Australia's leaders in the science of contamination and its remediation.

CRC CARE

A safer, cleaner environmental future

Annual Report

2019/2020

Australian Government
Department of Industry, Science, Energy and Resources

Business Cooperative Research Centres Program

CRC CARE is a partnership of organisations dedicated to developing new ways of dealing with and preventing contamination of soil, water and air including solid and liquid waste management. We focus Australia's foremost expertise and resources on this issue and to develop close links with research partners at the cutting edge in this field around the world.

OUR GOALS

Solutions for industry

To develop cost-effective and commercially sustainable solutions and technologies within regulatory and policy frameworks for the identification and remediation of contamination problems of key importance to Australia and the Asia-Pacific region.

Innovative research

To deliver research quality that positions CRC CARE as a national centre of excellence with international standing and reputation, ensuring our outcomes are recognised and adopted globally.

Develop the business

To lead the development of a new export industry in environmental risk assessment and remediation through the delivery of solutions and technologies, and support their implementation with training programs that develop and improve the environmental management skills of the industry's labour force.

Deliver public benefits

To ensure the effective adoption of our solutions and technologies, leading to health, environmental and economic benefits to the Australian public through reduced exposure to toxic contaminants and improved amenity of our cities as a result of cost-effective remediation/management of urban land.

Capacity building

Through university and short-term training, educate a generation of researchers and practitioners highly skilled at solving and preventing the problems of contamination, solid and liquid waste management and create employment opportunities in the industry for these specialists.

COVER IMAGE

A CRC CARE research team from the University of Newcastle's Global Centre for Environmental Remediation inspects a derelict mine site in rural NSW.

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CHAIRMAN'S FOREWORD

CRC CARE is a trusted, independent broker of expert knowledge on preventing and solving environmental contamination problems by uniting stakeholders to work collaboratively to develop mutually agreed, science-based approaches.

These stakeholders include contaminated site owners and developers from industry and government, environment protection authorities and other government agencies, environmental consulting companies, researchers, analytical laboratories, and communities dealing with contaminated sites.

The 2019/20 reporting period – originally scheduled to be our last – has presented unforeseen challenges. The closure of university campuses in response to the COVID-19 pandemic compromised our ability to meet a number of our remaining milestones. As a result, the CRC Program agreed to a 12-month protracted exit, extending our wind-up date to 30 June 2021.

One of our most significant achievements in 2019/20 was the launch of the National Remediation Framework. This world-first initiative harmonises remediation approaches nationally and has been endorsed as best practice by State and Territory environmental regulators.

CRC CARE has supported exponential growth in the Australian remediation industry. It has also boosted Australia's global standing in the contaminated land sector through educating and training thousands of environmental practitioners. These impacts were confirmed by an independent economic impact review that we commissioned in 2018/19.

During the 15-year period from the initiation of CRC CARE's first term of funding, the economic benefit due to practical roll-out and application of our research exceeds $5.4 billion (and growing). This amounts to a return of nearly $9 on every cash and in-kind dollar invested by the Commonwealth and our industry and research partners.

CRC CARE has helped Australia lead the world in the prevention, remediation and management of contaminated soil, water and air. A user-led 'Beyond 2020' Committee has developed strategies that will enable Australia to maintain such leadership in the future. Given widespread end-user recognition that waste and emerging contaminants pose major challenges to Australia's prosperity and health, the committee has submitted an application for a new CRC.

The prospective new CRC aims to support an innovative, prosperous, healthy and clean Australia by collaborating with industry and government to prevent, reduce and deal with hazardous waste and pollution, thereby strengthening Australia's reputation as a clean and green producer while safeguarding human health and the environment.

The 'Clean Australia CRC' would support a new paradigm for managing risk through innovative approaches. It would develop tools to improve waste management and re-use and boost resource recovery, improve management of existing pollution and prevent new pollution occurring, and harness machine learning and artificial intelligence to measure and assess the effects of complex and emerging contaminants.

Despite the severe disruption wreaked by COVID-19, Professor Ravi Naidu managed to ensure continuous support from Participants towards ongoing research. I compliment him and the CRC CARE staff on the success and impact of their efforts during an extremely challenging 2019/20 as well as in years past.

Dr Paul Vogel AM
Chairman
CRC CARE

01 EXECUTIVE SUMMARY

MANAGING DIRECTOR AND CEO'S REPORT

1.1. OVERVIEW

CRC CARE was launched in 2005 as part of the Australian Government's Cooperative Research Centres (CRC) Program. In 2010, CRC CARE successfully applied for a further nine years of funding.

A major strength of CRC CARE is strong collaboration with industry and government. With our 28 industrial, government and scientific participants, CRC CARE delivers industry-focused technologies and guidelines for the assessment and clean-up of environmental contamination. We have a worldwide network of partners and collaborators.

2020 was not the year we expected. The COVID-19 pandemic has presented the world with great challenges. From February, university closures and travel bans hampered the ability of CRC researchers to deliver outcomes. Almost every project was affected, particularly those that involved fieldwork nationally and internationally. In spite of this, most of our research milestones were delivered. Additionally, with support from the regulatory sector and other end-user participants, we also delivered most utilisation milestones.

The CRC's inability to deliver some milestones, however, led to the Commonwealth Government granting a one-year protracted exit. We are most grateful for this and for the ongoing support that we have received from our major shareholders and participants, particularly the Department of Defence (DoD), BHP and HLM Asia Group Ltd. The CRC also acknowledges the ongoing support from universities and environmental regulators across Australia.

While the completion of CRC CARE's activities has been delayed by a year, the CRC has provided Australia with a profound legacy. The CRC has reshaped the national approach to management of contaminated sites. Over CRC CARE's lifetime, the economic benefit of our activities has exceeded $5.4 billion, representing a return on investment of nearly 9 to 1. For more details on our economic impact, as described in an independent economic impact analysis conducted by Consulting & Implementing Services, see the Highlights and Achievements Report, pages 44–56.

The CRC has developed health screening levels (HSLs) for petroleum hydrocarbons, published best-practice strategies, and created technologies and guidance for managing sites contaminated with per- and polyfluoroalkyl substances (PFAS). The HSLs, along with standards for assessing bioavailability, are enshrined in legislation through the National Environment Protection (Assessment of Site Contamination) Measure ('the ASC NEPM'), ensuring they have been adopted by all environment protection authorities (EPAs) nationally. Our EPA-endorsed National Remediation Framework (NRF) provides for the first time a nationally harmonised approach to cleaning up contaminated sites.

CRC CARE's advocacy, policy development and strong collaboration with Australian small-to-medium enterprises (SMEs) have driven the establishment of a globally significant remediation industry in Australia. The industry has grown from $300 million per annum in 1999 (employing fewer than 500 people) to over $5 billion per year today (employing over 5,000 people).

CRC CARE also enjoys a stellar reputation beyond Australia's shores – exemplified in 2019/20 by an invitation from the influential US-based Interstate Technology & Regulatory Council (ITRC) to jointly work on guidance documents relating to PFAS and microplastics.

1.2. ACHIEVEMENTS

RESEARCH AND COLLABORATION

CRC CARE's Best Practice Policy Program, under the outstanding leadership of Dr Bruce Kennedy (who retired in March 2020), led a range of achievements over 2019/20.

CRC CARE has completed and released the NRF to complement the ASC NEPM. The framework aims to achieve greater certainty in environmental outcomes and promote consistent implementation of guidance across Australia. It provides practical guidance for both the remediation and the long-term management of remediated sites. The framework objectives are to protect human health and the environment, facilitate more effective and efficient remediation, and provide net societal benefit (including consideration of the broader economic context).

Development of policy guidance in such a complex area requires a considerable investment. The framework is the culmination of work that began at the inception of CRC CARE amidst a great deal of uncertainty. The Heads of EPA Australia and New Zealand (HEPA) forum has endorsed the NRF as best practice and all 25 guidance documents, plus a cost-benefit and sustainability analysis tool, are freely available via www.remediationframework.com.au. The NRF launch occurred online in June 2020, attended by 300 delegates across Australia and New Zealand.

Together, the ASC NEPM and the NRF provide Australia with a harmonised system of assessment, remediation and management of site contamination. This significant achievement is possibly unique worldwide and is duly receiving international recognition.

Contaminated sites, and even remediated sites, may suffer loss of local amenity and environmental values as well as reduced property prices. This loss is referred to as 'title blight'. CRC researchers are seeking to develop solutions to title blight by identifying the barriers to remediation and redevelopment, and the impacts of these barriers.

The Better Measurement Program, led by Dr Cheryl Lim at the National Measurement Institute (NMI), develops analytical methods and innovative field technologies to provide fast and efficient assessment of site contamination. An objective is to replicate laboratory measurements in the field using newly developed real-time monitoring tools. Our ability to manage the environment depends heavily on the extent to which we can reliably and economically identify and quantify environmental contamination.

The Global Centre for Environmental Remediation (GCER) at the University of Newcastle is developing a biosensor to measure concentrations of benzene in groundwater. Such monitoring is necessary with water that is to be used for drinking, cooking or agriculture. The sensor relies on differential protein expression of bacteria exposed to benzene. A prototype is expected next year.

There has been further progress towards commercialisation of the GCER's development of probeCARE™, a tool that allows irrigators to monitor real-time water quality in lakes and streams through measurement of metal ions in solution. probeCARE is now able to monitor sodium (Na), potassium (K), calcium (Ca) and nitrate (NO3-), and GCER has developed a number of prototypes for testing.

GCER's Dr Yanju Liu leads the Minimising Uncertainty in Risk Assessment Program. Risk assessment based on total contaminant concentration is becoming outdated due to the high uncertainty, which may lead to unnecessarily stringent and costly remediation, or remediation of sites that do not require it. Researchers seek to improve the certainty of risk assessment by considering the fate of chemical compounds in the environment, including emerging contaminants. An important variable is bioavailability, representing the amount of a contaminant that an organism can take up or adsorb.

The CRC has created a database of over 1,000 contaminants, with chemical and toxicological data. Included are metals, herbicides, insecticides, growth promoters, hormones, antibiotics and antimicrobial agents, industrial pollutants and solvents. We intend to make the database freely available.

The Cleaning Up Program, led by Professor Megharaj Mallavarapu, develops, evaluates and demonstrates the technologies, indicators and strategies for in situ management of contamination issues experienced by industry, government and the community. We seek sustainable and green remediation technologies. The program's work is particularly important considering that just 10 to 15 per cent of Australia's estimated 200,000 potentially contaminated sites have been remediated.

Research into the ability of native plants to decontaminate soils contaminated with polycyclic aromatic hydrocarbons (PAHs) highlighted the importance of native microbial biodiversity in remediation. The research also revealed that microbial structural and functional response to disturbance depends upon land management legacies, suggesting that appropriate management can increase soil's resilience.

CRC CARE's matCARE™ reduces human health risks from PFAS-contaminated water, soil and concrete. The treatment involves application of modified clay sorbent that removes PFAS. matCARE is now available to treat contaminated concrete using a nano-powder matCARE slurry, eliminating the need for expensive demolition and disposal of contaminated concrete. The clay sorbent soaks up toxic substances and binds them irreversibly. matCARE effectively immobilises perfluorooctanesulfonate (PFOS) in concrete blocks and prevents it from leaching into the environment. Applying matCARE slurry to PFOS-contaminated concrete reduced leaching by 99.97 per cent over a 5 day period, with 99.61 per cent of PFOS remaining locked up after almost a year. A few kilograms of matCARE can treat a typical contaminated site, protecting people and the environment.

CRC CARE's unique National Contaminated Sites Demonstration Program (NCSDP) extends lab-based work to field-based remediation, with these projects funded by three of our major end-user Participants: the Department of Defence, the Australian Institute of Petroleum (AIP) and BHP. This approach allows engineers, scientists and consultants to test, validate and optimise operating conditions for new site assessment and remediation technologies.

AIP is a founding participant of CRC CARE. The AIP Demonstration Program addresses policy and guidance related to the assessment, risk characterisation and remediation of sites contaminated with petroleum hydrocarbons (PHs) and related compounds.

As part of the AIP Program, CRC CARE completed a landmark study with the potential to transform the way in which petroleum-hydrocarbon-contaminated sites are managed. The study produced three free-to-access reports for site managers and state and federal regulators. The reports describe how to manage sites contaminated with hydrocarbons known as light non-aqueous phase liquids (LNAPLs), which can pollute soil and groundwater. The transformative research identifies industry best practices to deliver improved environmental outcomes and potentially save $320 million over the next 10 years through more effective remediation. CRC CARE found that the rate of hydrocarbon removal by natural degradation by microbes and chemical reactions will typically exceed that being achieved by active recovery within 3 to 5 years of site contamination. The findings have the potential to enable earlier decommissioning of petroleum storage facilities and handover of sites, as well as to avoid greenhouse gas emissions from unnecessary pollutant recovery systems.

In 2019/20 BHP supported work on artificial intelligence and machine learning aimed at improving the characterisation of contaminated sites. CRC CARE completed sampling of groundwater and surface and subsurface soils at BHP sites at Newman and Port Hedland, WA. The results suggest stronger mobility of short-chain PFAS. A review of PFAS toxicity on terrestrial organisms will lead to a guidance document.

Given limited resources, it is crucial that organisations appropriately prioritise contaminated sites slated for remediation. CRC CARE has produced, and is validating, a beta version of a web-based tool, rankCARE II™, which identifies risk factors at contaminated sites and compares human health risk factors across multiple sites.

CRC CARE's largest demonstration program is a collaboration with the Department of Defence, which sponsors research into contaminants commonly found at their sites. There were pilot-scale trials of PFAS remediation using matCARE at Royal Australian Air Force (RAAF) Base Richmond, NSW. The trials entailed the establishment of monitoring bores and groundwater wells. Laboratory-based modifications of matCARE appear to have led to improvements, with the new product removing all quantifiable PFAS active ingredients to concentrations less than 20 parts per trillion – well below Australian health-based guidance values.

In related research, the CRC employed remote-controlled driverless vehicles to carry instruments for real-time monitoring of volatile organic compounds (VOCs). The approach allows safe monitoring of dangerous or difficult-to-access sites.

The CRC is developing green remediation technology to tackle 1,4-dioxane, a recalcitrant and persistent contaminant. The approach involves dioxane-degrading bacteria (Bacillus sp.). Researchers have tested the effect on the bacteria of additional sources of carbon (acetate, sucrose and glucose) and nitrogen (nitrate, ammonia and yeast extract). If present in the environment, glucose and sucrose may reduce the bacteria's dioxane-degrading ability. Conversely, yeast extract and nitrate enhanced the bacteria's degrading ability.

COMMERCIALISATION AND UTILISATION

During 2019/20, CRC CARE had six patent families registered, one patent family accepted and awaiting the grant, two patent families at the Patent Cooperation Treaty (PCT) application stage and one patent family under examination.

The CRC has seven trademarks registered, and one accepted, in Australia.

All of CRC CARE's new technologies have the potential for commercial application. The CRC has sought evaluation agreements with end-users, such as site operators, remediation contractors, manufacturers and suppliers of equipment.

Although no registered intellectual property (IP) was sold, transferred or licensed for commercialisation during the reporting period, Australian businesses are considering commercialising 2 of the CRC's products (matCARE and probeCARE).

By the end of the 2019/20 reporting period, the CRC had achieved 14 out of 17 utilisation milestones.

STAFF, EDUCATION AND TRAINING

Through its Education Program, CRC CARE provides scholarship stipends and operational funding for high-calibre PhD and Honours students. The program provides additional training to help students develop skills desired by prospective employers. The CRC aims to have its graduates 'industry-ready'; in some cases, students are co-supervised by end-users.

During the reporting period, one student completed their PhD, with 9 students continuing studies. The CRC has significantly exceeded its Commonwealth Agreement target PhD numbers for its current term of funding.

Our Industry Training Program disseminates research outcomes and technical knowledge to stakeholders, including industry professionals and government regulators. This is achieved through multiple channels, including seminars, webinars, workshops and conferences. Although COVID-19 forced the postponement or cancellation of several events, we quickly switched to a predominantly online delivery model, allowing around 1,500 participants to receive knowledge and training.

CRC CARE organised and hosted CleanUp 2019 – the 8th International Contaminated Site Remediation Conference, incorporating the 2nd International PFAS Conference – in Adelaide in September 2019. The conference showcased research and industry best practice, drawing on Australian and international experience. Around 700 delegates attended from Australia and more than 30 other countries, representing a wide range of fields and industries. We were privileged to have His Excellency the Honourable Hieu Van Le, Governor of SA, launch the conference, and the Honourable Mrs Zuraida Kamaruddin MP, Malaysian Minister of Housing and Local Government, present the Brian Robinson memorial lecture. The latter inspired a joint effort to host the 2nd Global CleanUp Congress, which will take place in Kuala Lumpur, Malaysia, under the theme of 'Trash to cash'. CleanUp also visited South Korea for the first time, with CleanUp Korea 2019 held in Seoul in December.

A successful 'From Risk to Remediation' Summer School in 2019 led to plans for a follow-up in March 2020. Instead, due to COVID-19, the CRC ran an 8-week self-paced online masterclass on contaminated site assessment, management and communication. This was due to start in early 2020/21 with around 100 participants from government, regulators, consultants, academia and research agencies.

INTERNATIONAL PARTNERSHIPS

A hallmark of CRC CARE is its extensive international collaboration. However, the COVID-19 pandemic significantly curtailed activities.

CRC CARE's China Program is run in partnership with HLM Asia Group Ltd, Huazhong University of Science and Technology (HUST) in Wuhan, and Shaoguan University in Guangdong. A highlight project combined two techniques – Phoslock®, a commercially available product, plus microbial biofilm technology – to remediate phosphate in situ and tackle eutrophication (potentially harmful nutrient build-up) and algal blooms in a large freshwater lake in Wuhan. In Shandong province, the CRC collaborated on a project to install solar cells on a former mining site that has elevated levels of copper and other metals.

1.3. RISKS AND IMPEDIMENTS

A significant challenge is the cessation of CRC CARE's funding. There is potential for Australia to lose significant expertise in tackling pressing pollution problems associated with existing and emerging contaminants such as PFAS. Prior to CRC CARE, remediation was achieved largely through costly and risky excavation and transport to landfills. The CRC's work has led to the development of policy guidance and remediation technologies that have helped clean up around 5% of the contaminated sites in Australia. The complex nature of not only contaminants themselves, but also the soil environment, requires robust science that underpins both innovative technologies and policy guidance. With CRC CARE ceasing to operate, there is a real risk that the progress of the past 15 years will dissipate, with dire consequences for the Australian and global economies, our environment and human health.

In 2019/20, COVID-19 was the major impediment to the CRC's activities. We have since implemented COVID-safe workplace practices for our researchers, in line with those undertaken at our research provider organisations. Related risks include a resurgence in COVID-19 and associated restrictions, and delays in the production of an effective vaccine.

1.4. CONCLUDING REMARKS

I am particularly proud of CRC CARE's creation of the NRF. Harmonisation of approaches to remediation and management of site contamination in Australia creates commercial benefits and provides governments and the public an assurance of uniformity and competence.

A harmonised national approach supports portability of best practice and consistency across jurisdictions, and cost savings. We can now ensure that practitioners meet a recognised professional standard, offer enhanced workforce mobility and recognition of skills, and enhanced recognition of the site contamination profession. Ultimately, we have improved certainty and confidence in remediation outcomes. The framework is forecast to deliver the remediation sector savings of at least 5 per cent, amounting to more than $200 million through to 2026.

Since its launch in 2005, the CRC CARE has consistently provided a unique resource to Australia that has delivered enormous economic and environmental benefits to key growth industries, communities, governments, SMEs and regulatory agencies.

Highlights of our recent economic impact analysis include the technologies that we have developed for analysing and cleaning up PFAS contamination, and best-practice strategies for managing PFAS-contaminated sites. CRC CARE's HSLs for petroleum hydrocarbons have been incorporated into national legislation via the ASC NEPM and adopted by all regulators nationally. Our innovative remediation technologies are expected to generate cumulative benefits of over $950 million for industry and government through to 2026.

The CRC has helped create a skilled workforce to meet Australia's remediation and contamination needs across industries of national importance, and has significantly advanced remediation research capacity.

It is clear that CRC CARE and its partners have delivered substantial value to the nation. We acknowledge the extensive support we have received from government, industry and partner research agencies here and overseas.

Thank you, particularly in these difficult times, to our research providers and host universities. I'd like to acknowledge the insights, advice and support from our Chairman Dr Paul Vogel, and the Board.

I especially thank all CRC CARE staff members, both research and administrative. The CRC's success reflects their professionalism and hard work.

Ravi Naidu

Professor Ravi Naidu
Managing Director and CEO
CRC CARE

02 PERFORMANCE AGAINST ACTIVITIES

CRC CARE is an independent organisation that performs research, develops technologies and provides technical guidance to support policy development for assessing, cleaning up and preventing contamination of soil, water and air. Environmental contamination is a major threat to the health of our communities, the environment, and our economies. Australia alone is estimated to have more than 200,000 potentially contaminated sites, with an estimated 5 million worldwide.

The CRC works with organisations that deal with contamination – including the mining and petroleum industries, state environmental regulators, government agencies, and environmental consultants – to create industry-ready solutions to real-world problems. By collaborating with leading environmental research groups around the world, CRC CARE is at the forefront of international scientific developments in the field of environmental contamination assessment and remediation.

Established under the Australian Government's Cooperative Research Centre (CRC) Program in 2005, CRC CARE represents Australia's foremost expertise in the development, utilisation and extension of advanced technologies and methods for:

- assessing contamination risks in land, groundwater and air
- managing and remediating contamination
- developing safe options for land use and the reuse of wastes on land
- developing solutions that are acceptable to regulatory agencies and the public
- capacity building.

Originally funded for a seven-year term, in 2010 CRC CARE applied for and received an additional nine years of funding through the CRC Program. Having commenced on 1 July 2011, CRC CARE's second term was originally scheduled to continue through to 30 June 2020. As a result of COVID-19 restrictions preventing the completion of some milestones, the CRC Program granted CRC CARE a 12-month protracted exit, pushing back the wind-up date to 30 June 2021.

A recent independent economic impact analysis estimated that since CRC CARE was launched in 2005, its work has contributed over $5.4 billion of economic benefit to Australia, which equates to nearly $9 return on every dollar invested by government and industry.

This annual report details the activities of CRC CARE from 1 July 2019 to 30 June 2020.

PROGRESS AGAINST THE KEY CHALLENGES/OUTCOMES

The 2019/20 financial year was the ninth of CRC CARE's second term. The CRC's four main research programs build upon and extend the work done in the six years of the Centre's first term.

CRC CARE's four research programs are:

- Program 1: Best Practice Policy
- Program 2: Better Measurement
- Program 3: Minimising Uncertainty In Risk Assessment
- Program 4: Cleaning Up.

In its second term, CRC CARE has an increased focus on national harmonisation of guidance on environmental contaminants. The NRF is a major initiative to this end. Crucially, CRC CARE consults both regulators and industry on its work to provide guidance that underpins policy development by regulators. Thus the CRC ensures buy-in from two key groups that, historically, have at times been at odds. This consultative approach increases the likelihood that, once it is developed, the guidance is adopted.

Together, the 2019/20 research programs comprise 6 research and 17 utilisation milestones for the reporting period. Overall, 5 (83.3%) of the research milestones and 14 (82.3%) of the utilisation milestones were completed.

Research milestones

PROGRAM	MILESTONES COMPLETED	REASON FOR DELAYS
1	1 of 1	All completed.
2	0 of 1	A key researcher resigned, resulting in a delay while a new researcher was identified. The project will be delivered by June 2021.
3	2 of 2	All completed.
4	2 of 2	All completed.

Utilisation milestones

PROGRAM	MILESTONES COMPLETED	REASON FOR DELAYS
1	5 of 6	Late completion of PhD thesis; milestone will be achieved by June 2021.
2	4 of 4	All completed.
3	2 of 3	Given the high fieldwork component of the project associated with this milestone (contaminant fate and transport studies on all major Australian soil types), progress was disrupted by COVID-related closure of universities and bans on interstate travel. The milestone will be met by June 2021.
4	3 of 4	Given the high fieldwork component of the project associated with this milestone (potential new technologies for the remediation of PFAS-contaminated soil and groundwater), progress was disrupted by COVID-related closure of universities and bans on interstate travel. The milestone will be met by June 2021.

SUPPLEMENTARY PROGRAMS

In addition to its four research programs, CRC CARE manages the NCSDP, which takes research from the lab to demonstration sites in the field. The NCSDP operates with the support of AIP, DoD, BHP and HLM Asia Group Ltd. It also included a project on Innovative Acid Sulfate Soil Remediation, which was completed in the 2017/18 reporting period. The CRC's research activities are also augmented by the CRC's China Program, which focuses on environmental remediation research. The NCSDP and China Program are managed separately by their own program coordinators, but for milestone purposes, projects within them sit under the four main research programs.

03 RESEARCH

3.1. PROGRAM 1: BEST PRACTICE POLICY

Program Leader:
Dr Bruce Kennedy, CRC CARE

CRC CARE's Best Practice Policy program develops the principles, indicators and strategies to support the development of policy by environmental regulators and other agencies, as well as a national guidance framework, for remediation of site contamination.

The program's key research areas are:

- guidance for emergent and priority contaminants prioritised for end users and regulators
- use of contaminant flux for assessing and managing groundwater contamination
- a national guidance framework for remediation in Australia (the NRF)
- classification and ranking of incentives for remediation and for the reduction of 'title blight'
- decision-making strategies for selecting remediation technologies based on available technologies, cost and effective community engagement.

PROGRAM HIGHLIGHTS

Program 1 highlights for the 2019/20 financial year are summarised below.

GUIDANCE FOR EMERGENT AND PRIORITY CONTAMINANTS

Aqueous film-forming foams (AFFFs) containing PFOS and perfluorooctanoic acid (PFOA) have historically been used in firefighting, and the resulting environmental contamination is of particular concern to the Australian community.

In 2018 CRC CARE published CRC CARE Technical Report 43: *Practitioner guide to risk-based assessment, remediation and management of PFAS site contamination*, which focuses on providing detailed guidance for practitioners in the assessment remediation and management of sites contaminated with PFAS, and complements the broadly based PFAS National Environmental Management Plan 2.0 published by the Department of Agriculture, Water and the Environment in 2020. Following publication of marine guideline values for PFOS by CRC CARE in Technical Report 43, the methodology for derivation of such values was revised as part of the National Water Quality Strategy update. Subsequently, the Commonwealth approached CRC CARE to update the marine guideline values for PFOS and submit these for inclusion in the national water quality guidelines. This work has been completed and submitted for consideration by the Commonwealth.

All CRC CARE guidelines on emerging contaminants have been included in the NRF toolbox, accessible via the NRF website.

Project status: All guidelines have been successfully completed.

FLUX-BASED ASSESSMENT AND MANAGEMENT OF GROUNDWATER

Flux-based approaches to assessment (which consider the rate of movement of contaminants through groundwater) complement the concentration-based criteria commonly used by decision-makers in regulatory agencies and in industry. CRC CARE previously published CRC CARE Technical Report 37: *Flux-based groundwater assessment and management*. This report is now included in the NRF toolbox.

NATIONAL REMEDIATION FRAMEWORK

CRC CARE has completed and released a harmonised NRF to complement the National Environment Protection (Assessment of Site Contamination) Measure ('the ASC NEPM'). The NRF aims to achieve greater certainty in environmental outcomes and promote consistent implementation of guidance across Australia.

The NRF is based on existing guidance, expertise and hard-won experience, and provides practical guidance for both the remediation and the long-term management of remediated sites.

Its development has been overseen by the NRF Steering Group, which comprises senior representatives from industry and government.

The objective of the NRF project has been met, and where harmonisation was difficult to achieve, the NRF has outlined common ground for achieving the same intent. The framework complements the ASC NEPM.

The completed NRF was endorsed by:

- the NRF Steering Group in August 2019
- HEPA in October 2019.

The NRF Steering Group recognised the NRF as a technically robust and dynamic tool that has been developed through an extensive process and through broad engagement with stakeholders.

In its submission to CRC CARE, the Australasian Land & Groundwater Association (ALGA) stated that:

"ALGA considers that the NRF is a valuable document in providing guidance on the requirements for remediating contaminated land and groundwater in Australia. It will assist in achieving a more consistent approach to remediation of contaminated land and groundwater across the various Australian jurisdictions. As such, ALGA sees that the preparation of the document is to be applauded..."

The CRC CARE Managing Director referred the completed framework to HEPA for consideration for endorsement in September 2019. At HEPA's October 2019 meeting, the framework was endorsed by HEPA as best practice. In HEPA's correspondence to CRC CARE in November 2019, HEPA recognised the significant efforts of CRC CARE to deliver the framework, mentioning that it is a "significant body of work" and that it is a "considerable achievement to finalise 24 guidelines" after "extensive consultation".

The framework was released as an independent, user-friendly website (www.remediationframework.com.au) in mid-2020. The release of the website coincided with the official launch of the NRF by the then Chair of HEPA Ms Cheryl Batagol. The launch was attended by more than 400 participants Australia-wide, as well as some international attendees.

The NRF website includes provision for feedback on the implementation of individual guidelines, as actual use will identify gaps or enhancements that may be required. Not being a legal instrument (in contrast to the NEPM), it will be relatively easy to update individual guidelines/modules.

With the release of the NRF, Australia will have a harmonised system of assessment, remediation and management of site contamination via the ASC NEPM and the NRF. This significant achievement is receiving international recognition.

There is consensus among the NRF Steering Group (end-users) on the need for a mechanism for maintaining and updating the NRF into the future, either through CRC CARE or its successor entity. HEPA is also supports continuation of the NRF.

CRC CARE Interim Program Leader Dr Joytishna Jit presented on the NRF at the RemTech Europe Conference in September 2020 and was invited to join the RemTech Europe Scientific Committee.

Key issue: The challenge is to provide certainty on the continuation of the NRF beyond CRC CARE's wind up.

INCENTIVES FOR REMEDIATION AND REDUCTION OF TITLE BLIGHT

Contaminated sites, and even remediated sites, may suffer title blight – loss of local amenity and environmental values as well as reduced property prices. Identifying the barriers to remediation and redevelopment, as well as the extent of the impact of these barriers, will create a significant knowledge base from which to develop intervention measures.

CRC CARE-supported PhD student Ms Kerry Scott (University of Newcastle) undertook research on title blight and has submitted her thesis and is awaiting external assessment.

Key issue: the longer-term challenge is to develop practical strategies for the amelioration and management of title blight.

