreased environmental risks as a result of lower N and P run offs.

	<ul style="list-style-type: none"> • Potentially, some contribution to reduced negative environmental outcomes associated with stockpiles of piggery effluents such as flies, odour, and contamination of soil and water supplies. • Potential contribution to future maintenance of the Australian pork industry's social licence to operate as a result of reduced environmental risks. • Potentially, some contribution to improved regional community wellbeing from profitability spillovers from the piggery industry.
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Table 7: Logical Framework for APL Project 2014/488

Code and Title	Project 2014/488: Energy Audit Program.
Project Details	<p>Organisation: The Energy Guys. Period: October 2014 to January 2017. Principal Investigator: Nick Bullock (<i>Principal</i>).</p>
Rationale	<p>Australia's ability to lift pork production is constrained by high input costs for feed, energy and labour (Mornement & Duver, 2020). Energy costs in particular have increased between 25-40% in recent years across the majority of pig producing areas (Heath, Darragh, & Laurie, 2018) and are forecast to continue to increase in each state. Further, results of an APL energy efficiency program showed that there was considerable variation in energy use between piggeries of similar production types, indicating that there may be opportunities to improve energy use efficiency across the industry. Project 2014/488 was funded to develop and carry out an energy audit program for the Australian pork industry to identify and quantify energy use on farm and suggest efficiency strategies to reduce energy use.</p>
Objectives	<ol style="list-style-type: none"> 1. Delivery of site-specific energy audits for 50 pig enterprises: data collection, reporting, staff training, ongoing support and mentoring. Identify case studies/ demonstration sites. 2. Delivery of a site-specific report and Action Plan for each participating producer indicating: reconciliation of energy use on farm, tariff review, benchmarking with other producers and recommendations for enhanced energy efficiency on site. 3. Delivery of 5 Energy Workshops across the pig production regions. 4. Development and extension of energy resources for pig enterprises.
Activities	<ul style="list-style-type: none"> • On farm data collection was carried out for a total of 42 farms across NSW, QLD, SA, VIC and WA. • A monitoring program was undertaken that focussed on recording and reporting actual energy consumption in farrowing crates to provide a better understanding of the range of energy used and the factors that lead to energy inefficiencies. • Monitoring tools used included plug-in monitors (over 50 plug-in monitors sent to 20 farms), Auzimax energy loggers on six farms, and one Envirovision monitor installed independently by a participating farmer. • Gas monitoring data also were collected from Lyndsay Walkers piggeries and was reviewed to gain a better understanding of the cost effectiveness of new, energy efficient boilers installed at the piggery to heat the heat pads in the farrowing rooms. • A case study about the new boilers then was developed to highlight the costs and potential benefits. • A farm-specific assessment of the options and potential of biogas to replace current energy consumption (electricity or heating) was carried out for each participating piggery (except for those piggeries with existing biogas plants in place). A total of 37 reports were prepared. • Participating piggeries also received a farm-specific assessment of the feasibility for solar photovoltaic (PV) systems to offset grid electricity costs. The assessments included information on system capacity and potential energy generation, energy offset and savings, costs and Standard Test Condition (STC) discounts. • Energy Efficiency Options reports were developed for each participating piggery. The reports summarised the potential actions available to save energy consumption and the associated costs and potential benefits. • The reports were developed in two sections: <ol style="list-style-type: none"> 1) a breakdown of energy consumption highlighting where energy was consumed in the

	<p>piggery operation and how this breakdown compared to other, similar piggeries, and 2) options to reduce energy bills based on the results of the monitoring program and equipment specific to each piggery such as piglet heating, cooling and ventilation, lights, pumping, and other energy consumption requirements.</p> <ul style="list-style-type: none"> • A total of three energy workshops were held. The workshops were carried out in Young (NSW), Echuca (VIC), and Murray Bridge (SA) in August 2016. • The workshops provided information for piggery operators to better understand their energy consumptions and ways to reduce energy use. • Ten extension resources were developed. Resources were targeted at piggery operators and included factsheets and a spreadsheet calculator to graph monitoring data from plug-in monitors.
Outputs	<ul style="list-style-type: none"> • A series of farm-specific reports for piggery operators assessing energy usage and identifying options (such as biogas, solar PV, etc.) to reduce energy use and/or improve energy use efficiency. • A number of extension materials and information provided through targeted workshops to help piggery operators understand their energy consumption and ways to reduce energy use.
Outcomes	<ul style="list-style-type: none"> • Increased awareness and understanding of energy consumption and options to reduce energy use and/or improve energy use efficiency for some Australian piggery operators. • More piggeries undertaking energy monitoring programs to self-assess energy use. • Some Australian pork enterprises adopting new or additional energy saving measures through better understanding the available options and potential costs and benefits of different energy technologies and practices.
Impacts	<ul style="list-style-type: none"> • Reduced energy costs for some Australian piggeries through adoption of new and improved energy technologies and practices. • Reduced GHG emissions for some Australian piggeries adopting new, more energy efficient technologies and practices. • Some contribution to maintained or enhanced social licence to operate for some Australian pork producers. • Increased regional community wellbeing through spillover benefits of a more profitable Australian pork industry.

Table 8: Logical Framework for APL Project 2015/010

Code and Title	Project 2015/010: Effect of feed wastage on piggery manure characteristics and methane potential.
Project Details	<p>Organisation: Department of Agriculture and Fisheries² (DAF) Queensland (QLD). Period: May 2015 to September 2016. Principal Investigator: Alan Skerman (<i>Principal Environmental Engineer</i>).</p>
Rationale	<p>Feed wastage represents a significant production cost for the Australian pork industry. Feed waste also contributes to greenhouse gas emissions and the energy potential from anaerobic treatment of piggery effluent; however, feed wastage is very difficult to measure directly. Project 2015/010 was funded to build on work conducted in previous projects that developed a model, known as PigBal (projects 2010/4446 and 2010/1011.334). Data produced by project 2015/010 would be used to validate the feed wastage estimation algorithms in the PigBal 4 program to improve the tool for use by producers and the broader Australian pork industry.</p>
Objectives	<ol style="list-style-type: none"> 1. To quantify the effects of different rates of feed wastage on piggery effluent characteristics and potential methane yields. 2. To validate the method for estimating piggery feed wastage incorporated in the PigBal 4 model.
Activities	<ul style="list-style-type: none"> • Shed effluent samples representing four different rates of piggery feed wastage were simulated by mixing various amounts of feed with faeces, urine, flush water and shed effluent collected from a grower shed at a commercial grower piggery in southern QLD.

² Formerly the Department of Agriculture, Fisheries and Forestry (DAFF) QLD.

	<ul style="list-style-type: none"> • The trial shed housed approximately 1,080 grower pigs grown out in batches, entering and exiting the shed at average live weights (lwt) and ages of 25-30kg at 9-10 weeks and 100-110 kg at up to 22 weeks, respectively. • On the day of sampling, the trial shed housed 535 pigs (average lwt 45kg, average age 13 weeks, fed 1.81 kg/pig/day). • Duplicate samples, prepared in the DAF Toowoomba laboratory, representing the four levels of feed wastage were: <ul style="list-style-type: none"> i. Simulated 0% feed wastage (mixture of faeces, urine and flush water). ii. Raw shed effluent (including some unknown amount of in-shed feed wastage). iii. Raw shed effluent + additional 5% feed wastage. iv. Raw shed effluent + additional 10% feed wastage. • Samples were analysed at UQ Advanced Water Management Centre (AWMC) in Brisbane, and at the DAF Toowoomba laboratories, to evaluate effluent characteristics including: <ul style="list-style-type: none"> - Total solids (TS), volatile solids (VS) and fixed solids (FS) or ash, - Total chemical oxygen demand (tCOD), soluble chemical oxygen demand (sCOD), ammonium nitrogen (NH₄-N), phosphate phosphorus (PO₄-P), total volatile fatty acids (tVFA), total Kjeldahl nitrogen (TKN), total Kjeldahl phosphorus (TKP), - Various individual volatile fatty acids (VFA), - Various trace elements and nutrients, and - Biochemical methane potential (methane yield). • Data provided by the piggery operator for the batch of pigs housed in the trial shed were entered into the AUSPIG model³ to simulate the growth performance and estimate the feed intake for the batch of grower pigs in the trial shed where the effluent samples were collected. • The PigBal 4 model then was used to predict characteristics of effluent and feed wastage over the 24-hour effluent collection period using the feed intake estimates, average daily lwt gain (ADG) and feed-conversion ratio (FCR) values, for each of the four treatments. • Statistical validation measures for the four treatments were calculated, as suggested by Mayer and Butler (1993), to assist in validating the PigBal predictions against the trial data.
Outputs	<ul style="list-style-type: none"> • A final report was developed presenting the effects of different rates of feed wastage on piggery effluent characteristics and potential methane yields. The project found that: <ul style="list-style-type: none"> - Increasing levels of feed wastage in piggery effluent resulted in incrementally increasing concentrations of TS, VS, tCOD, sCOD, most nutrients and VFAs in the four treatment samples. - Increasing feed wastage level increased methane yields. - Increased piggery biogas energy cost savings, resulting from higher levels of feed wastage, would be insufficient to offset increased feed costs. • High quality piggery manure was produced with lower production costs and reduced GHG emissions. • The project found that the availability of a relatively simple tool to assist in the assessment and improved management of feed wastage could have a major impact on profitability for the Australian pork industry. The study suggested that a 5% improvement in feed wastage could reduce feed wastage by 82,000 tonnes/year with an annual value of approximately \$38 million. • The project recommended that further, comprehensive AUSPIG simulations be conducted to provide revised growth curves and feed intake data for derivation of updated algorithms for inclusion in PigBal 4. • Further, the existing PigBal diet ingredient database should be reviewed to improve consistency between measured and modelled feed composition.

³ AUSPIG is an advanced decision support system for pig producers. AUSPIG integrates the latest R&D from around the world into four components: (1) AUSPIG growth and production simulation model, (2) Feedmania optimal-cost diet formulation system, (3) Pigmax pig enterprise model, and (4) Expert Systems to analyse and interpret the model output (Pork CRC, n.d.)

	<ul style="list-style-type: none"> • The project developed and trialed a new methodology for assessing piggery feed wastage for adoption in subsequent research. • A number of articles in industry publications, presentations at industry forums, and conference/Journal papers were produced.
Outcomes	<ul style="list-style-type: none"> • The information generated by the project has been used to inform additional investment to revise and improve the PigBal model and decision tool.
Impacts	<ul style="list-style-type: none"> • Potential reduction in GHG emissions from the Australian pork industry due to additional use of quality piggery manures, adoption of covered digester systems, and development of feed wastage estimation models. • Potential increase in industry profitability and efficiency through reduced waste by the piggery industry. • Potential improvement of industry sustainability through enhancement of social licence with reduced financial and environmental consequences.

Table 9: Logical Framework for APL Project 2015/018

Code and Title	Project 2015/018: National Environmental Guidelines for Piggeries (NEGP) Update.
Project Details	<p>Organisation: Livestock Environmental Planning. Period: May 2015 to April 2016. Principal Investigator: Robyn Tucker (<i>Principal Consultant</i>).</p>
Rationale	The NEGP provide a national approach to environmental management of Australian piggeries. The NEGP were last reviewed and revised in 2010. Since the last review, APL had funded a range of environmental research generating new and improved knowledge that needed to be incorporated into the NEGP to ensure they continued to be relevant and credible. Project 2015/018 was funded to review past environmental research associated with Australian piggeries and make recommendations how the research findings could be incorporated into the NEGP.
Objectives	<ol style="list-style-type: none"> 1. To review recent piggery environmental research and identify findings to incorporate into the NEGP by 28 September 2015. 2. To make specific recommendations on how to incorporate recent piggery environmental research findings into the NEGP by 21 December 2015.
Activities	<ul style="list-style-type: none"> • Environmental research reports (published and unpublished) were collected from the APL website and directly from APL. • Reports collected covered research funded by APL, the CRC for High Integrity Australian Pork and the National Agriculture Manure Management Program. • Over 60 research reports were reviewed as part of the NEGP update project. • A report outlining the findings of the review was completed and submitted to APL in January 2016. • Following submission of the review summary report, a second report was developed outlining the specific recommendations for how to incorporate recent research findings into the NEGP.
Outputs	<ul style="list-style-type: none"> • Key recommendations from the project were: <ul style="list-style-type: none"> ○ To incorporate PigBal 4 SPU lwt regression method into the NEGP in place of age groups for progeny. ○ To expand the energy efficiency component of the Cleaner Production section. ○ To modify the housing section to cover sows on litter and outdoor pigs (nutrient accumulation/ management). ○ To modify the pond sizing information section to recognise that PigBal 4 includes sizing for large anaerobic ponds, heavily loaded ponds and covered anaerobic ponds (CAPs). ○ To update the sludge accumulation rate and to expand the pond desludging section by adding the various methods (pump, dredge, excavator) and details around managing removed sludge. ○ To include information on engineered digesters and hybrid systems (e.g. stirred and/or heated CAPs). ○ To add new findings around reuse, particularly spent bedding management and soil health information.

	<ul style="list-style-type: none"> ○ To add a separate section of practical odour minimisation. ○ To include a range of practical and cost effective GHG options. ○ To update and expand the sections on GHG reporting and regulation. ○ To introduce PigBal 4 as the accepted industry standard for manure estimation. ○ To tweak some of the S factors in the odour guidelines.
Outcomes	<ul style="list-style-type: none"> ● The findings of the project were used to inform the next steps in the process to update the NEGP. ● The next steps included consultation with industry and regulator representatives to address the recommendations with the aim of reaching consensus on their inclusion into the NEGP.
Impacts	<ul style="list-style-type: none"> ● Potentially, some contribution to the future economic and environmental sustainability of the Australian pork industry through ongoing use of the NEGP. ● Potentially, some contribution to the maintenance or enhancement of the social licence to operate for the Australian pork industry.

Table 10: Logical Framework for APL Project 2015/021

Code and Title	Project 2015/021: Promoting the utilisation of spent pig bedding in broadacre cropping systems
Project Details	<p>Organisation: Rural Directions Pty Ltd. Period: May 2015 to August 2016. Principal Investigator: Tony Craddock (<i>Consultant/Director</i>).</p>
Rationale	Spent pig bedding has commonly been used as an alternative fertiliser and soil improver for broadacre cropping systems. However, little is known about the nutrient content of spent pig bedding, appropriate application rates, or potentially negative crop effects. A recent APL-funded project (APL 2010/1015) investigated such issues and demonstrated the utilisation of spent eco-shelter bedding in broadacre cropping systems. Project 2015/021 then was funded to extend the results to producers to further promote the utilisation of spent pig bedding in cropping systems.
Objectives	<ol style="list-style-type: none"> 1. Communication of practical guidelines to cropping farmers on how to utilise spent bedding from straw-based pig housing. 2. Awareness of the potential for spent bedding from eco-shelters to supply nutrients for broadacre crops. 3. Increased utilisation of spent bedding from straw-based pig housing on broadacre cropping farms.
Activities	<ul style="list-style-type: none"> ● A series of five workshops for broadacre crop growers (35% of participants), mixed piggery and broadacre growers (40% of participants), agronomists/cropping advisors (7% of participants), and other industry participants e.g. Natural Resource Management (NRM) officers, composters, and pork industry advisors (18% of participants) were conducted in Victoria (VIC) (St Arnaud, September 2015), New South Wales (NSW) (Corowa, September 2015), Western Australia (WA) (Narrogin, March 2016), QLD (Monto, April 2016), and South Australia (SA) (Coomandook, June 2016). ● The workshops were conducted in areas that had substantial pig herds in conjunction with nearby cropping farms. ● To maximise participation, in addition to advertising the workshops using local media, local pork producers were also enlisted to identify potential participants from their local area. ● A range of topics were covered at the workshops regarding the utilisation of spent pig bedding in cropping systems to address frequently asked questions by users including: <ul style="list-style-type: none"> - Nutrient content of spent bedding, - Appropriate use patterns for broadacre cropping soils, - Calculation of appropriate application rates, - Timing of application, - Application methods and equipment, - Minimising adverse effects to crops, the environment, and neighbours, - Economics of spent bedding as a nutrient source. ● A media campaign was undertaken to promote the utilisation of spent pig bedding. This involved the development of case studies in each target state.