COMMUNITY ENGAGEMENT

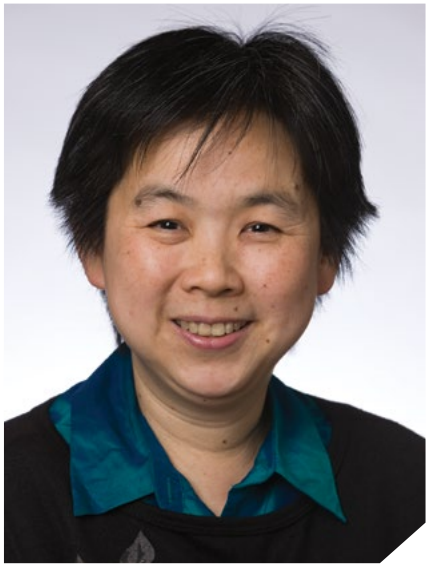
Community engagement – not just consultation – is important as society becomes more aware of the impacts of remediation activities. CRC CARE has published Technical Report 45: *Societal perceptions on remediation technologies: guidance for engagement with residents*, which includes both guidance and a tool to assist remediation service providers, auditors, local governments, health professionals and environmental regulators to develop and implement plans for remediation using an evidence-based understanding of residents' perceptions and acceptance of remediation technologies.

In early 2020, NSW Trust released the complementary step-by-step *Guide for Creating Stakeholder Engagement Plans for Contaminated Sites in NSW*. Plans to launch the step-by-step guide and Technical Report 45 were affected by COVID 19. A video launch, to be led by University of Technology Sydney (UTS), is planned.

Key issue: the longer-term challenge is for the guidance to help develop practical strategies for effective community engagement when selecting remediation strategies.

3.2. PROGRAM 2: BETTER MEASUREMENT

Program Leader:
Dr Cheryl Lim, National Measurement Institute



The Better Measurement Program's goal is to ensure that Australia's key environmental contaminants can be characterised with enough certainty so that end users can make informed decisions. End users include site assessors, remediation practitioners and policy-makers.

Our ability to manage the environment depends heavily on the extent to which we can reliably identify and quantify environmental contamination within a reasonable amount of resources. CRC CARE's Better Measurement Program develops next-generation analytical methods and innovative field technologies to provide fast and more efficient assessment of site contamination. A major target is to replicate laboratory outcomes in the field using newly developed real-time monitoring tools. The program also seeks to improve end-user confidence in environmental data by:

- contributing to CRC CARE guidance on environmental analysis, optimisation and validation of common analytical methods
- developing quality assurance tools such as proficiency testing and reference materials.

The key research areas for this program are:

- sensitive analytical techniques for emerging and priority contaminants
- novel assessment and remote online monitoring systems
- integrated information management tools
- standards for sampling contaminated material.

PROGRAM HIGHLIGHTS

- RMIT completed a significant collaboration with EPA Victoria on the development of integrated decision-making methodology and tools for groundwater remediation. These developments are expected to help environmental regulators prioritise resources and make evidence-based decisions in urban re-development projects. Much of this work formed the basis for Dr Emily Hepburn's successful PhD candidature, which was granted in December 2019.
- The joint ChemCentre/CSIRO project Mine Pit Lakes – *Their Characterisation and Assessment for In-Situ Metal Recovery Opportunities and Cost Effective Environmental Management* will be continuing into the 2020/21 financial year, with support from the Minerals Research Institute of WA. The project seeks to develop the first comprehensive database of mine pit lakes water quality in WA, which can be used to validate current practices in geochemical modelling and to enable the development of decision support tools for mine closure. A substantial amount of data from mine pit lakes was collected and analysed in the 2019/20 financial year, with a similar amount of data projected to be collected in 2020/21 financial year.
- Further progress has been made on the commercialisation of the University of Newcastle's development of probeCARE™, a tool that allows agricultural irrigators to monitor water quality in lakes and streams through real-time measurement of metal ions in solution. The research team have successfully demonstrated probeCARE for Na, K, Ca and NO3-, and have developed a number of prototypes for testing. The technology has formally entered the commercialisation phase.
- A team at GCER (University of Newcastle) is developing a biosensor to monitor benzene in groundwater. Despite benzene undergoing natural attenuation, monitoring is required, especially where the water is to ultimately be used for drinking, cooking or agriculture. The sensor is based on differential protein expression of bacteria (*Burkholderia* sp.) exposed to benzene. A prototype is expected to be available in 2020/21.
- Efforts are also continuing into the commercialisation of irCARETM, a handheld Fourier transform infrared (FTIR) spectroscopy tool for monitoring the presence of PAHs in surface and subsurface soils.
- NMI conducted an inter-laboratory study as the final stage in the development of guidance on silica gel clean-up methods for total recoverable hydrocarbon measurement. As a measure of petroleum hydrocarbon pollution, total recoverable hydrocarbon is subject to bias because it does not discriminate between petroleum hydrocarbons and polar compounds from naturally occurring biological material or generated from weathering processes. The inter-laboratory study compared the results from a number of laboratories and identified precision in the >C10 – C16 range as a potential challenge for laboratories. NMI's research has shown that the miniaturised silica gel column method is suitable for removing non-petrogenic compounds (such as phenols and other polar oxygenated compounds).
- NMI's fifth annual PFAS proficiency study took place in 2019/20, continuing the work initiated in a 2015 CRC CARE project to develop a new national capability for PFAS proficiency testing. In this latest study, NMI conducted its first proficiency test investigation of the Total Oxidisable Precursor (TOP) Assay. The aim of the study was to evaluate the oxidative methods employed by participant laboratories to convert precursors to C4-C14 PFAS compounds as well as the potential analyte losses during this process. Twenty-two laboratories participated in the study.

KEY ISSUES CONFRONTING THE RESEARCH

Measurement is a vital link in the chain of knowledge that underpins effective environmental management. There is a need for measurement solutions which provide accurate, reliable and comparable data, especially for emerging and priority contaminants. Field and remote analysis present their own challenges, with the need for robust measurement technologies able to address issues such as environmental and matrix variability.

3.3. PROGRAM 3: MINIMISING UNCERTAINTY IN RISK ASSESSMENT

Program Leader:
Dr Yanju Liu, The University of Newcastle

Health risk assessment has its origins in toxicology: the classical statement that 'the dose makes the poison' remains true today. Contemporary environmental and health risk assessment required by regulators, industry and health agencies demands a refined, evidence-based approach. Risk assessment based on total contaminant concentration is becoming outdated due to the high degree of uncertainty, which may lead to unnecessarily stringent and costly remediation, or remediation of sites that do not require it.

Program 3 aims to improve the certainty of risk assessment by considering:

- the fate of chemical compounds in the environment, including emergent contaminants
- the influence of ageing, weathering and soil properties
- the bioavailability of contaminants (to achieve a more refined exposure assessment).

It also focuses on the risk characterisation and assessment of contaminant mixtures, with particular reference to matrix properties and mixture interactions, and how their effects on bioavailability lead to adverse health effects.

Program outcomes aim to help regulators, industry, environmental consultants and risk assessors make informed decisions with reduced uncertainty, and thus better protect human and ecological health at sites with complex mixtures of contaminants. The program focuses on:

- the fate of chemicals in the main Australian soil types
- quantifying toxicity and bioavailability of individual and mixed contaminants
- quantifying pathways of exposure and transient risks
- creating databases for prioritised and emerging contaminants
- developing a robust risk and compliance model.

The program's main aim is to develop new technology, methods and knowledge that will minimise uncertainties in assessing health and environmental risks. Through national, international, and in-house collaborations, it will contribute to creating the next generation of health-screening levels and risk assessment approaches.

PROJECT HIGHLIGHTS

- *Assessing the risk to human health and the environment from mixed contamination*
  This project, a collaboration between the University of Newcastle and the University of Queensland, continued during the reporting period, with the project team demonstrating the impact of mixed inorganic contaminants on plant growth and toxicity and metal bioavailability. A predictive tool has been developed to estimate metal bioavailability based on total metal content and soil properties. This tool is now available to researchers and practitioners.
- *Mineralogical constraints associated with contaminant bioaccessibility in mine- and smelter-impacted soils*
  This project has generated a significant volume of data, led to several journal papers, and yielded two PhD graduation. Data generated from this project contributes to the database that inputs into risk-compliance modelling (reported in 2018/19). In 2019/20, the second PhD associated with this project – on lead contamination in soils, with varying sources of lead and soil properties – was awarded.
- *Create a database for prioritised and emerging contaminants*
  We have developed a fully operational stand-alone relational database package (infoCARE™) comprising more than 1,000 chemicals, with a corresponding suite of more than 8,000 rows of chemical and toxicological data. Categories of chemicals include, but are not limited to, metals, herbicides, insecticides, growth promoters, hormones, antibiotics/antimicrobial agents, industrial pollutants and solvents of both classical and emerging contaminants. In 2019/20, work continued on developing manuals and making the database freely available via a web-based application.
- *Minimising uncertainty in human health risk assessment – inorganic contaminants*
  CRC CARE researchers at GCER conducted in vitro and in vivo studies aimed at developing a standard operating procedure for assessing mixed metal(loid) bioavailability (the proportion of a substance that enters the circulation when introduced into the body). The CRC is also developing a predictive tool to estimate mixed metal(loid) bioavailability based on total metal content and soil properties. In 2019/20, bioavailability and bioaccessiblity data were collected and several research papers were prepared for peer review and publication.
- *Assessing the risk to human health and the environment from PAH-contaminated soils*
  This project, which is a collaboration with the SA Health and Medical Research Institute, is investigating bioavailability of PAHs in soils with the aim of improving human health risk assessment. Previous work established that results from animal studies using rats correlated well with those using swine. Hence, we are using rat models to estimate bioavailability of PAH contaminants that are: mixtures that originate from different contaminant sources; aged; at different remediation stages; or have been treated with different remediation approaches. In 2019/20, we conducted further animal studies to obtain sufficient data to verify and further improve the in vitro bioaccessibility models that will be used to predict risks from PAH exposure.
- *Bioaccessibility of PAHs in soil: investigations into the potential risks associated with exposure to residual PAHs in soil*
  The traditional approach to the risk assessment assumes that the total contaminant concentrations in contaminated soils are 100% bioavailable. This conservative and unrealistic approach has contributed to the expensive nature and slow pace of contaminated site clean-up. As a result, many contaminated sites that do pose substantial risks are not remediated, either in a timely manner or at all. The alternative risk-based approach to clean-up is more realistic, faster and more cost-effective, but uncertainties constrain its adoption by environmental regulators globally. One such uncertainty is whether highly sequestered PAHs in soils pose risks to human and ecological health. This project sought to minimise this uncertainty through detailed investigations of the bioaccessibility and potential risks of up to six model carcinogenic PAHs and their non-extractable residues in aged soils. Overall, PAH non-extractable residues were highly sequestered in aged soils, meaning that only very small quantities remobilised in the soils, bioaccumulated in earthworms, or were released into a simulated human gut fluid (to simulate cancer risk). Hence, PAH non-extractable residues in long-term contaminated soils are unlikely to cause significant harm to human or ecological health, and do not need to be considered in routine risk assessments. In 2019/20, one PhD on PAH non-extractable residues was awarded, with another to be submitted in 2020/21.

- *Gut microbe–heavy metal(loid) interactions*
  This PhD project sought to develop a greater understanding of the interactions between selected gut bacteria and heavy metal(loid)s – including arsenic, cadmium, lead and mercury – in relation to: (a) toxicity to gut bacteria; and (b) gastrointestinal bioaccessibility and bioavailability of heavy metal(loid)s as influenced by gut bacteria and chelating agents (chemical agents that bind the metal(loid)s). The results indicated that bioaccessibility in the gut was reduced by both gut bacteria, which potentially adsorb heavy metal(loid)s, and chelating agents. Laboratory studies using an artificially cultured human intestinal cell (a 'Caco cell') demonstrated that intestinal permeability decreased in the presence of chelating agents and gut bacteria, thereby potentially protecting the intestinal epithelial cells. The outcomes of this research will inform both fundamental and applied research in the area of gut microbe–heavy metal(loid) interactions. This project wound up in 2019/20 with the PhD student graduating and publishing several peer-reviewed papers.
- *Toxic effects of PFAS on terrestrial and subterranean environmental biota*
  This project is investigating the toxic effects of priority PFAS compounds on terrestrial and subterranean bioindicators. A lack of PFAS toxicity data has constrained the derivation of ecological screening levels (ESLs) for priority PFAS, especially perfluorohexane sulfonate (PFHxS), using the sensitive species distribution approach. We are exposing a wide range of plants and soil biota to PFHxS to determine toxicity. The information will support the derivation of ESLs for contaminated soils..

AWARDS/RECOGNITION

- Dr Ayanka Wijayawardena was invited to be a PhD thesis reviewer, in recognition of her expertise in mixed metal bioavailability.

KEY ISSUES FACING RESEARCH

Environmental and health risk assessments are largely based on toxicological data. However, there is a scarcity of data on both mixtures of contaminants and emerging contaminants of concern. Without sufficient data, risk assessment is based on assumptions, resulting in large uncertainties. CRC CARE has generated limited but significant data that fill some of these knowledge gaps. It is important to acknowledge that it is impossible to generate comprehensive datasets for many more mixture combinations or emerging contaminants within the current term of the CRC's funding.

Progress in Program 3 was constrained in 2019/20 by the COVID-19 global pandemic, which limited researchers' access to laboratories and other resources. With most facilities now operating normally, work is back on track in 2020/21 (notwithstanding the possibility of further COVID outbreaks).

3.4. PROGRAM 4: CLEANING UP

Program Leader:
Professor Megharaj Mallavarapu, University of Newcastle

The Cleaning Up Program aims to develop, evaluate and demonstrate the technologies, indicators and strategies for *in situ* management of contamination issues experienced by industry, government and the community. It addresses the limitations of existing assessment and remediation technologies for effective reduction of risks to human and environmental health, and develops sustainable and 'green' remediation technologies. The green approach seeks to exploit the unique properties of biological material (e.g. plants or microorganisms) rather than potentially dangerous synthetic chemicals that may pose a subsequent risk to people or the environment. The program also promotes techniques that reduce greenhouse gas and other pollutant emissions by, for example, reducing the need to transport contaminated soils to landfills or using renewable energy (including solar power) to power remediation infrastructure.

The program also establishes the parameters for effective risk reduction via manipulation of contaminant bioavailability in unique Australian soils and aquifers. It is the engine room for technologies scaled up and demonstrated in the field as part of the CRC's DoD, BHP, China and Petroleum demonstration programs.

Program 4's work is particularly important when we consider that a mere 10 to 15% of Australia's 200,000 potentially contaminated sites have been remediated. There are several reasons for this slow rate of remediation, including the complex nature of contaminated sites (and associated commercial drivers) along with the heterogeneous nature of surface and subsurface environments. Furthermore, contamination is occurring and legacy contaminated sites are being identified at a pace that far exceeds that of the improvement in remediation approaches and technologies.

Key research areas include:

- novel remediation technologies for emerging and priority contaminants
- development, testing and validation of sustainable and green remediation technologies.

Currently, this program comprises eight projects:

- development of nanoparticles and molecular-imprinted polymers – immobilised electrospun polymeric nanofibrous mats for environmental remediation
- validation of technology developed for organic micropollutant removal as part of the Sydney Olympic Park Authority's Water Reclamation and Management Scheme
- development of a novel framework to identify, predict and improve the efficiency of bioremediation
- energy and nutrient recapture from solid wastes (Southern Cross University), which aims to capture the nutrients from organic wastes through hydrothermal carbonisation and generate energy (methane) from both solid and liquid wastes through anaerobic digestion
- novel bioremediation tools for nitrogen-contaminated groundwater.
- remediating lakes contaminated with agrochemicals, including a field trial using Phoslock as an immobiliser of nutrient phosphorus and microbial biofilm to remove nitrogen

- phytoremediation (using plants) of soil contaminated with heavy metals; this project is now conducting field-scale trials
- rehabilitation of metalliferous mine sites – now at field-scale trial stage.

In addition to these projects, the CRC's NCSDP (see pages 14-17) oversees and scales up projects that address Program 4 utilisation milestones.

PROGRAM HIGHLIGHTS

The program's main achievements in 2019/20 were:

- Developed a cost-effective nano zerovalent iron (nZVI) loaded membrane to treat metal-rich wastewater and also to recover precious metals from mining wastewater streams (UTS.)
- Developed and validated an efficient technology for simultaneous removal of organic micropollutants and dissolved organic carbon from reverse osmosis concentrate. Suitable for industrial-scale application, this technology will reduce the potential harm posed by this type of waste disposal and increase the volume of water available for sustainable reuse (UTS).
- A study conducted using native plants to decontaminate PAH-contaminated soils highlighted the importance of native microbial biodiversity in remediation. The research also indicated that microbial structural and functional response to disturbance depends upon land management legacies, suggesting that appropriate management can increase soil's resilience to disturbance (Western Sydney University).
- Isolated acid-tolerant microalgae and developed a microalgal-based technology for acid mine drainage remediation with simultaneous biomass production for energy and metal recovery (University of Newcastle).
- Developed technology based on microalgae-bacteria consortia (mixtures) for brewery and piggery wastewater remediation (University of Newcastle).
- Developed a bioremediation technology for treating dimethylformamide-contaminated wastewater (University of Newcastle).

Program 4 also had considerable success in field application of several new or improved technologies through the NCSDP, including our BHP, AIP and DoD programs (see pages 15–17).

KEY ISSUES CONFRONTING THE RESEARCH

Environmental contamination with emerging contaminants such as PFAS continues to be a major human and environmental health issue. Additionally, microplastics alone or as a vector for persistent contaminants have recently emerged as potential threats to human and ecological health. These chemicals are designated as emerging contaminants of environmental concern. Developing next-generation, sustainable remediation technologies for such contaminants continues to be a challenge, and requires novel approaches and considerable funding.

Progress in Program 4 was constrained in 2019/20 by the COVID-19 global pandemic, which limited researchers' access to laboratories and other resources. With most facilities now operating normally, work is back on track in 2020/21 (notwithstanding the possibility of further COVID outbreaks).

AWARDS/RECOGNITION

- Professor Ravi Naidu was ranked in the top 100 most productive authors in environmental science, published as part of the 2019 China Agricultural Science and Technology Papers and Patent Global Competitiveness Analysis report.
- Prof. Naidu was also listed in the 2019 Clarivate Web of Science Highly Cited Researchers list, in the cross-field category.
- Distinguished Professor Saravanamuthu Vigneswaran from the UTS School of Civil and Environmental Engineering presented a keynote lecture on *Dissolved organic carbon fractions and micro-organic pollutants removal from reverse osmosis concentrate using granular activated carbon and ion exchange resin* at the WEF-EESS Conference on Advancement in Water and Wastewater Treatment and Reuse, 29 July to 1 Aug 2019.
- Dr Jiawei Ren was awarded the Faculty of Engineering and IT PhD Post-Thesis Publication Award at UTS in September 2019. After completing his PhD on "Immobilisation of Nanoscale Zerovalent Iron (NZVI) onto Electrospun Nanofiber Membrane for Groundwater Remediation", Dr Ren began work as a Research Engineer at the UTS Centre for Technology in Water and Wastewater.
- Dr Gayathri Danasamy Naidu, who worked from 2015 to 2017 as a postdoctoral research fellow for a CRC CARE-funded project, won a prestigious Australian Research Council (ARC) Discovery Early Career Researcher Award (DECRA) of over $400,000 entitled "Nanoparticle with metal organic framework for lithium recovery from brine". This will support her development of new technology to sustainably extract lithium more cost-effectively from seawater brine, which significantly offsets desalination treatment costs. Dr Naidu's work on the CRC CARE project, as well as an ARC Discovery Project, enabled her to build a strong network of research and industrial collaborators on reuse applications of industrial wastewater, as well as generate numerous high-impact publications. This paved the way for a number of highly competitive fellowships and early-career seed grants, including the DECRA.

3.5. NATIONAL CONTAMINATED SITES DEMONSTRATION PROGRAM

The NCSDP demonstrates integrated multidisciplinary solutions to complex and highly challenging soil, groundwater and air contamination problems faced by a number of CRC CARE participants. Projects address issues that require extensive laboratory research. Once solutions are generated, the project is extended to the field. Such an approach provides an opportunity for engineers, scientists and consultants to test, validate and optimise operating conditions for new site assessment and remediation technologies. Along with tackling technical problems, the NCSDP develops guidance in concert with industry and regulators. Demonstration projects within the program are co-sponsored by AIP, BHP and DoD.

3.5.1. Petroleum Program

AUSTRALIAN INSTITUTE OF PETROLEUM PROGRAM

Program Coordinator:
Dr Prashant Srivastava, CRC CARE

The petroleum industry is represented by AIP, a founding Participant of CRC CARE. The AIP Demonstration Program was initiated to address policy and guidance issues related to the assessment, risk characterisation and remediation of sites contaminated with PHs and other related compounds associated with the industry. It also addresses constraints to site characterisation and remediation from policy guidance perspectives. The program seeks guidance and advice from jurisdictions (e.g. regulatory agencies) on the development of policies and guidance documents relating to petroleum hydrocarbon (PH)-contaminated sites. The Project Advisory Group established under the AIP Program – which includes industry, jurisdiction and research representatives – develops scope, invites tenders and advises on the development of guidance documents.

Petroleum Program projects include:

- Endpoints for petroleum LNAPL remediation technology performance and risk reduction (ongoing)
- Analysis of weathered hydrocarbons using a silica gel clean-up method (completed)
- Methodologies to assess LNAPL natural source zone depletion (NSZD) (completed)
- Management of sites impacted by LNAPL using NSZD approach (completed)
- Demonstration of LNAPL NSZD (completed).

In 2019/20, CRC CARE continued to work on the end points for remediation of LNAPL contamination of subsurface soils. This project will help stakeholders determine endpoints for remediating LNAPL in the subsurface and when clean-up has met its aims such that site closure can occur.

Supported by funding from National Energy Resources Australia (NERA) and the oil and resources sector, in 2019/20 CRC CARE completed the project to develop guidance documents on using an NSZD approach to manage sites impacted with LNAPLs. The research showed that the rate of hydrocarbon removal by natural degradation (i.e. NSZD) due to source zone microbial and chemical reactions will typically exceed that being achieved by active recovery within three to five years of the initial contamination event. The findings have the potential to enable earlier decommissioning of petroleum storage facilities and handover of sites – forecast to save more than $300 million over the next 10 years – as well as to avoid greenhouse gas emissions from unnecessary LNAPL recovery systems. This work complements the completed work on LNAPL NSZD measurement.

The LNAPL NSZD project involved three components:

- Development of a guidance document describing the methods for measurement of NSZD (led by Jacobs); this was published in 2018/19 as CRC CARE Technical Report 44: *Technical measurement guidance for LNAPL natural source zone depletion.*
- Collection of data to demonstrate NSZD at LNAPL-contaminated sites with varying geology (completed in 2019/20); led by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and published as CRC CARE Technical Report 47: *Australian case studies of light non-aqueous phase liquid (LNAPL) natural source zone depletion rates compared with conventional active recovery efforts.*
- Development of a guidance document on managing LNAPL NSZD (completed in 2019/20); led by GHD and published as CRC CARE Technical Report 46: *The role of natural source zone depletion in the management of light non-aqueous phase liquid (LNAPL) contaminated sites.*

BHP PROGRAM

Program Coordinator:
Dr Sreeni Chadalavada, CRC CARE

This program reflects BHP's strong support for environmental sustainability and recognition that mining activities can impact the so-called critical zone, which includes both soil and groundwater. While focussing on contaminated site assessment, risk characterisation and remediation, BHP is also prioritising artificial intelligence and machine learning with a view to improving characterisation of contaminated sites. To this end, in 2019/20 BHP funded projects that employ these exciting new approaches, as well as traditional methods, to assess sites and investigate the fate and dynamics of contaminants. The following provides a summary of BHP initiatives during the current reporting period.

Enhanced phytoremediation of hydrocarbon-contaminated soils using native Australian plant species

CRC CARE has identified plant species that are tolerant to total petroleum hydrocarbons (TPH) and is now carrying out phytoremediation trials. The grass species *Chloris truncata* was the most promising plant for 'rhizoremediation' of TPH-contaminated soil, with the river banksia *Banksia seminuda*, the shrub *Hakea prostrata* also showing good potential. Rhizoremediation is the degradation of soil contaminants in the rhizosphere, the narrow region of soil that is directly influenced by root secretions and associated soil microorganisms. In addition, soil microbial activity was enhanced in the rhizosphere compared to unplanted control. *C. truncata, B. seminuda* and *H. prostrata* increased TPH degradation rates by 30-50% relative to the unplanted control, irrespective of the TPH concentration.

Work also started on identifying cost-effective amendments to enhance phytoremediation technologies using the selected plant species, with good progress made on methodology establishment. Rather than using native plant species, we focused on maize due to its fast growth rates, drought tolerance and applicability to phytoremediation.

Natural attenuation of hydrocarbons in the vadose zone

CRC CARE established laboratory-based analytical methods for analysing volatile petroleum hydrocarbons. The research team found that both the amount and rate of vapour taken up by soil depends on the fractions of soil organic matter and secondary soil mineral (clay) fractions. For sites where the contaminant source is underneath uncontaminated soil with greater clay and/or soil organic matter contents, vapour equilibrium models tend to overestimate the human risk due to vapour intrusion.

Identify the chemistry and transport mechanisms of the ingredients of AFFF in soil and groundwater

CRC CARE completed sampling of groundwater and surface and subsurface soils from BHP sites in Newman and Port Hedland, WA. The samples were analysed to determine any correlation between soil properties and PFAS in soils, including PFAS mobility. The results suggest stronger mobility of short-chain PFAS. The leaching concentration of PFOS + PFHxS exceeded the interim landfill acceptance criteria for unlined landfill sites for one sample, and PFOA concentrations were within the interim landfill acceptance criteria.

PFAS toxicity on terrestrial organisms in an AFFF-impacted area in WA

We conducted a detailed review of PFAS toxicity on terrestrial organisms. Many studies have shown that exposure of aquatic organisms to typical PFAS (e.g. PFOS and PFOA) can adversely affect the development and reproductive and immune systems of exposed organisms. However, limited information is available on the potential impact on terrestrial organisms exposed to PFAS. Soil and water samples were analysed for concentration of PFAS including the potential impact of these contaminants on soil microorganisms. The team also completed a toxicological analysis of PFAS with various bio-indicators in soils in the Pilbara region. A guidance document is under development.

Formation of hexavalent chromium by natural process in the Pilbara

In 2019/20 we completed the biogeochemical characterisation of Pilbara soils for chromium contamination. Chromium was naturally present at elevated concentrations in the Pilbara due to the mineralogy of the region. In south-eastern Pilbara, relatively low levels of hexavalent chromium (Cr(VI)) were found in soil, despite elevated concentrations of total chromium. We also completed research that explained the mechanisms involved in the formation of Cr(VI), with manganese oxide (MnO_2) identified as the main oxidiser of chromium in the environment.

FTIR spectroscopy method for the analyses of weathered hydrocarbon mixtures in standard solutions

CRC CARE completed the development of a handheld FTIR method for the analyses of weathered petroleum hydrocarbon (PH) mixtures in standard solutions. Through this BHP-funded project, the CRC developed irCARE™, which integrates novel algorithms and methods of using FTIR, allowing rapid in-field quantification of TPH and rapid in situ classification of dominant PH fractions in soils for contaminated site risk assessment. Hydrocarbons with longer the carbon chains are considered to be heavier fractions, which have higher viscosity, density and boiling points, and longer residence times in soil, compared with lighter fractions. Knowledge of the carbon fractions in a PH-contaminated site provides valuable information for site assessment and remediation.

rankCARE II™ site ranking software

rankCARE II is a user-friendly graphical interface, designed to identify risk factors at individual contaminated sites and compare human health risk factors across multiple sites. In 2019/20, CRC CARE completed the beta version of the web-based software tool, which is currently being validated.

Electrokinetic remediation of subsurface hydrocarbon-contaminated soils

Bench-scale electrokinetic remediation of PH-contaminated soils revealed extremely positive results, with PH concentrations decreasing from more than 80 mg/L to less than 7 mg/L in 90 days. This work is ready to be scaled up to field validation of the technology.

Aging effect on natural attenuation of diesel in contaminated soil

In 2019/20 we identified chemical (decrease of different TPH fractions) and microbial (soil enzyme activity) indicators of natural attenuation of soils contaminated with diesel-related PHs. We are currently undertaking laboratory studies with the aim of developing protocols for analysing natural PH attenuation at contaminated sites.

Co-disposal of hydrocarbon-contaminated soils with mine waste

When disposing of PH-contaminated soils mixed with mine waste, bioremediation (via microbial activity) can be limited due to the waste having low levels of nutrients – particularly nitrogen (N) – for microbes. CRC CARE is developing a remediation approach that supplements mine waste with organic amendments, especially N. The amendments to be trialled include compost (1.07 % N), cow manure (1.71% N) and liquid fertiliser (3.5 % N). This work is continuing.

3.5.2. Department of Defence Program

Program Coordinator:
Dr Sreeni Chadalavada, CRC CARE

The Australian DoD sponsors a demonstration program focused on contaminants commonly found at DoD sites. This multidisciplinary program involves laboratory and field investigations of potentially contaminated sites, and the testing and validation of innovative technologies developed for site assessment and remediation. CRC CARE technologies and applications are now operational at several DoD sites. This partnership has produced a patentable new product for the international market for the detection of residual contaminants from PFASs. Highlights from 2019/20 are outlined here.

Risk-based management of petroleum-hydrocarbon-contaminated groundwater

We met significant milestones in this research into the remediation of PHs in groundwater, which built on an earlier non-targeted analysis of groundwater for the presence of PH metabolites. Groundwater samples from the source zone contained several groups of PH metabolites, including ethers, thiophenes, aldehydes, alcohols, dienes, ketones, galaxolide, and amides compared to up-gradient and down-gradient wells.

We assessed acute toxicity of PHs to the water flea *Daphnia carinata* (a small planktonic crustacean) and the freshwater microalga *Raphidocelis subcapitata*. *D. carinata* was the more sensitive of the two species to PH exposure, reinforcing its relevance for the evaluation of the toxicity of PHs and their metabolites. Many PH metabolites were found to be more toxic than the parent petroleum hydrocarbons.

Portable gas chromatography–mass spectrometry for in situ real-time monitoring of volatile organic compounds at contaminated sites

Building on our previous work, we developed a remote VOC monitoring system by rigging the handheld FTIR device to a remote-controlled driverless vehicle capable of navigating difficult outdoor terrain. The system communicates wirelessly with a remote computer, allowing safe monitoring of potentially dangerous or difficult-to-access sites.

Horizontal soil vapour bore installation and gas chromatography–mass spectrometry (GC-MS) measurement were delayed due to COVID-19 travel restrictions.