	<ul style="list-style-type: none"> • Broadacre farmers already utilising spent pig bedding were interviewed and their motivations for spent bedding utilisation, use patterns and techniques for application were recorded and written up as the case studies. • The sources used for the media campaign were: <ul style="list-style-type: none"> - Two Twitter feeds transmitted prior to the Narrogin workshop and Coomandook workshops, - A Grains RDC (GRDC) radio interview/podcast http://bit.ly/IWM6mmD in September that discussed the use of manure-based products in broadacre cropping systems, - Agricultural Bureau Networks (SA), and - The Rural Directions Pty Ltd Management Training e-newsletter. • A number of articles and factsheets for rural press publications were developed, informed by the case studies, to educate and promote the use of spent pig bedding in broadacre cropping systems in target states.
Outputs	<ul style="list-style-type: none"> • A number of workshops were successfully conducted throughout Australia. • Overall, 99 participants attended the workshops; 35% of participants were broadacre crop growers, 40% were mixed piggery and broadacre growers, 7% agronomists/cropping advisors and 18% other industry stakeholders. • Several articles and factsheets based on the case studies were published as rural press publications to educate and promote the use of spent bedding in broadacre cropping systems in target states including: <ul style="list-style-type: none"> - Corowa Free Press in NSW, - The North Central News in VIC, - The Narrogin Observer and The Farm Weekly in WA, and - The Murray Valley Standard in SA.
Outcomes	<ul style="list-style-type: none"> • A broader awareness and understanding by pig producers and cropping farmers of: <ul style="list-style-type: none"> - The nutrient content of spent pig bedding, - The potential of spent pig bedding to provide nutrients for crops, - Practical aspects of using spent pig bedding on cropping soils, and - The potential for spent bedding to improve poor cropping soils. • As a result of the extension activities (e.g. workshops), crop producers have increasingly adopted the utilisation of spent pig bedding in broadacre cropping systems.
Impacts	<ul style="list-style-type: none"> • Increased profitability for some Australian crop farmers through increased utilisation of spent pig bedding leading to increased average crop yield and reduced fertiliser costs. • Reduced risk of negative environmental outcomes associated with stockpiles of spent pig bedding such as flies, odour, and contamination of water supplies. • Potentially enhanced economic and environmental sustainability for the Australian pork industry and some associated cropping farmers.

Table 11: Logical Framework for APL Project 2015/051

Code and Title	Project 2015/051: Establishment of a soluble and insoluble NSP database by University of New England for all feed ingredients commonly fed in the pig and poultry industry to replace crude fibre values in feed formulation.
Project Details	Organisation: University of New England (UNE). Period: Jan 2016 to Jan 2017. Principal Investigator: Natalie Morgan (<i>Postdoctoral Scientist</i>).
Rationale	Measurement of soluble and insoluble non-starch polysaccharides (NSP) content of feeds has been used as an indicator of fibre content of diets in the pig and poultry industry. The characteristics and the amount of soluble and insoluble NSP vary greatly between different ingredients, therefore they must be measured precisely to predict the effects of fibre on nutrient and energy digestibility. There was no database available providing precise descriptions for feed ingredients commonly fed in the pig and poultry industry. Hence Project 2015/051 was funded to establish a database for use in feed formulation through measuring the soluble and insoluble NSP contents of feed ingredients used in the pig and poultry industry.

Objectives	<ol style="list-style-type: none"> I. To establish a NSP database that can replace crude fibre values in feed formulation by measuring soluble and insoluble NSP content of all feed ingredients commonly fed in the pig and poultry industry.
Activities	<ul style="list-style-type: none"> • Values presented for soluble, insoluble and total NSP and oligosaccharide content of pig/poultry feed ingredients in Australia were collected from journal articles, scientific abstracts and industry presentations. • The values were collated into a database using Microsoft Excel® and a list was derived of any ingredients for which NSP data were unavailable or incomplete. • The list was then disseminated to feed millers, feed producers and animal nutrition specialists across Australia. A total of 835 feed ingredient samples were dispatched to the UNE for analysis. • Each sample (with a minimum of 10 replicates) was fat extracted and free sugars removed, and the starch was gelatinised by α-amylase and amyloglucosidase. • The prepared samples then were incubated and centrifuged and the resulting supernatant and residue was analysed by a Gas Chromatograph (Varian CP3800). • All information was presented in a user-friendly database compatible with most feed formulation programs.
Outputs	<ul style="list-style-type: none"> • A database that presents average sugar composition of the soluble, insoluble and total NSP and oligosaccharide contents of conventional and unconventional ingredients used in the pig and poultry industry. • Increased knowledge on detailed chemical structures and physiological activities of NSP that enables the pig and poultry industries to make accurate predictions about the true fibre values in diets.
Outcomes	<ul style="list-style-type: none"> • Information on feed ingredient NSP has been used by pig and poultry feed producers to improve animal feed formulations. For example, the project provided values for the soluble and insoluble NSP content of unconventional feed ingredients that could be actively used in feed formulations as an alternative to soybean meal. • The NSP database may be used in the development of future technologies that can potentially improve nutritional value of fibre in pig and poultry diets and increase accuracy and flexibility in least-cost feed formulations. • Potentially producers would be able to feed livestock better quality and/or cheaper feed products.
Impacts	<ul style="list-style-type: none"> • Potentially, some contribution to decreased cost of feed formulations for some pig feed producers as a result of access to the new NSP database. • Potentially, some contribution to decreased cost of feed formulations for some poultry feed producers as a result of access to the new NSP database. • Potentially, increased sustainability for the pig industry as a result of more sustainable feed formulation. • Potentially, increased sustainability for the poultry industry as a result of more sustainable feed formulation.

Table 12: Logical Framework for APL Project 2015/2221

Code and Title	Project 2015/2221: NEGP Update – Consultation with Industry and Regulators and Finalisation of Content for 3 rd Edition.
Project Details	<p>Organisation: Livestock Environmental Planning.</p> <p>Period: April 2016 to May 2017.</p> <p>Principal Investigator: Robyn Tucker (<i>Principal Consultant</i>).</p>
Rationale	Project 2015/2221 was funded as a direct follow on from project 2015/018. The project was funded to undertake consultation with industry and regulators to reach a consensus about new information to be included in an updated version of the NEGP.
Objectives	<ol style="list-style-type: none"> 1. To develop updated NEGP content based on the latest industry environmental research. 2. To consult with industry and key researchers to gain acceptance of the proposed changes to the NEGP. 3. To educate regulators on key findings of the latest pig industry environmental research. 4. To gain regulator consensus on the proposed changes to the NEGP.

Activities	<ul style="list-style-type: none"> • A copy of the existing NEGP was marked with proposed changes and submitted to APL for review. • A working group of selected producers, researchers and regulators was formed and invited to review the initial proposed changes to the NEGP. • A workshop then was held with the members of the working group to gain a consensus about the changes first among industry participants (workshop day 1) and then amongst industry personnel, researchers and regulators (workshop day 2). • Specific changes to the wording and content of the NEGP were identified through the review and workshop process and a table of changes and suggested actions covering the agreed position from the workshop (and identifying any unresolved issues) was prepared. • The document outlining agreed changes and unresolved issues was submitted to APL for review.
Outputs	<ul style="list-style-type: none"> • A report summarising the major changes (wording and content) recommended for the revised edition of the NEGP agreed to by industry, researchers and regulators.
Outcomes	<ul style="list-style-type: none"> • The findings of the project were used to develop the NEGP 3rd Edition, published in May 2018 and available on the APL website. • The NEGP was re-titled as the National Environmental Guidelines for Indoor Piggeries (NEGIP) to avoid confusion between the reference documents for indoor and outdoor rotational piggeries.
Impacts	<ul style="list-style-type: none"> • Some contribution to the future economic and environmental sustainability of the Australian pork industry through ongoing use of the NEGP. • Potentially, some contribution to the maintenance or enhancement of the social licence to operate for the Australian pork industry.

Table 13: Logical Framework for APL Project 2016/083

Code and Title	Project 2016/083: Strategic evaluation of opportunities and R&D needs for water management in piggeries.
Project Details	<p>Organisation: University of Queensland. Period: January 2017 to June 2018. Principal Investigator: Marie-Lure Pype (<i>Postdoctoral Research Fellow</i>).</p>
Rationale	<p>Wastewater management is an important aspect of piggery management. The Australian pork sector aims to reduce its total water consumption and it was thought that water recycling may be an effective solution. The actual quality to which water was being treated for various uses, such as flushing, was unknown and some previous research had indicated there may be financial incentives with improved pig health and potentially reduced mortalities. However, use of treated wastewater is governed by various legislation and it was uncertain whether recycling of secondary effluent would be permissible under future legislation. Project 2016/083 was funded to provide the Australian pork industry with a framework that would logically sort important water recycling issues to identify gaps and needs for future research and investment.</p>
Objectives	<ol style="list-style-type: none"> 1. Determine the quality requirements for water treatment at piggeries. 2. Involve producers and industry early-on in the project to tailor the project to industry needs. 3. Define the present and likely future legislative environment for water and wastewater management. 4. Propose a framework for future investment and research in water management across the pork sector.
Activities	<ul style="list-style-type: none"> • The project set out to develop a framework that would address three key future issues: 1) How water treatment infrastructure would be paid for in the medium term; 2) What technologies would be suitable for wastewater treatment; and 3) What are the potential regulator risks in terms of guidelines and requirements for treated wastewater quality for future applications. • A detailed literature review was undertaken covering international peer reviewed journals, publicly available project literature, national and international regulation guidelines, APL research reports and trade journals. • A knowledge gap analysis was completed to identify needs for future research and investment.

	<ul style="list-style-type: none"> • A number of pork industry service providers and regulators were consulted about current activities in water recycling in the pork industry and the regulatory framework relevant to wastewater treatment and recycling in piggeries. • Based on the findings of the literature review, gap analysis and stakeholder consultation, a proposed future research plan was developed.
Outputs	<ul style="list-style-type: none"> • The literature review produced the following outputs: <ul style="list-style-type: none"> - Identification of water streams for reuse and possible end-use applications according to water quality required including cost-benefit analysis, - A comparison of Australian versus international guidelines, - A case study of water recycling use in meat factories in other developed countries, - Water use targets and a value proposition/risk exposure related to water consumption were established, - Knowledge gaps and areas for subsequent research and/or process optimisation were identified, and - Future research priorities were identified. • The gap analysis identified the following areas for further research: <ol style="list-style-type: none"> 1) There is a need to clarify effluent quality requirements for various reuse purpose at Australian piggeries, including for: <ol style="list-style-type: none"> a) current base case of irrigated effluent and treated wastewater recycling for flushing, and b) the future quality requirements for pig drinking water reuse. 2) Once the financial business case for wastewater treatment and recycling has been established, and water quality requirements have been confirmed, the following treatment approaches should be considered and further evaluated within pork industry-specific constraints: <ol style="list-style-type: none"> a) coagulation/ flocculation, b) sand filtration, c) ion exchange resin, d) membrane bioreactors, e) microfiltration, f) ultrafiltration, g) nanofiltration, h) reverse osmosis, i) forward osmosis, j) chlorination, k) ozone, and l) UV. • Consultation with industry service providers and regulators confirmed that piggeries in Australia are not currently treating effluent for recycling to high-end uses, including potable reuse. • A proposed future research plan that recommended the following research projects/ research directions: <ol style="list-style-type: none"> 1) Understanding the relationship between recycled water quality and production performance factors such as pig health and growth and antimicrobial use. 2) Clarifying guidelines and requirements for treated wastewater quality for the applications of effluent irrigation. 3) Development of cost effective water conservation methods, and wastewater treatment and recycling approaches for piggeries.
Outcomes	<ul style="list-style-type: none"> • The project findings have been used by APL to identify and prioritise future RD&E associated with wastewater treatment and water recycling options for the Australian pork industry.
Impacts	<ul style="list-style-type: none"> • Increased efficiency of RD&E resource allocation associated with wastewater and water recycling associated with the Australian pork industry. • Potentially, some contribution to the future economic and environmental sustainability of the Australian pork industry through the development and adoption of improved wastewater management technologies. • Potentially, some contribution to the maintenance or enhancement of the social licence to operate for the Australian pork industry.

Table 14: Logical Framework for APL Project 2016/085

Code and Title	Project 2016/085: Anaerobic pond sludge profiling and trigger point determination.
Project Details	<p>Organisation: DAF QLD. Period: Feb 2017 to May 2019. Principal Investigator: Alan Skerman (<i>Principal Environmental Engineer</i>).</p>
Rationale	<p>Management of sludge in anaerobic effluent treatment ponds has been a difficult, time consuming, and expensive process for Australian piggeries especially when the sludge accumulates over time. Large volume of highly dense sludge can lead to increased odour emission, ineffective treatment of piggery effluent, and carryover of solids into secondary effluent storage ponds.</p> <p>Several factors have constrained producers from effectively managing sludge including: the lack of reliable Australian data on sludge accumulation rates, pond designs which have not adequately considered the need for periodic desludging, lack of relatively simple and inexpensive technology for effectively monitoring sludge levels in anaerobic ponds, lack of reliable information and knowledge regarding effective desludging methods, and lack of guidance on the most appropriate timing of desludging for ease of removal. Project 2016/085 was funded to address such constraining factors and to provide reliable guidelines and information on effective sludge management practices using sludge profiling and modelling techniques.</p>
Objectives	<ol style="list-style-type: none"> 1. To develop and trial methods for effectively monitoring sludge profiles and accumulation rates and collecting sludge samples from uncovered anaerobic effluent ponds. 2. To determine sludge profiles in approximately 15 existing anaerobic effluent ponds at southern Queensland piggeries. 3. To estimate the sludge accumulation rates in each of the ponds, based on site-specific data relating to the pond loading rate (pig herd, diet and production performance), the original pond dimensions and desludging history. 4. To collect several sludge samples from selected ponds (including one covered anaerobic pond) to determine the solids and nutrient contents and the biochemical methane potential of sludge sampled at various depths and locations within the ponds. 5. To further develop (including calibration) and use an integrated hydrodynamic-biochemical model to provide predictions of sludge behaviour. 6. To determine optimal desludging intervals for ease of pumping while avoiding significant losses of methane potential. 7. To provide recommendations for the design of anaerobic ponds to enhance the ease of desludging.
Activities	<ul style="list-style-type: none"> • Sludge profiling was carried out by Premise Agriculture on eleven primary anaerobic ponds and four secondary effluent storage ponds operating at ten commercial piggeries located on the Darling Downs in southern QLD. • A digital terrain model (DTM) of the sludge surface was generated using the resulting sludge depth and position data and specialised computer software. • Sludge volumes were determined from the sludge DTMs and the original design or as-constructed survey data for the various ponds. • The PigBal 4 model was used by DAF to estimate the TS loading rates which had contributed to the sludge volumes measured in each of the ponds using historical pig herd, feed consumption and pond management data provided by the piggery operators. • Sludge accumulation rates were estimated for each of the surveyed ponds using TS loading rates, the sludge volumes, and the available pond desludging history. • A procedure developed by DAF was used to obtain several samples of the pond sludge and supernatant from three uncovered anaerobic ponds. • A further sludge sample was obtained from a covered anaerobic pond undergoing desludging. • The samples were analysed at the DAF Toowoomba and the University of Queensland Advanced Water Management Centre laboratories. The analyses included: <ul style="list-style-type: none"> – TS, VS and FS or ash, – Biochemical methane potential, – tCOD, sCOD, NH₄-N, PO₄-P, tVFA, TKN, TKP,

	<ul style="list-style-type: none"> – Various individual VFAs, and – Various trace elements and nutrients. • Computational models were developed to predict hydrodynamics and sludge behaviour within four selected ponds surveyed during previous stages. • A hydrodynamics or computational fluid dynamics (CFD) simulation platform was developed to predict the liquid, solid and combined liquid-solid dynamics occurring within the ponds under three different bases: <ul style="list-style-type: none"> i. 2D single phase flow to provide information on hydraulic channelling, ii. 3D single-phase flow to provide process characteristics, and iii. 3D two-phase flow to indicate solids' distribution profile. • A compartmental based model (CBM) was then applied to a biochemical model to provide long-term predictions of sludge behaviour and overall pond performance.
Outputs	<ul style="list-style-type: none"> • The sludge profiling method used in the project was found to be effective, however, it involved considerable labour and the use of specialised equipment and computer software that limited its application for regular sludge monitoring at commercial piggeries. • The results demonstrated that the current pond design standard was within the measured range of sludge accumulation rates and there was insufficient evidence to suggest any major changes to the current standard. • The CBM showed that the optimal pond design was 150 day Hydraulic Retention Time (HRT) that balanced pond lifetime, capital cost, and performance. • Further, pond depth was found to be the primary design factor affecting solid settling and sludge accumulation. A deep pond (6m+) was preferred to a shallow pond to: <ul style="list-style-type: none"> a) increase sludge holding capacity, b) decrease the hydrodynamic impacts of sludge accumulation, c) minimise internal recycles and bypass flows, and d) enable in-situ desludging. • Sloped sidewalls were found to be important to minimise dead zones and allow the sludge to accumulate in designated desludging zones. • A number of specific conclusions and recommendations were made based on the project findings including: <ul style="list-style-type: none"> - HRTs should be maintained within 100 to 300 days to retain active fraction, minimise short circuiting, and maintain effective lifetime. - Where covered anaerobic lagoons are used, solids load should be minimised, and solids management considered carefully, possibly by active withdrawal. - Desludging intervals should be selected according to individual pond performance results but should be higher than 100 days to maximise methane potential. <ul style="list-style-type: none"> – Regular sludge profiling would greatly assist with the ongoing management of commercial piggery ponds. – The development of a remote-controlled raft to convey the sonar and GPS units over the pond surface would further improve the safety and convenience of sludge profiling operations while reducing the labour investment. – Solids substantially impact hydraulics and 3D two-phase flow was required for effective simulation of hydraulics. – The CFD was too computationally expensive for long-term lagoon simulations but generated effective profiles to validate CBMs. – Modelling on additional pond designs was recommended to verify current conclusions and determine applicability to generic ponds. • A number of conference and journal papers were produced.
Outcomes	<ul style="list-style-type: none"> • Improved future hydrodynamic modelling for anaerobic ponds to assess sludge behaviour. • Potentially, adoption of project guidelines and recommendations to improve designs of anaerobic ponds and consequently enhance sludge management practices for some Australian piggeries. • Potentially, additional use of sludge profiling and modelling techniques to determine effective sludge accumulation management practices by piggery producers.
Impacts	<ul style="list-style-type: none"> • Potentially, reduced cost of sludge management practices as a result of improved anaerobic pond designs and better sludge management.

Table 15: Logical Framework for APL Project 2016/093

Code and Title	Project 2016/093: Explainer Videos: Piggery Planning Requirements.
Project Details	Organisation: Livestock Environment and Planning. Period: October 2016 to November 2017. Principal Investigator: Robyn Tucker (<i>Principal Consultant</i>).
Rationale	Australian piggeries are required to submit applications for new developments, expansions and changes in material use. However, planning requirements vary from state to state and the information and advice available to piggery operators was unclear. In some cases, producers were told they did not need a permit and then later advised this was incorrect, while in other cases producers have had to provide very detailed information that was beyond typical planning requirements. In both cases there were increased risks and costs for both the individual producers and the councils involved. Project 2016/093 was funded to provide a simple resource to educate planners about when planning approval is required, the major planning and environmental considerations, information that should accompany an application, the guidelines that would be most useful in assessing applications and other available resources and help.
Objectives	<ol style="list-style-type: none"> 1. To produce an Explainer Video that provides guidance on piggery planning requirements and the assessment of planning permit applications for indoor piggeries. 2. To produce an Explainer Video that provides guidance on piggery planning requirements and the assessment of planning permit applications for outdoor piggeries.
Activities	<ul style="list-style-type: none"> • Project leader Robyn Tucker developed draft scripts and animation ideas for two explainer video clips: one for indoor piggeries and one for outdoor piggeries. • The drafts were reviewed by APL and then finalised. • A voiceover artist was selected and asked to record the script as though it were a casual explanation from a senior colleague. • Storyboards were developed for each video (indoor and outdoor) to plan the dialogue and directions for the animation for each Explainer Video. • The clips then were animated by transforming the storyboards into moving images. • The final Explainer Videos were completed and delivered to APL via DropBox.
Outputs	<ul style="list-style-type: none"> • Two Explainer Videos targeted at piggery planners were produced: <ol style="list-style-type: none"> 1) Indoor Piggeries: A Guide for Planners 2) Outdoor Piggeries: A Guide for Planners.
Outcomes	<ul style="list-style-type: none"> • The Explainer Videos were uploaded to the APL website: http://australianpork.com.au/industry-focus/environment/planning-and-development/ • The videos have been used by piggery planners and producers to better understand planning requirements.
Impacts	<ul style="list-style-type: none"> • Increased efficiency of planning and development application processes for Australian pork producers and councils through improved understanding of application requirements and increased confidence in their respective ability to complete the application process.

Table 16: Logical Framework for APL Project 2016/099

Code and Title	Project 2016/099: Soil Sustainability Indicator extension material.
Project Details	Organisation: Integrity Ag Services. Period: September 2016 to December 2017. Principal Investigator: Stephen Wiedemann (<i>Managing Director</i>).
Rationale	One of the largest interactions between piggeries and the surrounding land occurs as a result of by-product application. By-products (effluent, spent bedding, solids) can be either beneficial or harmful to soil health and crop or pasture performance, and also influences the risk of nutrient losses. One key aspect of appropriate soil nutrient management is a clear understanding of by-product characteristics and soil nutrient status. These are typically assessed via laboratory analysis, but anecdotal evidence suggested that many farm managers,

	<p>some advisors, and Australian Pork Industry Quality Assurance Program (APIQ) auditors and regulators, did not have the necessary skills to properly interpret the analytical results. Project 2016/099 was funded to provide extension materials to improve the ability of producers, advisors and regulators to interpret soil tests through a better understanding of nutrient requirements and nutrient loss risks.</p>
Objectives	<ol style="list-style-type: none"> 1. Produce easy to understand information to help producers interpret effluent, manure and soil tests. 2. Produce technical information supporting interpretation of effluent, manure and soil tests for advisors and regulators. 3. Produce 'print ready' materials for dissemination to industry via the website and via hand-outs at pig industry events. 4. Produce simple content (calculations and 'rules of thumb') for incorporation into the APL tech toolbox app. This will be supplied in Word and/or Excel. 5. Produce recommendations for new 'safe upper limits' or alternative approaches for guiding decisions around high soil nutrient levels in by-product application areas. 6. Develop a nutrient risk tool to help producers and advisors understand nutrient risks and how to mitigate these risks from outdoor pig farms and potentially effluent application areas.
Activities	<ul style="list-style-type: none"> • The first stage of the project involved a targeted review of the scientific literature in Australia regarding nutrient availability and recommendations for key nutrients such as N, P, potassium (K), sulphur (S), cations, and soil indicators such as electrical conductivity (EC) and pH. • Following the technical review, available extension literature was reviewed. This review included information targeted to the grazing and cropping industries such as the 'Better Fertiliser Decisions' manual, soil acidification manual, soil phosphorus manual and the pig industry's own environmental guidelines. • Based on the technical and extension literature reviews, a technical report was produced that summarised the technical basis for new guidance around soil indicators and nutrient risks related to soil nutrient levels on pig farms. • The Farm Nutrient Loss Index (FNLI) was then assessed for its relevance to the pig industry, and the relative importance given to soil nutrient levels in the FNLI approach compared to other factors. • The FNLI also was compared with the NEGP and NEGROP risk assessment tools currently available to the industry. • The technical information was compiled and then simplified and converted into an easy to read, print ready guidebook. The information also was provided for incorporation into the APL tech toolbox app. to provide an interactive tool that helps with basic decision making. • Information associated with nutrient trigger levels and risk of nutrient loss for outdoor pig production was integrated into the FNLI tool. The new component of the tool was named the Piggery Nutrient Loss Index (PNLI) and enables the tool to be used for outdoor pig production and effluent areas (permanent pasture).
Outputs	<ul style="list-style-type: none"> • A technical report summarising key information for understanding soil and manure tests in the pig industry. • A soil and nutrient interpretation guide for understanding soil and manure tests in the pig industry titled "Soil Indicator Guide for Piggeries: A guide for interpreting soil, manure and effluent analyses". • A range of factsheets addressing important soil health indicators and the impacts of manure and effluent applications. • Information and calculations incorporated into the APL tech toolbox app. • A PNLI within the existing FNLI tool that can be used for outdoor pig production and effluent areas. The PNLI determines risk based on a number of site factors and nutrient source factors. The tool extends guidance surrounding agronomic nutrient target levels by providing an assessment of risk associated with common pig farm scenarios as opposed to thresholds based on soil tests.

Outcomes	<ul style="list-style-type: none"> The outputs of the project have provided new resources to pig farmers/farm managers, regulators and APIQ auditors that have improved their understanding of the results of soil, effluent and manure analyses. Improved understanding of soil, effluent and manure analyses is likely to contribute to improved nutrient management on pig farms for some Australian pork producers.
Impacts	<ul style="list-style-type: none"> Improved decision making associated with nutrient management for some Australian pork producers potentially leading to: <ul style="list-style-type: none"> i) improved soil health, ii) increased pasture performance, and/or iii) reduced risk of nutrient losses. Potentially, some contribution to the ongoing economic and environmental sustainability of the Australian pork industry. Potentially, some contribution to maintained or enhanced social licence to operate for some Australian pork producers.

Table 17: Logical Framework for APL Project 2016/2207

Code and Title	Project 2016/2207: Review of a new water purification technology – bubble column evaporator.
Project Details	<p>Organisation: SciTek Consulting. Period: November 2016 to March 2017. Principal Investigator: Lu Jin (<i>Principal Consultant</i>).</p>
Rationale	<p>Water conservation and recycling through pig farm effluent management has been considered an important aspect of sustainable farming for the Australian pork industry. Bubble column evaporators (BCEs) are a new technology that has been identified as having potential for application in the Australian pork industry to improve management of water and other resources on pig farms. The BCE is a water treatment process, that utilises an air pump and controlled salt concentrations to formulate air bubbles that flow through a contaminated water column. The stable bubbles in the BCE system rise to the top of the column and carry water vapour to the surface, creating potable distilled water as an end product.</p> <p>Project 2016/2207 was funded as part one of a two stage process to fully understand the potential and application of BCE technology, and to evaluate and commercialise BCEs for the Australian pork industry.</p>
Objectives	<ol style="list-style-type: none"> Review technology for applicability in the Australian industry with respect to piggery requirements for water quantity, quality and price point, and potential co-benefits for installation and operation of the technology.
Activities	<ul style="list-style-type: none"> The project team and key researchers met in Canberra to discuss, understand and assess the suitability of the BCE technology and to understand the RD&E requirements to bring the technology to the market. Following the meeting, a desktop review was undertaken. The purpose of the review was to collate existing information about the technology, focussing on technical capability and suitability, and the costs and potential benefits at different scales of pig operations common in water stressed pig growing regions of Australia. The review included pig industry water requirements and characteristics, effluent characteristics, characteristics of output product from BCE technology, the current status of BCE technology, the application of BCE technology to treatment of piggery effluent, costs of operation, and current costs of water and water treatment in the Australian pork industry.
Outputs	<ul style="list-style-type: none"> The project produced an independent report that concluded that BCE technology offers a promising solution for treating piggery effluent. Operational costs of BCE technology varied from \$484 to \$2,348/ megalitre. The largest impact on costs was related to the heating requirements for air. Where low cost heat sources are available from biogas, the net cost was lower. The BCE technology was found to be a unique approach to water treatment that may have the ability to recover large volumes of clean water from saline or contaminated water sources.

Outcomes	<ul style="list-style-type: none"> The positive findings of the project lead to further research investment to understand and potentially commercialise BCE technology for the Australian pork industry through the funding of a follow-on Project (2016/2250: <i>The bubble column evaporator feasibility study via a demo unit</i>).
Impacts	<ul style="list-style-type: none"> Potentially, some contribution to increased future farm profitability driven by increased piggery productivity and reduced operating costs from potential adoption of the BCE technology. Potentially, some contribution to reduced future GHG emissions as a result of using biogas on pig farms to produce heat required for BCEs. Potentially, some contribution to improved animal health due to improved water quality from the adoption of BCE technology. Potentially, some contribution to enhanced social licence for the pork industry due to the increased uptake of biogas systems and reduced GHG emissions. Potentially, some contribution to improved economic and environmental sustainability of the Australian pork industry.