Accelerated remediation of TCE contamination in groundwater at Edinburgh, SA

During the reporting period, we undertook monthly performance assessments of pump-and-treat trichloroethylene (TCE) remediation technology at the source, serviced the pump-and-treatment plant, and repaired the peristatic pump, allowing normal operations to resume. COVID-19 social distancing and state border restrictions forced the postponement of soil subsidence rectification work, in situ chemical oxidation field injection at the source zone, and field groundwater monitoring. These activities are scheduled to resume in 2020/21.

Field-scale research for parameter optimisation of shooting range remediation technology

During the reporting period, having optimised the lead (Pb) separation process, we treated approximately 700 m^3 of Pb-contaminated soil at the Mount Stuart Training Area, Townsville. COVID-19 restrictions forced a postponement, with work resuming in 2020/21. The remediation target is the NEPM health investigation level of < 600 mg/kg for suitable onsite use without further amendment. CRC CARE prepared a site closeout plan, designed to prevent contamination of nearby sensitive areas, such as the creek lines to the north and south of the site. After completing the Mount Stuart Training Area remediation, CRC CARE will relocate the equipment to SA and optimise remediation parameters for local soils there.

Pilot-scale trials of PFAS remediation using matCARE™ technology at RAAF Richmond, NSW

CRC CARE completed laboratory studies and operation optimisation tests for matCARE™–permeable reactive barrier technology for PFAS remediation. Monitoring bores and 16 groundwater wells were installed at the RAAF Richmond investigation area. The work was postponed due to COVID-19 restrictions and will resume in 2020/21. Given the fieldwork constraints, researchers focussed on laboratory-based modifications of matCARETM, including its ability to remove PFAS from wastewater. The resulting modified product appears to be superior to original matCARE in removing all currently quantifiable PFAS active ingredients to < 20 parts per trillion.

Green remediation technology for a recalcitrant and persistent hydrocarbon (1,4-dioxane)

This project made significant progress towards achieving its milestones. Building on from our previous work on the isolation and characterisation of 1,4-dioxane degrading bacteria and ecotoxicity of dioxane, we tested the effect of additional carbon (acetate, sucrose and glucose) and nitrogen (nitrate, ammonia and yeast extract) sources on the dioxane-degrading ability of bacteria (Bacillus sp.). Among the additional carbon sources, acetate performed better than glucose and sucrose. If present in the environment, glucose and sucrose are preferentially utilised by Bacillus and thus may slow down the bacteria's dioxane-degrading ability. Among the nitrogen sources, yeast extract and nitrate enhanced the dioxane degradation by the bacteria compared with ammonia. Using a metabolomics approach, we are now seeking to better understand the bacterial dioxane degradation pathway.

3.6. CHINA PROGRAM

Program Coordinator:
Dr Luchun Duan, University of Newcastle

CRC CARE's China Program is run in partnership with HLM Asia Group Ltd, HUST, Wuhan, and Shaoguan University, Guangdong.

In 2019/20, the outbreak of the COVID-19 pandemic in Wuhan significantly curtailed progress on ongoing projects.

CRC CARE–China (HUST) Communication Program

Initiated in 2005, the CRC CARE–China 'Commun' Communication Program provides annual opportunities for CRC CARE and its collaborator universities in China to exchange ideas about environmental science, focusing on contamination monitoring, remediation and risk assessment. CRC CARE organises annual communication workshops that bring together all researchers working on research funded by CRC CARE. This includes Masters and PhD students.

The program has been postponed due to COVID-19. An online workshop may be arranged in 2020/21, if possible.

Scholarship for Masters students

CRC CARE provided a 2.5-year scholarship to a HUST Masters student working on a project on removal of phosphate from lake water. The student successfully completed study in mid-2019 and is now working in an industry role.

Research projects

CRC CARE funded four major projects, which included both laboratory-based study and field scale-up of new technologies for testing and validation:

- *Waste management via bio-conversion of wastes to energy* – completed
- *Red mud and degraded mine-site rehabilitation* – lab and glasshouse study has been completed with the project now extended to field-based phytoremediation of mine-site degraded land
- *Algae farming using piggery wastewater and conversion of algae to energy* – completed
- *Lake remediation* – lab- and bench-scale technology has been delivered with the project extended to a contaminated lake.

Two new projects were formed based on previous outcomes: 1) lake remediation using Phoslock (to lock nutrient phosphate) coupled with biofilm (for the removal of nitrate), and 2) phytoremediation of heavy metal–contaminated mine site soils. Progress in both projects has been significantly curtailed by COVID-19.

Piggery waste remediation project – pooCARE™

Piggery waste is a major source of environmental pollution in China. Developed in collaboration with HUST, CRC CARE's pooCARE is a piggery waste remediation system capable of converting pig waste into biogas and nutrient-rich fertiliser. This project also included a demonstration of an 'underground river' bioreactor. pooCARE is currently in use for piggery farm waste management in Wuhan.

Algae as renewable energy

Naturally occurring algae, especially blue–green algal blooms (which can result from excess nutrients in water), can pollute large water bodies and devastate local fish populations. It can also be toxic to humans. This project aims to harvest algae and produce clean energy from the biomass.

CRC CARE has focused on algae produced using effluent from piggery waste, and investigated conversion routes from algae to fuel. Previous research identified *Diplosphaera* sp. as a promising algal strain. Current research focuses on using the Automatic Methane Potential Test System II to estimate biomethane potential of different algal biomasses.

Rehabilitation of red mud

Red mud is a highly alkaline waste generated during alumina production. There are many old red mud storage sites around the world and it is estimated that 100 million tonnes are produced globally every year. Hybrid giant Napier grass is a fast-growing species that tolerates the alkalinity at old red mud storage sites. The grass is cultivated to cap the surface soil and prevent dust generation. Furthermore, the biomass from Napier grass can be fed back into the soil to improve soil health, or collected to produce biochar for carbon sequestration and soil improvement. This approach allows red mud residue to be gradually rehabilitated. Excess biomass can also be used to generate energy and thus, potentially, income.

Field trials of phytoremediation of metal-contaminated soil began in June 2018. The project has moved to phase two, where combinations of soil amendments for plant growth and rehabilitation are being tested in the field. Ultimately, we will transfer the Napier grass system to highly contaminated soils for phytoremediation.

Along with field trials using Napier grass, alternate uses of the contaminated area were assessed by converting part of the red mud–impacted area into a solar farm to harvest solar energy (*pictured, below*), with the energy generated sold to a photovoltaic company. This was a highly successful initiative, which will be expanded to enable local farmers impacted by red mud to use their farms to supply solar energy and generate income.

Due to COVID-19, very little progress was made on the field study in 2019/2020.

Removal of phosphate from East Lake using Phoslock® coupled with biofilm

Phoslock is a commercially available product that removes phosphates from water. Sorption to Phoslock converts phosphate into a stable form (rhabophane). This project aims to combine Phoslock application with biofilm technology to manage eutrophication (excessive richness of nutrients, often because of fertiliser run-off) and algal blooms in lakes.

Preliminary laboratory studies using Phoslock showed its capacity to immobilise nearly 10,000 µg of phosphate per gram of Phoslock used. The research team also: (a) isolated some aerobic denitrifiers that were highly efficient in nitrogen removal; and (b) developed a microbial biofilm technology that can be used for *in situ* lake remediation. In 2019/20, an *in situ* remediation device was installed at a small contaminated lake. Monitoring of lake water phosphate and nitrogen has been ongoing.

COVID-19 restrictions prevented significant progress in 2019/20.

Phytoremediation of heavy metal-contaminated mine-site soils

CRC CARE conducted lab- and field-based research on phytoremediation of heavy metal-contaminated mine-site soils using Napier grass. The study included a small plot design with a control (no treatment) and plots treated with metal-locking amendments. This approach was very effective in remediating the contaminants while also establishing Napier grass as a source for biochar, paper pulp, fibre and biomass-to-energy.

As a potential alternative use for degraded land, we also established a solar power plant (photovoltaic panels) for harvesting energy for placement into the grid. This was successful, allowing a local company to generate income from solar farming.

04 COMMERCIALISATION

'Utilisation' in the CRC context means the deployment of research outputs and encourage take-up by end-users. It includes: technology transfer and take up by end-users; the manufacture, sale, hire or other exploitation of a product or process developed by the CRC; or the provision of a service, which may also incorporate IP developed by the CRC. 'Commercialisation is one aspect – typically the most demanding – of utilisation.

To enhance utilisation by end users of research outputs, more than 1,000 environmental managers attended CRC CARE workshops, seminars, webinars or conferences during the reporting period. Furthermore, 16 PhD students completed their study, enabling their entry into the workforce and thus facilitating the take-up of research outputs.

CRC CARE progressed its assessment of commercialisation/utilisation arrangements with industry. This includes engaging SMEs and other end users that are candidates to adopt several technologies. This assessment has provided a platform for development in future years.

Further information on the specific utilisation and commercialisation activities of CRC CARE can be found in relevant sections of this report. A summary of these activities includes:

- the production of technical guidance reports, publicly and freely available on the CRC CARE website
- workshops and training offered to industry professionals
- the submission and maintenance of patent applications
- activities of the NCSDP (see pages 14-17)
- support provided to PhD, Masters and Honours students, who work in conjunction with CRC CARE researchers on research activities
- the publication of journal papers and presentation of conference papers (a full list for the financial year can be found in the *Publications* section of this report).

CRC CARE'S PATENTED TECHNOLOGIES AND TRADE MARKS

The following tables summarise CRC CARE's pending patent and trade mark families. A selection of our technologies are described on the following pages. Highlights in 2019/20 included:

- PCT application filed *(A method of determining petroleum hydrocarbon fractions in a sample)*
- Patent on a method of recalibrating a device for assessing concentration of at least one analyte ion in a liquid granted in France, Germany and UK.

PATENTS AND PATENT APPLICATIONS HELD
A method and system for quantifying a concentration of anionic surfactants in a sample
Patent application filed (2017331805)
A method of determining petroleum hydrocarbon fractions in a sample
PCT application filed (PCT/AU2019/050912)
Amine-modified clay sorbents (matCARE™)
National phase applications in Australia (AU2010330678) and the USA (9,284,201)
Australia and USA – granted
Modified clay sorbents (matCARE™)
Patent granted in Australia (2009326853), Canada (2,746,067), Germany (2376221), France (2376221) and UK (2376221)
Analyte ion detection method and device (probeCARE™)
Patent granted in Australia (2011349050), Canada (2,822,876), USA (10,119,927), Germany (2656059), France (2656059) and UK (2656059)
Accepted in Canada (2,822,876),
Anionic surfactant detection (astkCARE™)
Patent granted in Australia (2008310306, 2014200985), Japan (5523324) and USA (9,103,797)
Contaminant separating method using a modified palygorskite clay sorbent
Patent granted in USA (9,199,184)
Method, composition and system for degrading a fluorinated organic compound
Patent application filed in Australia (2017320329)
A method of recalibrating a device for assessing concentration of at least one analyte ion in a liquid (probeCARE+™)
Patent accepted – USA (15/558,982) / Patent granted – France, Germany, UK (3271712)

TRADE MARKS HELD
CleanUp (logo) – image mark (Class 41)
Registered in Australia (1765036), China (1329303), India (3516206) and internationally under the Madrid Protocol, (1329303); accepted in Nigeria (F/TM/O/2016/109960)
CleanUp – word mark (Class 41)
Registered in Australia (1765037) , China (1329304), India (3518752) and internationally under the Madrid Protocol, (1329304); accepted in European Union (1329303) and Nigeria (F/TM/O/2016/109959); accepted in European Union (1329303) and Nigeria (F/TM/O/2016/109959)
CRC CARE – combined word and image mark
Registered in Australia (1150159)
globalCARE – word mark (Class 35, 40, 41, 42)
Registered in Australia (1637278), USA (5,314,281) and internationally under the Madrid Protocol (1323742)
matCARE – word mark
Australian registered trade mark no. 1352133
pooCARE – word mark (Class 11, 40)
Registered in Australia (1487165) and China (11607975, 11607976)
irCARE – word mark (Class 9)
Registered under the Madrid Protocol (1522221); accepted in Australia (2030005); pending in USA (79/281,908) and China (1522221)
probeCARE – word mark (Class 9, 42)
Registered in Australia, the European Union and internationally under the Madrid Protocol (2007409); pending in China (1503533), India (1503533) and USA (79/274,133)
svbCARE – word mark (Class 9)
Registered in Australia (2007410)

Amine-modified clay sorbents (matCARE)

CRC CARE developed matCARE, an amine-modified clay, to remove toxic contaminants such as PFAS found in some AFFFs and those on the Stockholm Convention list. matCARE has undergone field trials and has now been dispensed to or utilised by DoD at four sites, and to Airservices Australia at one site. matCARE removes PFAS from wastewater and soil.

Modified clay sorbents (matCARE)

This remediation product is being developed for removal of problematic pollutants, including some of those featured in the Stockholm Convention on Persistent Organic Pollutants. These contaminants represent serious hazards to humans and animals. This technology is cheap, effective and easy to use; uses recoverable materials; requires the use of standard industrial plant, low-skill operators and low-cost equipment; and is applicable to major remediation problems and contaminated brownfield sites.

Analyte ion detection method and device (probeCARE)

probeCARE offers a novel technique for the real-time measurement of metal ions in solution. It allows common ions such as sodium, potassium and calcium to be measured in complex solute matrices, even in coloured solutions. This is of value to agricultural irrigators and for monitoring water quality in lakes and streams. Existing techniques utilise laboratory equipment that is too large and heavy for in-field measurements, leading to time and cost constraints. probeCARE supports cost-effective, in-situ, real-time monitoring, together with improved management strategies for cropping, improved fertigation (applying fertilisers or other amendments through an irrigation system), effective use of recycled water, and monitoring for possible pollutants to ensure regulatory standards are met. Internet connectivity will support remote sensing and continuous monitoring of resources.

probeCARE+ determines analyte concentrations in unknown samples. It is particularly practical for end users because it can be recalibrated with a small number of standard solutions.

Anionic surfactant detection (astkCARE)

The anionic surfactant test kit provides a safe, sensitive and reliable method for detecting and measuring the concentration of highly toxic surfactants in the environment. These surfactants can come from a range of sources including industrial cleaning solutions and effluent, AFFFs, and personal hygiene products (e.g. soaps, shower gels and domestic cleaning solutions). astkCARE is simple to use, does not require highly skilled operators and can be used in the field. It achieves rapid results, is cheaper and safer than established techniques that rely on hazardous solvents, and has high specificity and reliability. CRC CARE is developing colour-response strips and electronic sensing. The technology is at an early stage of commercialisation.

Contaminant separating method using a modified palygorskite clay sorbent

CRC CARE developed a modified palygorskite clay sorbent, which can be used for separating different contaminants in a mixture through sorption of chemical compounds. The sorbent has particular application for the sorption of anionic and/or hydrophobic compounds. The modified palygorskites possess several properties that make them desirable as sorbents, including nanoscale fibrous or acicular (needle-shaped) particle morphology and high initial surface area. These properties are particularly advantageous for sorption of organic contaminants where fast kinetic rates are required for successful application.

A method of determining petroleum hydrocarbon fractions in a sample (irCARE)

Coupled with a handheld FTIR spectrometer, irCARE allows rapid in-field quantification of TPH and rapid in situ classification of dominant PH fractions in soils for contaminated site assessment. Conventional ex situ methods for PH fraction analysis are highly labour-intensive and time-consuming, have a high skill requirement, and provide only a snapshot in time. Accordingly, these methods require frequent sampling intervals to provide representative temporal variations in PH levels. irCARE provides rapid predictions that support fast-reacting, risk-based contaminated site assessment. The method is non-destructive, does not require sample preparation or solvent extraction, and is easy to use with minimal training.

05 EDUCATION AND TRAINING

Through its Education Program, CRC CARE provides scholarship stipends and operational funding for high-calibre PhD and Honours students. The program also provides additional training to help students develop skills desired by prospective employers. One of the Education Program's main aims is to ensure that the CRC's graduates are industry-ready. In some cases, this is achieved by having students co-supervised by end users.

The CRC's Industry Training Program is designed to ensure that research outcomes and technical knowledge are disseminated to all stakeholders, from industry professionals to government regulators. The CRC uses a number of approaches to share this knowledge, including seminars, webinars, workshops and conferences.

5.1. EDUCATION PROGRAM

In 2019/20, one PhD student completed and nine PhD students were continuing their study as of 30 June 2020. It is extremely pleasing to note that, with four years of Commonwealth funding remaining, the CRC has already met its target PhD numbers in the Commonwealth Agreement.

It has been pleasing to see the level of student participation in the CRC's industry training program, which supports the CRC's objective of developing the students' transferable and functional skills expected by future employers.

CRC CARE STUDENTS IN 2019/20

Programs

1. Best Practice Policy
2. Better Measurement
3. Minimising Uncertainty in Risk Assessment
4. Cleaning Up

PhD GRADUATES

Student name	Program	University	Thesis title
Ren Jiawei	4	UTS	Development of immobilization of nanoscale zerovalent iron (NZVI) onto electrospun nanofiber membrane for groundwater remediation.

CONTINUING PhD STUDENTS

Student name	Program	University	Thesis title	Expected completion
Kerry Scott	1	UON	Classification and ranking of incentives for remediation and reduction of title blight	20/21
William McCance	2	RMIT	Novel Tracers for groundwater management	20/21
Shruti Sharma	3	UON	Indigenous communities' dietary intake and associated health implications	20/21
Rangana Kulathunga	3	UON	Identification of factors affecting chronic kidney disease of unknown aetiology prevailing in North Central Province of Sri Lanka	20/21
Justin Morrissey	4	RMIT	Bioremediation for nitrogen management in groundwater	20/21
Exhaussée Boukaka	4	SCU	Nutrient recapture from solid waste	20/21
Simranjit Kaur	4	WSU	Plant-Microbiome interactions and communication	20/21
Ramesh Jayaramaiah	4	WSU	Metagenomics approaches to predict efficiency of bioremediation	20/21
Scott Warner	4	UON	Impact of climate change on groundwater systems.	20/21

RMIT = RMIT University; SCU = Southern Cross University; UON = University of Newcastle; UTS = University of Technology Sydney; WSU = Western Sydney University

5.2. END-USER TRAINING

CRC CARE's Industry Training Program is
CRC CARE's Industry Training Program is
aimed at building capacity for the Australian contamination industry. The program provides opportunities for hundreds of contamination experts every year, and builds and disseminates professional skills in this field across Australia.

In 2019/20, the Program was heavily disrupted by COVID-19 disruptions. Although this meant that we did not deliver as many training opportunities as usual, more than 1,500 participants attended our events over the reporting period. The pandemic also forced us to rapidly increase our capability for online delivery, which has opened up opportunities such as self-paced courses that participants can start and complete at the time and speed of their choosing.

8TH INTERNATIONAL CONTAMINATED SITE REMEDIATION CONFERENCE (CLEANUP 2019) INCORPORATING THE 2ND INTERNATIONAL PFAS CONFERENCE

CRC CARE, GCER and globalCARE jointly organised the CleanUp 2019, incorporating the 2nd International PFAS Conference, held in Adelaide on 8-12 September 2019. This internationally acclaimed event provides a global forum for all aspects of contaminated site assessment, management and remediation. The 2019 conference was the most successful CleanUp event so far, with around 700 delegates from more than 35 countries, representing industry, research and government. The program included a wide range of professional development workshops, more than 260 oral presentations and 50 posters, and 23 exhibitors.

CLEANUP KOREA

CleanUp Korea 2019 took place in Seoul, South Korea, on 5-6 December 2019. CRC CARE hosted the event with co-organisers the Korean Ministry of Environment, the Korean Environmental and Industry Technology Institute, the Korean Society of Soil and Groundwater Environment, Korea University, Seoul National University and Jeonbuk National University. The program managed by Prof. Yong Sik Ok (Korea University) and Prof. Kitae Baek (Jeonbuk National University). The conference was attended by approximately 150 delegates, representing academia, industry, government, from Korea and around 10 other countries.

FROM RISK TO REMEDIATION 2020: CRC CARE SUMMER SCHOOL ON CONTAMINATED SITE ASSESSMENT, MANAGEMENT AND COMMUNICATION

Given the overwhelmingly positive feedback of From Risk to Remediation 2019, CRC CARE had planned to run this week-long, face-to-face course again in March 2020. Given COVID-19 restrictions, however, the CRC postponed the event to June. When it became clear that a face-to-face event would not be possible, we converted the course to a fully online event (From Risk to Remediation 2020: CRC CARE Online Masterclass on Contaminated Site Assessment, Management and Communication) second Summer School to CRC CARE Online Masterclass 2020 on contaminated Site Assessment, Management and communication. The event was re-organised as an eight-week, four-module, self-paced course developed for early- to mid-career professionals who manage, regulate, investigate, remediate, or are affected by contaminated sites. A series of live webinar Q&A sessions punctuated each module. The course was scheduled to take place from 20 July 2020. CRC CARE received a high level of interest, with around 100 registrations.

LAUNCH OF THE NATIONAL REMEDIATION FRAMEWORK

CRC CARE formally launched the NRF – including a dedicated website, www.remediationframework.com.au – via a 3 June 2020 webinar, which was attended by more than 300 environmental professionals (including consultants, EPA staff, members of the petroleum, mining, water and transport sectors, and researchers) from all Australian states and territories, as well as New Zealand, Hong Kong and the USA. The event was emceed by CRC CARE Chair Dr Paul Vogel AM, with presentations from Dr Bruce Kennedy, (former Best Practice Policy Program Leader, CRC CARE), Ross McFarland (AECOM and the NRF Steering Group), Dr Mark Bowman (Department of Defence) and Gavin Price (BHP), with then EPA Victoria Chair Cheryl Batagol presenting the official launch. All 25 NRF guidance documents are free to download via the website.

TRAINING COURSES, WORKSHOPS, SEMINARS AND WEBINARS

CRC CARE's usual schedule of workshops, seminars and other training events was disrupted heavily by COVID-19 restrictions. Apart from the events described above, the CRC ran two webinars:

- Impact of COVID-19 on the contaminated land sector
- Petroleum hydrocarbon risk assessment in the 2020s.

The COVID-10 webinar demonstrated the Industry Training Program's agility in offering training on in-demand, current topics.

Mrs Zuraida Kamaruddin MP, Malaysian Minister of Housing and Local Government, presents the Brian Robinson memorial lecture at CleanUp 2019.

06 INTELLECTUAL PROPERTY MANAGEMENT

During the 2019/20 reporting period, CRC CARE had the following patent families and applications:

- Six patent families registered:
  - Amine modified clay sorbents (Australia, USA)
  - Analyte ion detection method and device (Australia, Canada, France, Germany, UK, USA)
  - Anionic surfactant detection (Australia, Japan, USA)
  - Contaminant separating method using a modified palygorskite clay sorbent (USA)
  - Modified clay sorbents (Australia, Canada, France, Germany, UK)
  - A method of recalibrating a device for assessing concentration of at least one analyte ion in a liquid (France, Germany, UK).
- One patent family accepted and awaiting the grant:
  - A method of recalibrating a device for assessing concentration of at least one analyte ion in a liquid (USA).
- Two patent families at the PCT application stage:
  - A method and system for quantifying a concentration of anionic surfactants in a sample (Australia)
  - A method of determining petroleum hydrocarbon fractions in a sample (Australia)
- One patent family under examination:
  - Method, composition and system for degrading a fluorinated organic compound (Australia).

The CRC has seven trade marks registered in Australia (pooCARE, matCARE, globalCARE, probeCARE, svbCARE, CleanUp – word and image, and CRC CARE – word and image), and one (irCARE) accepted in Australia. Two marks (CleanUp and pooCARE) have been registered in China. globalCARE is also registered as a trade mark in USA, Australia and under the Madrid protocol. CleanUp (word) and CleanUp (logo) have been registered as trade marks in Australia, China, Europe, India and USA, and accepted in Nigeria.

Existing trade marks:

- matCARE (Australia)
- CleanUp (Australia, China, India, Europe, Madrid Protocol)
- CleanUp (Logo) (Australia, China, India, Europe, Madrid Protocol)
- globalCARE (Australia, USA, Madrid Protocol)
- irCARE (Madrid Protocol)
- pooCARE (Australia, China)
- probeCARE (Australia, European Union, Madrid Protocol)
- svbCARE (Australia).

Pending trademarks:

- CleanUp (Nigeria)
- CleanUp (Logo) (Nigeria)
- irCARE (Australia, China, USA)
- probeCARE (China, India, USA)

All of CRC CARE's new technologies have potential for commercial application. The focus to date has been on securing appropriate agreements with end users – such as site operators, remediation contractors, manufacturers and suppliers of equipment – for evaluation. Continuing protection of IP is important until the commercial potential has been fully assessed.

Details of CRC CARE patents are available on the IP Australia website (https://ra.sourceip.ipaustralia.gov.au).

CRC CARE has the essential mechanisms in place to ensure adherence to the National Principles of IP Management. Provisions within the Commonwealth and Participants' Agreements provide the key elements for IP management. In addition to the Agreements, CRC CARE has implemented appropriate policies and procedures, including those for:

- identification and disclosure of IP
- assessment of existing IP
- protection of IP
- record keeping via an IP register
- business case development and approval
- benefit sharing.

Although no registered IP was sold, transferred or licensed for commercialisation during the reporting period, two of the CRC's products (matCARE and probeCARE) are being considered for possible commercialisation by local SMEs.

07 COLLABORATION

In addition to SME engagement, CRC CARE has built strong collaborations in all aspects of its research program, including proposal development, advisory panels, research, demonstration sites and industry training programs. CRC CARE's research and demonstration nodes are distributed widely across Australia, with hubs in NSW, SA, WA, Victoria and Queensland. For international collaboration, see the list below.

Significant collaborations are undertaken through the NCSDP with CRC CARE's partners DoD, BHP and AIP (see *National Contaminated Sites Demonstration Program* on pages 14–17 for further details). Dedicated CRC CARE coordinators manage the projects associated with these organisations, drawing on universities, consultants, SMEs and end users to deliver research objectives. The unique structure of the demonstration program is mutually beneficial for researchers and industry alike – industry partners can investigate and assess potential clean-up options for their sites, while CRC CARE researchers fast-track the application of science to the field by working directly with industry in contaminated environments to test scientific ideas and new technologies.

This reporting period also saw CRC CARE collaborate with:

- NERA on LNAPL NSZD (see Australian Institute of Petroleum Program, page 15).
- The NSW Department of Planning and Environment to develop a methodology for management of health and environmental risks associated with contaminated derelict mine sites in NSW.
- The Victorian water industry (South East Water, Melbourne Water, Gippsland Water and Western Water) on two RMIT-based projects:
  - *Novel tracers for groundwater remediation*
  - *Novel bioremediation tools for nitrogen-contaminated groundwater.*
- Several non-Participant EPAs (NSW, ACT, Tasmania and Northern Territory) on guidance to inform policy, including the NRF.
- The NSW dairy industry (Richmond Dairies and Norco Cooperative Ltd with Richmond Valley Council) on optimising technologies to extract energy and nutrients from milk processing wastes, and from biosolids generated at sewage treatment plants. Three solid-waste treatment methods (anaerobic digestion, pyrolysis and hydrothermal carbonisation) are being trialled and optimised for the production of energy and soil ameliorants from solid sludge waste generated by project partners.
- The Australian Department of Agriculture, Water and the Environment to develop marine water guideline values for PFOS for inclusion in the Australian Water Quality Strategy.
- The Minerals Research Institute of WA on the project *Mine Pit lakes – their characterisation, assessment and management to inform mine site closure and for in-situ remediation opportunities.*
- Airservices Australia on remediation of PFAS-contaminated wastewater in Darwin.
- Veolia on remediation of PFAS-contaminated wastewater in Townsville.
- Spotless Australia on maintenance of a treatment plant for PFAS-contaminated water at RAAF Townsville.

INTERNATIONAL LINKS

CRC CARE researchers continue to collaborate extensively with international scientists, leading research and development on contamination assessment and remediation. Part of this involves extensive work in China via our China Program (see pages 17–18). This collaboration includes work with overseas researchers based in their home countries as well as numerous visiting scientists, who spend three to six months with CRC CARE researchers in Australia. The reporting period's record number of visiting scientists provides evidence of the global recognition that CRC CARE has established.

In addition to direct project work, CRC CARE maintains an international presence on its Research and Technology Committee, which includes internationally renowned researcher Prof. Ming H. Wong (Hong Kong Institute of Education) as a member. Other international collaborations established through the CRC, and which continued into the 2018/19 financial year, are outlined below.

Bangladesh

The CRC has linked with Dhaka Community Hospital and the Bangladesh Agricultural Research Institute to investigate arsenic contamination in drinking water and the local food supply. An estimated 35 million people are exposed to water with an arsenic concentration above 50 micrograms per litre in Bangladesh, and a further 4.2 million people are exposed in West Bengal, India. Many people in these two regions suffer from arsenic-related diseases. Journal papers based on the work continue to be published.

China

CRC CARE continues to further build and strengthen collaboration with Prof. Xiao Bo (HUST) and Prof. Lena Ma (Nanjing University). Research on bioavailability of contaminants continues. The CRC supports a number of PhD scholarships at HUST and CRC CARE staff (including the Managing Director) and board member Charles Wong visited HUST in June 2019 for the annual 'Commun' event, which helps build the capacity of students to communicate their science in English. In 2019/20 the CRC also continued collaboration with the Chinese Academy of Sciences to collaborate on bioavailability of arsenic and other metal(loid)s.

Germany

Active collaboration continues with the German research agency RUBIN and remediation experts Mull and Partners gmbh in the deployment of permeable reactive barrier technology for the treatment of groundwater contaminated with chlorinated hydrocarbons and heavy metals. Prof. Volker Birke, at Ostfalia University of Applied Sciences, has been actively involved with CRC CARE since 2008 and contributes his expertise to a number of DoD projects.

India

Established collaborations with Tamil Nadu Agricultural University (TNAU), Pandit Deendayal Petroleum University, Gujarat, and PSG Institute of Technology, Coimbatore.

Japan

Program 3 Leader Prof. Jack Ng continued his work with Prof. Tetsuya Suzuki from the Graduate School for the Creation of new Photonics Industries on utilising Euglena species as a model single-celled in vivo organism for developing a unicellular cell tool for the toxicity assessment of metals and metalloids (pure or mixtures) – the 'cell-on-a-chip' concept.

Korea

Extensive collaboration is occurring with Prof. Yong Sik Ok (Kangwon National University) and Dr Kwon Rae-Kim (Gyeongnam National University of Science and Technology) on synchrotron-based studies.

Malaysia

The Honourable Mrs Zuraida Kamaruddin MP, Malaysian Minister of Housing and Local Government, attended the CleanUp 2019 Conference to present the Brian Robinson memorial lecture. Subsequent discussions resulted in an invitation for CRC CARE to host, with the Malaysian Government's support, the 2nd Global CleanUp Congress, which will take place in November 2021 in Kuala Lumpur under the theme of "Trash to cash".