Table 18: Logical Framework for APL Project 2016/2250

Code and Title	Project 2016/2250: The bubble column evaporator feasibility study via a demo unit.
Project Details	<p>Organisation: SciTek Consulting. Period: May 2017 to Oct 2018. Principal Investigator: Lu Jin (<i>Project Manager and Scientist</i>).</p>
Rationale	Project 2016/2250 was funded as stage two of a two stage APL investment to evaluate and commercialise BCEs for the Australian pork Industry. Stage one (project 2016/2207) concluded that the BCE is a viable technology for farm usage in Australia if factors driven by local energy and water prices are taken into consideration. Thus, project 2016/2250 was funded to design BCE demonstration units to test the BCE technology for farm deployment and to conduct tests on real commercial piggery effluent.
Objectives	<ol style="list-style-type: none"> Complete an industrial design for a continuous flow bubble column evaporator unit. Build a demonstration BCE continuous flow unit according to the design. Conduct experiments with piggery effluent and dam water samples using the demonstration unit for data collection and analysis. Report on the experimental results and provide future recommendations on the next steps regarding the bubble column evaporator.
Activities	<ul style="list-style-type: none"> A BCE test unit was designed using computer-aided design (CAD) software. Two identical BCE continuous flow units were constructed (a hot bubble pilot plant (HBPP) with an open condenser) with technical assistance from the University of NSW (UNSW). Each of the two units then were connected together and installed as mobile BCE pilot plants. The units each had a liquid petroleum gas (LPG) generator attached as a source of hot gas to mimic biogas in the laboratory. The HBPP was deployed in both laboratory and field conditions for tests and results analysis. Various water samples representing different water sources used at commercial piggeries containing differing levels of contaminants were tested. The following water testing activities were undertaken: <ul style="list-style-type: none"> Piggery dam water and effluent water samples were taken and then analysed at the commercial lab of ALS Water Resource Group to determine the contents. UNSW did not allow contaminated water to be collected, transported and used in its laboratories (as part of its corporate workplace health and safety (WHS) requirements). Thus, synthetic piggery effluent samples were then made by mixing corresponding additives to produce a mimic of actual piggery water and these samples were tested at UNSW. A real piggery effluent water sample was tested during an on-site experiment at a farm near Young. The BCE pilot plant was used to test piggery effluent and dam water samples from the Young pig farm. Potable water was collected via condensation in all experiments to analyse the water recovery yield and pathogen inactivation.

	<ul style="list-style-type: none"> All experimental results were presented in a report along with future recommendations on the next steps regarding the BCE.
Outputs	<ul style="list-style-type: none"> Two BCE demo units were designed and constructed. The BCE units were shown to provide: <ul style="list-style-type: none"> A commercially viable solution to contribute to the water and environmental management targets of the pork industry. An affordable and technically simple water treatment technology for Australian pig farms, especially producers in dry areas, to enable them to reduce their production cost through recycling water. A technology that can be integrated with biogas flaring to utilise the surplus energy, hence reducing overall costs. A low cost water treatment method to disinfect water sources used on farm, leading to increased animal production yields and improved animal welfare. The project also identified a number of improvements that could be made in future phases of BCE RD&E to achieve higher performance for BCE/HBPP systems. Key areas identified included: <ul style="list-style-type: none"> The existing design of the open condenser. Although up to 51% of all water was captured in bubbles in one hour of operational time, the system only achieved 3-12% condensation with the majority of the vapour captured in bubbles lost to the external environment before being condensed. Therefore, a closed condenser with much larger condensation surface areas was recommended. The system was not designed to function in cold temperatures. Inlet gas temperature was a key element for system performance and low external temperatures greatly affected system efficiency. Hence a new insulation design was recommended. The HBPP test unit relied on 'retail' electricity for heating the air to approximately 500°C. This action constituted nearly 90% of the total energy consumption for the unit. The project identified that biogas integration with flaring could provide waste gas at 500°C, hence it would be possible to utilise the surplus energy of biogas to reduce production costs. The existing BCE technology relied on economies of scale as the water volume that could be treated and recovered increased exponentially with the power of pumping and heating components. Thus, the units only became commercially viable once they reached a certain scale, e.g. 34.5L water storage capacity for a commercial test unit. A comprehensive report on the experimental results including recommendations for the next steps regarding RD&E for the BCE technology was produced.
Outcomes	<ul style="list-style-type: none"> Further focused development and investment in RD&E for the BCE technology. Contribution to potential commercialisation and adoption of the BCE technology in the Australian pork industry.
Impacts	<ul style="list-style-type: none"> Increased farm profitability driven by increased piggery productivity and reduced operating costs from potential adoption of the BCE technology. Reduced greenhouse gas emissions as a result of using biogas on pig farms to produce heat required for BCEs. Improved animal health due to improved water quality from the adoption of BCE technology. Contribution to enhanced social licence for the pork industry due to the increased uptake of biogas systems and reduced GHG emissions. Contribution to improved economic and environmental sustainability of the Australian pork industry.

Table 19: Logical Framework for APL Project 2017/006

Code and Title	Project 2017/006: Planning for Piggery Development.
Project Details	<p>Organisation: Livestock Environmental and Planning. Period: August 2017 to April 2018. Principal Investigator: Robyn Tucker (<i>Principal Consultant</i>).</p>

Rationale	<p>The NEGP (NEGIP and NEGROP) have been developed to provide a national approach to effective environmental management. The guidelines were intended to provide consistency and avoid variable and inappropriate planning and development requirements. However, not everyone was using the guidelines to assess piggery development applications. Staff at some planning agencies were found to be using outdated state guidelines or guidelines designed for sewage and industrial wastewater to assess piggery applications. Thus, there was a need to educate planners and agency staff on how to assess piggery applications using the NEGIP and NEGROP, and also to provide planners with resources for developing clear, practical and appropriate permit conditions that will effectively protect the environment and amenity. Project 2017/006 was funded to address these industry needs.</p>
Objectives	<ol style="list-style-type: none"> 1. To develop a set of clear and practical standard planning conditions for piggeries that protect amenity and the environment, that could be applied to the majority of piggery sites and designs by 31st August 2017. 2. To develop materials for a 'Planning for Piggeries' workshop designed for anyone involved in assessing planning permit applications that covers siting requirements, potential amenity and environmental issues, accepted design management standards, environmental monitoring, recommended steps for proponents to follow and suggested planning conditions by 29th September 2017. 3. To run a pilot 'Planning for Piggeries' workshop involving local government planners and others involved in the piggery planning approval process by 30th November 2017. 4. To collect and analyse feedback from the 'Planning for Piggeries' workshop and make recommendations for changes to workshops and the standard conditions by 21st December 2017.
Activities	<ul style="list-style-type: none"> • Thirty-three sets of recent approval conditions for piggeries were collected. They included conditions for: <ol style="list-style-type: none"> i) 12 conventional piggeries in four states, ii) 5 conventional plus deep litter piggeries in four states, iii) 6 deep litter only piggeries: five in VIC, one in WA, iv) 9 rotational outdoor piggeries in three states, and v) 1 outdoor bred (rotational outdoor + deep litter) in QLD. • The 33 sets of approval conditions then were reviewed. Approval conditions were found to include a mix of generic conditions that could apply to many types of development, and a series of piggery-specific conditions. • Piggery-specific conditions were evaluated to assess their general suitability for addressing piggery amenity or environmental risks. • The NEGIP and NEGROP were used to evaluate the conditions and to identify gaps that could be filled with additional conditions. • A set of clear and practical standard planning conditions for piggeries then was developed that could be applied to the majority of piggery sites and designs to ensure environmental and amenity protection without being overly restrictive. • A set of PowerPoint slides aimed at staff of local government planning departments, catchment management authorities, water boards and environmental authorities was developed for a 'Planning for Piggeries' pilot workshop. • The material covered siting requirements, potential amenity and environmental issues, accepted design and management standards, environmental monitoring, an overview of APIQ, recommended steps for proponents to follow and the standard planning conditions. • A half-day 'Planning for Piggeries' pilot workshop was conducted at Tatura (VIC) in November 2017. • The workshop was attended by 13 planners and referral agency personnel representing Gannawarra Shire, Moira Shire, Goulburn Murray Water and North Central Catchment Authority. • Feedback from the pilot workshop was positive. The feedback was analysed and used to develop a set of recommendations for changes to the workshop materials.
Outputs	<ul style="list-style-type: none"> • A set of standard planning conditions for piggery development applications. • Materials for workshops targeted at educating planners and agency staff about permit conditions for Australian piggeries.

	<ul style="list-style-type: none"> • A design for future workshops to extend the materials and new standards to planners and agency staff.
Outcomes	<ul style="list-style-type: none"> • Workshop attendees from VIC planning organisations now can consistently apply the new standard planning conditions to piggery development applications. • The materials and workshop design have been used to organise additional workshops and extension activities to educate planners and agency staff in other regions/states about piggery development conditions.
Impacts	<ul style="list-style-type: none"> • Increased efficiency of planning and development application processes for Australian pork producers and councils through improved understanding of standard planning conditions and the NEGP for the Australian pork industry.

Table 20: Logical Framework for APL Project 2017/2203

Code and Title	Project 2017/2203: Pathogens and Piggery Effluent – An Updated Review.
Project Details	<p>Organisation: DAF QLD. Period: April 2018 to April 2019. Principal Investigator: Nalini Chinivasagam (<i>Senior Research Scientist</i>).</p>
Rationale	<p>Piggery effluent typically is subjected to minimal treatment before being re-used. A range of pathogens are potentially present in pig effluent, thus minimal treatment practices mean that there is potential for pathogens to be present in the effluent as it is re-used in the environment. A set of guidelines was developed between 1998 and 2004 on how to re-use effluent to ensure minimal risk to public health and the environment. However, more recently, regulators had again started to question the potential of health risks associated with piggery effluent. Project 2017/2203 was funded to review the current state of knowledge of potential health risks and update the guidelines for piggery effluent re-use.</p>
Objectives	<ol style="list-style-type: none"> 1. To assemble a comprehensive overview of past pig industry research in the area of health risks associated with piggery effluent re-use. 2. To review the literature to identify new information on the potential pathogens present in piggery effluent and the availability of more recent quantitative data on pathogens in piggery effluent. 3. To update where necessary and where possible the recommendations on guidelines on piggery effluent made in the early 2000s. 4. To identify any risks that have emerged since the last active Australian based research in this area. 5. To identify gaps in knowledge, if present, where additional research on pathogens and their levels are required to improve the management of health risks associated with piggery effluent re-use.
Activities	<ul style="list-style-type: none"> • The research summary was built on previously funded APL research, undertaken from 1998 to 2004, that comprehensively addressed risks attributed to piggery effluent re-use as adopted by the pig industry. • The past Australian research that contributed to the original effluent re-use guidelines (including relevant project reports and published data cited in those reports) was reviewed. • This review enabled identification of the zoonotic pathogens of concern linked to pigs. The pathogens then were prioritised in terms of those of most concern to humans. • The levels of the identified high-risk organisms were enumerated in ponded piggery effluent from a representative set of 13 farms across South East QLD. The pathogen survey provided prevalence and levels of the key pathogens <i>Campylobacter</i> and <i>Salmonella</i>. • The pathogen survey found no evidence of rotavirus at the 13 representative piggeries tested. Thus, subsequent work focused on <i>Campylobacter</i> and <i>Salmonella</i> along with indicator organism <i>E. Coli</i> to address risk. • In-shed pathogen studies and risk assessment modelling approaches were undertaken to quantify potential risks to humans attributed to the transfer of pathogens via aerosols.

	<ul style="list-style-type: none"> • Transfer via direct irrigation of both pasture and crops were identified as potential pathways. This was addressed by undertaking pathogen survival studies on effluent irrigated foliage under laboratory conditions. • A further literature review was undertaken and <i>Arcobacter</i> was identified as an emerging pathogen, although there was little evidence to support linkage to pigs. • Soil survival studies were undertaken to address pathogen die-off in piggery effluent irrigated pasture soils. • The die-off of both <i>Campylobacter</i> and <i>Arcobacter</i> (due to their appreciable levels in piggery effluent) was studied across four piggeries. • Using pathogen survival data from soil, die-off was calculated and die-off periods across seasons was established. • The risk of overland pathogen mobilisation that can occur during random heavy rain events was simulated using a rainwater machine on effluent irrigated land to understand run-off. • Common antibiotics used by the Australian industry were tested from organic and conventional piggery environments that had a long history or re-use for their ability to demonstrate population shifts in two common soil organisms. • Australian and international human effluent guidelines were summarised to assist and address/ manage pig effluent re-use. • Griffith University (project partner) conducted a review of current approaches to managing piggery waste in Australia and a review of the literature for any Quantitative Microbial Risks Assessments (QMRAs) carried out in relation to piggery effluent. • A final report was prepared that included the full review of literature, identification of any new health risks, recommendations for any additional research where required and recommendations for any updates to the current effluent re-use guidelines.
Outputs	<ul style="list-style-type: none"> • The survey of the literature revealed that there were no specific guidelines addressing piggery effluent re-use. Further, one of the differences between the other guidelines reviewed 20 years ago and the more recent guidelines is a general deviation of approach. • While the older guidelines adopted a more prescriptive approach, more recent guidelines target microbial risk management. • Some of the end uses of the summarised guidelines are similar to what may occur with piggery effluent, for example, the irrigation of food crops to pasture. Both environmental and human risks including animal health were recognised • Key food borne pathogens including <i>Salmonella</i>, <i>Campylobacter</i>, and <i>E. Coli</i> (as an indicator) along with rotavirus were identified as high priority pathogens. • The pathogen survey found no evidence of rotavirus at the 13 representative piggeries tested. • For <i>Campylobacter</i> and <i>Salmonella</i> (along with <i>E. Coli</i> as an indicator organism), the aerosol pathway was identified as a concern both within pig housing (effluent flushing) and the external environment to a piggery (spray irrigation of pasture or crops). • Survival in soil also was identified as a pathway of concern due to the possibility of movement of pathogens by large irrigated pasture and the need to understand withholding periods for human or animal activities. • The soil survival studies suggested that <i>Arcobacter</i> was well distributed in Australian piggery effluent. <i>Arcobacter</i> levels were quantified and reported. Further, a new species was identified (<i>A. cibarius</i>) that was linked to pigs. • QMRA was suggested as a best approach to quantify risk based on variable application/ uses as adopted by the Australian pig industry. This approach requires numerical data of pathogen levels. • In general, the review found that the food safety focus identified in the research literature 20 years ago was still current and pathogen data extracted from other studies were comparable to the levels of <i>Salmonella</i>, <i>Campylobacter</i> and <i>E. Coli</i> levels in Australian piggery effluent. • This suggested that this data could be used for the purpose of developing guidelines or addressing risk management approaches, as it is more relevant Australian data.

	<ul style="list-style-type: none"> • The risks (assessed by QMRA) for inhalation of pathogens by Australian pig workers was deemed an acceptable risk when compared to United States Environmental Protection Act levels (1 infection per 10,000 people per year). • Further, the guidance provided in the current Australian guidelines (NEGIP) for nutrient management and the summary of recent literature on pathogens provide appropriate guidance on vegetative filter strips to help manage pathogen run-off to sensitive area. • In the absence of specific guidelines for addressing the pathogen risk from Australian piggeries, the project recommended that some of the approaches adopted in the national and international guidelines be used as a basis to address pathogen risks linked to piggery effluent re-use. • It also was recommended that the research undertaken by the pig industry be made available to the regulators who address such concerns.
Outcomes	<ul style="list-style-type: none"> • The project findings were used to inform RD&E investment priorities associated with piggery waste management. • To date, no updated guidelines associated with Australian piggery effluent re-use have been developed as a result of the project.
Impacts	<ul style="list-style-type: none"> • Increased efficiency of RD&E resource allocation associated with piggery effluent and wastewater management. • Potentially, some contribution to improved human health outcomes through the reduced risk of the spread of pathogens because of improved management of piggery effluent in the future. • Potentially, some contribution to improved environmental outcomes through the reduced risk of the spread of pathogens because of improved management of piggery effluent in the future. • Potentially, some contribution to the maintenance or enhancement of the social licence to operate for the Australian pork industry.

Table 21: Logical Framework for APL Project 2017/2212

Code and Title	Project 2017/2212: Trends in environmental impacts from the pork industry.
Project Details	<p>Organisation: Integrity Ag Services. Period: September 2017 to January 2019. Principal Investigator: Stephen Wiedemann (<i>Managing Director</i>).</p>
Rationale	The Australian pork industry, like other livestock industries, has been under continuous scrutiny regarding environmental practices and performances. There are international targets for reducing GHG emissions and all Australian primary industries have been under pressure to demonstrate improvement over time. Project 2017/2212 was funded to benchmark the Australian pork industry's environmental performance and show how environmental performance has changed since 1980 to demonstrate the industry's commitment to environmental improvement.
Objectives	<ol style="list-style-type: none"> 1. Demonstrate trends in environmental (GHG and energy) performance of the pig industry in decade time steps for 1980, 1990, 2000 and compare this with 2010. 2. Describe key changes in the Australian pig industry over this time and the impact on environmental performance. 3. Demonstrate improvements in production efficiency and consequences for environmental performance in the Australian pig industry from 1980 to 2010, and project these to 2020 (part of the Pork CRC project objectives).
Activities	<ul style="list-style-type: none"> • The study was conducted using an attributional Life Cycle Assessment (LCA) approach to investigate the environmental impacts of national Australian pork production from 1980 to 2020. • GHG emissions (across the period studied) were investigated using the Intergovernmental Panel on Climate Change (IPCC) AR4⁴ global warming potentials of 25 for methane (CH₄) and 298 for nitrous oxide (N₂O).

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	<ul style="list-style-type: none"> • GHG emissions arising from land use and direct land use change were calculated and reported. • Energy demand was assessed using the fossil fuel energy demand method, and freshwater consumption and stress also were assessed. • Modelling was conducted using SimaPro 8.5 software. • The study covered Australian pig housing and manure management systems, manure production and management emissions, feed grain system inputs, general services, water and energy, and land use and direct land use change emissions. • Impacts were reported per kilogram of pork lwt produced each decade.
Outputs	<ul style="list-style-type: none"> • Changes in GHG emission intensity and key resource use efficiency indicators (freshwater consumption, water stress, fossil fuel energy demand and land occupation) were determined at decade intervals between 1980 and 2010. • Results for 2020 were projected from trends identified from data for the period 1980 to 2017. • The analysis showed that, over the four decades since 1980, there has been a decrease in GHG emission intensity (excluding land use and direct land use change emissions) of 69% from 10.6 to 3.3 kg CO₂-e per kg lwt. • GHG emissions associated with land use and direct land use change were estimated to have declined by 89% since 1980. • Fresh water consumption decreased from 441 L per kg lwt in 1980 to a projected 90 L per kg lwt in 2020. • Water stress followed a similar trend, decreasing from 442 L H₂O-equivalent per kg lwt in 1980 to a projected 79 L H₂O-equivalent per kg lwt in 2020. • Fossil energy use decreased from 34 MJ per kg lwt in 1980 to a projected 14 MJ per kg lwt in 2020. • Land occupation decreased by 63% from 31 m² per kg lwt in 1980 to a projected 11 m² per kg lwt in 2020. • Improvements were principally driven by improved herd productivity, changes in housing and manure management, and improved feed production systems. • Improvements in feed grain production systems also resulted in lower impacts per tonne of feed grain produced. This was related to reduced tillage, higher yields, and a decrease in the proportion of irrigation water used for grain production.
Outcomes	<ul style="list-style-type: none"> • The project findings showed that continuous improvements in production efficiency have resulted in large gains in environmental performance for the Australian pork industry. • The project also identified future prospects and challenges associated with further reductions in GHG emissions intensity and gains in resource use efficiency for Australian pork production that may be used to guide future investment in such areas. • The results have been used to demonstrate the past improvements in environmental performance of the Australian pork industry and its commitment to ongoing environmental improvement to industry, the research community and the broader Australian public.
Impacts	<ul style="list-style-type: none"> • Potential contribution to the enhancement of the social licence to operate for the Australian pork industry. • Potentially, some contribution to increased efficiency of resource allocation associated with investment targeted at further improving the environmental performance of the Australian pork industry.

Table 22: Logical Framework for APL Project 2018/0003

Code and Title	Project 2018/0003: Pork water balance model development.
Project Details	<p>Organisation: DAF QLD.</p> <p>Period: August 2018 to April 2019.</p> <p>Principal Investigator: Alan Skerman (<i>Principal environmental engineer</i>).</p>
Rationale	Piggery effluent storage ponds need to be managed to minimise the risk of overflow into adjoining properties or downstream aquatic environments, in particular during rainfall events/wet weather when the soil in the effluent reuse area is too wet to allow effective

	<p>effluent irrigation. In the past, monthly water balance modelling has been used to design effluent storage systems to meet regulatory standards for the spill recurrence interval. However, it was widely recognised by the industry and regulators that the most comprehensive and realistic design methods involved using a daily water balance approach. Project 2018/0003 was funded to modify and improve the existing WatBal model to provide a simple, widely accessible, daily water balance model for Australian piggeries.</p>
Objectives	<ul style="list-style-type: none"> To develop a daily water balance model to realistically model effluent collection, treatment, storage and use at Australian piggeries.
Activities	<ul style="list-style-type: none"> A new, web-based WatBal model was developed based on the previous spreadsheet model design. The revised model incorporated management formulae and equations from the pre-existing model (WaterBal 6P.03) and the HowLeaky simulation engine to simulate pond management and irrigated cropping. <ul style="list-style-type: none"> Pond design and management equations were extracted from the WaterBal 6P.03 spreadsheet using semi-automated code generation tools including parameter extraction (name, default value, type and description) and formula extraction for non-time series variables. The HowLeaky model was modified by replacing the existing irrigation storage module with the new effluent pond model. A new simulation engine then was developed that provided the initial static calculations for estimating pond dimensions before calculating pond and paddock water-balance on a daily time-step. The model calculation process included: <ul style="list-style-type: none"> Loading data (e.g. soil and crop parameters and climate data). Calculation of pond dimension based on farm and pond characteristics. Calculation of pond activity ratio from average daily temperature. Simulation of paddock water balance and iterating this step day by day through climate data. Comprehensive model testing was carried out by the project team during the development phase of the project. A realistic piggery scenario was modelled to demonstrate the modelling capabilities and results. Several experienced industry service providers (consultants, researchers and regulators) were invited to review and/or beta test a prototype version of the model prior to its formal release.
Outputs	<ul style="list-style-type: none"> The project demonstrated that the updated WatBal model could be used to effectively and conveniently carry out daily water balance analyses for piggery effluent management systems. The new, web-based WatBal model had several advantages over previous model versions including: <ul style="list-style-type: none"> Ready access across Australia and internationally by logging into a custom-made website (http://web9.dhmssoftware.hypervps.com.au/). Seamless and prompt selection and importation of relevant climatic data. Ability to run analyses over extended time periods, from 1900 to the present. Builds on existing, widely accepted models, such as HowLeaky, providing more rigorous soil water balance and cropping simulations in the effluent irrigation area and a wider, more readily expandable range of crop/pasture species and soil types. More comprehensive graphical outputs. Enhanced administrative and user support features. Reduced input requirements (70 inputs down from 90 in previous versions of the WatBal model). The new model was able to produce a range of outputs including: <ul style="list-style-type: none"> Graphical representation of ponds with key dimensions and volumes. Monthly pond storage levels (mean, 80 percentile and 33 percentile bands). Table of storage/single pond water balance components. Monthly irrigation amounts (mean, 80 percentile and 33 percentile bands).

	<ul style="list-style-type: none"> – Interactive daily time-series charts which show storage/single pond levels, overflows, soil-water, rainfall and Irrigation.
Outcomes	<ul style="list-style-type: none"> • Better decision making/effluent management design and practices because of use of the improved model across Australian piggeries.
Impacts	<ul style="list-style-type: none"> • Reduced risk of contaminating the environment by excessive spillage of effluent storage ponds. • Potential contribution to improved social licence of Australian piggeries.

4.2 Project Investment Costs

The following tables show the annual investment (nominal \$, cash and in-kind) for APL (Table 23) and other investors (Table 24). Table 25 provides the total investment by year for all sources for each project in the evaluation population.

Table 23: APL Investment by Project for the Years Ending 30 June 2013 to 30 June 2019

Project Code	Year Ended 30 June							Total
	2013	2014	2015	2016	2017	2018	2019	
2013/027	0	50,000	0	0	0	0	0	50,000
2013/031	0	47,500	0	0	0	0	0	47,500
2013/032	0	0	37,000	24,655	5,000	0	0	66,655
2013/034	0	0	30,000	18,620	0	0	0	48,620
2014/446	0	0	0	0	0	145,000	0	145,000
2014/488	0	100,000	233,088	149,543	262,828	40,000	0	785,460
2015/010	0	0	0	0	0	7,930	25,018	32,948
2015/018	0	0	0	0	121,285	30,482	52,307	204,074
2015/021	0	0	0	72,000	8,000	0	0	80,000
2015/051	0	0	30,000	30,000	0	0	0	60,000
2015/2221	0	50,000	0	0	0	0	0	50,000
2016/083	0	0	80,000	157,400	30,600	0	0	268,000
2016/085	0	0	25,000	5,000	0	0	0	30,000
2016/093	0	0	0	18,548	39,452	0	0	58,000
2016/099	0	0	0	0	26,000	2,000	0	28,000
2016/2207	0	0	0	0	14,950	26,500	0	41,450
2016/2250	0	0	0	0	35,000	73,716	0	108,716
2017/006	0	0	0	0	30,000	0	0	30,000
2017/2203	0	0	0	0	0	30,000	0	30,000
2017/2212	0	0	0	0	0	15,000	5,000	20,000
2018/0003	0	0	0	0	0	50,000	50,000	100,000
Total	0	247,500	435,088	475,766	573,115	420,628	132,325	2,284,423

Source: APL project documentation (e.g. project proposals, project agreements, and formal project variations)

Table 24: Investment by Researchers and Others by Project for the Years Ending 30 June 2013 to 30 June 2019

Project Code	Year Ended 30 June							Total
	2013	2014	2015	2016	2017	2018	2019	
2013/027	0	0	0	0	0	0	0	0
2013/031	0	0	0	0	0	0	0	0
2013/032	0	0	25,602	125,397	0	0	0	150,999
2013/034	0	0	0	0	0	0	0	0
2014/446	0	0	0	0	0	0	0	0
2014/488	0	0	63,000	0	0	0	0	63,000
2015/010	0	0	0	0	0	0	0	0
2015/018	0	0	0	0	72,718	109,417	27,517	209,652
2015/021	0	0	0	318,500	23,000	0	0	341,500
2015/051	120,640	208,395	119,485	0	0	0	0	448,520
2015/2221	0	0	0	0	0	0	0	0
2016/083	0	0	0	0	0	0	0	0
2016/085	0	0	0	0	0	0	0	0
2016/093	0	0	0	0	60,000	0	0	60,000
2016/099	0	0	0	0	37,000	0	0	37,000
2016/2207	0	0	0	0	0	0	0	0
2016/2250	0	0	0	0	0	0	0	0
2017/006	0	0	0	0	0	0	0	0
2017/2203	0	0	0	0	0	12,500	0	12,500
2017/2212	0	0	0	0	0	34,346	5,708	40,054
2018/0003	0	0	0	0	0	0	0	0
Total	120,640	208,395	208,087	443,897	192,718	156,263	33,225	1,363,225

Source: APL project documentation (e.g. project proposals, project agreements, and formal project variations)

Table 25: Total Investment (All Sources) by Year for APL Environment RD&E Program Evaluation Population (nominal \$)

Year ended 30 June	APL Investment	Researcher and Others Investment	Total Investment
2013	0	120,640	120,640
2014	247,500	208,395	455,895
2015	435,088	208,087	643,175
2016	475,766	443,897	919,663
2017	573,115	192,718	765,833
2018	420,628	156,263	576,891
2019	132,325	33,225	165,550
Totals	2,284,423	1,363,225	3,647,648

4.2.1 Program Management Costs

For the APL investment, the cost of managing the APL funding (management and administration costs) was added to the APL contribution for each project in Table 23 via a management cost multiplier of x1.069. This multiplier was estimated based on the average (5-year) share of 'payments to suppliers and employees' in total APL expenditure reported in the APL Statement of Cash Flows (APL, 2015 to 2019).

For the investment by researchers and others it was assumed that the management and administration costs for each project were already built into the nominal dollar amounts appearing in Table 24.

4.2.2 Real Investment and Extension Costs

For the purposes of the investment analysis, the investment costs of all parties were expressed in 2018/19-dollar terms using the Implicit Price Deflator for Gross Domestic Product (Australian Bureau of Statistics, 2020).

Further, some industry extension and communication costs were included as part of the individual project budgets. However, some extension costs were funded through a separate APL extension budget in addition to what was included in the project funding (Gemma Wyburn, pers. comm., 2020). To accommodate such additional APL extension and communication costs an extension cost multiplier of x1.025 was applied to the APL investment costs (Table 23).

5. Impacts

5.1 Summary of Impacts

The individual impacts identified and described for each project in Table 2 to Table 22 were summarised and then categorised into economic, environmental and social impacts (Table 26).

Table 26: Triple Bottom Line Categories of Impacts for the APL Environment RD&E Program Evaluation Population

Project Code	Triple Bottom Line Impacts		
	Economic	Environmental	Social
2013/027	<ul style="list-style-type: none"> Potentially, reduced production costs for some pork producers through feed/energy efficiencies and/or improved manure management. Potentially, increased incomes for some Australian pork producers through realisation of alternative income streams (e.g. ACCUs and electricity). 	<ul style="list-style-type: none"> Reduced GHG emissions for the Australian pork industry through increased adoption of GHG abatement strategies. 	<ul style="list-style-type: none"> Enhanced social licence to operate for the Australian pork industry. Increased regional community wellbeing through spillover benefits from more profitable pork production enterprises.
2013/031	<ul style="list-style-type: none"> Potentially, reduced operating costs for some Australian farms through increased adoption of the BMPs. 	<ul style="list-style-type: none"> Potentially, improved environmental outcome as a result of increased adoption of the BMPs. 	<ul style="list-style-type: none"> Potential contribution to enhanced social licence to operate for the Australian pork industry because of potentially improved environmental outcomes.
2013/032	<ul style="list-style-type: none"> Nil 	<ul style="list-style-type: none"> Improved compliance of some Australian pork enterprises with the NEGP and various state planning requirements. Potentially, reduced negative environmental impacts from pork production activities through improved identification of environmental risks and associated mitigation strategies to minimise impacts. 	<ul style="list-style-type: none"> Potentially, some contribution to maintained or enhanced social licence to operate for some Australian pork producers.
2013/034	<ul style="list-style-type: none"> Potential contribution to future generation of renewable energies for use on farms through capturing the produced GHG emissions resulting in reduced energy cost for farmers. Potential contribution to future economic and environmental sustainability improvement for intensive piggery operations. 	<ul style="list-style-type: none"> Potential contribution to future reduction in GHG emissions generated by the Australian pork industry through the implementation of more effective and efficient waste management technologies. 	<ul style="list-style-type: none"> Potential contribution to strengthening the future social licence for the pork industry with less GHG emissions.