Netherlands

Collaboration on bioavailability continues with Dr Joop Harmsen from the Alterra Research Institute at Wageningen University and Research Centre. In 2014/15, this work led to a joint European COST (Cooperation in Science and Technology) Action proposal involving more than 12 scientists. The proposal was resubmitted in 2017/18, with a funding decision pending.

Nigeria

After establishing a memorandum of understanding (MoU) with Nigerian company Contec Global Agro Ltd (CGAL) in 2016/17, both parties are developing a project on bioremediation of hydrocarbon-contaminated soils. Collaboration was also established with Professor Obinna Chukwu, University of Lagos, on heavy metal contamination.

Singapore

CRC CARE researchers and the National University of Singapore continue to work together on nanomaterials, including the characterisation of clays and synthetic materials potentially used for wastewater and soil remediation.

Spain

Collaboration on bioavailability continues with Prof. José-Julio Ortega-Calvo from the Spanish National Research Council.

Sweden

Collaboration established with Prof. Ian Cousins, Stockholm University, on PFAS dynamics in the context of assessing and remediating PFAS-contaminated sites.

Taiwan

Collaboration on soil and groundwater remediation has been undertaken with Prof. Zueng-Sang Chen from National Taiwan University. Prof. Chen is also leading an Asian soil and groundwater research cluster, which involves collaboration with CRC CARE.

United Kingdom

CRC CARE continues to work with Cranfield University on risk communication activities, in particular with risk management expert Prof. Simon Pollard. Prof. Naidu continued his collaboration with Prof. Paul Nathaniel (University of Nottingham and Land Quality Management Ltd), Dr Mark Cave (British Geological Survey) and Prof. Kirk Semple (Lancaster University) on bioavailability and risk assessment.

United States of America

US company EthicalChem continues to be involved in the CRC's research into the use of chemical oxidation techniques for groundwater remediation, in conjunction with the Australian DoD. The CRC works closely on training on dense non-aqueous phase liquid (DNAPL) contamination with ITRC, a public-private coalition working to reduce barriers to the use of innovative environmental technologies that reduce compliance costs and maximise clean-up efficacy. Through ITRC's Integrated DNAPL Site Strategy Team Lead, Naji Akladiss, collaboration continued with the Maine Department of Environmental Protection, where Mr Akladiss is a NAPL site project manager. The CRC is also working with Dr Kurt Pennell from Brown University, Rhode Island, on PFAS fate and transport.

Vietnam

CRC CARE continued its collaboration with Thai Nguyen University of Agriculture and Forestry following a MoU in 2017/18 to:

- promote collaboration on a joint education program between the two universities, focusing on a Masters in Environmental Assessment and Clean-up After Mining
- with GCER, provide support to Vietnamese students including those studying the Masters program.

08 SMALL-TO-MEDIUM ENTERPRISE ENGAGEMENT

CRC CARE pays particular attention to building the mechanisms and structures to engage with not only our 28 Participants, but also the broader industry, especially Australian SMEs. SMEs are seen as risk takers and hence have a crucial role in the Australian economy as leaders in innovation. This recognises the strategic value to Australia of having an internationally competitive, innovative and highly skilled local industry to protect both human and environmental health and grow sustainable Australian businesses.

Our means of engaging with SMEs include: face-to-face meetings, technical guidance reports, industry training workshops, seminars and webinars, hosting and participating in stakeholder and policy groups, industry-focused print and online publications, national and international conferences, our website, project reports, newsletters, and other methods of direct contact including face-to-face meetings.

Since its establishment, CRC CARE has had a long-standing relationship with the Australian Contaminated Land Consultants Association (ACLCA), ALGA, and the Australasian College of Toxicology and Risk Assessment – member-based organisations that represent contaminated land consultants, risk assessors, and environmental and laboratory service providers. We work with ACLCA (a CRC Participant) and ALGA to disseminate knowledge of the CRC's strategic activities and projects to consulting and service-providing SMEs throughout the industry.

Contamination assessment and remediation is a highly contested space, with stakeholders often holding competing interests. CRC CARE provides an independent evidence base enabling these interests to come together and be mediated. In this context, stakeholder engagement in general, and SME engagement in particular, is at the core of our operations and central to our success.

One measure of CRC CARE's impact on SMEs is the role our work has had in growing the value of the remediation industry in Australia. In the late 1990s, before CRC CARE was established, the remediation industry was valued at $300 million per annum. Since that time, and in part due to the CRC's efforts to not only develop the industry but also bring it into the mainstream, this value has grown ten-fold to now be estimated at over $3 billion. This has driven an exponential increase in the number of SMEs involved with contaminated sites assessment and remediation, with a commensurate surge in SME-based employment.

Highlights of our SME engagement in 2019/20 included:

- Dr Dawit Bekele presented a module on vapour intrusion investigation at an ALGA short course on *Vapour intrusion and ground gas 101: site sampling, characterisation & risk assessment* in Sydney (5 July 2019).
- Dr Cheng Fang presented on "Microplastics: environmental impacts, sources and need for remediation?" at an Australian Sustainable Business Group seminar on *Contaminated land – current trends and updates* (1 August 2019).
- Prof. Megh Mallavarapu presented on "Bromated fire retardants, the emerging POPs and issues for contaminated land" at an Australian Sustainable Business Group seminar on *Contaminated land – new reporting, new contaminants* (12 December 2019)
- CRC CARE helped ACLCA organise a 'young professionals' session that took place at CleanUp 2019 in September.
- Discussions with James Cumming & Sons, a company that manufactures water filtration and purification materials and systems, regarding remediation research involving carbon-based products (despite initial promise, the company decided not to proceed).
- Commenced collaboration with StygoEcologia, a consultancy that provides expertise in surface and groundwater biology, on sampling of stygofauna (animals, mostly small crustaceans, that live in groundwater systems or aquifers) for environmental risk assessment and management. CRC CARE researchers received training from StygoEcologia on use of sampling equipment and methods.
- Collaboration with Hunter Water on sample analysis and water treatment research, including supply of water samples.

WORKSHOPS, CONFERENCES AND SEMINARS

CRC CARE organises workshops and webinars with and/or for SMEs, both directly and via industry groups. In 2019/20, our scheduled series of events was heavily disrupted by COVID-19 restrictions. The CRC ran two webinars (*Impact of COVID-19 on the contaminated land sector* and *Petroleum hydrocarbon risk assessment in the 2020s*) as well as the online launch of the NRF. All of these events were well attended by SME personnel, as was the CleanUp 2019 Conference.

09 COMMUNICATION

CRC CARE's communication strategy underpins the delivery and dissemination of the CRC's outputs. It also aims to increase public awareness of CRC CARE and its work both nationally and internationally, to further expand the growing recognition of the CRC as an international centre of excellence and an independent expert voice on contamination and remediation issues. As the CRC moves towards cessation of operations (now scheduled for 30 June 2021), it is increasingly seeking to commercialise its knowledge and products. As a result, communication is taking on more of a marketing focus.

INDUSTRY, RESEARCH AND GOVERNMENT STAKEHOLDERS

The CRC directs much of its communication efforts at its industry market, made up primarily of businesses and consultants dealing with contamination assessment and remediation in mining and mineral processing, fuel storage and transport, land development, manufacturing and waste. In the public sector, key players include all levels of government (local, state and federal), regulators, and managers of sites with a history of industrial or chemical use (e.g. resources companies and DoD). All these groups include CRC Participants. In addition, the Managing Director provides regular written updates to Participants and meets in person with Participant representatives throughout the year.

CRC CARE Technical Reports

Completed research is published not only in peer-reviewed journals, but also in CRC CARE's Technical Report series. This comprises a comprehensive collection of work carried out by the CRC and its partners, published to address technical and policy issues of importance to end users in industry and government. These are made freely available to users via the CRC's website and in some cases (e.g. anticipated high demand) in print form. Two new Technical Reports were published in 2019/20 (see *Publications*, page 63). The CRC also completed 15 confidential technical or guidance reports through the DoD and BHP Programs.

National Remediation Framework

Launched in June 2020, the NRF currently comprises 25 guidance documents and an Excel-based cost-benefit and sustainability analysis tool, all of which are freely available via the NRF website (www.remediationframework.com.au).

Training courses, conferences, workshops, seminars and webinars

The CRC's series of training courses, workshops, seminars and webinars are an excellent example of our commitment to disseminating knowledge to professionals working in the contaminated land industry. These events are facilitated by CRC CARE experts or renowned external national and international experts invited by the CRC. Presenters come from a wide pool that includes researchers, regulators and industry practitioners, with a view to providing knowledge that supports both researchers and SMEs.

In 2019/20, COVID-19 restrictions heavily disrupted CRC CARE's usual schedule of training events. Nevertheless, we hosted two major CleanUp conferences (the 8th International Contaminated Site Remediation Conference and the inaugural CleanUp Korea) in the second half of 2019, with three webinars (including the launch of the NRF) in 2020, reaching a total of more than 1,500 participants (see *End-user training*, page 22).

In response to the pandemic, we also enhanced our capacity and capabilities for online delivery. For example, after twice postponing "From Risk to Remediation 2020: CRC CARE Summer School on Contaminated Site Assessment, Management and Communication", we converted this to a 100% online masterclass, scheduled for early 2020/21.

CRC CARE helps promote the GCER seminar series. This forum, which can be attended in person or online, gives GCER PhD students and early-career researchers (ECRs) the chance to showcase their work in front of peers. It is also often attended by senior university staff and visiting researchers, giving ECRs invaluable exposure to scrutiny from established scientists. The series also features presentations from senior researchers from other institutions, providing CRC CARE ECRs important networking opportunities. Seminar organisers include former CRC CARE PhD students now employed as GCER Research Fellows.

Remediation Australasia

Remediation Australasia, CRC CARE's industry-targeted magazine, informs the remediation industry about new research and developments that may influence their business, and aims to help them meet the challenges of dealing with contamination. The publication has more than 2,000 subscribers (subscription is free, with all issues also publicly available at www.remediationaustralasia.com.au), which span the breadth of CRC CARE's stakeholders: industry participants, environmental consultants, regulators, government departments and agencies, universities and other research organisations. During the reporting period, COVID-19 disruptions and an increased focus on Beyond 2020 activities forced a hiatus in some activities, *Remediation Australasia*'s publication, which is set to resume in 2020/21.

Conference representation and sponsorship

As part of its effort to communicate its scientific findings, CRC CARE researchers regularly attend national and international conferences. To further enhance its visibility in the research sector, the CRC from time to time sponsors key events in its field, receiving prominent exposure via branding, acknowledgements and exhibition booths. In 2019/20 CRC CARE was an Association Sponsor at the Emerging Contaminants Summit in Westminster, Colorado, USA, 10-11 March 2020. The CRC also reserved a trade booth at the OzWater'20 conference, scheduled for 5-7 May in Adelaide, and had developed a range of marketing materials for matCARE; however, the event was cancelled due to COVID-19.

Website

The website (www.crccare.com) is an essential part of the CRC's information delivery strategy, providing among other things: information about CRC CARE and its work; various publications for downloading; event information and registration; and online subscription to the CRC's e-newsletter and *Remediation Australasia*. The website integrates social media, allows contact database management, facilitates email-marketing campaigns (e.g. electronic newsletters and event promotion), and incorporates event registration and payment systems.

The main CRC CARE website is also supported by separate websites developed for each CleanUp event, under the cleanupconference.com domain.

Web engagement in 2019/20 increased substantially compared with the previous reporting period:

METRIC	ENGAGEMENT FY 2019/20	ENGAGEMENT FY 2018/19	% CHANGE
# unique site visits (number of users)	59,160	29,825	+ 98
# unique site visits (number of sessions)	80,365	42,915	+ 87
# page views	240,171	84,393	+ 185
Average visit duration (minutes)	01:17	01:49	- 29

A major reason for this increase, apart from improved awareness of the CRC more generally, was our decision to engage a marketing agency to help promote events. This resulted in a major increase in traffic flowing to the website via social media and Google advertising. There was, however, a trade-off in visit duration, which fell.

PUBLIC AWARENESS AND MEDIA

Another area of the CRC's communication effort involves generating broader public awareness. The CRC maintains a range of non-technical material on its website, such as brochures, fact sheets, infographics and videos. CRC CARE staff and researchers also take opportunities to present at public forums.

CRC CARE issued ten media releases in 2019/20 (available at www.crccare.com/news-and-media/media-releases), including seven associated with CleanUp 2019.

Media releases (general)

- 22 August 2019 – *Australian invention provides a concrete solution to PFAS contamination* (Australian researchers have developed and patented an invention, nano-matCARE™, that prevents the spread of PFAS and other pollutants from contaminated concrete).
- 14 October 2019 – CRC CARE *delivers economic, environmental and community benefits for Australia* (CRC CARE's economic impact and return on investment, following an independent economic impact review).
- 29 April 2020 – *Call for a Global Contamination Accord* (CRC CARE Managing Director Prof. Ravi Naidu of calls for worldwide action to reduce the impact of chemical contamination).

Media releases (CleanUp 2019)

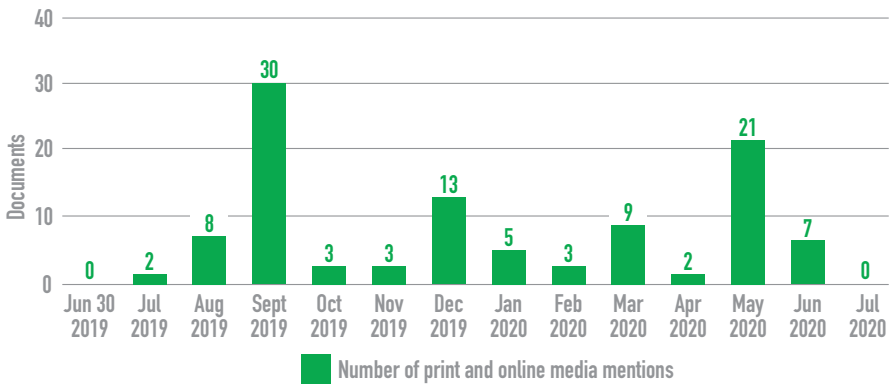
- 8 September 2019 – *Malaysian Minister to present environmental, women's rights lectures in Adelaide* (Malaysia's Minister of Housing and Local Government, The Hon Zuraida Kamaruddin MP, is in Adelaide this week to present two lectures on globally important issues).
- 9 September 2019 – *New method for detecting microplastics beneath our feet* (Researchers from CRC CARE have developed a new method to detect microplastics in the ground using infrared light and powerful visualisation software).
- 10 September 2019 – *Arsenic detected in rice around the world – including Australia* (CRC CARE researcher shows that some rice being imported into Australia contains higher than the recommended levels of arsenic, absorbed from contaminated groundwater).
- 10 September 2019 – *Modified clay locks up PFAS in soil* (CRC CARE researchers have developed a technique to lock up PFAS in contaminated soil, reducing its ability to cause environmental harm).
- 10 September 2019 – *Dusty maps, frozen photographs and crumbling tomes: developing a high-tech map of environmental contamination in Australia from historical artefacts* (The first Australia-wide historical land-use database for assessing site contamination has been developed from open-source and licensed historical artefacts). This featured work by non-CRC CARE delegates, as a means for further promoting the conference.
- 12 September 2019 – *Innovation the key to combat environmental contamination: growing concern keeping pace with multiplying solutions* (Professor Ravi Naidu, Managing Director of the CRC CARE, told the CleanUp 2019 global forum that collaboration is key to cleaning up the environment).
- 20 September 2019 – *CleanUp 2019 awards: excellence in testing, cleaning up and reflection on environmental contamination* (Impressive leaps in technology and understanding of contamination and its remediation were awarded at the CleanUp 2019 conference).

Media highlights in 2019/20

- CleanUp 2019 generated significant media coverage in more than 15 print and online news publications, including ABC Radio, *The Adelaide Advertiser* and *The Courier Mail*. On 23 September 2019, ABC Radio National's Big Ideas program broadcast a CleanUp panel discussion on "Cleaning up chemical contaminants: Trust and expert risk communication in the age of social media".
- The Managing Director interviewed about PFAS on ABC Radio Brisbane's Breakfast show on 31 October 2019.
- CRC CARE and GCER researcher Dr Cheng Fang was quoted in the 3 October 2019 *Newcastle Herald* in relation to winning an ARC Linkage grant for research on pfasCARE™ PFAS remediation technology.
- The Managing Director was quoted in relation to matCARE™ in a feature article reporting on various PFAS remediation technologies published on The Fifth Estate online news service on 7 November 2020.
- The CleanUp Korea conference (held 5-6 December in Seoul) was reported in a 4 December 2020 news.korea.com report on events related to World Soil Day (5 December).
- The August 2019 nano-matCARE press release generated media coverage in *Footprint News*, 14 regional News Ltd regional news publications (e.g. *The Sunshine Coast Daily*), *The Daily Mercury* and *The Fifth Estate*.
- A paper in *Scientific Reports* (published by *Nature*), "Microplastics generated when opening plastic packaging", generated media coverage in March 2020 on over 20 websites globally (in English and other languages), including *New Scientist*, *Cosmos* and Phys.org. CRC CARE supported the research and authors included Prof. Naidu, Cleaning Up Program Leader Prof. Megh Mallavarapu, and GCER Senior Research Fellow Dr Cheng Fang (lead author).
- In the wake of Australia's disastrous bushfire season, Prof. Naidu was quoted on bushfire-related contamination issues in *China Daily* (7 million online readers) on 22 January 2020.

CRC CARE research and/or people were featured online more than 100 times in 2019/20 (the figure above right, generated by Meltwater media monitoring, does not capture radio or print exposure that is not accompanied by an online item).

CRC CARE media coverage 2019/20



Communication support for early-career researchers

CRC CARE encourages its PhD students and ECRs to communicate their science to a wider audience beyond conferences and peer-reviewed journals. In 2019/20, CRC CARE-supported ECRs had the opportunity to receive coaching in storytelling with a view to entering the CRC Association ECR Showcase. GCER Research Fellow Dr Ayanka Wijayawardena submitted the 30-second video entry (despite an admirable effort, she was not shortlisted).

SOCIAL MEDIA

CRC CARE continued to grow its social media presence in 2019/20.

The CRC's key social media channels are as follows:

SOCIAL MEDIA	WEB ADDRESS	KEY AUDIENCE(S)	PURPOSE
Facebook	www.facebook.com/CRCCARE	ECRs (current/former PhD students/postdocs); senior researchers/industry; interested members of the public.	Updates on CRC achievements, awards, publications and events; non-CRC contamination issues and research of interest.
LinkedIn group	www.linkedin.com/groups/3971093	Industry (e.g. contaminated site practitioners); researchers.	Updates on CRC publications and events and research results; policy developments.
LinkedIn company page	www.linkedin.com/company/crc-care	Participant representatives (research/industry), CRC staff.	Updates on CRC achievements, awards, publications and events.
Twitter	www.twitter.com/crccare	Mixed: industry, government, media, students, researchers and the general public.	Updates on CRC publications, achievements and events; links to research papers and news articles of interest.

The CRC also uses a YouTube channel (www.youtube.com/crccare) to promote its research via videos. As of 30 June 2020, there were 51 videos available, with six added since the previous reporting period. In 2019/20, these videos were collectively viewed more than 16,000 times for a total of more than 302 hours (an average of just over one minute per view).

Social media followers continued to rise steadily in 2018/19.

SOCIAL MEDIA	ENGAGEMENT 30 JUNE 2019	ENGAGEMENT 30 JUNE 2020	% CHANGE
LinkedIn company page	1,602 followers	1,925 followers	+ 20
LinkedIn group	825 members	881 members	+ 7
Twitter profile	1,110 followers	1,184 followers	+ 7
Facebook page	722 followers	826 followers	+ 14

Given the platforms' monetisation strategies, it is increasingly necessary to pay for promotion and engagement (paid promotions are not offered for LinkedIn groups).

Policy communication

A third area of communication for CRC CARE involves our contribution to national policy directions set by government. It is important to make clear that the CRC does not develop policy for state or national governments, but instead provides scientific and technical support that underpins such policy development. This is achieved primarily via:

- working with environmental regulators on the CRC's many project steering groups
- publication of CRC CARE Technical Reports – particularly those that focus on technical guidance
- ongoing informal communication and engagement with regulators.

In 2019/20, the launch of the NRF – the culmination of many years of work – represented our most significant work in this area.

Internal communication and event promotion

CRC CARE places a high degree of importance on effective internal communications among its nodes across five Australian states and China. The main vehicle for communicating with these groups – as well as external audiences in the contaminated site sector – is via electronic direct mail (eDM) campaigns (including our Remediator newsletter) to around 3,000 subscribers. We use this channel to promote CRC CARE training and events as well as to provide research and personnel updates. These eDMs drive traffic to the CRC website and social media platforms, and provide analytics that can be used to improve the product. For training and events marketing, we have also engaged a marketing agency, Mihell & Lycos, who create eDMs for a wider audience, develop paid social media promotions, place Google Ads, and use AdRoll retargeting (displaying relevant online ads to people who have previously visited our website).

10 PARTICIPANTS AND THIRD PARTIES

PARTICIPANTS

In 2019/20, one Participant (CH2M Hill) exited the CRC as a result of being acquired by another company, bringing the total number of Participants to 28.

The Participant list as at 30 June 2020 is as follows:

PARTICIPANT	PARTICIPANT TYPE	AUSTRALIAN BUSINESS NUMBER (ABN)	ORGANISATION TYPE
Agilent Technologies Australia Pty Ltd	Supporting	29 088 510 605	Industry/private sector
Australian Contaminated Land Consultants Association Incorporated	Supporting	36 533 132 904	Consulting industry association
Australian Institute of Petroleum Ltd	Core	11 005 152 581	Industry/private sector
BHP Billiton Iron Ore Pty Ltd	Supporting	46 008 700 981	Industry/private sector
ChemCentre (WA)	Supporting	40 991 885 705	Industry/private sector
Chevron Australia Pty Ltd	Core	29 086 197 757	Industry/private sector
CSIRO	Supporting	41 687 119 230	Australian Government
Curtin University	Supporting	99 143 842 569	University
Department of Defence	Core	68 706 814 312	Australian Government
Department of Environment and Science (Qld)	Supporting	46 640 294 485	State government
Department of Industry, Science, Energy and Resources	Supporting	74 599 608 295	Australian Government
EPA Victoria	Supporting	85 899 617 894	State government
EthicalChem	Core	International	Industry/private sector
FibreCell Australia Pty Ltd	Supporting	60 114 025 759	Industry/private sector
GHD Pty Ltd	Core	39 008 488 373	Industry/private sector
HLM Asia Group Limited	Core	International	Industry/private sector
JBS&G Pty Ltd	Supporting	62 100 220 479	Industry/private sector
Master Builders Australia Ltd	Supporting	68 137 130 182	Industry/private sector
RMIT University	Core	49 781 030 034	University
SA EPA	Core	85 393 411 003	State government
Southern Cross University	Core	41 995 651 524	University
Technological Resources Pty Ltd (Rio Tinto)	Supporting	12 002 183 557	Industry/private sector
University of Newcastle	Core	15 736 576 735	University
University of Queensland	Core	63 942 912 684	University
University of South Australia	Core	37 191 313 308	University
University of Technology Sydney	Core	77 257 686 961	University
Western Sydney University	Core	53 014 069 881	University
WA Department of Water and Environmental Regulation	Supporting	38 052 249 024	State government

THIRD PARTIES

In 2019/20, CRC CARE worked with the following third parties, which provided resources (cash or in-kind) to support our activities:

THIRD PARTY	ABN	ORGANISATION TYPE
National Energy Resources Australia (NERA)	24 609 540 285	Australian Government
Minerals Research Institute of WA	86 779 457 072	Research organisation
NSW Department of Planning, Industry and Environment	38 755 709 681	State government
Department of Agriculture, Water and the Environment	34 190 894 983	Australian Government
Airservices Australia	59 698 720 886	Australian Government
Richmond Valley Council	54 145 907 009	Local government
Richmond Dairies	79 106 445 881	Large industry
Norco Foods (a division of Norco Co-operative Ltd)	17 009 717 417	Large industry
Spotless Australia	83 072 293 880	Large industry
Veolia	20 051 316 584	Large industry
South East Water	89 066 902 547	State government
Melbourne Water	81 945 386 953	State government
Gippsland Water	75 830 750 413	State government
Western Water	67 433 835 375	State government
NSW EPA	30 841 387 271	State government
TAS EPA	58 259 330 901	State government
ACT EPA	n/a	State government
NT EPA	n/a	State government

11 GOVERNANCE – BOARD, COMMITTEES AND KEY STAFF

11.1. COMPANY STRUCTURE

CRC CARE Pty Ltd (the Company) is an incorporated venture established on 13 September 2005 to carry out the activities of CRC CARE. The Company is a limited liability entity with 14 shareholders. Voting and dividend rights are determined by the value of contributions by shareholders ('Core' Participants) in the relevant financial year. Voting rights and the payment of returns from any commercialisation of IP for 'Supporting' (non-shareholder) Participants of CRC CARE are provided for through the ownership of shares in projects.

The Company is governed by a shareholder-elected skills-based board. The maximum number of directors is 10, with the majority of members required to be independent of the shareholders, and with a further and more specific requirement for the Chairperson to be independent of Participants (Core and Supporting) as well as the management of CRC CARE and CRC CARE Pty Ltd. In 2019/20 the CRC's Board had nine directors.

The Chairperson is elected at each annual general meeting (AGM) with the balance of Directors serving a term of two years, after which they are eligible to seek another term.

During 2019/20 the Board met five times. The AGM took place on 29 November 2019 in Newcastle.

Prof. Deborah Hodgson (University of Newcastle) resigned as a director on 22 November 2019. Prof. Janet Nelson (University of Newcastle) was elected on 13 March 2020 with Prof. Frances Kay-Lambkin (University of Newcastle) as her proxy. Prof. Nelson resigned on 4 June 2020 due to a conflict of interest. Prof. Alan Broadfoot (University of Newcastle) was appointed on 11 June 2020 with Prof. Kay-Lambkin continuing as proxy. Dr Don Sinnott stepped down on 26 June 2020.

11.2. THE CRC CARE BOARD

The following table presents details of the members of the CRC CARE Board in 2019/20:

NAME	ROLE	KEY SKILLS	INDEPENDENT/ORGANISATION
Dr Paul Vogel AM	• Independent Chair of Board • Remuneration & Succession Committee • Commercialisation Committee • Research & Technology Committee • Audit & Risk Management Committee (observer)	Regulatory	Independent
Prof. Ravi Naidu	• CEO and Managing Director • Research & Technology Committee • Remuneration & Succession Committee • Project Advisory Group • Policy Advisory Committee • Management Committee • Commercialisation Committee • Beyond 2020 Committee • Audit & Risk Management Committee (observer)	Research leadership, regulatory policy, management, commercial, policy and end-user linkages	CRC CARE
Dr Don Sinnott	• Board Director • Research & Technology Committee (Chair)	Research	Independent
Dr Rod Lukatelich	• Board Director • Research & Technology Committee • Remuneration & Succession Committee (Chair) • Policy Advisory Committee • Commercialisation Committee (Chair) • Beyond 2020 Committee	Petroleum industry, research, environmental management	Independent
Ms Anthea Tinney	• Board Director • Audit & Risk Management Committee • Remuneration & Succession Committee • Policy Advisory Committee (Chair)	Regulatory, policy and governance	Independent
Mr Charles Wong	• Board Director • Audit & Risk Management Committee • Commercialisation Committee	Venture capital/finance	HLM Asia Group Ltd
Mr Ralph Hardy	• Board Director • Audit & Risk Management Committee (Chair)	Finance	Independent
Mr Tony Circelli	• Board Director • Beyond 2020 Committee	Regulatory	Independent
Prof. Deborah Hodgson	• Board Director • Audit & Risk Management Committee • Remuneration & Succession Committee	Research, academic and management	University of Newcastle
Prof. Janet Nelson	• Board Director • Audit & Risk Management Committee	Research, academic and management	University of Newcastle
Prof. Alan Broadfoot	• Board Director • Audit & Risk Management Committee • Remuneration & Succession Committee	Research, academic and management	University of Newcastle
Company Secretary			
Ms Cathy Cooper	• Board • Audit & Risk Management Committee • Remuneration & Succession Committee	Legal	Independent

The Board's roles include:

- appointing the CEO and Managing Director
- providing strategic direction to the Company
- overseeing the financial management of the Company
- ensuring that effective governance practices are in place, including an integrated and detailed approach to risk management
- monitoring senior management performance
- developing succession plans
- ensuring that the Company adheres to a high ethical standard.

The Board provides the overall strategic direction necessary to ensure that the above roles are carried out, and exercises stewardship of the Company's resources in a manner that enables its objectives to be met.

Where particular agreements apply (e.g. the Commonwealth Agreement and the Participants' Agreement), the Board will use its best endeavours to ensure that the objectives, policies, strategies and plans applicable to the Company are met.

In 2019/20, Board meetings were held in August, October, November, March and May. Attendances were as follows:

BOARD MEMBER	NUMBER OF MEETINGS ELIGIBLE TO ATTEND	NUMBER OF MEETINGS ATTENDED
Dr Paul Vogel	5	5
Prof. Ravi Naidu	5	5
Mr Tony Circelli	5	3
Dr Rod Lukatelich	5	5
Mr Charles Wong	5	5
Ms Anthea Tinney	5	4
Dr Don Sinnott	5	4
Mr Ralph Hardy	5	5
Prof. Deborah Hodgson	2	0
Prof. Janet Nelson	1	0
Prof. Alan Broadfoot	1	1

BOARD PROFILES

DR PAUL VOGEL AM
CHAIRMAN

Paul Vogel was elected to the position of Chairman of CRC CARE at the AGM of shareholders in December 2015. He has a PhD in chemistry from the University of WA. From 2007 to 2015, Dr Vogel was Chairman of the WA EPA and prior to that he was the inaugural Chief Executive and Chairman of SA EPA.

Dr Vogel has been and continues to be a key advisor to governments on the environmental acceptability of development and on important environmental issues. He has extensive knowledge and experience of the environmental issues and regulatory regimes in WA, SA and the Northern Territory and their interaction with Commonwealth environmental legislation, and in engaging key industry, government and community stakeholders. In 2016 Dr Vogel was appointed Chairman of the Northern Territory EPA. He holds directorships of Global Aquatica (Australia) Pty Ltd and the Australian Technology Network of Universities Research Impact Advisory Board, and is a member of the Australian Institute of Company Directors. In 2019, Paul was named a Member (AM) in the General Division of the Order of Australia for "significant service to public administration through environmental leadership roles".

PROFESSOR RAVI NAIDU
MANAGING DIRECTOR AND CEO

Ravi Naidu has been a research leader in environmental contaminants, bioavailability and remediation for over 30 years. He is co-author of more than 700 technical publications and co-editor of 11 books in the field of environmental science including field remediation of contaminated sites. He was the initiator and inaugural director of the Centre for Environmental Risk Assessment and Remediation where he conceived, developed and led the successful bid for CRC CARE in 2004. He was also the initiator and founding managing director/CEO of CRC CARE, having engaged significant local and international collaboration, and led the successful bid for CRC CARE's nine-year extension in 2010. Prior to joining the University of South Australia (UniSA) in December 2002, Prof. Naidu was Chief Research Scientist and Leader of the Remediation of Contaminated Environments Program at the Commonwealth Scientific and Industrial Research Organisation (CSIRO) Land and Water Division, and Component Coordinator of CSIRO's Land and Water Sector. He is a University of Newcastle Global Innovation Chair and the initiator and inaugural director of GCER.

Prof. Naidu was awarded a Gold Medal in environmental science in 1998 by TNAU, has been awarded the status of Chartered Chemist, and is a Fellow of the Soil Science Society America (elected in 2000), the Soil Science Society of New Zealand (2004), the American Society of Agronomy (2006) and the American Association for the Advancement of Science (2012). He was elected in 2016 as a member of the European Academy of Sciences and Arts, and in 2017 as a Fellow of the Royal Australian Chemical Institute, Fellow of the Royal Society of Chemistry, and Fellow of the Australian Academy of Technological Sciences and Engineering. Ravi is Chair of the International Committee on Bioavailability and Risk Assessment and a sitting member of the EPA Victoria Contaminated Sites Auditor Panel. He has also been Chair of the Standards Australia Technical Committee on Sampling and Analyses of Contaminated Soils (1999–2000), Chair of the International Union of Soil Sciences Commission for Soil Degradation Control, Remediation and Reclamation (2002–10), and President of the International Society on Trace Element Biogeochemistry (2005–07).

PROFESSOR ALAN BROADFOOT

Professor Alan Broadfoot is the Executive Director of the Newcastle Institute for Energy and Resources (NIER) at the University of Newcastle, a position he has held since 2010. At NIER, Alan leads an ambitious agenda linking industry and academia for transformational research in energy and resources. Under Prof. Broadfoot's leadership, NIER has grown to host over 360 staff across 19 research centres. Alan holds a Doctor of Philosophy, Master of Engineering and Bachelor of Electrical Engineering (Honours) from the University of Newcastle. An Electrical Engineer in various roles from 1985, Prof. Broadfoot joined electrical design and manufacturing company Ampcontrol in 1991 and held senior management positions, including Managing Director and CEO from 2005 to 2010. He is a Fellow of the Institution of Engineers Australia and in 2006 he was awarded Engineers Australia's Professional Engineer of the Year. He was Chair of the Australian Industry Group Hunter Manufacturing Council from 2004 to 2009. Prof. Broadfoot is a Graduate of the Australian Institute of Company Directors, a Fellow of The Royal Society of NSW, and Director of the NSW Energy and Resources Knowledge Hub. He is also a Board member of TUNRA (The University of Newcastle Research Associates) and sits on a number of executive industry and research advisory committees including NTCP (India) Energy Technology Research Advisory Council.

MR TONY CIRCELLI

Tony Circelli is Chief Executive of the SA EPA. Having worked at the EPA since its establishment in 1995, he has led national and state policy and strategy development, EPA operations, and corporate governance. He has significant knowledge and experience in regulatory science and building better regulatory practice into EPA policy, operations and organisational culture. Mr Circelli has overseen reform to site contamination services in SA, including strengthened risk communication protocols and capabilities to better build trust and confidence with affected communities. Under his leadership, the EPA established Australia's first formal government-led program to manage health risks associated with orphan sites.

Mr Circelli has an honours degree in Mechanical Engineering from the University of Adelaide and a Master of Business Administration from Deakin University. He is a Director of the SA EPA Board, the national Asbestos Safety and Evaluation Council, and Presiding Member of the SA Radiation Protection Committee. He is also a member of SA's Senior Management Council and the Australian Institute of Company Directors, and a Fellow of SA's Governor's Leadership Foundation.

MR RALPH HARDY

Ralph Hardy is a senior manager with extensive finance, commercial, and systems experience in the manufacturing and service industries. He currently leads multinational finance teams for the Ampcontrol Group, a role which provides the strategic direction, finance policies and governance framework to all companies in the Group. He holds functional responsibility for provision of consolidated financial and management accounting support and reports, multinational shared service centres, treasury, finance funding, tax compliance, statutory compliance and mergers and acquisitions, together with financial management and advice. Mr Hardy has strong experience in ensuring statutory compliance, internal control, risk management, business planning, systems technology design, systems implementation, staff development and leadership in a number of jurisdictions including Australia, Hong Kong, UK and Singapore.

PROFESSOR DEBORAH HODGSON

Deb Hodgson is the Pro Vice-Chancellor, Research and Innovation at the University of Newcastle. As a member of the executive team, Prof. Hodgson is responsible for overseeing research and research training across the University. She provides strong leadership in driving the university's research and innovation agenda with a particular focus on engagement with industry, business and the University of Newcastle's stakeholder community. Prof. Hodgson has substantial expertise in working with all levels of government and relevant national and international agencies across the sector. She has built an excellent network of industry and academic partners, and is a highly respected senior leader across the University of Newcastle and the sector. In addition to her executive role, Prof. Hodgson is a highly respected neuroimmunologist and director of the University of Newcastle's Laboratory of Neuroimmunology.

DR ROD LUKATELICH

Rod Lukatelich's career has spanned academia, environmental consulting and industrial environmental management. As a lecturer/research officer (1982–89) at the Centre for Water Research at the University of WA his research included studies on the impacts of eutrophication on algae and seagrasses in lakes and estuaries; development of ecological models; and the relationships between hydrodynamics and water quality in reservoirs, rivers and estuaries. In 1989 Dr Lukatelich joined Kinhill Engineers as Senior Aquatic Ecologist and in 1990 joined BP Refinery Kwinana as Environmental Manager. In various roles at BP he led a team of environmental engineers and was responsible for environmental management systems, monitoring and reporting emissions, wastewater treatment, environmental impact assessment for major projects, solid waste management, groundwater production, soil and groundwater remediation, dangerous goods management, and Major Hazardous Facility Safety Reports. He has also supported BP's global refining businesses as a Senior Environmental Technologist (1995–97) and as Water Technology Advisor (2004–06) in the areas of contaminated site assessment and remediation, and wastewater treatment, respectively.

Dr Lukatelich has broad experience in regulatory systems, having completed major contaminated site remediation projects in Asia, Europe, the Americas and the Middle East. He retired from BP in 2014 and now works part time as an environmental consultant. He has published more than 50 refereed papers and book chapters in environmental science. He has been a director of CRC CARE since its inception and director of Perth Racing since 2017. He is a member of CSIRO's Oceans and Atmosphere Strategic Advisory Committee. He chaired the Great Australian Bight Research Program Management Committee and was a member of the Environmental Protection Authority of WA (2009–14). Dr Lukatelich was appointed to the Northern Territory Environmental Protection Authority in January 2019.

DR DON SINNOTT

Don Sinnott is an independent electronic systems consultant and author. Since 2003 he has been an Adjunct Professor with the University of Adelaide and, earlier, as Professor of Sensor Systems at UniSA, was CEO of the CRC for Sensor Signal and Information Processing and Company Board Chairman of that CRC's spin-off companies (2000–03). Prior to that he was chief of a number of research divisions in sensing and information technology disciplines within Australia's Defence Science and Technology Organisation (now Defence Science and Technology Group) from 1987 to 2000, and the DoD's Canberra-based First Assistant Secretary Science Policy from 1995 to 1997. He played a major role in development of Australia's Jindalee over-the-horizon radar system and has chaired a number of academic and government technology policy committees and boards. Dr Sinnott has extensive professional research and development experience in applied electromagnetics, including radio and radar systems, antennas and radio propagation, signal processing, and global navigation satellite systems (global positioning systems and related systems). He joined the Board in March 2013.

MS ANTHEA TINNEY

Anthea Tinney has wide board experience including as Chair of the Marine Estate Expert Knowledge Panel (NSW), a director on the NOPSEMA Advisory Board and Chair and/or independent member of public sector audit committees. She was previously Chair of the Sydney Harbour Federation Trust, the Australian National Commission for the United Nations Educational, Scientific and Cultural Organization (UNESCO), Chair of Land and Water Australia and a member of the Australian Government's Independent Communications Committee.

Ms Tinney was a deputy secretary in the federal environment portfolio and, prior to leaving the Australian Public Service, was appointed as the Interim CEO of the National Film and Sound Archive. Her public service career also included a period as the head of the Cabinet Office in the Department of Prime Minister and Cabinet and some years in the Treasury. Ms Tinney has served on several boards and has wide experience in government administration and advising on public policy. She has a Bachelor of Economics degree and was awarded a Public Service Medal in 1995 for services to the Australian Cabinet system.

MR CHARLES WONG

Charles Wong is a professional engineer who worked in the telecommunications industry in Canada for over 25 years until his move in late 2005 to work as a project manager at HLM Asia Group Ltd Hong Kong, a financial consulting and investment firm with offices in Hong Kong and Beijing. His responsibilities in the telecommunications industry included research and development, manufacturing, marketing and product management for a multinational telecommunication company. He has a BASc from the University of Toronto. Mr Wong's main focus with HLM Asia Group includes corporate financing, mergers and acquisitions, investment fundraising, and initial public offerings. HLM has significant involvement in traditional and renewable energy businesses in the People's Republic of China. Mr Wong is currently overseeing CRC CARE's research activities in China.

11.3. BOARD COMMITTEES

The CRC CARE Board has several subcommittees to oversee aspects of the Company's strategic planning and decision making. Chaired by directors from the Board, the following committees have been delegated powers as detailed below:

- Audit and Risk Management Committee
- Remuneration and Succession Committee
- Research and Technology Committee.

AUDIT AND RISK MANAGEMENT COMMITTEE

The primary purpose of the Committee is to assist the Board in fulfilling its responsibilities relating to the financial reporting and risk management practices of the Company.

In particular, the Committee:

- oversees, coordinate and appraise the quality of the external audit, and recommend appointment, and the terms of such appointment, of the external auditor to the Company
- maintains, through regular meetings, open lines of communication between the Board and the external auditors to exchange views and information as well as to confirm their respective authority and responsibilities
- serves as an independent and objective party to review the financial information submitted by management to the Board for issue to members and regulatory authorities
- oversees compliance with the Commonwealth and Participant Agreements and the requirements of the Corporations Act as they apply to the operations of the Company
- reviews the adequacy of the reporting and accounting controls
- reviews the Company's overall risk profile to ensure that material risks are dealt with appropriately, including in conjunction with other Board committees where required
- oversees the development and maintenance of policies and practices to identify, assess, monitor and report risk.

The Audit and Risk Management Committee meets five times a year.

AUDIT AND RISK MANAGEMENT COMMITTEE MEMBERSHIP:		
Name	Role	Independent/organisation
Mr Ralph Hardy	Chair	Independent
Prof. Deborah Hodgson^	Member	University of Newcastle
Prof. Alan Broadfoot^^	Member	University of Newcastle
Ms Anthea Tinney	Member	Independent
Mr Charles Wong	Member	HLM Asia Group Ltd
Ms Cathy Cooper	Company Secretary	

^ Until 22 November 2019

^^ From 11 June 2020

REMUNERATION AND SUCCESSION COMMITTEE

The Committee:

- ensures that levels of remuneration are sufficient to attract and retain executives of the quality required to successfully manage the Company
- ensures that a succession plan is in place for the Company, noting that some of the key individuals may not be in the direct employ of the Company
- reviews and recommends to the Board remuneration policies and packages for the Managing Director and senior executives directly reporting to the Managing Director so as to link remuneration to corporate and individual performance
- recommends to the Board any changes in remuneration policy including superannuation, and remuneration structure for executives identified above
- ensures there is a proper performance-management process in place throughout the organisation and that it is operating effectively
- reviews and recommends to the Board any changes to non-executive directors' fees.

The Remuneration and Succession Committee comprises four Company directors (including the Chair) and during 2019/20 was chaired by Dr Rod Lukatelich. The Committee meets as often as is required by the Board or as the Committee may determine, but generally not less than once a year.

REMUNERATION AND SUCCESSION COMMITTEE MEMBERSHIP:		
Name	Role	Independent/organisation
Dr Rod Lukatelich	Chair	Independent
Ms Anthea Tinney	Member	Independent
Prof. Deborah Hodgson^	Member	University of Newcastle
Prof. Alan Broadfoot^^	Member	University of Newcastle
Dr Paul Vogel	Member	Independent
Ms Cathy Cooper	Company Secretary	

^ Until 22 November 2019

^^ From 11 June 2020

RESEARCH AND TECHNOLOGY COMMITTEE

The purpose of the Committee is to provide:

- oversight of the research activities of the Company
- advice to the Board and Managing Director on strategic issues and individual projects
- advice on any other matters referred to the Committee by the Board.

The Research and Technology Committee meets at least twice a year.

RESEARCH AND TECHNOLOGY COMMITTEE MEMBERSHIP:		
Name	Role	Independent/organisation
Dr Don Sinnott	Chair	Independent
Dr Rod Lukatelich	Member	Independent
Prof. Ravi Naidu	Member	CRC CARE
Dr Brent Clothier	Member	Plant & Food Research Ltd, NZ
Mr Andrew Pruszinski (policy)	Member	SA EPA
Mr Timothy Carr (minerals industry)	Member	Rio Tinto
Mr Andrew Kohlrusch (consultancy/ environmental practitioner)	Member	ACLCA
Dr Paul Vogel	Member	Independent
Prof. Ming Wong (research)	Member	Hong Kong Institute of Education
Mr Barry Warwick	Member	EPA Victoria

11.4. NON-BOARD COMMITTEES

POLICY ADVISORY COMMITTEE

The purpose of the Committee is to advise the Managing Director on:

- environmental policy matters, including those matters referred to it by the Managing Director or the Board
- policy projects and/or the policy implications of projects undertaken by CRC CARE
- the path to adoption for policy projects and policy acceptance for the outcome of other projects
- new directions for research as well as on technical matters and technologies, from a public policy perspective, as they relate to CRC CARE's research directions
- any other matters referred to the Committee by the Managing Director or the Board.

The Committee provides its advice on a 'best endeavours' basis taking into account the resources available to the Committee (noting that such advice cannot be binding on any Commonwealth, State or Territory regulatory agency or local government authority concerned with land management and/or site assessment and remediation).

The Committee is a resource for sharing policy experience on site contamination assessment, remediation and management issues among its members and other stakeholders.

The Policy Advisory Committee meets not less than twice per year.

POLICY ADVISORY COMMITTEE MEMBERSHIP:		
Name	Role	Independent/organisation
Ms Anthea Tinney	Chair	Independent
Dr Joytishna Jit	Responsible	CRC CARE
Dr Rod Lukatelich	Member	Independent
Prof. Ravi Naidu	Member	CRC CARE
Dr Janet Macmillan (regulatory agency)	Member	Regulatory (WA Department of Water and Environment Regulation)
Mr Timothy Carr (mining industry experience)	Member	Rio Tinto
Mr Ross McFarland (site auditing experience)	Member	AECOM
Mr Andrew Pruszinski (policy)	Member	Regulatory (SA EPA)
Ms Mirella Goetzmann	Member	Dept. of Health, WA
Ms Anne Northway	Member	EPA Victoria
Mr Barry Warwick	Member	EPA Victoria

MANAGEMENT COMMITTEE

The Management Committee assists the Managing Director in managing the CRC and is responsible for day-to-day operations. This committee, which meets at least four times per year comprises the Managing Director (Chair), senior managers of CRC CARE, and the CRC's Program Leaders.

COMMERCIALISATION COMMITTEE

The Commercialisation Committee advises on opportunities and sets strategies for commercialising CRC CARE–developed technologies. It comprises Rod Lukatelich (Chair), Ravi Naidu, Paul Vogel, Charles Wong and Alan Broadfoot.

BEYOND 2020 IMPLEMENTATION COMMITTEE

The Beyond 2020 Implementation Committee advises develops CRC CARE's strategy and transition arrangements for post-CRC Programme activity. See *Future plans and transition arrangements* (page 41) for the list of committee members.

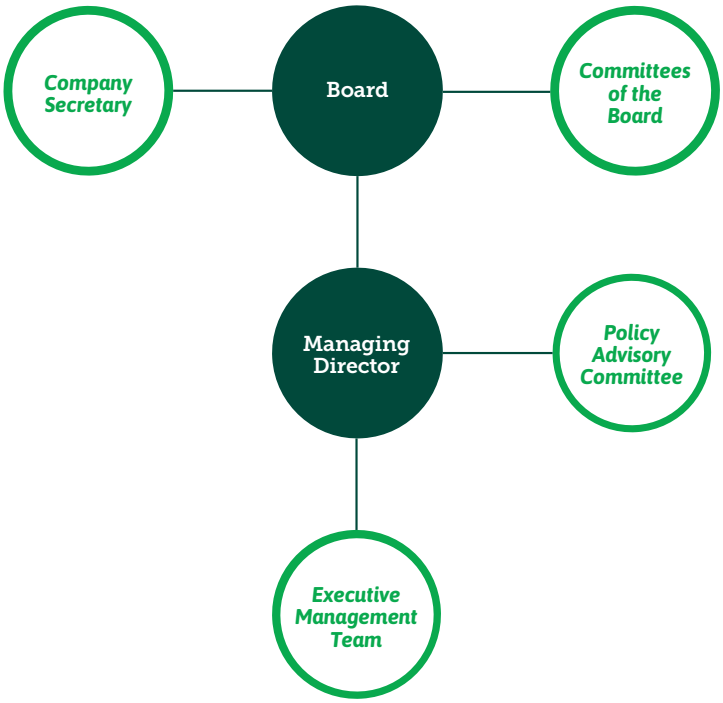
11.5. CRC CARE STAFF AND PROGRAM LEADERS

Key CRC CARE staff and Program Leaders during 2019/20 were:

KEY STAFF		
Name	Organisation	CRC CARE position/role
Prof. Ravi Naidu^	CRC CARE	CEO, Managing Director and Chief Scientist
Dr Bruce Kennedy	CRC CARE	Program 1 Leader
Dr Cheryl Lim	NMI	Program 2 Leader
Dr Yanju Liu	University of Newcastle	Program 3 Leader
Prof. Megharaj Mallavarapu	University of Newcastle	Program 4 Leader
Dr Prashant Srivastava	CRC CARE	Business Manager
Mr Mark Flick	CRC CARE	Finance Manager
Dr Sreenivasulu Chadalavada	CRC CARE	Research Manager and Principal Hydrogeologist
Mr Adam Barclay	CRC CARE	Communication Director
Ms Caryn McArthur	CRC CARE	Executive Personal Assistant to the CEO

^ 0.2 EFT Director of GCER (University of Newcastle).

11.6. ORGANISATIONAL STRUCTURE



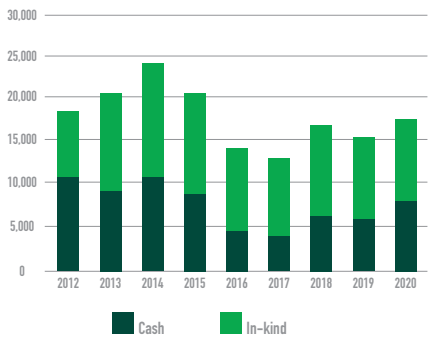
12 FINANCIAL MANAGEMENT

CRC CARE has depended on the continued support from its Participants and the Commonwealth Government for its ongoing operations during the term of the Funding Agreement, which completed its term on 30 June 2020. Prior to 30 June, the Commonwealth granted the CRC permission to complete a protracted exit, terminating on 30 June 2021 and during which the CRC will receive Participant funding but no Commonwealth funding. During the 2019/20 financial year, 91% (2018/19 82%) of CRC CARE's contributions were sourced from Participants and 9% (2018/19 18%) from the Commonwealth.

The overall financial performance of CRC CARE is on track to achieve its milestones within the committed contribution levels. Strategies during the 2019/20 financial year included maintaining tight cost control and securing additional end-user Participant project contributions. The CRC maintained strong research expenditures (cash and in-kind) of $17,632,722 in 2019/20, which represents a 14% increase over the previous year. This increase takes into account the 48% decrease in Commonwealth contributions in 2019/20 and, furthermore, occurred in the year of completing the grant term and in the midst of COVID-19 restrictions.

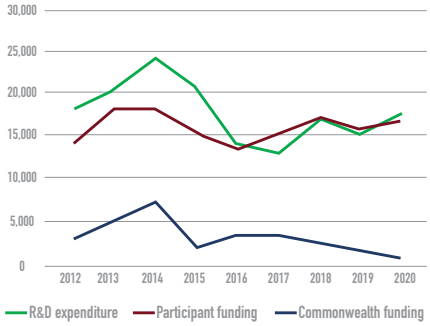
The graph below plots research expenditure over the 9 years of the CRC:

CRC CARE research expenditure A$000s



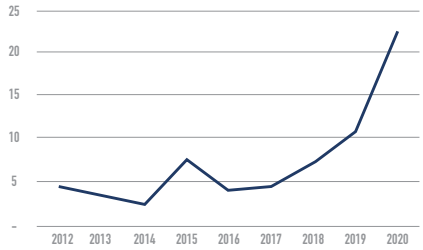
The following graph plots the research expenditure against the funding sources from the Commonwealth and the CRC's Participants:

Research and funding $000s



The final graph plots the return on Commonwealth funding, derived from the summation of Participant cash and in-kind contributions divided by Commonwealth funding.

Commonwealth return on investment



As for all CRCs, the continuing financial sustainability of CRC CARE and its ability to support existing and new projects depend on the Company:

- receiving the continuing support of its Participants
- negotiating additional funding
- achieving sufficient future cash flows to enable its obligations to be met.

The Directors believe that the Company will be successful in the above matters and, accordingly, the accounts have been prepared on a going concern basis.

The independent auditor's report to the members of CRC CARE for the financial year 2019/20 has expressed the opinion that the financial report of CRC CARE has been prepared in accordance with the Corporations Act 2001. Their opinion further states that the financial report as at 30 June 2020 gives a true and fair view of the Company's financial position as at that date and of its performance for the year ended on that date, and complies with Australian Accounting Standards.

13 FUTURE PLANS AND TRANSITION ARRANGEMENTS

CRC CARE pursues its aims through a range of focused initiatives and activities, which can be summarised as:

- industry-wide and public-good objectives
- industry partner and commercial objectives.

CRC CARE's funding under the CRC Program ceased on 30 June 2020, but we are operating until 30 June 2021 (with Participant support) following approval from the CRC Program for a protracted exit. Given Australia's ongoing need for an organisation that is able to play CRC CARE's unique role, in 2012 we established an end-user-led Beyond 2020 Implementation Committee to develop strategies for the CRC's continuation. The committee reviewed three options:

a. applying for a continuation of CRC CARE under the CRC Program (not permitted under current guidelines)

b. a model of funding that ensures continuing support from Participants

c. a commercial mode of operation.

The committee concluded that option (c) is not suitable for CRC CARE and originally favoured option (b) as the priority strategy unless option (a) became a possibility through changes to CRC Program rules. However, the impact of the COVID-19 pandemic thwarted progress on option (b), resulting in a change of strategy.

Given widespread end-user recognition that waste and emerging contaminants pose major challenges to Australia's prosperity and health, the committee decided that he best way forward was a bid for an entirely new 'Clean Australia' CRC that aims to prevent, reduce and deal with hazardous waste and pollution. The bid was submitted in application round 22 in July 2020. Bids shortlisted for stage 2 are expected to be announced in November 2020.

The Clean Australia CRC, although substantially different from CRC CARE, would retain the role of a trusted entity, regarded by stakeholders as an independent, honest broker of knowledge with a whole-of-sector perspective.

The Beyond 2020 Implementation committee was formed in 2013 with Prof. Max Brennan as Chair and Paul Barrett (AIP) as Deputy Chair. With Prof. Brennan's retirement in 2017, Mr Barrett assumed the Chair role with Dr Mark Bowman (DoD) as Deputy. In March 2020, Dr Bowman assumed the Chair's role after Mr Barrett stepped down as Chair to focus on COVID-related disruption to the petroleum industry. Following the decision to develop the Clean Australia CRC bid, the committee was expanded to ensure input from a wide range of end users.

BEYOND 2020 IMPLEMENTATION COMMITTEE MEMBERS IN 2019/20:

Name	Role/representing	Organisation
Mark Bowman	Chair	Director Environmental Remediation Programs, DoD
Paul Barrett	Deputy Chair	CEO, AIP
Gavin Price	Minerals industry	BHP (Head of Environment, Minerals Australia)
Tony Circelli	Regulators	CEO, SA EPA
Anthony McGregor^	Commonwealth Government	Department of Agriculture, Water and the Environment
Tim Eaton	Regulators	EPA Executive Director Assessments, EPA Victoria
Peter Gniel	Petroleum industry	General Manager Policy, AIP
Andrew Pruszinski	Regulators	Head, Contaminated Sites, SA EPA
Ross McFarland	Environmental consultants	AECOM
Bryan Jenkins	Remediation practitioners	Environment Institute of Australia and New Zealand
Ravi Naidu	CRC CARE	CRC CARE
Stuart Rhodes	Minerals industry	Rio Tinto

^ Anthony McGregor replaced long-serving member Andrew McNee, who moved to another government role.

ADDITIONAL COMMITTEE MEMBERS INVOLVED WITH CLEAN AUSTRALIA CRC BID:

Name	Role/representing	Organisation
Parry Agius	Indigenous communities	Linking Futures
Karl Baltpurvins	Waste management industry	Cleanaway
Nick Crosbie	Water industry	Melbourne Water
Frank Henry	Local government	Brisbane City Council
Rod Lukatelich	Petroleum industry	Environmental consultant
Peter Nadebaum	Environmental consultants	ALGA/GHD
James Stening	Chemicals industry	Orica
Aravind Surapaneni	Water industry	South East Water
Stephen Wills	State government	NSW Department of Planning, Industry and Environment
Adam Barclay	CRC CARE	CRC CARE
Steven Brown	CRC bid development	Innov8ED Pty Ltd
Greg Spinks	CRC bid development	Consulting Implementation Services
Prashant Srivastava	CRC CARE	CRC CARE
Stephen White	Minerals industry	BHP

14 MONITORING AND REVIEW ACTIVITY UPDATE

Following the extension of CRC CARE into a second term of funding, it is now regarded as a round-13 CRC. CRC CARE underwent its first-year review in March 2013. All recommendations from that review have been implemented.

Overall, the CRC Committee was very pleased with the progress of CRC CARE in its second term. As a result of this, the Committee recommended that the CRC's first independent performance review should be moved to early 2015 and that the Commonwealth Agreement should be varied to accommodate this. Since the performance review took place in May 2015, all recommendations were implemented prior to the 2019/20 reporting period.

15 ACTIVITIES NOT COVERED BY THE GRANT AGREEMENT

The CRC occasionally sells publications, videos and software, though no sales were recorded in 2019/20.

MEMORANDA OF UNDERSTANDING

National Energy Resources Australia

NERA is the not-for-profit company responsible for delivering the activities of the Oil, Gas and Energy Resources Growth Centre. In 2015/16, we signed a MoU with NERA, which will see an industry contribution towards a silica gel method for quantifying weathered hydrocarbons.

CRC CARE has also worked with NERA to develop guidance documents on using an NSZD approach to manage sites impacted with LNAPLs (see *AIP Program*, page 15).

China

In 2017/18 CRC CARE signed two MoUs with Chinese organisations:

1. Jiangxi Nuclear Industry Geological Bureau for cooperation on innovative in-situ remediation technologies and capacity building.
2. In 2017/18 CRC CARE signed a MoU with the Ecology Institute of the Shandong Academy of Sciences, China, to foster the following activities:
   - research projects on soil ecological health and remediation, including agricultural and industry-impacted land and groundwater
   - team-building and talent-development activities, including hosting visitors and conducting seminars, conferences and public lectures
   - investment in purchasing and maintaining research equipment and research and office space to support the collaboration
   - joint funding applications to support talent development and for research projects that lead to soil remediation and improved soil health
   - joint publications in high-impact international journals
   - joint supervision of PhD students.

India

In 2009, CRC CARE and the Indian Institute of Technology (IITK), Kanpur, signed a MoU to collaborate on research projects and to train experts in contamination risk assessment and clean-up. One of India's premier research institutes, IITK is known worldwide for technological and engineering expertise. The agreement also offers opportunities for Australian companies specialising in clean-up technologies to take advantage of the rapid growth of the Indian market.

A second agreement is also operational with Bharatiar University, India. This targets collaboration in the development of novel nanomaterials for remediation. The agreement provides for the exchange of both staff and students. Strong links with TNAU have also enabled a continuing flow of high-quality graduates taking up PhD scholarships in Australia through CRC CARE.

Nigeria

In 2015/16, CRC CARE signed a MoU with the University of Lagos with a view to collaborating to combine the respective organisations' expertise in producing new technologies for assessment and remediation of contaminated sites, and to having students undertake exchange visits between Nigeria and Australia. The agreement is based on the common objectives of original cutting-edge research and technology development, training students to a high, industry-ready standard, and building capacity of the respective organisations.

In 2016/17 CRC CARE signed a MoU with Nigerian company CGAL focused on collaborating to:

- develop remediation technologies to manage petroleum hydrocarbon contamination
- develop strategies for agricultural industries to mitigate the impacts of climate change
- convert waste into energy
- manage contaminated sites and help CGAL develop appropriate environmental solutions
- establish a bioremediation research laboratory at CGAL facilities in Nigeria and other African countries
- build capacity through education, training, workshops and conferences.

South Korea

In February 2010, a MoU was signed between CRC CARE and HUNIC, the Hub University of Industrial Collaboration, based at the Gyeongnam National University of Science and Technology in Korea (previously Jinju National University). This collaboration, based on green technologies, has resulted in the exchange of information, staff and students during the financial year. Through the MoU, CRC CARE-supported researchers assisted on a HUNIC-funded project on biochar and metal dynamics. This collaboration has significantly advanced the training and capacity around green approaches to contaminant containment and remediation.

United States of America

In 2017/18 CRC CARE signed a MoU with US-based ITRC to:

- produce technical and regulatory documents to address global environmental issues
- provide training through webinars, conferences and short educational films
- provide expert review panels to assess and provide advice on complex contaminated sites
- advise on the best use of technologies and products
- complement and expand the work of CRC CARE's globalCARE initiative in building global capacity to prevent, manage and clean up contamination, especially in developing countries.