2014/446	<ul style="list-style-type: none"> • Potentially, some contribution to improved profitability for some Australian crop producers as a result of a net reduction of fertiliser costs. • Potentially, some contribution to increased average crop performance as a result of utilisation of piggery-derived nutrients with better performance compared to commercial fertilisers. 	<ul style="list-style-type: none"> • Potentially, some contribution to decreased environmental risks as a result of lower N and P run offs. • Potentially, some contribution to reduced negative environmental outcomes associated with stockpiles of piggery effluents such as flies, odour, and contamination of soil and water supplies. 	<ul style="list-style-type: none"> • Potential contribution to future maintenance of the Australian pork industry's social licence to operate as a result of reduced environmental risks. • Potentially, some contribution to improved regional community wellbeing from profitability spillovers from the piggery industry.
2014/488	<ul style="list-style-type: none"> • Reduced energy costs for some Australian piggeries through adoption of new and improved energy technologies and practices. 	<ul style="list-style-type: none"> • Reduced GHG emissions for some Australian piggeries adopting new, more energy efficient technologies and practices. 	<ul style="list-style-type: none"> • Some contribution to maintained or enhanced social licence to operate for some Australian pork producers. • Increased regional community wellbeing through spillover benefits of a more profitable Australian pork industry.
2015/010	<ul style="list-style-type: none"> • Potential increase in industry profitability and efficiency through reduced waste by the piggery industry. 	<ul style="list-style-type: none"> • Potential reduction in GHG emissions from the Australian pork industry due to additional use of quality piggery manures, adoption of covered digester systems, and development of feed wastage estimation models. 	<ul style="list-style-type: none"> • Potential improvement of industry sustainability through enhancement of social licence with lowered financial and environmental consequences.
2015/018	<ul style="list-style-type: none"> • Potentially, some contribution to the future economic and environmental sustainability of the Australian pork industry through ongoing use of the NEGP. 	<ul style="list-style-type: none"> • Nil 	<ul style="list-style-type: none"> • Potentially, some contribution to the maintenance or enhancement of the social licence to operate for the Australian pork industry.
2015/021	<ul style="list-style-type: none"> • Increased profitability for some Australian crop farmers through increased utilisation of spent pig bedding leading to increased average crop yield and reduced fertiliser costs. • Potentially enhanced economic and environmental sustainability for the Australian pork industry and some associated cropping farmers. 	<ul style="list-style-type: none"> • Reduced risk of negative environmental outcomes associated with stockpiles of spent pig bedding such as flies, odour, and contamination of water supplies. 	<ul style="list-style-type: none"> • Nil
2015/051	<ul style="list-style-type: none"> • Potentially, some contribution to decreased cost of feed formulations for some pig feed producers as a result of access to the new NSP database. • Potentially, some contribution to decreased cost of feed formulations for some poultry feed 	<ul style="list-style-type: none"> • Potentially, increased sustainability for the pig industry as a result of more sustainable feed formulation. • Potentially, increased sustainability for the poultry industry as a result of more sustainable feed formulation. 	<ul style="list-style-type: none"> • Nil

	producers as a result of access to the new NSP database.		
2015/2221	<ul style="list-style-type: none"> Some contribution to the future economic and environmental sustainability of the Australian pork industry through ongoing use of the NEGP. 	<ul style="list-style-type: none"> Nil 	<ul style="list-style-type: none"> Potentially, some contribution to the maintenance or enhancement of the social licence to operate for the Australian pork industry.
2016/083	<ul style="list-style-type: none"> Increased efficiency of RD&E resource allocation associated with wastewater and water recycling associated with the Australian pork industry. Potentially, some contribution to the future economic and environmental sustainability of the Australian pork industry through the development and adoption of improved wastewater management technologies. 	<ul style="list-style-type: none"> Nil 	<ul style="list-style-type: none"> Potentially, some contribution to the maintenance or enhancement of the social licence to operate for the Australian pork industry.
2016/085	<ul style="list-style-type: none"> Potentially, reduced cost of sludge management practices as a result of improved anaerobic pond designs and better sludge management. 	<ul style="list-style-type: none"> Nil 	<ul style="list-style-type: none"> Nil
2016/093	<ul style="list-style-type: none"> Increased efficiency of planning and development application processes for Australian pork producers and councils through improved understanding of application requirements and increased confidence in their respective ability to complete the application process. 	<ul style="list-style-type: none"> Nil 	<ul style="list-style-type: none"> Nil
2016/099	<ul style="list-style-type: none"> Improved decision making associated with nutrient management for some Australian pork producers potentially leading to: <ul style="list-style-type: none"> i) improved soil health, ii) increased pasture performance, and/or iii) reduced risk of nutrient losses. Potentially, some contribution to the ongoing economic and environmental sustainability of the Australian pork industry. 	<ul style="list-style-type: none"> Nil 	<ul style="list-style-type: none"> Potentially, some contribution to maintained or enhanced social licence to operate for some Australian pork producers.
2016/2207	<ul style="list-style-type: none"> Potentially, some contribution to increased future farm profitability driven by increased piggery productivity and reduced operating costs from potential adoption of the BCE technology. 	<ul style="list-style-type: none"> Potentially, some contribution to reduced future GHG emissions as a result of using biogas on pig farms to produce heat required for BCEs. 	<ul style="list-style-type: none"> Potentially, some contribution to enhanced social licence for the pork industry due to the increased uptake of biogas systems and reduced GHG emissions.

	<ul style="list-style-type: none"> • Potentially, some contribution to improved animal health due to improved water quality from the adoption of BCE technology. • Potentially, some contribution to improved economic and environmental sustainability of the Australian pork industry. 		
2016/2250	<ul style="list-style-type: none"> • Increased farm profitability driven by increased piggery productivity and reduced operating costs from potential adoption of the BCE technology. • Contribution to improved economic and environmental sustainability of the Australian pork industry. 	<ul style="list-style-type: none"> • Reduced greenhouse gas emissions as a result of using biogas on pig farms to produce heat required for BCEs. 	<ul style="list-style-type: none"> • Contribution to enhanced social licence for the pork industry due to the increased uptake of biogas systems and reduced GHG emissions. • Improved animal health due to improved water quality from the adoption of BCE technology.
2017/006	<ul style="list-style-type: none"> • Increased efficiency of planning and development application processes for Australian pork producers and councils through improved understanding of standard planning conditions and the NEGP for the Australian pork industry. 	<ul style="list-style-type: none"> • Nil 	<ul style="list-style-type: none"> • Nil
2017/2203	<ul style="list-style-type: none"> • Increased efficiency of RD&E resource allocation associated with piggery effluent and wastewater management. 	<ul style="list-style-type: none"> • Potentially, some contribution to improved environmental outcomes through the reduced risk of the spread of pathogens because of improved management of piggery effluent. 	<ul style="list-style-type: none"> • Potentially, some contribution to improved human health outcomes through the reduced risk of the spread of pathogens because of improved management of piggery effluent. • Potentially, some contribution to the maintenance or enhancement of the social licence to operate for the Australian pork industry.
2017/2212	<ul style="list-style-type: none"> • Potentially, some contribution to increased efficiency of resource allocation associated with investment targeted at further improving the environmental performance of the Australian pork industry. 	<ul style="list-style-type: none"> • Nil 	<ul style="list-style-type: none"> • Potentially, some contribution to the enhancement of the social licence to operate for the Australian pork industry.
2018/0003	<ul style="list-style-type: none"> • Nil 	<ul style="list-style-type: none"> • Reduced risk of contaminating the environment by excessive spillage of effluent storage ponds. 	<ul style="list-style-type: none"> • Potential contribution to improved social licence of Australian piggeries.

5.2 Principal Impact Types

The individual impacts identified and described for each of the 21 projects then were categorised based on their contribution to key impact types. Table 27 shows the contribution of each project to the key impact types identified. Projects were identified as contributing to one or more of the impact categories (indicated by a ✓ beneath the relevant impact column in the table below).

Table 27: Summary of Project Contributions to Key Impact Categories for the APL Environment RD&E Program^(a)

Project Code	Increased productivity and/ or profitability	Increased efficiency of resource allocation (e.g. RD&E investment)	Improved economic sustainability	Reduced GHG emissions	Reduced negative environmental impacts from pork production activities (excludes GHG emissions)	Improved environmental sustainability	Maintained or enhanced social licence to operate	Increased regional community wellbeing	Other (including potential impacts on other Australian primary industries)
2013/027	✓✓			✓			✓	✓	
2013/031	✓				✓		✓		
2013/032					✓		✓		✓
2013/034	✓		✓			✓	✓		
2014/446					✓✓		✓	✓	✓✓
2014/488	✓			✓			✓	✓	
2015/010	✓			✓			✓		
2015/018			✓			✓	✓		
2015/021			✓		✓	✓			✓
2015/051	✓					✓			✓✓
2015/2221			✓			✓	✓		
2016/083		✓	✓			✓	✓		
2016/085	✓								
2016/093									✓
2016/099	✓		✓		✓	✓	✓		

2016/2207	✓		✓	✓		✓	✓		✓
2016/2250	✓		✓	✓		✓	✓		✓
2017/006									✓
2017/2203		✓			✓		✓		✓
2017/2212		✓					✓		
2018/0003					✓		✓		

(a) Multiple ✓ symbols against a project for a single impact type indicates that the project had more than one impact that contributed to that specific impact type.

5.2.1 Public versus Private Impacts

The impacts from the APL Environment RD&E Program are likely to produce both private and public impacts. Private impacts will accrue to Australian pork producers through increased productivity and profitability, increased efficiency of RD&E resource allocation, improved economic sustainability and, potentially, through enhanced social licence to operate.

Public benefits may occur as a result of environmental and social impacts such as reduced GHG emissions, reduced negative environmental outcomes, and increased regional community wellbeing through spillover benefits from a more productive and profitable Australian pork industry.

5.2.2 Distribution of Private Impacts along the Supply Chain

The primary private impacts from the APL Environment RD&E Program are related to increased productivity and/or profitability for Australian pork producers. Benefits are therefore likely to accrue primarily to pork producers. However, such benefits likely will be distributed along the pork supply chain according to the various supply and demand elasticities.

5.2.3 Impacts on Other Australian Industries

Impacts were identified that may affect various Australian cropping industries (e.g. Project 2014/446: Fertilisers from piggery liquid effluent and solids via nutrient extraction and solid formulations and Project 2015/021: Promoting the Utilisation of Spent Pig Bedding in Broadacre Cropping Systems) and, potentially, the Australian poultry industry (Project 2015/051: Establishment of a soluble and insoluble NSP database by University of New England for all feed ingredients commonly fed in the pig and poultry industry to replace crude fibre values in feed formulation).

5.2.4 Impacts to Overseas Interests

No significant impacts to overseas interests were identified. However, there may be some benefits to some primary industries in other countries through the sharing of research findings, scientific knowledge, and best practice for piggery management.

5.3 Assessment of Impacts Against RD&E Strategies

5.3.1 APL Strategic Objectives

Investment in projects under APL's Environment RD&E Program is overseen by APL's Research and Innovation (R&I) Division. The R&I Division invests and manages producer levies and matching government funds in RD&E projects across a range of areas to address industry and National priorities. Key focus areas include, production, animal welfare, traceability, food safety, pork quality, environmental management, biosecurity, and antimicrobial stewardship (APL, 2019).

APL defined five key Strategic Objectives in its Strategic Plan 2015-2020. APL's Strategic Objectives include (APL, 2018):

1. Growing consumer appeal,
2. Building markets,
3. Driving value chain integrity,
4. Leading sustainability, and
5. Improving capability.

The impacts types identified for the APL Environment RD&E Program largely address APL Strategic Objective 4: Leading Sustainability (APL, 2018). Objective 4 aims to address opportunities to ensure sustainable industry growth through the re-use of by-product nutrients to enhance soil health, generate revenue and energy, develop new emission reduction methodologies and support environmental planning and regulation (APL, 2019). There also may be some contribution to Strategic Objective 1 as a spillover from improved environmental practices in the Australian pork industry.

5.3.2 Australian and Rural Research and Development Priorities

The Australian Government’s National Science and Research Priorities and Rural Research and Development (R&D) priorities are reproduced in Table 28. The projects included in this analysis have contributed to National Science and Research Priorities 1, 2, 5, and 7 and Rural R&D Priorities 1, 3 and 4.

Table 28: Australian and Rural R&D Priorities

Australian Government	
National Science and Research Priorities (2015)	Rural R&D Priorities (2015)
<ol style="list-style-type: none"> 1. Food – optimising food and fibre production and processing; agricultural productivity and supply chains within Australia and global markets. 2. Soil and Water – improving the use of soils and water resources, both terrestrial and marine. 3. Transport – boosting Australian transportation: securing capability and capacity to move essential commodities; alternative fuels; lowering emissions. 4. Cybersecurity – improving cybersecurity for individuals, businesses, government and national infrastructure. 5. Energy and Resources – supporting the development of reliable, low cost, sustainable energy supplies and enhancing the long-term viability of Australia’s resources industries. 6. Manufacturing – supporting the development of high value and innovative manufacturing industries in Australia. 7. Environmental Change – mitigating, managing or adapting to changes in the environment. 8. Health – improving the health outcomes for all Australians. <p>Source: 2015 Australian Government <i>Science and Research Priorities</i>. http://www.science.gov.au/sciencegov/scienceandresearchpriorities/pages/default.aspx</p>	<ol style="list-style-type: none"> 1. Advanced technology, to enhance innovation of products, processes and practices across the food and fibre supply chains through technologies such as robotics, digitisation, big data, genetics and precision agriculture; 2. Biosecurity, to improve understanding and evidence of pest and disease pathways to help direct biosecurity resources to their best uses, minimising biosecurity threats and improving market access for primary producers; 3. Soil, water and managing natural resources, to manage soil health, improve water use efficiency and certainty of supply, sustainably develop new production areas and improve resilience to climate events and impacts; and 4. Adoption of R&D, focussing on flexible delivery of extension services that meet primary producers’ needs and recognising the growing role of private service delivery. <p>Source: 2015 <i>Agricultural Competitiveness White Paper</i>. http://www.agriculture.gov.au/ag-farm-food/innovation/priorities</p>

6. Valuation of Impacts

Nine broad impact types were identified from the investment in the APL Environment RD&E Program (see Table 27). The Program level impact types identified included:

Economic Impacts:

1. Increased productivity and/ or profitability,
2. Increased efficiency of resource allocation, and
3. Improved economic sustainability.

Environmental Impacts:

4. Reduced GHG emissions,
5. Reduced negative environmental impacts from pork production activities (excluding GHG emissions), and
6. Improved environmental sustainability.

Social Impacts:

7. Maintained or enhanced social licence to operate for Australian piggeries,
8. Increased regional community wellbeing, and

Other/Unknown Impacts:

9. Other (including potential impacts on other Australian primary industries).

Some, but not all, of the Program level impacts identified were valued in monetary terms. Environmental and social impacts are difficult to value and may involve the application of non-market valuation techniques that were beyond the scope of the current assessment. Impacts were not valued due primarily to:

- A lack of evidence and/or data on which to base credible assumptions,
- The complexity of assigning monetary values to the impact (e.g. capacity built),
- Uncertainty regarding the pathways to impact, and
- The relative importance of the impact compared to the primary impact(s) valued.