Vietnam

In 2017/18 CRC CARE signed a MoU with Thai Nguyen University of Agriculture and Forestry to:

- organise an international conference on pollution prevention, management and remediation, especially rehabilitation of mining sites (CleanUp Vietnam), to be held in late 2019
- promote collaboration on a joint education program between the two universities, focusing on a Masters in Environmental Assessment and Clean-up After Mining
- with GCER, provide support to Vietnamese students including those studying the Masters program.

16 HIGHLIGHTS AND ACHIEVEMENTS REPORT

16.1. ECONOMIC, ENVIRONMENTAL AND COMMUNITY BENEFITS FOR AUSTRALIA

Since its creation in 2005, the Cooperative Research Centre for Contamination Assessment and Remediation of the Environment (CRC CARE) has consistently provided a unique resource to Australia that has delivered enormous economic and environmental benefits to the nation's key growth industries, communities, governments, small-to-medium enterprises (SMEs), and regulatory agencies.

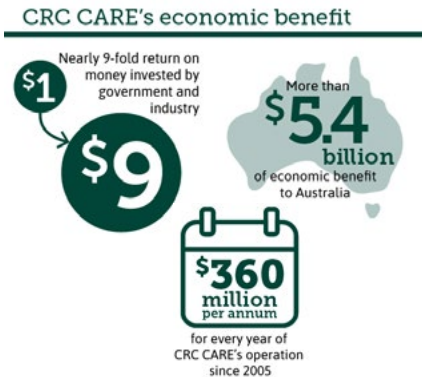
- ✓ **More than $5.4 billion of economic benefit to Australia**
- ✓ **Nearly $9 return on every dollar invested by government and industry**

In 2018/19, CRC CARE commissioned an independent economic impact review, which was conducted by Consulting & Implementing Services (CIS), Melbourne. This section of the Highlights and Achievements Report summarises the CIS review.

During the 15-year period from its initiation, the economic benefit due to practical roll-out and application of CRC CARE research now exceeds $5.4 billion. This amounts to a cost-benefit ratio of 8.6 on the total cash and in-kind investment made by the Commonwealth and CRC CARE industry and research partners.

By focusing Australia's contamination research and development capabilities, the CRC has been central to establishing Australia's enviable global reputation as a leader in research on contaminated site assessment and remediation. CRC CARE's work has boosted the sector's professionalism and fostered a more skilled and internationally well-regarded industry. The CRC's international collaboration, including a dedicated research node in China, has forged global connections and opened up potential trade opportunities for the sector.

In addition to the direct economic benefits of the CRC for its partners and target industries, there are significant and broad flow-on benefits as a result of CRC CARE's work. The application of the CRC's research nationally has unlocked the productive potential of contaminated land and provided communities with confidence that land has been restored to a state that will not threaten their health and safety.



CRC CARE HAS DRIVEN IMPROVEMENTS TO AUSTRALIAN CONTAMINATED SITE REGULATIONS

The CRC has generated extensive knowledge from 14-plus years of research to enable government, environmental regulatory agencies and businesses – large and small – to effectively manage established and emerging high priority contaminants.

- CRC CARE's best practice strategies and guidance for managing sites contaminated with per- and poly-fluoroalkyl substances (PFAS) have improved the national effort to assess and remediate these high-priority emergent contaminants. The CRC's work, which complements and informs the PFAS National Environmental Management Plan, has delivered significant direct economic benefits for industry. This includes more than $200 million through reduced need for remediation of PFAS that – based on the CRC's risk-based approach – does not pose an environmental or health threat. In addition, sectors relying upon PFAS clean-up are now able to commence or accelerate project operations on this land, reducing their costs of development and spurring new economic activity.

As a national leader in PFAS management, CRC CARE has developed:

- ✓ **technologies for analysing and cleaning up PFAS contamination**
- ✓ **best practice strategies for managing PFAS-contaminated sites.**

- CRC CARE developed health screening levels (HSLs) for petroleum hydrocarbon remediation, which provide a minimum concentration of contaminant that triggers further action (including monitoring and clean-up). The HSLs, as well as other best practice strategies for managing petroleum hydrocarbon contamination, were incorporated into national legislation known as the National Environment Protection (Assessment of Site Contamination) Measure ('the ASC NEPM'), ensuring that they were adopted by all regulators (environment protection authorities) across Australia. This work has already resulted in, and will continue to allow, substantial reductions in remediation costs for the mining, petroleum, defence and other sectors. The total benefits to industry and government so far amount to more than $1.3 billion.

CRC CARE's health screening levels for petroleum hydrocarbons have:

- ✓ **been incorporated into national regulatory frameworks**
- ✓ **been adopted by all regulators nationally**
- ✓ **provided a $1.3 billion (and growing) benefit to industry and government.**

- CRC CARE's research on heavy metalloid bioavailability (the proportion of a substance that enters the circulation when introduced into the body) has provided substantial benefits to industry and the Commonwealth. The increased understanding of bioavailability (lower bioavailability implies lower risk) has reduced the need for remediation of some contaminants and allowed limited resources to be focused on priority sites, resulting in reduced costs of $60 million.
- The CRC's National Remediation Framework (NRF), which has recently been recognised by the Heads of EPAs, ensures consistent best practice approaches to contaminated site clean-up across all Australian states and territories. The Framework will make it easier to identify the sites needing remediation, provide advice on the most effective clean-up approaches, and create certainty for companies

[1] Figures are cumulative over a 15-year period from the beginning of CRC CARE's current term of funding in 2011. Figures are risk-adjusted and provided in present value terms at a discount rate of 5%.

and regulators nationally. These benefits will drive savings across the remediation sector. The efficiencies gained are forecast to deliver a minimum 5% reduction in total costs, amounting to more than $200 million through to the end of the 15-year impact period.

INNOVATIVE ASSESSMENT, MONITORING AND REMEDIATION TECHNOLOGIES

In addition to the knowledge harnessed from significant and comprehensive research that has been translated into public policy, the CRC has delivered a range of highly innovative remediation strategies and technologies.

Innovative remediation technologies developed by CRC CARE are forecast to provide nearly $1 billion of savings for industry and government by 2026.

CRC CARE has conceived and developed a wide range of assessment, monitoring and remediation technologies. These are trademarked and/or at an industry demonstration stage, with expected widespread uptake beyond the life of the CRC. Examples include:

- matCARE™ and pfasCARE™ for PFAS remediation
- astkCARE™ for PFAS detection and analysis
- pooCARE™, developed at CRC CARE's China node, for piggery waste remediation and biofuel production
- leadCARE™ for *in situ* remediation of lead-contaminated soils at shooting ranges and munitions facilities
- Permeable reactive barriers and other technologies for groundwater contamination.

These technologies have provided substantial benefits to CRC partners and end users, with anticipated further uptake expected to generate for industry and government cumulative benefits of over $950 million through to the end of the 15-year impact period.

The CRC has continued to develop, trademark and is in the process of licensing further technologies with flow-on benefits to other industries. An example of this is probeCARE™ for real-time, *in situ* detection of metal ions in water, with applications for crop management. The forecast annual savings to greenhouse growers through more efficient fertiliser management amount to $2.5 million p.a. nationally with additional benefits in improved productivity of crops and potential savings in wastewater monitoring and management.

CRC CARE HAS CREATED A SKILLED INDUSTRY WORKFORCE

By the end of its current funding term, CRC CARE will have completed more than 150 PhDs since it was launched in 2005. This is the most of any CRC to date and greatly exceeds our own targets:

- An estimated 40% of these graduates are, or will be, employed in industry-based roles and will achieve an earnings premium of $19,000 to $26,000 higher than comparable graduates. Cumulatively, this amounts to $4.7 million in additional earning power.[2]

- CRC CARE has driven substantial improvements in the level of skilled workforce available to service Australia's remediation and contamination needs across industries of national importance, and has significantly advanced remediation research capacity in the public sector.
- Furthermore, CRC CARE developed Site Contamination Practitioners Australia, a professional certification scheme (now operated by a third-party) that has contributed to a more skilled and professional industry. This in turn has resulted in benefits to site developers through reduced assessment times and reduced need for assessment rework. This scheme has resulted in an expected benefit of $63 million through to the end of the 15-year period.[3]

STEWARDSHIP OF A RAPIDLY GROWING SECTOR, WITH MUCH MORE TO BE DONE

In the past two decades, the size of Australia's remediation industry has grown tenfold from around $300 million p.a. to more than $3 billion p.a. Based on CIS's economic impact review, it is clear that a significant portion of this growth is directly linked to CRC CARE's activities since its launch in 2005. Had the CRC not existed, not only would Australia's remediation sector be smaller, less professional and less organised, but industry and government would also have borne substantially higher costs in their efforts to deal with contamination issues – costs that would compound into the future. Furthermore, and perhaps most importantly, the Australian people and environment would be exposed to greater and more persistent contaminant threats that they are now. Despite these achievements, Australia's legacy of more than 160,000 potentially contaminated sites and the constant recognition of emerging contaminants mean that much work remains to be done.

Background and context

In 2015, Consulting & Implementation Services (CIS) conducted the four-year midterm review of CRC CARE. CIS has been engaged to conduct a final review of CRC CARE's impact. The figures provided result from revision of existing modelling and new impact assessment based on consultations with industry and research CRC CARE stakeholders across the four research programs. The revised benefits have exceeded the expected benefits during the midterm review. Consultations indicated the successful delivery of outputs having been achieved, and the provided insight on the retrospective level of adoption of these outputs into industry. Consequently, the associated probability of achieving certain outputs and their usage in revised modelling have also been adjusted to reflect this more likely realisation of research translation.

[2] In risk-adjusted net present value (NPV) terms.

Australian Institute of Petroleum (representing the petroleum and oil industries)

[3] risk-adjusted NPV

CASE STUDY OF THE SUCCESSFUL COMMERCIALISATION OF CRC CARE RESEARCH OUTPUTS

matCARE™ – cleaning up PFAS contaminants

CRC CARE has worked closely with the Australian Department of Defence (DoD) to develop matCARE – a modified natural clay that irreversibly locks up potentially toxic PFAS in wastewater, groundwater and soil that have been contaminated as a result of firefighting foam use.

PFAS are extremely stable chemical compounds. Their stability gives them very useful properties for multiple industrial uses, including in firefighting foams, nonstick cookware, food packaging, insecticides, and waterproof and fire-resistant fabric. But this same property also means that they don't break down easily and therefore accumulate in the environment. They are now so widespread that almost every person on Earth has been exposed to PFAS and has them in their blood. PFAS can enter ecosystems and move up food chains, accumulating in animal and human tissue, including the liver and blood. They have been linked to bladder and liver cancer, endocrine disruption and developmental and reproductive toxicity (including neonatal mortality).

Many PFAS contaminated sites are located at and adjacent to firefighting training areas, especially at Air Force and commercial airports, country and metropolitan fire services, and industrial sites such as mining and petroleum facilities. In some cases, the chemicals have leached into groundwater, affecting residential areas and causing considerable community concern.

Working with DoD, CRC CARE has so far remediated on-site more than 2 million litres of wastewater at three RAAF bases, reducing annual clean-up costs by 90%. As a result of this success, the CRC has initiated commercialisation efforts. Although these are still at an early stage, we have already performed commercial clean-up operations for Airservices Australia at one civilian airport. The CRC is also in discussions with a commercial resources company regarding supplying the raw matCARE clay. CRC CARE plans to expand its commercialisation and marketing activities in 2019/20, and to this end has commissioned a marketing agency to carry out a pilot campaign to test national and international markets.

In 2018/19, the CRC developed a related product, nano-matCARE™. This employs a nanoparticle slurry of the matCARE modified clay material, which can be applied to contaminated concrete (such as the slabs often found at fire training sites) to immobilise the PFAS molecules and prevent them from leaching into the surrounding soil or groundwater. The CRC is investigating the potentially significant untapped market for this application.

16.2. CRC CARE'S IMPACT ON INDUSTRY COLLABORATION

BREAKDOWN OF PARTICIPANTS AND COLLABORATIONS OVER THE LIFE OF THE CRC

As well as working closely with its 29 Participants, CRC CARE has a strong record of collaboration with research and industry partners both in Australia and internationally. The following table lists our non-Participant collaborators over the current funding period (for our current list of Participants, see page 30).

NATIONAL	
Organisation name	Organisation type
AECOM	Industry/private sector
Ramboll Australia	Industry/private sector
Spotless Australia	Industry/private sector
Richmond Dairies	Industry/private sector
Norco Foods	Industry/private sector
Thiess Services (now Ventia)	Industry/private sector
Coffey Environments	Industry/private sector
URS (since acquired by AECOM)	Industry/private sector
Veolia	Industry/private sector
Australasian Land & Groundwater Association	Industry representative body
South East Water	Water authority
Melbourne Water	Water authority
Gippsland Water	Water authority
Western Water	Water authority
SA Water	Water authority
Airservices Australia	Australian Government
WA Department of Health	State government
NSW EPA	State government
NT EPA	State government
ACT EPA	State government
TAS EPA	State government
NSW Department of Planning, Industry and Environment	State government
SA Health	State government
Minerals Research Institute of WA	State government/research
Salisbury Council, SA	Local government
Brisbane City Council, QLD	Local government
Kogarah City Council, NSW	Local government
Richmond Valley Council, NSW	Local government
James Cook University	University

INTERNATIONAL		
Organisation name	Organisation type	Country
Dhaka University	University	Bangladesh
Environment and Climate Change Canada	Government	Canada
Huazhong University of Science & Technology	University	China
Nanjing University	University	China
Shaoguan University	University	China
Chinese Academy of Sciences	Government/research	China
Ecology Institute of the Shandong Academy of Sciences	Government/research	China
Jiangxi Nuclear Industry Geological Bureau	Government/research	China
Mull and Partners gmbh	Industry/private sector	Germany
Ostfalia University of Applied Sciences	University	Germany
Wismar University	University	Germany
RUBIN (German Permeable Reactive Barrier Network)	Industry/private sector	Germany
Indian Institute of Soil Science (Indian Council of Agricultural Research)	Government/research	India
Indian Institute of Technology	University	India
Tamil Nadu Agricultural University	University	India
Pandit Deendayal Petroleum University	University	India
Bharatiar University	University	India
PSG Institute of Technology	University	India
University of Rome Tor Vergata	University	Italy
Graduate School for the Creation of new Photonics Industries	Research	Japan
Kangwon National University	University	Korea
Gyeongnam National University of Science & Technology	University	Korea
HUNIC, the Hub University of Industrial Collaboration	University	Korea
Alterra Research Institute at Wageningen University and Research Centre	Research	Netherlands
Contec Global Agro Ltd	Industry/private sector	Nigeria
University of Lagos	University	Nigeria
National University of Singapore	University	Singapore
Hub University of Industrial Collaboration	University	South Korea
Instituto de Recursos Naturales y Agrobiología de Sevilla (Spanish National Research Council)	Government/research	Spain
Stockholm University	University	Sweden
National Taiwan University	University	Taiwan
US Environmental Protection Agency, Maine	Government/regulatory	USA
Interstate Technology & Regulatory Council	Regulatory	USA
Brown University	University	USA
Lancaster University	University	UK
Cranfield University	University	UK
University of Leeds	University	UK
University of Nottingham	University	UK
British Geological Survey	Government/research	UK
Land Quality Management Ltd	Industry/private sector	UK
Thai Nguyen University of Agriculture and Forestry	University	Vietnam

NUMBER OF PUBLICATIONS PUBLISHED WITH/FOR PARTICIPANTS DURING THE AGREEMENT PERIOD			
Year	Public	Confidential^	Total
2019/20	27^^	15	42
2018/19	4	15	19
2017/18	2	11	13
2016/17	8	14	22
2015/16	4	9	13
2014/15	3	6	9
2013/14	7	11	18
2012/13	2	13	15
2011/12	7	8	15
Total	64	102	**166**

^Some reports are kept confidential at the Participants' request for commercial reasons.

^^Includes the 25 NRF guidance documents.

INDUSTRY GROWTH CENTRES WITH WHICH CRC CARE WORKED DURING THE AGREEMENT PERIOD

CRC CARE has worked with NERA (National Energy Resources Australia) on two projects:

- Weathered PHs (silica gel clean-up)
- Guidance for LNAPL natural source zone depletion.

THE VALUE THAT PARTICIPANTS PLACE ON BEING PART OF CRC CARE

CRC CARE sought statements from three key Participants:

- **GHD Pty Ltd**, one of the world's leading professional services companies operating in the global market sectors of water, energy and resources, environment, property and buildings, and transportation. GHD represents the environmental consulting industry, whose role is to manage and clean up contaminated sites.
- **South Australian Environment Protection Authority** (SA EPA), representing government environmental regulators.
- **Australian Department of Defence** (representing industry in the sense that they are owners of contaminated sites, which need to be remediated).

GHD statement

We see it to be very important to be a participant in CRC CARE, and also for CRC CARE to exist. In terms of being a participant, it gives us an opportunity to participate in leading edge research in collaboration with leading scientists and policy makers, particularly in our case in the preparation of guidance on new approaches and thinking in the industry, and for the increased capability that this provides to our company and its ability to win work and provide effective services to our clients. It also promotes our company's involvement in activities that are associated with the CRC, such as conferences, seminars and meetings, and benefiting from the learning and networking opportunities that flow from this.

All in all, we consider that our involvement in CRC is important and essential, that the investment (both in cash and in kind) that we make in this is well spent, that we have obtained significant value from being a participant and that it has significantly contributed to the success of our business in this field of endeavour. With regard to the importance to the industry more generally: we consider that CRC CARE has made a significant contribution in advancing the industry. We consider that, if CRC CARE did not exist, the field would be significantly held back, the industry would not be able to respond as effectively and efficiently to the contamination problems that it faces, and there would be a significantly greater cost to our community in dealing with contamination problems.

Dr Peter Nadebaum, *Principal and Senior Technical Director – Environment*

SA EPA statement

CRC CARE has played a crucial role in strengthening the response to contaminated environments, through supporting policy development, pursuing technology R&D, and capacity building, providing leadership both here in Australia and with international site contamination networks. CRC CARE's guidance development work is based on a collaborative approach with regulators and practitioners, with the goal of improving assessment, remediation and management of site contamination using leading edge approaches across national and international jurisdictions

Cash contributions alone from EPAs have leveraged substantial co-investment from CRC CARE to deliver national site contamination guidance and robust and innovative solutions to serious site contamination problems and issues identified by end-users. Over the past 13 years, EPAs including the WA Department of Water and Environment Regulation have contributed $2.25 million into projects worth $12.43 million. This equates to a leverage of 5.5 times the investment. There has also been significant in-kind investment from senior technical staff of EPAs from across the country.

CRC CARE has enabled the South Australian EPA to deliver work at best practice, to collaborate with international researchers and to rely on world class technical documents that have been adopted nationally. That is, the benefits of working with CRC CARE have been significant.

Andrew Pruszinski, *Manager Site Contamination*

Australian Institute of Petroleum statement

The Australian Institute of Petroleum (AIP), and its members (BP, Caltex, Mobil and Viva Energy), have benefited substantially from CRC CARE since becoming a foundation participant. The CRC's Petroleum Demonstration Program was created to address policy issues related to the assessment, risk characterisation and remediation of sites contaminated with petroleum hydrocarbons and related compounds. AIP has also benefited from other CRC CARE programs, including its world-leading research on the management and remediation of per- and poly-fluoroalkyl substances (PFAS). AIP's engagement with the CRC has been extremely valuable to the petroleum industry while also delivering excellent outcomes for other industries, government, the environment and human health.

Paul Barrett, *CEO*

Department of Defence statement

See next page.

Department of Defence statement

UNCLASSIFIED

Australian Government

Department of Defence
Estate and Infrastructure Group

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ASEE-ID/OUT/2019/BS3917868

Professor Ravi Naidu
Cooperative Research Centre
Contamination Assessment & Remediation of the Environment
University of Newcastle
Callaghan, NSW, 2308

Dear Ravi,

Statement from the Department of Defence for CRC CARE II Exit Report

The Department of Defence has been a partner with CRC CARE since the first agreement in 2003. Over that time we have had a close working relationship with Professor Ravi Naidu and his dedicated research teams achieving many positive outcomes for Defence. Through the CRC CARE research efforts, we have been able to better understand the fate and transport of contaminants in the environment and apply practical risk based solutions to many of our challenging contaminated sites across our estate.

CRC CARE has also supported us in other aspects of contaminated land management and we would particularly like to mention their education and training program. CRC CARE has trained many Defence personnel in aspects of contaminated land management thereby increasing our capacity to be an informed buyer of services from our industry partners. In a reciprocal way we have also been able to build capacity within CRC CARE by imparting knowledge of managing Defence specific contaminants and provide access to real world examples to validate research outcomes.

The value we place on our relationship with CRC CARE is evidenced by our participation in two agreements and our continuing support of the CRC model. Your efforts to bring together the diversity of participants from industry, government and academia, to create a centre of excellence, sharing knowledge for the common good, is exceptional. The Department of Defence has benefited by our relationship with CRC CARE.

Yours sincerely,

Dr Mark Bowman
Director Contamination Assessment & Remediation Management
Environment and Engineering Branch

19 August 2019

CASE STUDIES ILLUSTRATING HOW PARTICIPANTS WORKING TOGETHER LED TO AN IMPACT THAT WOULD NOT HAVE BEEN ACHIEVABLE WITHOUT THE CRC COLLABORATION

1. Risk-based remediation and bioremediation of contaminated soil for BHP in WA

To remediate hydrocarbon-contaminated soil at multiple sites in the Pilbara, WA, BHP was required to meet regulatory criteria that were practicably unachievable in the local environmental conditions. Accordingly, the size and cost of BHP's landfarms (areas of contaminated soil where contaminants undergo microbial degradation) were growing rapidly. At one site alone, the assessment and management costs were around $600,000 per year and rising. BHP commissioned CRC CARE to develop a risk management framework that ensured no increase in risk to people or the environment. This was presented to and subsequently endorsed by the WA regulator. In addition, CRC CARE and BHP trialled bioremediation through 'biopiling' – piling contaminated soil in conditions that allow microbial activity to reduce concentrations of contaminants – as a means to attain contaminant concentrations that met risk criteria. This was achieved in less than three months (half the originally predicted time). Over the life of the affected mines, port and railways, the CRC's approach has reduced treatment costs to less than 30% compared with previous methods, saving BHP millions of dollars and achieving a better result for the environment.

This outcome would have been virtually impossible if not for CRC CARE's ability to: (a) bring together stakeholders from all sectors; and (b) ensure that guidance on contaminated site assessment and remediation is underpinned by robust science, such that it is acceptable to all parties.

Key collaborating organisations:

- BHP (site owner; CRC Participant)
- WA Dept of Water & Environment Regulation (state government regulator; CRC Participant)
- UniSA (research partner; CRC Participant)
- Centrals (civil engineering – responsible for constructing the biopile)
- JBS&G (environmental consulting; CRC Participant)
- Otek (now Fyfe – environmental consulting).

2. Health screening levels for petroleum hydrocarbons

Much of CRC CARE's guidance – which is developed in collaboration with EPAs, contaminated site owners, and the environmental consulting sector – has been incorporated into national legislation. A prime example of this is the development of CRC's HSLs for total petroleum hydrocarbons (TPHs), which provide a minimum concentration of contaminant that triggers further action (including monitoring and clean-up). The TPH HSLs were included in the National Environment Protection (Assessment of Site Contamination) Measure ('the ASC NEPM'), ensuring that they were adopted by all Australian regulators. By ensuring that limited resources are committed only to contamination that represents an environmental or human health threat, this work has already resulted in, and will continue to allow, substantial reductions in remediation costs for the mining, petroleum, defence and other sectors. The CRC's recent environmental impact review estimated total benefits to Australian industry and government so far amount to $1.3 billion.

Collaboration was crucial to the success of this initiative: for HSLs to be developed and applied, comprehensive understanding and agreement was required on multiple fronts, including health impacts, regulatory implications, and analytical approaches and clean-up approaches.

Key collaborating organisations:

- GHD (environmental consulting; co-developed the HSLs)
- CSIRO research partner; CRC Participant
- All state and territory EPAs (regulators; Victoria, SA, WA, Queensland as CRC Participants)
- Federal and State health departments
- Site owners (Participants): Rio Tinto, AIP (representing BP, Caltex, Mobil and Shell), Chevron
- Research partners: Monash University, University of Technology Sydney, University of South Australia, University of Queensland (all Participants except for Monash University)
- Analytical labs: ALS, Envirolab, NMI (a CRC Participant).

16.3. IMPACT OF EDUCATION PROGRAMS ON INDUSTRY, THE SECTOR, AND SKILLS DEVELOPMENT

POSTGRADUATE INFORMATION OVER CRC CARE'S CURRENT TERM OF FUNDING

Total number of postgraduates and PhD graduates

From the start of its second term of funding in July 2011 until 30 June 2020, CRC CARE has had a total of 91 graduates, including:

- 14 Honours
- 6 Masters
- 72 PhDs

A remaining 9 PhD students are due to complete their studies by 30 June 2021. When the CRC's first term of funding is included, the total number of PhD students exceeds 150.

Total number of postgraduates taking up employment in the industry

The CRC's recent economic impact review, conducted by CIS, estimated that 40% of our graduates are, or will be, employed in industry-based roles and will achieve an earnings premium of $19,000 to $26,000 higher than comparable graduates. Cumulatively, this amounts to $4.7 million in additional earning power for these graduates.

At the time of writing, 4 honours and 9 PhD graduates were employed by industry, with the majority of the remainder working for universities on end-user projects. CRC CARE is in the process of a comprehensive survey of past students, as we all as others who have been associated with the CRC (available at www.surveymonkey.com/r/crccarealumni), in order to obtain more details about alumni activities. The results of this survey will be included in the 2020/21 Highlights and Achievements Report.

Industry and other non-university staff supervising postgraduates

At the time of writing, CRC CARE was in the process of collating this information for inclusion in the 2020/21 Highlights and Achievements Report.

THE KEY EDUCATIONAL OUTPUTS, INCLUDING DETAILS OF ANY COURSES DEVELOPED

CRC CARE education and training

Since the start of its current term of funding in 2011, CRC CARE has conducted more than 60 conferences, workshops, seminars, webinars and symposia, with a total of more than 9,000 participants. A number of these have supporting educational resources, including the ASC NEPM and petroleum hydrocarbon HSLs.

The CRC has published almost 50 technical guidance documents that are available for free download from the CRC CARE website. A CRC CARE educational book on community engagement, *Engaging the community: a handbook for professionals managing contaminated land,* is also available for sale. The CRC also played a significant role in the development of the University of Newcastle's Masters in Environmental Risk Assessment and Remediation course.

EDUCATION AND TRAINING EVENTS				
Event name	Type of event	City	Month	Number of participants
2019/20				
1. 8th International Contaminated Site Remediation Conference (CleanUp 2019)	Conference	Adelaide	September	700
2. CleanUp Korea 2019	Conference	Seoul, Korea	December	150
3. Launch of the National Remediation Framework	Webinar	-	June	300
4. Impact of COVID-19 on the contaminated land sector	Webinar	-	May	195
5. Petroleum hydrocarbon risk assessment in the 2020s.	Webinar	-	February	56
2018/19				
6. Human Health Risk Assessment	Workshops (3)	Perth, Melb, Syd	June	37
7. Mined Land Rehabilitation Conference 2019	Conference	Newcastle	June	285
8. From Risk to Remediation 2019: CRC CARE Summer School on Contaminated Site Assessment, Management and Communication	Workshop	Newcastle	March	62
9. National Remediation Framework Roadshow	Seminars / Q&A (8)	All capitals	February	300
10. Establishing remediation Objectives, Performing Cost-Benefits and Sustainability Analysis	Workshop	Perth	November	9
11. Principles of Remediation Costing	Webinar	-	November	30
12. 1st Global CleanUp Congress	Conference	India	October	350
13. Assessment and management of benzo[a]pyrene-contaminated land	Webinar	-	September	37
14. Societal Perception and Acceptance of Remediation Technologies (SPART)	Workshop (2)	Perth, Syd	September	12
15. Comprehensive and Innovative guidance for DNAPL site characterisation and remediation	Workshop (2)	Melb, Syd	August	11
16. Technical and Regulatory Issues resulting from the use of PFAS contaminated sites	Workshop (2)	Melb, Syd	August	47
17. Designing a site Investigation from conceptual model to sampling and analytical strategy	Webinar	-	August	21
2017/18				
18. Contaminated Land Management of Local Governments	Webinar	-	May	22
19. Emerging Contaminants – What are they and what do we do about them?	Webinar	-	May	41
20. Human Health Risk Assessment	Workshops (5)	Adel, Melb, Syd, Bris, Perth	March	64
21. The National Remediation Framework – What's new and what to expect in 2018	Webinar	-	March	44
22. CleanUp 2017 Conference	Conference	Melbourne	September	650
23. Light non-aqueous phase liquid (LNAPL) natural source zone depletion	Workshop	Sydney	August	17
24. Light non-aqueous phase liquid (LNAPL) natural source zone depletion	Workshop	Perth	August	13
2016/17				
25. CleanUp Indonesia 2017	Conference	Bandung, Indonesia	May	100
26. Human Health Risk Assessment	Workshops (5)	Adel, Melb, Syd, Bris, Perth	March	93
27. CleanUp India 2016	Conference	Coimbatore, India	December	540
28. Dealing with Derelict Mines 2016 – International Summit on Derelict Mines	Conference	Singleton	December	99
29. CleanUp Conference in China 2016	Conference	Beijing, China	October	575
30. PFAS Contamination from AFFFs: Toxicity, Sampling, Remediation and Management	Workshop (5)	Adel, Melb, Syd, Bris, Perth	September	135
31. Guidance on Methyl Tert-Butylene (MTBE) in Groundwater	Webinar	-	August 2016	44
32. Statistics for Environmental Practitioners	Workshop	Melbourne	July	9
33. Statistics for Environmental Practitioners	Workshop	Sydney	July	19
2015/16				
34. Risk Ranking of Contaminated Sites	Webinar	-	June	64
35. Life Cycle of Petroleum Biodegradation Metabolite Plumes and Implications for Risk Management at Fuel Release sites	Webinar	-	February	78
36. Environmental Forensics – Utilisation of Established and Evolving Techniques	Workshop	Sydney	November	13
37. CleanUp 2015	Conference	Melbourne	September	650

EDUCATION AND TRAINING EVENTS				
Event name	Type of event	City	Month	Number of participants
2014/15				
38. National Workshop on Nuclear Energy for Australia	Workshop	Adelaide	June	28
39. Analysis, Management and Remediation of LNAPL in Australia	Workshops (5)	Adel, Melb, Syd, Bris, Perth	May	69
40. Who do People Trust? A Resident's perception of Risk communication on Industrial Contamination	Seminar/ webinar	Adelaide + national	May	31
41. Recent Advances in Risk Assessment for Mixed Contaminants	Seminar/ webinar	Adelaide + national	April	46
42. Recent Advances in the Measurement Accuracy for Total Recoverable Hydrocarbon Analysis	Workshop	Sydney	November	15
43. Launch of Site Contamination Practitioner Australia Certification Scheme	Seminar/ webinar	Adelaide + national	November	116
44. Acid Sulfate Soil: The World's Nastiest Soil	Seminar/ webinar	Adelaide + national	October	33
45. DNAPL and LNAPL workshops	Workshops (2)	Melb, Syd	October	59
46. Best practice approaches for ensuring successful bioremediation outcomes	Seminar/ webinar	Adelaide + national	September	15
47. Communicate 2014	Conference	Adelaide	September	107
48. Biogas Basics Seminar	Seminar	Adelaide	August	13
49. A unified approach for the analysis, management and remediation of LNAPL in Australia	Seminar/ webinar	Adelaide + national	August	37
50. Technical writing workshop	Workshop	Adelaide	July	31
2013/14				
51. A technical guide for demonstrating monitored natural attenuation of petroleum hydrocarbon in groundwater	Seminar	Adelaide	June	99
52. Contaminants of emerging concern	Seminar	Adelaide	May	93
53. National Remediation Framework	Seminar	Adelaide	April	175
54. Certification of Site Contamination Practitioners Scheme	Seminar	Adelaide	March	221
55. CleanUp 2013	Conference	Melbourne	September	600
2012/13				
56. ASC NEPM Roadshow	Workshops (8)	All capitals	May	620
57. Unlocking soil's secrets to open the door to agricultural productivity gains	Symposia (4)	Syd, Bris, Adel, Perth	November	195
58. All State and Territory capitals Petroleum Vapour Intrusion assessment	Workshops (3)	Syd, Melb, Perth	October	200
59. International Workshop on the Risk Assessment of Manufactured Nanomaterials	Workshop		October	69
60. Communicate 2012	Conference	Adelaide	September	122
2011/12				
61. Health-based screening levels for petroleum hydrocarbons	Workshops (5)	Perth, Syd, Adel, Bris, Melb	November	202
TOTAL NUMBER OF PARTICIPANTS				**9,068**

THE IMPACT OF EDUCATION AND TRAINING PROGRAMS IN AREAS OF SKILL SHORTAGES

CRC CARE tailors its education and training program around industry, government and academia needs, particularly where skill shortages exist. Examples include:

National Remediation Framework training

CRC CARE led the development of a national framework for the remediation of contaminated sites (NRF), which aims to achieve greater certainty in environmental outcomes and promote consistent implementation of guidance across Australia. The NRF, which was recognised and supported by the Heads of EPAs in October 2019, will complement ASC NEPM. In performing the role of national harmonisation, the NRF effectively identifies areas of skill shortage. In response to this, we have run a series of workshops that focus on NRF-related topics, including: establishing remediation objectives; performing cost-benefit and sustainability analyses; and stakeholder engagement. Furthermore, as part of the consultation process, the CRC held an NRF roadshow that included presentations and Q&A sessions in all State and Territory capital cities in February 2019. With the NRF officially launched in June 2020, CRC CARE is planning a modular course based on the components of the framework.

Management of PFAS-contaminated sites

In recent years, a class of chemicals known as per- and poly-fluoroalkyl substances (PFAS) have emerged as contaminants of concern, especially at fire-training sites where years of use of firefighting foams that contain PFAS have resulted in soil and groundwater contamination. As is the case with most so-called emerging contaminants, industry and government have limited understanding of the effects of PFAS and how to clean it up. CRC CARE has been a leader in developing knowledge of and tools for PFAS remediation. One of our roles in this area has been to host a series of workshops around the country on *Technical and regulatory issues resulting from the use of PFAS* and *PFAS contamination from AFFFs: toxicity, sampling, remediation and management.*

SCP Australia professional certification scheme

During its current term of funding, CRC CARE worked with industry-wide stakeholders to develop, launch and manage Site Contamination Practitioners Australia (SCP Australia) – Australia's first certification scheme for contaminated site professionals. SCP Australia aimed to improve the professionalism of the industry as a whole by using a recognised certification process to ensure that those dealing with contaminated site issues have the necessary level of knowledge, expertise and skill. The impetus for creating SCP Australia was wide recognition that there was an unacceptable level of variation in the quality of and approach to contaminated site management among practitioners in the private sector.

In 2018/19, SCP Australia merged with the Environment Institute of Australia and New Zealand Certified Environmental Practitioner scheme to allow certification to be directly managed by the sector and ensure the initiative's enduring future. While it operated under CRC CARE's management, SCP Australia awarded 77 certificates and attracted 183 subscribers.

LNAPL natural source zone depletion for cost-effective contaminated site management

Research led by CRC CARE and supported by NERA has found that allowing LNAPLs to degrade naturally via NSZD is often the most effective approach for remediating sites contaminated with petroleum hydrocarbons, particularly after 3-5 years of active remediation. Applying this world-first research will deliver improved environmental outcomes and potentially save end users $320 million over the next 10 years through more effective remediation.

The results of the study, which compared six contaminated sites across Australia, are presented for environmental professionals in three CRC CARE Technical Reports, available for free download:

- CRC CARE Technical Report 44: *Technical measurement guidance for LNAPL natural source zone depletion*
- CRC CARE Technical Report 46: *The role of NSZD in the management of LNAPL contaminated sites*
- CRC CARE Technical Report 47: *Australian case studies of LNAPL NSZD rates compared with conventional active recovery efforts.*

To help industry adopt the findings of the research, CRC CARE and NERA are running a self-paced online course that covers the science of LNAPL NSZD, including measurement and options for incorporating NSZD into LNAPL conceptual site model development and site management strategies.

NEPM Roadshow

See case study below.

CASE STUDY THAT ILLUSTRATES HOW CRC CARE EDUCATION PROGRAMS HAVE INFLUENCED THE UPTAKE OF NEW KNOWLEDGE, PRODUCTS OR PROCESSES

ASC NEPM Roadshow

The NEPM is the national guideline on contaminated land assessment in Australia. It was first released in 1999, and was varied in May 2013. CRC CARE contributed to the variation of the ASC NEPM by developing guidelines on a range of issues, including PHs (particularly focusing on human health–based screening levels and site characterisation).

In May 2013, when the varied NEPM was released, CRC CARE, in partnership with state EPAs, organised a national roadshow to provide regulators, site assessors, consultants, environmental auditors, landowners, developers and industry practitioners with an opportunity to come together and gain an understanding of the changes, new elements, and implementation of the NEPM. Members of the NEPM variation team, along with the technical experts involved in developing guidance for inclusion into the NEPM Schedules, presented the changes and identified new aspects of the amended NEPM.

The workshops aimed to help people involved in the industry to interpret the guidance so as to enable its uptake and application. Local EPA representatives also presented on the transition and implementation plans relevant to their jurisdiction. A total of 620 delegates attended the roadshow, which spent two days in each State and Territory.

The varied NEPM has had a major impact on contaminated site assessment nationally, helping to save millions of dollars annually in site assessments alone. The CRC CARE roadshow played a significant role in in educating the environmental professional sector and building the capacity of Australian contaminated land industry. To further support the roadshow, a DVD of the workshop presentations was made available via the CRC CARE web site and YouTube.

16.4. SNAPSHOT SUMMARY

Chemical contamination of the environment, and its threat to human health, is one of the most intractable problems facing all nations. Conservative estimates suggest that there are more than 5 million potentially contaminated sites globally that threaten the wellbeing of hundreds of millions of people and ecosystems globally, including more than 200,000 in Australia. Since its launch, CRC CARE has performed ground-breaking research, developed innovative technologies, and provided practical guidance to tackle this challenge. CRC CARE is a unique in the contaminated site sector as the only body globally that brings together government, regulators, industry, contaminated site owners, environmental practitioners, research, science, and engineering.

CRC CARE's influence on Australia's approach to contaminated sites has:

- allowed all stakeholders – industry, government, research and community – to work together to solve problems in more transparent, efficient and cost-effective ways than were previously possible
- driven a shift to a risk-based, *in situ* approach to managing contaminated sites – cleaning up contamination where it lies, rather than the traditional 'dig and dump'
- demonstrated, with a transparent risk-based approach, that contaminants only pose a risk if they can be absorbed by humans, animals and plants, leading to more rational, effective and affordable clean-up
- supported growth in the Australian remediation industry from $300 million per year in 2005 to over $3 billion per year now
- boosted Australia's global standing in the contaminated land sector through education and training.

MAJOR ACHIEVEMENTS

- *Economic benefit for Australia:* CRC CARE's industry guidance and policy insights coupled with risk-based management of, and new insights into, both conventional and emerging contaminants (including PFAS) allows limited resources to be directed to where they are needed most. CRC CARE's work has saved its industry Participants millions of dollars annually. A 2019 economic impact review estimated that spread across the entire sector this amounts more than $5.4 billion of economic benefit to Australia – a return of more than $8.50 on every dollar invested by government and industry.
- *A national approach to best practice clean-up:* CRC CARE's National Remediation Framework (NRF) was recognised and supported by the Heads of EPAs in October 2019. The NRF, which harmonises best practice approaches to contaminated site clean-up across all Australian states and territories, is forecast to deliver a minimum 5% reduction in total costs, amounting to more than $200 million through to 2026.
- *Improving the national approach to managing PFAS contamination:* In recent years, there has been a steep increase in community concern over contamination of soil and water with PFAS, a component of some firefighting foams. CRC CARE's best practice strategies and guidance for managing PFAS-contaminated sites have improved the national effort to assess and remediate these high-priority emergent contaminants. The CRC's work, which complements and informs the PFAS National Environmental Management Plan, has delivered significant direct economic benefits for industry. According to the CRC's recent economic impact review, this includes more than $200 million through reduced need for remediation of PFAS that – based on the CRC CARE's risk-based approach – does not pose an environmental or health threat. In addition, sectors relying upon PFAS clean-up are now able to commence or accelerate project operations on this land, reducing their costs of development and spurring new economic activity. In 2018/19, the CRC CARE published *Practitioner guide to risk-based assessment, remediation and management of PFAS site contamination*. Freely available via the CRC's website (www.crccare.com/knowledge-sharing/pfas-practitioner-guide), this guide details current best practice in this area.

RESEARCH

- *Restoring wetlands devastated by acid sulfate soils*: CRC CARE's work on innovative acid sulfate soil remediation at East Trinity, Queensland, turned badly acidified land into a place where mangroves, native birds and other wildlife again flourish. The 774-hectare site became an environmental disaster in the 1970s after being drained to create a sugarcane farm. The CRC optimised a remediation approach known as lime-assisted tidal exchange (LATE). Compared with conventional methods, which would have used nearly $80 million in lime alone, LATE reduced lime use to less than 5% of the original requirements. Accordingly, the CRC has provided a blueprint for the affordable rejuvenation of similarly affected wetlands globally.
- *Driving innovative clean-up technologies:* The Global Centre for Environmental Remediation at the University of Newcastle, Australia, is the engine room for the development of CRC CARE's innovative contamination clean-up technologies. State-of-the-art laboratories allow CRC CARE-supported researchers to carry out research that is only possible at a small handful of labs worldwide.

COMMERCIALISATION AND UTILISATION

- *Health screening levels for petroleum hydrocarbons mean huge savings for industry:* CRC CARE developed health screening levels (HSLs) for total petroleum hydrocarbons, which provide a minimum concentration of contaminant that triggers further action (including monitoring and clean-up). The HSLs were included in the National Environment Protection (Assessment of Site Contamination) Measure ('the ASC NEPM'), ensuring that they were adopted by all Australian regulators. By ensuring that limited resources are committed only to contamination that represents an environmental or human health threat, this work has already resulted in, and will continue to allow, substantial reductions in remediation costs for the mining, petroleum, defence and other sectors. The CRC's recent environmental impact review estimated total benefits to Australian industry and government so far amount to $1.3 billion.

- *matCARE™ technology for remediating PFAS from firefighting foams:* Working with the Department of Defence (as well as Airservices Australia), CRC CARE developed matCARE technology to remediate PFAS contamination from firefighting foams. matCARE is a modified clay substance that irreversibly locks up PFAS molecules in contaminated soil, water or concrete. To date, the CRC has remediated on-site more than 3 million litres of wastewater, reducing annual clean-up costs by 90%.
- *Reducing BHP's environmental management costs and protecting human health:* To remediate hydrocarbon-contaminated soil at multiple sites in the Pilbara, WA, BHP was required to meet regulatory criteria that were practicably unachievable in the local environmental conditions. Accordingly, the size and cost of BHP's landfarms (areas of contaminated soil where contaminants undergo microbial degradation) were growing rapidly. At one site alone, the assessment and management costs were around $600,000 per year and rising. BHP commissioned CRC CARE to develop a risk management framework that ensured no increase in risk to people or the environment. This was presented to and subsequently endorsed by the WA regulator. In addition, CRC CARE and BHP trialled bioremediation through 'biopiling' – piling contaminated soil in conditions that allow microbial activity to reduce concentrations of contaminants – as a means to attain contaminant concentrations that met risk criteria. This was achieved in less than 3 months (half the originally predicted time). Over the life of the affected mines, port and railways, the CRC's approach has reduced treatment costs to less than 30% compared with previous methods, saving BHP millions of dollars and achieving a better result for the environment.
- *A better way to clean up shooting range soils:* Our improved technology for cleaning up shooting range soils contaminated with lead and other toxic metals has helped the Department of Defence clean up more than 100 tons of contaminated soil at major weapons ranges in WA and Queensland. The remediated soil is clean enough for reuse, while the economic value of the recycled lead offsets the cost of remediation.

SME ENGAGEMENT

- *Opening up opportunities for SMEs:* Small-to-medium sized enterprises (SMEs) have been major beneficiaries of CRC CARE's collaboration with industry. Commercialisation of CRC CARE technology along with the roll-out of its guidance on policies, procedures and protocols, have catalysed growth in Australian SMEs in the contaminated site sector and beyond. The growth of the sector over the past 20 years has delivered an attendant increase in employment and opened up unprecedented opportunities for SMEs in the environmental consulting sector – such as JBS&G, one of the CRC's Participants – to establish themselves and thrive. SMEs in other sectors, from development and construction to minerals and resources, also benefit through:
  - unlocking the productivity of billions of dollars of previously disused real estate at brownfield and other industrial sites such as derelict mines
  - improvements in contamination analysis and measurement that have created opportunities for analytical laboratories.
- *Raising the professionalism of the contaminated site remediation sector:* For many years there was widespread recognition that the contaminated site remediation sector suffered from a lack of standardisation and variable levels of professionalism. To address this, at the request of end users, CRC CARE initiated Site Contamination Practitioners Australia (SCP Australia) – the nation's first certification scheme for contaminated site professionals. SCP Australia was designed to improve:
  - outcomes for all stakeholders involved in the contaminated land industry
  - the professionalism of the industry as a whole by using a recognised certification process to ensure that those dealing with contaminated site issues have the necessary level of knowledge, expertise and skill.

The success of SCP Australia has been a major contributor to more consistent and higher standards throughout the sector. Recognised industry-wide, such certification benefits environmental consulting businesses by allowing them to demonstrate that their employees have achieved a minimum level of knowledge and skill. This has benefitted SMEs in particular by levelling the playing field and helping them compete with larger operators.

In 2018, after awarding 77 certificates and attracting 183 subscribers, SCP Australia merged with the Environment Institute of Australia and New Zealand's Certified Environmental Practitioner scheme. The two schemes were consolidated to allow certification to be directly managed by the sector and ensure the initiative's enduring future.

EDUCATION AND TRAINING

- *CleanUp conferences – world-leading knowledge exchange:* CRC CARE's CleanUp Conference series features the biennial International Contaminated Site Remediation Conference. In 2019, 700 delegates from more than 25 countries, representing industry, research and government, attended the 8th CleanUp Conference in Adelaide, Australia. The event included a program of professional development workshops, 260 oral presentations, 50 posters and the 2nd International PFAS Conference. CleanUp is considered one of the world's foremost forums for knowledge exchange on environmental contamination and its remediation.
- *Fostering the next generation of contamination science leaders:* In its current term of funding, CRC CARE has supported more than 70 PhD graduates. Since the CRC was launched in 2005, this figure exceeds 150. As well as representing a substantial proportion of all Australian PhD graduates in the field of contamination science, these students work directly with end users on real-world problems, ensuring that they enter the workforce 'industry-ready'. Further, the CRC's recent economic impact review estimated that 40% of CRC CARE graduates are, or will be, employed in industry-based roles and will achieve an earnings premium of $19,000 to $26,000 higher than comparable graduates. Cumulatively, this amounts to $4.7 million in additional earning power.

SPIN-OFF COMPANIES AND INVENTIONS

- *Real-time analysis of irrigation water for better crop management:* CRC CARE's probeCARE™ system allows farmers and agriculturalists to take real-time measurements of common ions (e.g. sodium, potassium and calcium) in irrigation water, providing vital information on water quality that informs decisions on crop management.
- *Faster, more cost-effective soil vapour analysis:* CRC CARE has developed a portable, retractable soil vapour bore for sampling volatile organic compounds in soil vapour from subsurface soils. The tool, named svbCARE™, improves the efficiency and speed of vapour intrusion assessments. Traditional methods are not as portable, involve lengthy installation, and require samples to be sent to a lab for costly analysis. When used in conjunction with portable gas chromatography / mass spectrometry equipment, svbCARE allows 30 to 50 samples to be measured and analysed per day on site at greatly reduced cost, with results comparable to those of a commercial laboratory.

INTERNATIONAL ENGAGEMENT

- *Exporting Australian know-how to build capacity in China:* CRC CARE engages with organisations globally, with the most significant collaboration based in China via our China Program. The program is run in partnership with HLM Asia Group Ltd, Huazhong University of Science and Technology, Wuhan, and Shaoguan University, Guangdong. China Program highlights include:
  - Piggery waste remediation (pooCARE™) – piggery waste is a major source of environmental pollution in China. Developed in collaboration with HUST, pooCARE employs a specially designed bioreactor to convert pig waste into biogas and nutrient-rich fertiliser.
  - Using Hybrid giant Napier grass to remediate red mud, a highly alkaline waste generated during alumina production.
  - Clean-up of a lake contaminated with phosphate as a result of agricultural chemical runoff. This project combines Phoslock (a commercially available product that removes phosphates from water) with biofilm technology to manage eutrophication (excessive richness of nutrients, often because of fertiliser run-off) and algal blooms.

Via the China Program, CRC CARE also builds local capacity via numerous training opportunities for Chinese scientists and practitioners. In 2018/19, for example, 13 staff from Jiangxi Nuclear Industry Geological Bureau were hosted at the Global Centre for Environmental Remediation, University of Newcastle, to complete a three-month risk assessment and remediation training course,

17 GLOSSARY OF TERMS

ACLCA
Australian Contaminated Land Consultants Association

AFFF
Aqueous film-forming foam

AGM
Annual general meeting

AIP
Australian Institute of Petroleum

ALGA
Australasian Land & Groundwater Association

ASC NEPM
National Environment Protection (Assessment of Site Contamination) Measure

CEO
Chief executive officer

CGAL
Contec Global Agro Ltd

CRC
Cooperative Research Centre

CRC CARE
CRC for Contamination Assessment and Remediation of the Environment

COVID
Coronavirus disease

CSIRO
Commonwealth Scientific and Industrial Research Organisation

DNAPL
Dense non-aqueous phase liquid

DoD
Department of Defence

eDM
Electronic direct mail

EPA
Environment Protection Authority

ESL
Ecological screening level

FTIR
Fourier transform infrared

GCER
Global Centre for Environmental Remediation

GC-MS
Gas chromatograph–mass spectrometer

HEPA
Heads of EPAs

HSL
Health screening level

HUNIC
Hub University of Industrial Collaboration

HUST
Huazhong University of Science and Technology

IITK
Indian Institute of Technology, Kanpur

IP
Intellectual property

ITRC
Interstate Technology & Regulatory Council

LATE
Lime-Assisted Tidal Exchange

LNAPL
Light non-aqueous phase liquid

MoU
Memorandum of understanding

MP
Member of Parliament

NCSDP
National Contaminated Sites Demonstration Program

NERA
National Energy Resources Australia

NIER
Newcastle Institute for Energy and Resources

NMI
National Measurement Institute

NRF
National Remediation Framework

NSW
New South Wales

NSZD
Natural source zone depletion

PAHs
Polycyclic aromatic hydrocarbons

PCT
Patent Cooperation Treaty

PFAS
Per- and polyfluoroalkyl substances

PFHxS
Perfluorohexane sulfonate

PFOA
Perfluorooctanoic acid

PFOS
Perfluorooctanesulfonate

PHs
Petroleum hydrocarbons

RAAF
Royal Australian Air Force

SA
South Australia

SCP Australia
Site Contamination Practitioners Australia

SCU
Southern Cross University

SME
Small-to-medium enterprise

TCE
Trichloroethylene

TNAU
Tamil Nadu Agricultural University

TPH
Total petroleum hydrocarbons

UniSA
University of South Australia

UK
United Kingdom

USA
United States of America

UTS
University of Technology Sydney

VOCs
Volatile organic compounds

WA
Western Australia

WSU
Western Sydney University

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Jit, J 2019, 'Australia's risk-based approach', presented at the RemTech Europe conference, Ferrara, Italy, 18–20 September.

Jit, J 2019, 'The National Remediation Framework for the remediation and management of contaminated sites in Australia (NRF)', presented at the RemTech Europe conference, Ferrara, Italy, 18–20 September.

Linge, KL, Black, S & Allen, D 2020, 'Mine pit lakes: geochemistry, water management and legacy', poster presented at Ozwater 20, Adelaide, Australia, May (postponed due to COVID-19).

Linge, KL, Black, S & Allen, DA 2020, 'Mine pit lakes: characterisation of water quality and geochemistry to inform mine closure', oral presented at the 10th Australian Workshop on Acid and Metalliferous Drainage, Dubbo, NSW, Australia, May (postponed due to COVID-19).

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CRC CARE 2019, *Glossary and acronyms, National Remediation Framework*, CRC for Contamination Assessment and Remediation of the Environment, Newcastle, Australia.

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Rayner, JJ, Bekele, E, Donn, M, Bastow, T, Davis, GB, Woodbury, R, Furness, A & Geste, Y 2020, *Australian case studies of light non-aqueous phase liquid (LNAPL) natural source zone depletion rates compared with conventional active recovery efforts*, CRC CARE Technical Report no. 47, CRC for Contamination Assessment and Remediation of the Environment, Newcastle, Australia.

FINANCIAL STATEMENTS

CRC CARE PTY LTD ACN 113 908 044

COOPERATIVE RESEARCH CENTRE

FOR CONTAMINATION ASSESSMENT AND REMEDIATION OF THE ENVIRONMENT

FINANCIAL STATEMENTS FOR THE YEAR ENDED 30 JUNE 2020

Financial Statements

CRC CARE Pty Ltd

ACN 113 908 044

Directors' Report

30 June 2020

The directors present their report on CRC CARE Pty Ltd (the 'Company' or "CRC CARE") for the financial year ended 30 June 2020.

Directors

The names of each person who has been a director during the year and to the date of this report are:

Dr Paul Vogel, Chairman
Prof Ravi Naidu, CEO & Managing Director
Mr Alan Broadfoot, Appointed 11 June 2020
Ms Anthea Tinney
Dr Deborah Hodgson, Resigned 22 November 2019
Mr Charles Wong
Adj Prof Donald Sinnott, Resigned 26 June 2020
Ms Frances Joy Kay-Lambkin, Appointed 13 March 2020, Resigned 11 September 2020
Ms Janet Elizabeth Nelson, Appointed 13 March 2020, Resigned 4 June 2020
Mr Ralph Hardy
Dr Rod Lukatelich
Mr Tony Circelli

Directors have been in office since the start of the financial year to the date of this report unless otherwise stated.

Principal activities

The principal activity of CRC CARE Pty Ltd during the financial year was to manage and govern the Cooperative Research Centre for Contamination Assessment and Remediation of the Environment ("the Centre").

The objective of the Centre is to promote research and capacity building for the development and extension of advanced technologies and methods for:

a) assessing contamination risks to the land, groundwater and air;
b) preventing, managing and/or remediating contamination;
c) developing safe options for land use and the reuse of wastes on land;
d) developing solutions that are acceptable to regulatory agencies and the public; and
e) capacity building.

No significant changes in the nature of the Company's activity occurred during the financial year.

Dividends paid or recommended

No dividends were paid or declared since the start of the financial year. No recommendation for payment of dividends has been made.

Review of operations

The Company specialises in research and development of technologies to overcome and prevent contamination of soil, water and air. During the year, the Company received cash contributions of $8,509,000 (2019: $8,187,000) and in-kind contributions of $ 9,252,013 (2019: $9,352,258).

CRC CARE Pty Ltd

ACN 113 908 044

Directors' Report

30 June 2020

Review of operations (cont'd)

Costs directly attributable to Research expenditure totaled $17,606,722 (2019: $15,531,567) which is reflective of the research performed in order to complete the projects of the Company.

Significant changes in state of affairs

There have been no significant changes in the state of affairs of the Company during the year.

Events after the reporting date

No matters or circumstances have arisen since the end of the financial year which significantly affected or may significantly affect the operations of the Company, the results of those operations or the state of affairs of the Company in future financial years.

Future developments and results

On 10 June 2020, the Company received approval from the Department of Industry, Science, Energy & Resources to undertake protracted wind-up activities until 30 June 2021. Accordingly, these financial statements have been prepared on a realisation basis. Commonwealth funding concluded on 30 June 2020 and participant funding concludes on 30 June 2021. The Board is following the appropriate process with regard to the funding finalisation and the future of the entity.

Environmental issues

The Company's operations are subject to significant environmental regulations under the laws of the Commonwealth and State of Australia, briefly discussed below:

(i) The Company is subject to regulation relating to the testing of contaminated sites and the formulation of proposals for the remediation of contamination in the environment;

(ii) Personnel of the entity and entities providing research services to the Company are required to conform to the site specific Environmental Health and Safety plans when entering and working on contaminated sites.

There have been no breaches of such environmental regulations or plans that have a material effect on the financial statements.

Indemnification and insurance of officers and directors

During the financial year, the Company paid a premium of $4,599 (2019: $4,280) to insure Directors and Officers of the Company.

The liabilities insured are legal costs that may be incurred in defending civil or criminal proceedings that may be brought against Directors and Officers in their capacity as officers of the Company, and any other payments arising from liabilities incurred by the officers in connection with such proceedings. This does not include such liabilities that arise from conduct involving wilful breach of duty by the officers or the improper use by the officers of their position or of information to gain advantage for them or someone else to cause detriment to the Company.

Auditor's independence declaration

The lead auditor's independence declaration in accordance with section 307C of the *Corporations Act 2001*, for the year ended 30 June 2020 has been received and can be found on page 4 of the financial report

CRC CARE Pty Ltd

ACN 113 908 044

Directors' Report
30 June 2020

Signed in accordance with a resolution of the Board of Directors:

Chairman of Board of Directors: .....
Dr Paul Vogel

CEO & Managing Director: .....
Prof Ravi Naidu

Dated 12 October 2020

PKF

Auditor's Independence Declaration under Section 307C of the Corporations Act 2001 to the Directors of CRC CARE Pty Ltd

I declare that, to the best of my knowledge and belief, during the year ended 30 June 2020, there have been:

(i) no contraventions of the auditor independence requirements as set out in the *Corporations Act 2001* in relation to the audit; and

(ii) no contraventions of any applicable code of professional conduct in relation to the audit.

PKF

PKF

MARTIN MATTHEWS
PARTNER

12 OCTOBER 2020
NEWCASTLE, NSW

PKF(NS) Audit & Assurance Limited Partnership
ABN 91 850 861 839

Liability limited by a scheme approved under Professional Standards Legislation

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CRC CARE Pty Ltd

ACN 113 908 044

Statement of Profit or Loss and Other Comprehensive Income

For the Year Ended 30 June 2020

	Note	2020 $	2019 $
Revenue from continuing operations	4	20,706,270	17,588,046
Consultants fees		(322,100)	(279,727)
Employee benefit expense		(863,176)	(686,101)
IT expenses		(84,098)	(81,838)
Legal expenses		(83,572)	(51,275)
Research expenditure - cash		(8,354,709)	(6,179,309)
Research expenditure - in-kind		(9,252,013)	(9,352,258)
Travel expenses		(82,582)	(81,027)
Finance costs		(9,706)	(10,537)
Other expenses	5	(1,649,930)	(865,974)
Profit before income tax		4,384	-
Income tax expense	6	(4,384)	-
Other comprehensive income for the year, net of tax		-	-
Total comprehensive income		-	-

The accompanying notes form part of these financial statements.

CRC CARE Pty Ltd

ACN 113 908 044

Statement of Financial Position

As At 30 June 2020

	Note	2020 $	2019 $
ASSETS			
CURRENT ASSETS			
Cash and cash equivalents	7	3,066,102	5,848,109
Trade and other receivables	8	663,212	841,471
Current tax receivable		-	5,892
Other assets		91,978	303,935
Non-current assets held for sale		74,781	-
TOTAL CURRENT ASSETS		**3,896,073**	**6,999,407**
NON-CURRENT ASSETS			
Property, plant and equipment	9	-	89,218
TOTAL NON-CURRENT ASSETS		**-**	**89,218**
TOTAL ASSETS		**3,896,073**	**7,088,625**
LIABILITIES			
CURRENT LIABILITIES			
Trade and other payables	10	353,849	1,028,317
Current tax liabilities		19,108	-
Employee benefits	11	306,006	217,174
Other liabilities		2,030,466	1,938,302
Other financial liabilities	12	1,186,630	3,853,387
TOTAL CURRENT LIABILITIES		**3,896,059**	**7,037,180**
NON-CURRENT LIABILITIES			
Employee benefits	11	-	51,431
TOTAL NON-CURRENT LIABILITIES		**-**	**51,431**
TOTAL LIABILITIES		**3,896,059**	**7,088,611**
NET ASSETS		**14**	**14**
EQUITY			
Issued capital	13	14	14
Retained earnings		-	-
TOTAL EQUITY		**14**	**14**

The accompanying notes form part of these financial statements.

CRC CARE Pty Ltd

ACN 113 908 044

Statement of Changes in Equity

For the Year Ended 30 June 2020

2020

	Ordinary Shares	Retained Earnings	Total
	$	$	$
Balance at 1 July 2019	**14**	**-**	**14**
Profit for the year	**-**	**-**	**-**
Balance at 30 June 2020	**14**	**-**	**14**

2019

	Ordinary Shares	Retained Earnings	Total
	$	$	$
Balance at 1 July 2018	14	-	14
Loss for the year	-	-	-
Balance at 30 June 2019	14	-	14

The accompanying notes form part of these financial statements.