The follow sections describe the specific reasons for non-valuation of impact types and the valuation frameworks used to value other key impacts from the APL Environment Program investment.

6.1 Impacts Not Valued

6.1.1 Improved Economic and Improved Environmental Sustainability

The most widely used definition of sustainability states that sustainability means meeting the needs of the present without compromising the ability of future generations to meet their own needs (Reddy & Thomson, 2015). Improved economic and/or environmental sustainability impacts were not valued within the scope of the current analysis because of the complexity of assigning values to the concept of sustainability and the difficulty of making credible assumptions regarding the potential changes in sustainability attributable to the investments being evaluated. However, such impacts may be captured to some extent through the valuation of maintained social licence to operate for Australian pork producers.

6.1.2 *Reduced GHG Emissions*

Five of the 21 projects evaluated contributed either directly, or indirectly, to potential reductions to GHG emissions. This impact was largely driven by:

- Increased adoption of improved GHG abatement strategies,
- Increased adoption of new and improved technologies and practices to improve energy efficiency on farm,
- Improved feed and waste management, and
- Potentially, increased adoption of biogas systems in Australian piggeries.

This impact was not valued due to the difficulty defining the specific practice changes that may lead to GHG reductions, the extent of adoption of such changes, and the likely magnitude and type of any future GHG emission reductions across the Australian pork industry. Also, the impact is partially captured through the valuation of improved productivity/profitability (through reduced energy costs) for Australian piggeries. See Section 6.2.1 for further detail.

6.1.3 *Reduced Negative Environmental Impacts from Pork Production Activities (excludes GHG emissions)*

Reduced negative environmental impacts may include impacts such as reduced nutrient export off-farm, reduced odour, reduced risk of contamination of soil and/or groundwater, and reduced risk of pathogen spread. This impact was not valued because of the uncertainties associated with linking project outputs with the potential impacts and a lack of data required to make credible assumptions.

6.1.4 *Increased Regional Community Wellbeing*

This impact was not valued as, while productivity and profitability in the Australian pork industry may increase, it would be difficult to estimate the regional spillovers from such impacts due to the various uncertainties in the related pathway to impact.

6.1.5 *Other (including potential impacts on other Australian primary industries)*

Valuation of impacts to other industries was beyond the scope of the current analysis. Further, such impacts were considered minor relative to the impacts valued.

6.2 *Impacts Valued*

Three of the nine Program level impact types identified in Table 27 were valued in monetary terms. The impacts valued included:

- a. Increased productivity and/or profitability for the Australian pork industry,
- b. Increased efficiency of resource allocation (e.g. RD&E investment), and
- c. Maintained or enhanced social licence to operate for Australian piggeries.

A total of 18 of the 21 projects in the APL Environment Program evaluation contributed to the three impacts valued. Table 29 shows the projects that contributed to each of the three impacts valued.

Table 29: Projects Contributing to Impacts Valued
(✓ indicates contribution)

Project Code	Impact Type		
	Increased productivity and/or profitability	Increased efficiency of resource allocation	Maintained or enhanced social licence to operate
2013/027	✓		✓
2013/031	✓		✓
2013/032			✓
2013/034	✓		✓
2014/446			✓
2014/488	✓		✓
2015/010	✓		✓
2015/018			✓
2015/021	No specific contribution to impacts valued		
2015/051	✓		
2015/2221			✓
2016/083		✓	✓
2016/085	✓		
2016/093	No specific contribution to impacts valued		
2016/099	✓		✓
2016/2207	✓		✓
2016/2250	✓		✓
2017/006	No specific contribution to impacts valued		
2017/2203		✓	✓
2017/2212		✓	✓
2018/0003			✓

6.2.1 Increased Productivity and/ or Profitability

Improving energy, feed and waste management for Australian piggeries has been a focus of the APL Environment RD&E Program investment. Ten of the 21 project investments evaluated have contributed, either directly or indirectly, to potential improvements in productivity and/or profitability for the Australian pork industry (see Table 29). This impact is driven by:

- Reduced energy costs,
- Reduced waste and/or waste management costs (including effluent, sludge and/or other wastewater),
- Increased efficiency of planning and development application processes,
- Potentially reduced future feed costs, and
- Potentially, improved animal health.

The valuation is underpinned by an improvement in the gross margin for Australian pork. The current average cost of production for Australian piggeries is approximately \$2.70 per kg carcass weight (cwt) with non-feed costs, including labour, energy and transport, making up approximately 49% (\$1.32/kg cwt) of production costs (Mornement & Duver, 2020). The current average farm gate price for

Australian pork is approximately 412 cents per kg HSCW (APL, 2020). Specific assumptions are described in Table 31 below.

6.2.2 Increased Efficiency of Resource Allocation (e.g. RD&E investment)

The investment in the APL Environment RD&E Program was assumed to have marginally improved APL's RD&E investment prioritisation, selection and management for R&D investments, and therefore contributes to increased efficiency of future RD&E resource allocation (contributing project investments are identified in Table 27).

APL's total, average annual investment in RD&E was estimated to be \$10.28 million (3-year average) with an average annual investment of \$4.54 million for RD&E under Strategic Objective 4 (Leading Sustainability) (APL, 2017 to 2019). It was assumed that the investment in the APL Environment RD&E Program contributed to a 5% efficiency dividend for the period 2016/17 to 2020/21. Specific assumptions are described in Table 31.

6.2.3 Enhanced Social Licence to Operate

The APL Environment RD&E Program investment produced a range of outputs that have contributed to maintaining and enhancing the Australian pork industry's social licence to operate. For example, several projects produced resources and provided extension activities that have enabled Australia piggeries to improve their energy use efficiency on-farm, thereby reducing GHG emissions, improve waste management practices, meet Australian environmental guidelines and, potentially, improve animal health and welfare.

The average, annual gross value of production for the Australian pork sector is estimated to be \$1.245 billion (5-year average) (ABARES, 2019). Given current scrutiny of environmental sustainability faced by livestock enterprises in Australia, it was assumed that 50% of the gross value of production (GVP) for Australian pork production is at risk of some form of loss of social licence. Further, it was assumed that profits are represented by 10% of the GVP. The impact was estimated as a 1.0% reduction in the risk of a loss of profitability for these piggeries. For example, without the APL Environment RD&E Program investment the risk of loss of profitability for affected piggeries may be 10%. Then, given the adoption of improved practices as a result of the APL Environment RD&E Program investment, the risk may fall from 10% to a 9.0% reduction in the profitability of the piggeries at risk. Specific assumptions are provided in Table 31.

6.2.4 Key Industry Data: Summary

The Australian pork industry is made up of approximately 2,700 pig producers that range in scale from small scale pig keepers to large commercial facilities (aussiepigfarmers.com.au, n.d.). The Australian pig herd consists of an average (5-year) of approximately 2.4 million animals (ABARES, 2019) and pigs are farmed across most Australian states and territories (see Figure 1).

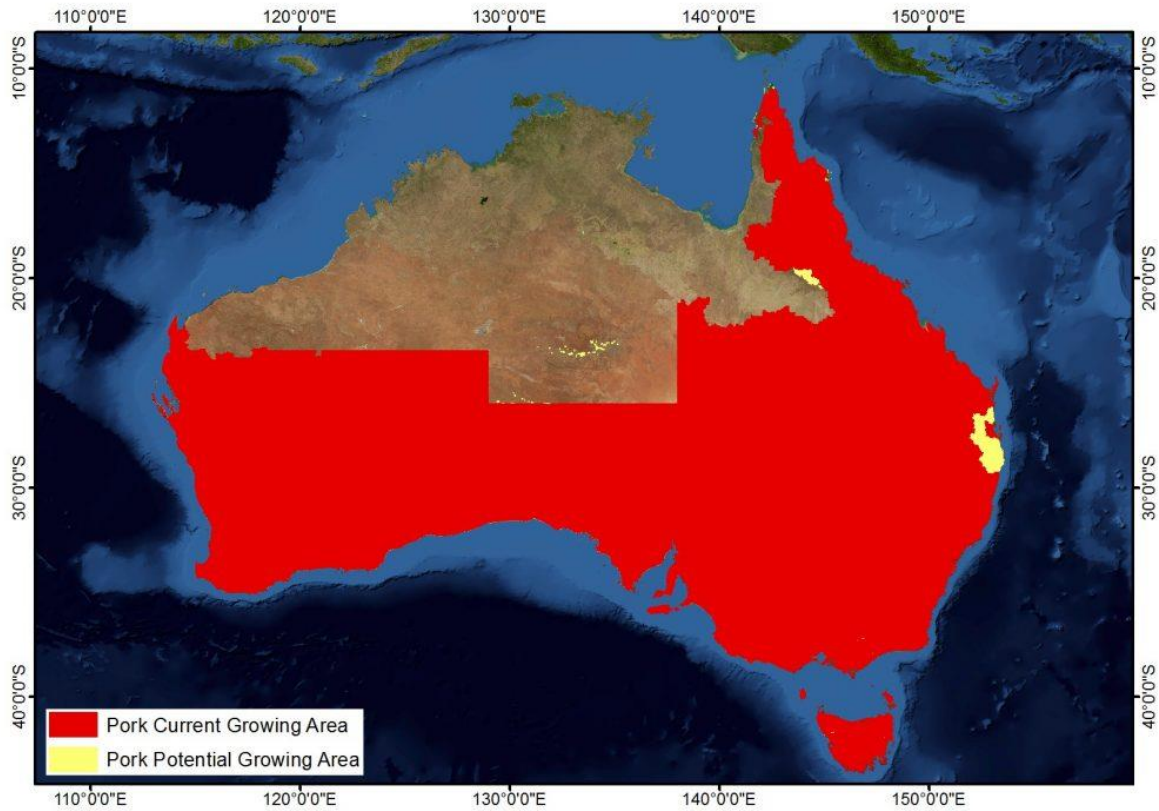


Figure 1: Actual and Potential Production Regions for Australian Pork
 Source: <https://www.agrifutures.com.au/farm-diversity/pigs-meat-pork/>

Australia produces about 396,000 tonnes of pig meat per annum (ABARES, 2019), around 8% of which is exported (AgriFutures Australia, 2017). Australian pig meat production and the gross value of the Australian pork industry over the past ten years are shown in Table 30.

Table 30: Australian Pig Meat Production and Pork Industry GVP for the period 2010 to 2019

Year ended 30 June	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	5-yr Average
Pig meat production (kt cwt)	331	342	351	356	360	371	378	397	417	414	396
Gross value of production at slaughter (\$m)	965	919	934	934	1,081	1,149	1,353	1,342	1,146	1,236	1,245

Source: ABARES, 2019.

6.2.5 Specific Valuation Assumptions

Specific assumptions used in the valuation of impacts are reported in Table 31

Table 31: Valuation Assumption – APL Environment RD&E Program Evaluation

Variable	Assumption	Source
Impact 1: Increased productivity/ profitability		
Average cost of production for Australian piggeries	\$2.70 per kg cwt	Mornement & Duver (2020), and supported by Morgan (2019)
Average non-feed costs as a component of production costs	\$1.32 per kg cwt	
Average annual pig meat production	396 kt cwt	Table 30
Estimated cost saving attributable to the APL Environment RD&E Program investment	2.5% of non-feed costs ^(a)	Analyst assumption ^(b)
Proportion of the Australian pork industry adopting/ implementing practices to achieve assumed cost reductions	20%	Conservative estimate based on the 25% of Australian production represented by the 55 piggeries modelled as part of APL project 2013/027: National PigGas Extension
First year of impact	2017/18	Based on completion of at least half of the 21 projects in the APL Environment RD&E Program evaluation population
Year of maximum impact	2021/22	5 years after first year of impact
Impact 2: Increased efficiency of RD&E resource allocation		
Total average, annual APL RD&E expenditure	\$10.28 million	APL Annual Report (2015 to 2019)
Total average, annual APL RD&E expenditure in projects for Strategic Objective 4	\$4.54 million	
Efficiency dividend due to improved identification, prioritisation, selection and management of RD&E investments	5.0%	Analyst assumption ^(b)
APL Strategic Objective 4 RD&E expenditure required to achieve similar outputs WITHOUT dividend	\$4.77 million p.a.	$\$4.54m \times (1.05 / 1)$
First year of impact	2017/18	Based on completion of at least half of the 21 projects in the APL Environment RD&E Program evaluation population
Period of efficiency dividend delivery (years ended 30 June)	2018 to 2022, then declining linearly to zero by 2025	Analyst assumption ^(b)

Impact 3: Enhanced social licence to operate		
Total, average annual GVP of the Australian pork industry	\$1,245.2 million	ABARES (2019)
Proportion of industry potentially at risk of loss of social licence to operate	50%	Analyst assumption ^(b)
Value of piggery production potentially at risk	\$622.6 million p.a.	50% x \$1,245.2 million
Farm profit as a percentage of GVP	10%	Analyst assumption ^(b)
Reduction in the risk of profitability loss (from potential loss of social licence) attributable to the APL Environment RD&E Program investment	1.0%	
Expected maximum potential profit benefit	\$0.623 million p.a.	1.0% X 10% X \$622.6 million
First year of impact	2017/18	Based on completion of at least half of the 21 projects in the APL Environment RD&E Program evaluation population
Period of impact (years ended 30 June)	2018 to 2022, then declining linearly to zero by 2029	Analyst assumption ^(b)
Risk Factors		
Probability of output (probability that the APL Environment RD&E Program successfully produced outputs required to delivery impact)	100%	Based on successful completion of each of the 21 projects in the APL Environment RD&E Program evaluation population
Probability of outcome (probability that outputs will be used/adopted to achieve impact)	80%	Based on anecdotal evidence that the industry has commenced adoption of improved practices
Probability of impact (probability that, given adoption, the assumed impact will be realised)	60%	Allows for exogenous factors that may affect realisation of impacts and also that the benefits estimated may not persist into the future
Other Factors		
Additional adoption/ implementation costs required to delivery impacts	The assumptions used in the valuation of impacts are assumed to be NET of any additional adoption/ implementation costs required to deliver the impact(s).	

(a) Note: this figure is net of any costs that may be incurred by Australian pork producers to adopt/ implement practice changes to achieve the associated cost savings.

(b) Analyst assumption based on discussions with project personnel.

6.2.6 *Counterfactual*

As described previously in Section 3.3, defining the counterfactual is an essential element of quantifying impacts but often is one of the more difficult assumptions to make in investment analyses.

Given the broad range of potential impacts identified as part of the evaluation of the cluster of 21 projects that made up the APL Environment RD&E Program RD&E investment, and the scope of the evaluation, it was necessary to take a relatively broad, Program level approach to the valuation of impacts. The assumptions used in the impact valuation were developed to estimate the benefits specifically attributable only to the investment in the population of projects evaluated.

Based on the above considerations, a broad Program level definition also was applied to the counterfactual. It was assumed that, without the investment in the APL Environment RD&E Program, the benefits estimated would not have been realised.

7. Results

The impact assessment for the APL Environment RD&E Program (1 July 2014 to 30 June 2019) was conducted according to the CRRDC Impact Assessment Guidelines (CRRDC, 2018). All past costs and benefits were expressed in 2018/19 dollar terms using the Implicit Price Deflator for Gross Domestic Product (ABS, 2019). For the APL components of the project investments, the cost of managing the APL funding was added to the APL contribution for each project (Table 23) via a management cost multiplier ($\times 1.069$). This multiplier was estimated based on the average (5-year) share of 'payments to suppliers and employees' in total APL expenditure reported in the APL Statement of Cash Flows (APL, 2015 to 2019). Further, to accommodate additional APL extension and communication costs, an extension cost multiplier of $\times 1.025$ was applied to the APL investment costs (Table 23).

All benefits after 2018/19 also were expressed in 2018/19 dollar terms. All costs and benefits were discounted to 2019/20 (year of evaluation) using a discount rate of 5%. The modified internal rate of return (MIRR) was estimated using a 5% reinvestment rate. The base analysis used the best estimates of each variable, notwithstanding a high level of uncertainty for many of the estimates. All analyses ran for the length of the investment period plus 30 years from the last year of investment (2018/19) to the final year of benefits assumed.

7.1 Investment Criteria

Eighteen of the 21 APL project investments evaluated contributed to the three key impacts valued in the assessment (see Table 29). Two analyses were carried out at an APL Program level. In the first analysis, the present value of the benefits (PVB) for the 18 projects valued was compared to the total investment in the APL Environment RD&E Program population (investment in all 21 projects). As there are likely to be some positive benefits from the projects where impacts were not explicitly valued, the results from this analysis are likely to represent a lower bound set of investment criteria for the Program.

Table 32 and Table 33 show the 'lower bound' investment criteria estimated for the different periods of benefits for the total investment and for the APL investment respectively.

Table 32: Lower Bound Investment Criteria for Total Investment in the APL Environment RD&E Program (21 Projects) (Discount rate 5%)

Investment Criteria (Total Investment - Lower Bound)	Years from last year of investment						
	0	5	10	15	20	25	30
Present value of benefits (\$m)	1.68	8.29	13.08	16.57	19.31	21.46	23.14
Present value of costs (\$m)	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Net present value (\$m)	-3.32	3.30	8.08	11.58	14.32	16.46	18.15
Benefit-cost ratio	0.34	1.66	2.62	3.32	3.87	4.30	4.63
Internal rate of return (%)	Negative	15.65	20.96	22.21	22.60	22.73	22.78
MIRR (%)	420.21	19.85	15.90	12.77	10.77	9.37	8.33

Table 33: Lower Bound Investment Criteria for the APL Investment in the APL Environment RD&E Program
(21 Projects) (Discount rate 5%)

Investment Criteria (APL Investment - Lower Bound)	Years from last year of investment						
	0	5	10	15	20	25	30
Present value of benefits (\$m)	1.08	5.35	8.43	10.69	12.46	13.84	14.93
Present value of costs (\$m)	3.19	3.19	3.19	3.19	3.19	3.19	3.19
Net present value (\$m)	-2.10	2.16	5.25	7.50	9.27	10.66	11.74
Benefit-cost ratio	0.34	1.68	2.65	3.36	3.91	4.35	4.69
Internal rate of return (%)	negative	16.50	21.94	23.18	23.55	23.67	23.71
MIRR (%)	453.38	20.55	16.26	13.00	10.94	9.51	8.45

The second analysis refers to the same set of valued benefits (estimated total PVB of \$23.14 million at a 5% discount rate, 30 years from the last year of investment) but compared them to the specific investment costs of only the 18 projects contributing to the benefits valued. This second analysis is likely to estimate an upper bound set of investment criteria for the APL Environment RD&E Program investment, as the analysis focused on the highest impact projects.

Table 34 and Table 35 show the ‘upper bound’ investment criteria estimated for the different periods of benefits for the total investment and for the APL investment respectively.

Table 34: Upper Bound Investment Criteria for Total Investment in the APL Environment RD&E Program
(18 Projects) (Discount rate 5%)

Investment Criteria (Total Investment - Upper Bound)	Years from last year of investment						
	0	5	10	15	20	25	30
Present value of benefits (\$m)	1.68	8.29	13.08	16.57	19.31	21.46	23.14
Present value of costs (\$m)	4.82	4.82	4.82	4.82	4.82	4.82	4.82
Net present value (\$m)	-3.14	3.47	8.26	11.75	14.49	16.64	18.32
Benefit-cost ratio	0.35	1.72	2.71	3.44	4.01	4.45	4.80
Internal rate of return (%)	negative	16.39	21.57	22.78	23.15	23.27	23.31
MIRR (%)	361.31	20.82	16.26	12.98	10.92	9.48	8.42

Table 35: Upper Bound Investment Criteria for the APL Investment in the APL Environment RD&E Program
(18 Projects) (Discount rate 5%)

Investment Criteria (APL Investment - Upper Bound)	Years from last year of investment						
	0	5	10	15	20	25	30
Present value of benefits (\$m)	1.08	5.35	8.43	10.69	12.46	13.84	14.93
Present value of costs (\$m)	3.02	3.02	3.02	3.02	3.02	3.02	3.02
Net present value (\$m)	-1.94	2.33	5.41	7.67	9.44	10.82	11.91
Benefit-cost ratio	0.36	1.77	2.79	3.54	4.12	4.58	4.94
Internal rate of return (%)	Negative	17.70	22.94	24.11	24.45	24.56	24.59
MIRR (%)	406.81	22.46	17.05	13.49	11.29	9.78	8.67

The upper bound investment criteria (e.g. BCR of 4.80) for the total investment were only slightly higher than the lower bound investment criteria (e.g. BCR of 4.63, total investment). This was because such a large number of projects (18 projects), representing approximately 96.5% of the total investment (present value terms) in the APL Environment RD&E Program evaluation population, contributed to the principal impacts valued. Thus, the difference between the upper and lower bound investment criteria is driven by only the investment costs of the three projects that did not directly contribute to the PVB. Assuming that some benefits existed in the projects not valued in monetary terms, the BCR for the total investment in all 21 projects could lie somewhere between 4.63 and 4.80 to 1.

Figure 2 illustrates the undiscounted cash flows for the estimated total benefits from the 18 projects valued and the total RD&E investment costs for the APL Environment RD&E Program.



Figure 2: Annual Undiscounted Cash Flows for Estimated Total Expected Benefits and Total RD&E Investment Costs for the APL RD&E Environment RD&E Program

7.2 Contribution to Total Benefits

The total PVB is made up of three key valued impacts described previously (see Section 6.2, and Table 29). **Error! Reference source not found.** shows the relative contribution of each of the three key benefits to the total PVB (Table 32).

Table 36: Contribution of Individual Impacts to the Total PVB

Benefit	PVB (\$m)	% of Total PVB
Impact 1: Increased productivity/ profitability for the Australian pork industry	20.29	87.7%
Impact 2: Improved efficiency of RD&E resource allocation	0.64	2.8%
Impact 3: Enhanced social licence to operate	2.21	9.6%
Total Benefits	23.14	100.0%

7.3 Sensitivity Analyses

Sensitivity analyses were undertaken for the total investment with benefits taken over the life of the investment plus 30 years from the last year of investment. All other variables were kept constant at base values. In general, the sensitivity analyses show how results change with changes to the assumptions tested. A high sensitivity would indicate that the assumption variable has a significant influence on the estimated investment criteria.

A sensitivity analysis was carried out on the discount rate as shown in Table 37. This analysis refers to the 18 projects where benefits were valued (total benefits) and includes the investment costs for all 21 projects (lower bound). The results showed a moderate sensitivity to the discount rate. The impact of the discount rate is largely due to the significant proportion of benefits from Impact I (increased productivity/ profitability) that occur well into the future and are therefore more heavily influenced by discounting.

Table 37: Sensitivity to Discount Rate (Lower Bound Analysis)
(Total investment, 30 years)

Investment Criteria	Discount rate		
	0%	5% (base)	10%
Present value of benefits (\$m)	40.64	23.14	15.84
Present value of costs (\$m)	4.12	5.00	6.03
Net present value (\$m)	36.52	18.15	9.81
Benefit-cost ratio	9.85	4.63	2.63

A sensitivity analysis then was conducted on the assumed reduction in non-feed operating costs attributable to the APL RD&E Environment RD&E Program investment for Impact I, the dominant source of benefits valued. Results are shown in Table 38. The results showed a moderate to high sensitivity to the reduction in non-feed operating costs assumed, this was to be expected as the benefits estimated for Impact I (increased productivity/ profitability for the Australian pork industry) made up 87.7% of the total PVB. A break-even analysis indicated that, with all other assumption's held at their base values, the lower bound investment criteria remained positive with a reduction in non-feed operating costs of 0.26%.

Table 38: Sensitivity to Reduction in Non-Feed Operating Costs
(Lower Bound Analysis, Total investment, 30 years)

Investment Criteria	Reduction in Non-Feed Operating Costs		
	0.5%	2.5% (base)	5.0%
Present value of benefits (\$m)	6.91	23.14	43.43
Present value of costs (\$m)	5.00	5.00	5.00
Net present value (\$m)	1.91	18.15	38.44
Benefit-cost ratio	1.38	4.63	8.69

7.4 Scenario Analysis

Further to the basic sensitivity analyses described in Section 7.3 above pessimistic and optimistic scenario analyses also was undertaken. The scenario analyses were undertaken for the total investment in all 21 projects with benefits taken over the life of the investment plus 30 years from the last year of investment. All other variables were kept constant at base values.

For the pessimistic scenario assumptions that were deemed to be key drivers of the investment criteria, or were particularly uncertain, were set to half ($\times 0.5$) their base value. The results, show in Table 39, indicate a 'worst-case scenario' for the estimated investment criteria for the APL Environment RD&E Program.

Table 39: Pessimistic Scenario Analysis – All Key/Uncertain Assumptions at Half Base Value
(Lower Bound Analysis, Total investment, 30 years, 5% discount rate)

Investment Criteria	Pessimistic Scenario – key/uncertain assumptions at half base values
Present value of benefits (\$m)	5.95
Present value of costs (\$m)	5.00
Net present value (\$m)	0.95
Benefit-cost ratio	1.19

For the optimistic scenario assumptions that were deemed to be key drivers of the investment criteria, or were particularly uncertain, were set to one and a half times ($\times 1.5$) their base value. The results, show in Table 40, indicate a 'best-case scenario' for the estimated investment criteria for the APL Environment RD&E Program.

Table 40: Pessimistic Scenario Analysis – All Key/Uncertain Assumptions at $\times 1.5$ Base Value
(Lower Bound Analysis, Total investment, 30 years, 5% discount rate)

Investment Criteria	Optimistic Scenario – key/uncertain assumptions at one and a half base values
Present value of benefits (\$m)	51.59
Present value of costs (\$m)	5.00
Net present value (\$m)	46.60
Benefit-cost ratio	10.33

Table 41 shows the investment criteria for all three scenarios: pessimistic (worst-case), base-case, and optimistic (best-case).

Table 41: Summary of Investment Criteria Across Three Scenarios
(Lower Bound Analysis, Total investment, 30 years, 5% discount rate)

Investment Criteria	Scenario		
	Pessimistic ($\times 0.5$)	Base-Case	Optimistic ($\times 1.5$)
Present value of benefits (\$m)	5.95	23.14	51.59
Present value of costs (\$m)	5.00	5.00	5.00
Net present value (\$m)	0.95	18.15	46.60
Benefit-cost ratio	1.19	4.63	10.33

The results in Table 41 indicate that the lower bound investment criteria (total benefits and total investment from all contributors for all 21 projects) remain positive even in the worst-case scenario where all key assumption were set to half their base value with an estimated benefit-cost ratio of 1.2 to 1.

7.5 Confidence Rating

The results produced are highly dependent on the assumptions made, many of which are uncertain. There are two factors that warrant recognition. The first factor is the coverage of impacts valued. Where there are multiple types of impacts it is often not possible to quantify all the impacts that may be linked to the investment. The second factor involves uncertainty regarding the assumptions made, including the linkage between the research and the assumed outcomes.

A confidence rating based on these two factors has been given to the results of the investment analysis and is reported in Table 42. The rating categories used are High, Medium and Low, where:

- High: denotes a good coverage of impacts valued or reasonable confidence in the assumptions made
- Medium: denotes only a reasonable coverage of impacts valued or some uncertainties in assumptions made
- Low: denotes a poor coverage of impacts valued or many uncertainties in assumptions made

Table 42: Confidence in Investment Criteria for the Program

Coverage of Impacts	Confidence in Assumptions
Medium	Medium-Low

Coverage of impacts was rated as Medium because, although several environmental and social impacts were not valued in monetary terms, the three impacts valued represented the primary impacts of the APL Environment RD&E Program Investment.

The Program level “cluster” assessment approach required the impact valuation to be conducted at a relatively high, aggregate Program level. Though the valuation was supported by credible industry data and other published literature, there was limited data/evidence available to support the specific assumptions used in the cost-benefit analysis (CBA). Key project personnel were consulted during the CBA process and the Program level assumptions were considered appropriate or reasonable by project researchers, however this is expert opinion only. Ideally, a sample of producers, industry personnel and/or other Program stakeholders would be interviewed to obtain additional data to further support the valuation of impacts. Such in depth surveying of additional stakeholders was not possible within the scope and resources of the current assessment. Thus, confidence in assumptions was rated as Medium-Low.

8. Discussion & Conclusions

Across the 21 projects evaluated as part of the APL Environment RD&E Program there was a wide range of impacts and/or potential impacts identified. Principal impacts of the Program investment included:

- Increased productivity/ profitability for the Australian pork industry,
- Improved efficiency of RD&E resource allocation, and
- Enhanced social licence to operate for Australian pork producers.

These three principal impacts were valued in monetary terms. Two sets of analyses and corresponding investment criteria were reported for the investment in the APL Environment RD&E Program. One analysis refers to the 18 projects that contributed to the impacts that were valued. Total funding for the 18 projects where impacts were valued totalled approximately \$4.82 million (present value terms) and produced aggregate total expected benefits of \$23.14 million (present value terms). This gave an estimated net present value (NPV) of \$18.32 million, a benefit-cost ratio (BCR) of 4.8 to 1, an internal rate of return (IRR) of 23.3% and a MIRR of 8.4%. The investment in the 18 projects valued represented approximately 96.5% of total Program funding (present value terms) for the 21 projects in the evaluation population.

When the benefits for the impacts valued were compared to the total investment in all 21 projects in the population, this slightly lowered slightly the investment criteria. Funding for all projects in the population totalled approximately \$5.00 million (present value terms). When compared to the same value of benefits from the 18 projects (\$23.14 million PVB), the investment produced an estimated NPV of \$18.15 million (present value terms), a BCR of approximately 4.6 to 1, an IRR of 22.8%, and a MIRR of 8.3%.

The analysis suggests that the APL Environment RD&E Program has delivered positive benefits to the Australian pork industry and other industry stakeholders. Further, a pessimistic/ optimistic scenario analysis demonstrated that, under a worst-case scenario with key assumptions set to half their base values, investment criteria for the APL Environment RD&E Program were still positive with an estimated BCR of 1.2 to 1. Also, as not all of the impacts for the Environment RD&E Program were able to be valued within the scope of the current assessment, the investment criteria reported are likely to represent an underestimate of the performance of the APL Environment RD&E Program investment.

The results should be viewed positively by APL, the Australian pork industry and other APL funding partners, as well as policy personnel responsible for allocation of public funds.

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