CRC CARE Pty Ltd

ACN 113 908 044

Statement of Cash Flows

For the Year Ended 30 June 2020

	Note	2020 $	2019 $
CASH FLOWS FROM OPERATING ACTIVITIES:			
Cash contributions received from Commonwealth (inclusive of GST)		834,900	1,612,600
Cash contributions received from all Participants (inclusive of GST)		8,525,000	7,393,100
Payments to suppliers and employees		(13,977,459)	(10,367,811)
Income tax (paid)/refunded		(4,384)	462
Interest received		59,360	79,600
Training fees received		1,108,012	393,752
Other income received		582,648	874,326
Grant income received		89,916	37,800
Net cash (used in)/provided by operating activities	21	**(2,782,007)**	**23,829**
CASH FLOWS FROM INVESTING ACTIVITIES:			
Net cash provided by/(used in) investing activities		**-**	**-**
CASH FLOWS FROM FINANCING ACTIVITIES:			
Net cash provided by/(used in) financing activities		**-**	**-**
Net (decrease)/increase in cash and cash equivalents held		**(2,782,007)**	**23,829**
Cash and cash equivalents at beginning of year		**5,848,109**	**5,824,280**
Cash and cash equivalents at end of financial year	7	**3,066,102**	**5,848,109**

The accompanying notes form part of these financial statements.

CRC CARE Pty Ltd

ACN 113 908 044

Notes to the Financial Statements

For the Year Ended 30 June 2020

The financial report covers CRC CARE Pty Ltd as an individual entity. CRC CARE Pty Ltd is a for-profit proprietary Company limited by shares, incorporated and domiciled in Australia.

The functional and presentation currency of CRC CARE Pty Ltd is Australian dollars.

1 Basis of Preparation

In the Directors opinion, the Company is not a reporting entity since there are unlikely to exist users of the financial statements who are not able to command the preparation of reports tailored so as to satisfy specifically all of their information needs. This special purpose financial report has been prepared to meet the reporting requirements of the *Corporations Act 2001.*

The financial statements have been prepared in accordance with the recognition and measurement principles of all applicable Australian Accounting Standards and Interpretations issued by the Australian Accounting Standards Board and the *Corporations Act 2001.*

Historical cost convention

These financial statements have been prepared under the historical cost convention.

Realisation Basis

On 10 June 2020, the Company received approval from the Department of Industry, Science, Energy & Resources to undertake protracted wind-up activities until 30 June 2021. Accordingly these financial statements have been prepared on a realisation basis.

2 Summary of Significant Accounting Policies

(a) Revenue and other income

Revenue is measured at the fair value of the consideration received or receivable. Amounts disclosed as revenue are net of returns, trade allowances, rebates and amounts collected on behalf of third parties.

The Company recognises revenue when the amount of revenue can be reliably measured, it is probable that future economic benefits will flow to the entity and specific criteria have been met for each of the Company's activities as described below. The Company bases its estimates on historical results, taking into consideration the type of customer, the type of transaction and the specifics of each arrangement.

Grant revenue

Grants from the government are recognised at their fair value where there is a reasonable assurance that the grant will be received and the Company will comply with all attached conditions.

Government grants relating to costs which have not yet been incurred are included in deferred revenue in current liabilities and are credited to the statement of comprehensive income in the period necessary to match them with the costs that they are intended to compensate.

Government grants relating to the purchase of property, plant and equipment are included in non-current liabilities as deferred revenue and are credited to the statement of comprehensive income over the expected lives of the related assets.

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Notes to the Financial Statements

For the Year Ended 30 June 2020

2 Summary of Significant Accounting Policies (cont'd)

(a) Revenue and other income (cont'd)

Participants' contributions

Contributions received in cash (recorded as deferred revenue on receipt - for further information refer note 12) and in-kind from the Participants during the financial year are applied to expenditure incurred in carrying out the affairs of the Company under the terms of the Participants Agreement between the Company and the entities who have undertaken to provide contributions to the Company (other than the Commonwealth of Australia).

Contributions received in-kind are recognised as detailed in note 2(b) and comprise material, labour and other costs, when sufficient documentation and information has been received to quantify the cost with reasonable certainty.

Contributions as detailed in note 14 are calculated on a cash basis for reporting purpose to Commonwealth of Australia.

(b) In-kind contributions

In-kind contributions of staff by research providers are valued in accordance with the Commonwealth Agreement, as per Table 1 of the Schedule 4 of the Agreement.

Non-staff in-kind contributions are valued on the following bases:

1. Buildings - a reasonable estimate of the commercial rental value related to the area and time period of occupation related to the activities of the Company.

2. Capital equipment - either an allocation of the replacement cost of the equipment apportioned over the proportion of the useful life utilized by the activities of the Company or an agreed value determined with reference to the cost of an equipment service from a commercial operator.

Office and laboratory accommodation is provided by the University of South Australia and the University of Newcastle as part of the Participants Agreement and are treated as in-kind contributions.

Where a value cannot be readily obtained by applying the policy rules set out above, a Directors' valuation is used.

(c) Cash and cash equivalents

Cash and cash equivalents includes cash on hand, deposits held at call with financial institutions, other short-term, highly liquid investments with original maturities of three months or less that are readily convertible to known amounts of cash and which are subject to an insignificant risk of changes in value.

(d) Financial instruments

Financial instruments are recognised initially on the date that the Company becomes party to the contractual provisions of the instrument.

On initial recognition, all financial instruments are measured at fair value plus transaction costs (except for instruments measured at fair value through profit or loss where transaction costs are expensed as incurred).

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Notes to the Financial Statements

For the Year Ended 30 June 2020

2 Summary of Significant Accounting Policies (cont'd)

(d) Financial instruments (cont'd)

Financial assets

All recognised financial assets are subsequently measured in their entirety at either amortised cost or fair value, depending on the classification of the financial assets.

Classification

On initial recognition, the Company classifies its financial assets into the following categories, those measured at:

- amortised cost
- fair value through profit or loss - FVTPL
- fair value through other comprehensive income - equity instrument (FVOCI - equity)
- fair value through other comprehensive income - debt investments (FVOCI - debt)

Amortised cost

The Company's financial assets measured at amortised cost comprise trade and other receivables and cash and cash equivalents in the statement of financial position.

Subsequent to initial recognition, these assets are carried at amortised cost using the effective interest rate method less provision for impairment.

Impairment of financial assets

Impairment of financial assets is recognised on an expected credit loss (ECL) basis for the following assets:

- financial assets measured at amortised cost
- debt investments measured at FVOCI

When determining whether the credit risk of a financial assets has increased significantly since initial recognition and when estimating ECL, the Company considers reasonable and supportable information that is relevant and available without undue cost or effort. This includes both quantitative and qualitative information and analysis based on the Company's historical experience and informed credit assessment and including forward looking information.

The Company uses the presumption that an asset which is more than 60 days past due has seen a significant increase in credit risk.

The Company uses the presumption that a financial asset is in default when:

- the other party is unlikely to pay its credit obligations to the Company in full, without recourse to the Company to actions such as realising security (if any is held); or

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Notes to the Financial Statements

For the Year Ended 30 June 2020

2 Summary of Significant Accounting Policies (cont'd)

(d) Financial instruments (cont'd)

Financial assets (cont'd)

- the financial assets is more than 90 days past due.

Credit losses are measured as the present value of the difference between the cash flows due to the Company in accordance with the contract and the cash flows expected to be received. This is applied using a probability weighted approach.

Trade receivables

Impairment of trade receivables have been determined using the simplified approach in AASB 9 which uses an estimation of lifetime expected credit losses. The Company has determined the probability of non-payment of the receivable and multiplied this by the amount of the expected loss arising from default.

The amount of the impairment is recorded in a separate allowance account with the loss being recognised in finance expense. Once the receivable is determined to be uncollectable then the gross carrying amount is written off against the associated allowance.

Where the Company renegotiates the terms of trade receivables due from certain customers, the new expected cash flows are discounted at the original effective interest rate and any resulting difference to the carrying value is recognised in profit or loss.

Other financial assets measured at amortised cost

Impairment of other financial assets measured at amortised cost are determined using the expected credit loss model in AASB 9. On initial recognition of the asset, an estimate of the expected credit losses for the next 12 months is recognised. Where the asset has experienced significant increase in credit risk then the lifetime losses are estimated and recognised.

Financial liabilities

The Company measures all financial liabilities initially at fair value less transaction costs, subsequently financial liabilities are measured at amortised cost using the effective interest rate method.

The financial liabilities of the Company comprise trade payables, current tax liabilities and accrued expenses.

(e) Impairment of assets

Assets that are subject to depreciation or amortisation are reviewed for impairment whenever events or changes in circumstances indicate that the carrying amount may not be recoverable. An impairment loss is recognised for the amount by which the asset's carrying amount exceeds its recoverable amount. The recoverable amount is the higher of an asset's fair value less costs to sell and value in use. For the purposes of assessing impairment, assets are grouped at the lowest levels for which there are separately identifiable cash flows (cash generating units).

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Notes to the Financial Statements

For the Year Ended 30 June 2020

2 Summary of Significant Accounting Policies (cont'd)

(f) Plant and equipment

Plant and equipment is stated at historical cost less depreciation. Historical cost includes expenditure that is directly attributable to the acquisition of the items.

Subsequent costs are included in the asset's carrying amount or recognised as a separate asset, as appropriate, only when it is probable that future economic benefits associated with the item will flow to the Company and the cost of the item can be measured reliably. The carrying amount of any component accounted for as a separate asset is derecognised when replaced.

Depreciation is calculated using the straight line method to allocate their cost or revalued amounts, net of their residual values, over their estimated useful lives.

Plant and equipment is depreciated over the useful life of 10 years.

The assets' residual values and useful lives are reviewed, and adjusted if appropriate, at the end of each reporting year.

An asset's carrying amount is written down immediately to its recoverable amount if the asset's carrying amount is greater than its estimated recoverable amount (note 2(f)).

Gains and losses on disposals are determined by comparing proceeds with carrying amount. These are included in profit or loss.

(g) Trade Creditors

All trade creditors unpaid as at the reporting date are recognised at the amount invoiced, net of any applicable taxes. The Company's policy is to pay trade creditors no more than 30 days from the date of invoice.

(h) Employee benefits

(i) Wages and salaries, annual leave and sick leave

Liabilities for wages and salaries, including non-monetary benefits, accumulating sick leave and annual leave expected to be settled within 12 months of the reporting date are recognised in respect of employee's services up to the reporting date and are measured at the amounts expected to be paid when the liabilities are settled.

Liabilities for non-accumulating sick leave are recognised when the leave is taken and measured at the rates paid or payable.

(ii) Long service leave

The liabilities for long service leave and annual leave are not expected to be settled wholly within 12 months after the end of the period in which the employees render the related service. They are therefore measured as the present value of expected future payments to be made in respect of services provided by employees up to the end of the reporting period using the projected unit credit method. Consideration is given to expected future wage and salary levels, experience of employee departures and periods of service.

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Notes to the Financial Statements

For the Year Ended 30 June 2020

2 Summary of Significant Accounting Policies (cont'd)

(h) Employee benefits (cont'd)

Expected future payments are discounted using market yields at the end of the reporting period of corporate bonds with terms and currencies that match, as closely as possible, the estimated future cash outflows. Remeasurements as a result of experience adjustments and changes in actuarial assumptions are recognised in profit or loss.

(i) Share capital

Ordinary shares are classified as equity. Incremental costs directly attributable to the issue of new shares or options are shown in equity as a deduction, net of tax, from the proceeds.

(j) Research expenditure

Research expenditure are recognised as incurred and consist of costs incurred as part of day to day research and development activities for research programs. The main items of expenditure are salaries, equipment, consumables and travel costs.

Salaries relate to research and non-research staff working directly on research programs. In some instances salary costs may be allocated between research expenditure and employee benefits when it is identified that time can be specifically attributed to research programs.

Equipment costs relate to expenses incurred in the procurement of equipment to assist directly with the research programs undertaken. Consumable and travel costs are incurred on an ongoing basis and relate to day to day expenses incurred as part of the research activities. Research expenditure is accounted for on an accrual basis.

(k) Income Tax

The income tax expense or revenue for the year is the tax payable/(receivable) on the current period's taxable income based on the notional income tax rate adjusted by changes in deferred tax assets and liabilities attributable to temporary differences between the tax bases of assets and liabilities and their carrying amounts in the financial statements, and to unused tax losses.

Deferred tax assets and liabilities are recognised for temporary differences at the tax rates expected to apply when the assets are recovered or liabilities are settled, based on those tax rates which are enacted or substantively enacted for each jurisdiction.

The relevant tax rates are applied to the cumulative amounts of deductible and taxable temporary differences to measure the deferred tax asset or liability. An exception is made for certain temporary differences arising from the initial recognition of an asset or a liability. No deferred tax asset or liability is recognised in relation to these temporary differences if they arose in a transaction, other than a business combination, that at the time of the transaction did not affect either accounting profit or taxable profit or loss. Deferred tax assets are recognised for deductible temporary differences and unused tax losses only if it is probable that future taxable amounts will be available to utilise those temporary differences and losses.

Current and deferred tax balances attributable to amounts recognised directly in equity are also recognised directly in equity.

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Notes to the Financial Statements

For the Year Ended 30 June 2020

2 Summary of Significant Accounting Policies (cont'd)

(l) Comparative figures

When required by Accounting Standards, comparative figures have been adjusted to conform to changes in presentation for the current financial year.

3 Critical Accounting Estimates and Judgments

The preparation of financial statements requires the use of certain critical accounting estimates. It also requires management to exercise its judgement in the process of applying the Company's accounting policies. Estimates and judgements are continually evaluated and are based on historical experience and other factors, including expectation of future events that may have a financial impact on the entity and that are believed to be reasonable under the circumstances.

The areas involving a higher degree of judgement or complexity, or areas where assumptions or estimates are significant to the financial statements are detailed below.

Key estimates - In-kind contributions

Staff contributions are valued in accordance with guidelines and the multiplier set by the Commonwealth of Australia and as detailed in note 2(b). The actual time recorded on project work requires a certain level of estimate and judgement by project leaders. In applying that judgement, consideration is given to project budgets and agreements, as set out and approved by Participants and the Company.

The capital and equipment rates and useful lives used for contributions are based on estimations and agreements as calculated by project Participants and the Company. Valuations are generally based on estimates of the percentage utilisation of capital and equipment depreciation directly related to project output. The Company believes that the estimates and assumptions in relation to in-kind contributions result in recognition of amounts that represent the fair value of contributions received.

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Notes to the Financial Statements

For the Year Ended 30 June 2020

4 Revenue and Other Income

	2020 $	2019 $
Contributions revenue		
- Allocated contributions from Participants/Commonwealth - Cash	9,667,289	6,668,832
- Allocated contributions from Participants - In-kind	9,252,013	9,352,258
Total contributions revenue	**18,919,302**	**16,021,090**
Other revenue		
- Interest received	59,360	79,600
- Training fees	1,108,012	393,752
- Other income	529,680	1,055,804
- Grant income	39,916	37,800
- Government grants	50,000	-
Total other revenue	**1,786,968**	**1,566,956**
Total Revenue	**20,706,270**	**17,588,046**

5 Other expenses

Education and training expenses	968,359	239,032
Board expenses	253,315	276,295
Insurance premium	90,846	109,418
Compliance costs	30,664	47,445
Communication expenses	229,947	135,207
Other expenses	76,799	58,577
Total other expenses	**1,649,930**	**865,974**

The majority of the education and training expenses incurred relate to the cost of generating training fees revenue of $1,108,012 (2019: $393,752).

6 Income Tax Expense

Local income tax - current period	4,384	-

7 Cash and Cash Equivalents

Cash on hand	128	127
Bank balances	99,544	232,484
Deposits at call	2,966,430	5,615,498
Total Cash and Cash Equivalents	**3,066,102**	**5,848,109**

Included in Cash and Cash Equivalents is restricted cash of $30,440 for use with respect to NESP and $44,076 for use with respect to Clean Australia CRC (2019: $61,435 for use with respect to Mine Rehabilitation Trust Fund), refer to note 10.

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Notes to the Financial Statements

For the Year Ended 30 June 2020

8 Trade and Other Receivables

	2020	2019
	$	$
CURRENT		
Trade receivables	663,212	791,573
GST receivable	-	49,898
Total current trade and other receivables	**663,212**	**841,471**

9 Property, plant and equipment

Plant and Equipment		
At cost	-	191,191
Accumulated depreciation	-	(101,973)
Total plant and equipment	-	89,218

(a) Movements in carrying amounts of property, plant and equipment

Movement in the carrying amounts for each class of property, plant and equipment between the beginning and the end of the current financial year:

	Plant and Equipment	Total
	$	$
Year ended 30 June 2020		
Opening balance	**89,218**	**89,218**
Depreciation expense	**(14,437)**	**(14,437)**
Reclassify non-current assets to held for sale	**(74,781)**	**(74,781)**
Balance at the end of the year	**-**	**-**
Year ended 30 June 2019		
Opening balance	106,376	106,376
Depreciation expense	(17,158)	(17,158)
Balance at the end of the year	89,218	89,218

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Notes to the Financial Statements

For the Year Ended 30 June 2020

10 Trade and Other Payables

	2020 $	2019 $
CURRENT		
Trade payables	224,930	885,686
Monies held in trust	74,516	-
GST payable	14,195	-
Other payables	40,208	142,631
Total Trade and Other Payables	**353,849**	**1,028,317**

11 Employee Benefits

CURRENT		
Provision for employee benefits	**306,006**	217,174

The current provision for employee benefits includes accrued annual leave and long service leave. Long service leave covers all unconditional entitlements where employees have completed the required period of service and also those where employees are entitled to pro-rata payments in certain circumstances. The entire provision is presented as current, since the Company does not have an unconditional right to defer settlement for any of these obligations and employee contracts have not been extended beyond 30 June 2021.

NON CURRENT		
Provision for employee benefits	**-**	51,431

12 Deferred Revenue

CURRENT		
Contributions from Commonwealth	-	665,385
Contributions from Participants	840,570	2,460,149
Other deferred revenue	346,060	727,853
Total Deferred Revenue	**1,186,630**	**3,853,387**

As per the accounting policy in note 2, contributions from the Commonwealth of Australia and Participants (both cash and in-kind) are treated as deferred revenue until matched against expenditure in the course of the Company's activities.

In the event of a wind up of the Company, any deferred revenue not matched against expenditure is required to be returned to the Commonwealth of Australia and individual Participants in accordance with the terms of the Agreements.

Deferred revenue arising from obligations to make contributions to the Company and not allocated to program expenses at balance date has been included as a current liability as it is anticipated that the relevant sum will be matched against expenditure during the next financial year.

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Notes to the Financial Statements

For the Year Ended 30 June 2020

13 Issued Capital

	2020 $	2019 $
14 (2019: 14) Ordinary shares	14	14

(a) Movement in ordinary share capital

	2020 No.	2019 No.
At the beginning of the reporting period	14	14
At the end of the reporting period	**14**	**14**

Ordinary shares entitle the holder to receive notice of and to attend and vote at all general meetings of the Company. On a show of hands, a member is entitled to one vote. On a poll, the number of votes is in proportion to the total level of contribution to CRC CARE Pty Ltd, as of the financial year prior to which the vote is taken.

If the Company is wound up, any assets remaining after payments of the debts and liabilities of the Company, inclusive of intellectual property, will be divided amongst Participants proportionate to their contributed percentage as at the date of the division of assets.

14 Participants' contributions (Cash basis ex GST as per note 2(b))

	2020 $	2019 $	Cumulative 2005 to 2018 $	Total $
Agilent Technologies Australia Pty Ltd				
Cash contributions	-	-	25,000	25,000
In-kind contributions				
- Salaries	91,500	78,500	118,500	288,500
- Other	197,000	196,667	888,537	1,282,204
Total	288,500	275,167	1,032,037	1,595,704
Alcoa World Alumina Australia				
Cash contributions	-	-	150,000	150,000
In-kind contributions				
- Salaries	-	-	94,750	94,750
- Other	-	-	-	-
Total	-	-	244,750	244,750

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Notes to the Financial Statements

For the Year Ended 30 June 2020

14 Participants' contributions (Cash basis ex GST as per note 2(b)) (cont'd)

	2020	2019	Cumulative 2005 to 2018	Total
	$	$	$	$
Australian Institute of Petroleum				
Cash contributions	250,000	250,000	2,950,000	3,450,000
In-kind contributions				
- Salaries	-	172,000	862,499	1,034,499
- Other	-	-	55,385	55,385
Total	250,000	422,000	3,867,884	4,539,884
BHP				
Cash contributions	1,031,000	740,000	6,323,158	8,094,158
In-kind contributions				
- Salaries	-	-	1,402,924	1,402,924
- Other	-	-	366,600	366,600
Total	1,031,000	740,000	8,092,682	9,863,682
CSIRO				
Cash contributions	-	-	-	-
In-kind contributions				
- Salaries	561,000	507,000	2,511,759	3,579,759
- Other	115,000	55,000	-	170,000
Total	676,000	562,000	2,511,759	3,749,759
Chemistry Centre Department of Industry and Resources (Western Australia)				
Cash contributions	156,000	125,000	1,603,750	1,884,750
In-kind contributions				
- Salaries	-	45,531	2,087,895	2,133,426
- Other	-	-	1,030,855	1,030,855
Total	156,000	170,531	4,722,500	5,049,031
CH2MHill Australia Pty Ltd				
Cash contributions	-	15,000	165,000	180,000
In-kind contributions				
- Salaries	-	10,500	43,462	53,962
- Other	-	-	-	-
Total	-	25,500	208,462	233,962
Coffey Environments Ltd				
Cash contributions	-	-	90,000	90,000
In-kind contributions				
- Salaries	-	-	38,850	38,850
- Other	-	-	-	-
Total	-	-	128,850	128,850

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Notes to the Financial Statements

For the Year Ended 30 June 2020

14 Participants' contributions (Cash basis ex GST as per note 2(b)) (cont'd)

	2020	2019	Cumulative 2005 to 2018	Total
	$	$	$	$
Curtin University of Technology				
Cash contributions	150,000	150,000	1,813,100	2,113,100
In-kind contributions				
- Salaries	54,000	-	3,631,174	3,685,174
- Other	-	-	288,879	288,879
Total	204,000	150,000	5,733,153	6,087,153
Department of Defence				
Cash contributions	3,005,000	2,979,000	33,464,982	39,448,982
In-kind contributions				
- Salaries	440,000	368,000	967,330	1,775,330
- Other	-	-	3,000	3,000
Total	3,445,000	3,347,000	34,435,312	41,227,312
Department of Environment Regulation (Western Australia)				
Cash contributions	-	-	2,068,444	2,068,444
In-kind contributions				
- Salaries	-	-	342,312	342,312
- Other	-	-	-	-
Total	-	-	2,410,756	2,410,756
Environment Protection Authority (South Australia)				
Cash contributions	-	-	1,300,000	1,300,000
In-kind contributions				
- Salaries	33,700	27,743	260,601	322,044
- Other	-	-	-	-
Total	33,700	27,743	1,560,601	1,622,044
Environment Protection Authority (Victoria)				
Cash contributions	-	20,000	658,000	678,000
In-kind contributions				
- Salaries	-	-	641,078	641,078
- Other	-	-	4,000	4,000
Total	-	20,000	1,303,078	1,323,078

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Notes to the Financial Statements

For the Year Ended 30 June 2020

14 Participants' contributions (Cash basis ex GST as per note 2(b)) (cont'd)

	2020	2019	Cumulative 2005 to 2018	Total
	$	$	$	$
Fibrecell Pty Ltd				
Cash contributions	-	-	-	-
In-kind contributions				
- Salaries	-	-	80,000	80,000
- Other	-	-	-	-
Total	-	-	80,000	80,000
GHD Pty Ltd				
Cash contributions	20,000	20,000	509,227	549,227
In-kind contributions				
- Salaries	27,000	-	443,440	470,440
- Other	-	-	1,606	1,606
Total	47,000	20,000	954,273	1,021,273
HLM Asia Group Limited				
Cash contributions	375,000	625,000	6,375,000	7,375,000
In-kind contributions				
- Salaries	2,602,500	1,443,276	18,219,867	22,265,643
- Other	-	-	-	-
Total	2,977,500	2,068,276	24,594,867	29,640,643
James Cook University				
Cash contributions	-	-	300,000	300,000
In-kind contributions				
- Salaries	-	-	352,038	352,038
- Other	-	-	-	-
Total	-	-	652,038	652,038
Southern Cross University				
Cash contributions	100,000	100,000	1,325,000	1,525,000
In-kind contributions				
- Salaries	716,300	868,250	6,551,307	8,135,857
- Other	154,000	158,600	5,210,132	5,522,732
Total	970,300	1,126,850	13,086,439	15,183,589
Technological Resources Pty Ltd (formerly Rio Tinto Services)				
Cash contributions	50,000	37,000	650,000	737,000
In-kind contributions				
- Salaries	-	-	426,193	426,193
- Other	-	-	44,629	44,629
Total	50,000	37,000	1,120,822	1,207,822

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Notes to the Financial Statements

For the Year Ended 30 June 2020

14 Participants' contributions (Cash basis ex GST as per note 2(b)) (cont'd)

	2020	2019	Cumulative 2005 to 2018	Total
	$	$	$	$
The University of Queensland				
Cash contributions	150,000	150,000	1,650,000	1,950,000
In-kind contributions				
- Salaries	-	-	3,811,083	3,811,083
- Other	-	-	4,450,638	4,450,638
Total	150,000	150,000	9,911,721	10,211,721
University of South Australia				
Cash contributions	100,000	100,000	3,100,000	3,300,000
In-kind contributions				
- Salaries	-	64,500	12,453,308	12,517,808
- Other	-	152,760	12,260,590	12,413,350
Total	100,000	317,260	27,813,898	28,231,158
University of Technology, Sydney				
Cash contributions	150,000	150,000	1,350,000	1,650,000
In-kind contributions				
- Salaries	-	679,875	6,489,586	7,169,461
- Other	-	37,500	1,422,967	1,460,467
Total	150,000	867,375	9,262,553	10,279,928
Victorian Urban Development Authority (VICURBAN)				
Cash contributions	-	-	120,000	120,000
In-kind contributions				
- Salaries	-	-	-	-
- Other	-	-	-	-
Total	-	-	120,000	120,000
VERUTEK				
Cash contributions	-	-	37,312	37,312
In-kind contributions				
- Salaries	-	-	15,000	15,000
- Other	-	-	-	-
Total	-	-	52,312	52,312
Chevron Australia				
Cash contributions	50,000	37,000	430,000	517,000
In-kind contributions				
- Salaries	-	-	7,950	7,950
- Other	-	-	-	-
Total	50,000	37,000	437,950	524,950

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Notes to the Financial Statements

For the Year Ended 30 June 2020

14 Participants' contributions (Cash basis ex GST as per note 2(b)) (cont'd)

	2020	2019	Cumulative 2005 to 2018	Total
	$	$	$	$
Mobil Australia (Third party)				
Cash contributions	-	-	1,617,103	1,617,103
In-kind contributions				
- Salaries	-	-	-	-
- Other	-	-	-	-
Total	-	-	1,617,103	1,617,103
Queensland Department of Environment and Resource Management				
Cash contributions	-	-	1,493,088	1,493,088
In-kind contributions				
- Salaries	-	-	2,290,794	2,290,794
- Other	-	-	1,654,436	1,654,436
Total	-	-	5,438,318	5,438,318
Other Commonwealth (Third Party)				
Cash contributions	-	-	213,615	213,615
In-kind contributions				
- Salaries	-	-	-	-
- Other	-	-	-	-
Total	-	-	213,615	213,615
Scholarship Support (Third Party)				
Cash contributions	-	-	-	-
In-kind contributions				
- Salaries	-	-	233,750	233,750
- Other	-	-	-	-
Total	-	-	233,750	233,750
National Measurement Institute (NMI)				
Cash contributions	-	-	-	-
In-kind contributions				
- Salaries	352,100	364,518	2,341,208	3,057,826
- Other	119,000	145,294	399,397	663,691
Total	471,100	509,812	2,740,605	3,721,517
Hort Resources (Third Party)				
Cash contributions	-	-	-	-
In-kind contributions				
- Salaries	-	-	6,400	6,400
- Other	-	-	25,000	25,000
Total	-	-	31,400	31,400

CRC CARE Pty Ltd

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Notes to the Financial Statements

For the Year Ended 30 June 2020

14 Participants' contributions (Cash basis ex GST as per note 2(b)) (cont'd)

	2020	2019	Cumulative 2005 to 2018	Total
	$	$	$	$
Lasse and Rumbaugh (Third Party)				
Cash contributions	-	-	-	-
In-kind contributions				
- Salaries	-	-	-	-
- Other	-	-	10,400	10,400
Total	-	-	10,400	10,400
JBS&G (Soil & Groundwater)				
Cash contributions	-	-	87,500	87,500
In-kind contributions				
- Salaries	-	-	-	-
- Other	-	-	-	-
Total	-	-	87,500	87,500
Other (Third party)				
Cash contributions	1,665,000	822,000	945,193	3,432,193
In-kind contributions				
- Salaries	-	-	53,550	53,550
- Other	-	-	-	-
Total	1,665,000	822,000	998,743	3,485,743
Capital Technic Group Pty Ltd				
Cash contributions	-	-	160,000	160,000
In-kind contributions				
- Salaries	-	-	8,000	8,000
- Other	-	-	-	-
Total	-	-	168,000	168,000
Worsley Alumina Pty Ltd				
Cash contributions	-	-	150,000	150,000
In-kind contributions				
- Salaries	-	-	13,500	13,500
- Other	-	-	-	-
Total	-	-	163,500	163,500
University of Western Sydney				
Cash contributions	50,000	50,000	250,000	350,000
In-kind contributions				
- Salaries	-	48,851	383,198	432,049
- Other	-	70,939	386,075	457,014
Total	50,000	169,790	1,019,273	1,239,063

CRC CARE Pty Ltd

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Notes to the Financial Statements

For the Year Ended 30 June 2020

14 Participants' contributions (Cash basis ex GST as per note 2(b)) (cont'd)

	2020	2019	Cumulative 2005 to 2018	Total
	$	$	$	$
Royal Melbourne Institute of Technology				
Cash contributions	100,000	100,000	400,000	600,000
In-kind contributions				
- Salaries	275,100	304,500	499,425	1,079,025
- Other	64,000	53,335	64,673	182,008
Total	439,100	457,835	964,098	1,861,033
University of Newcastle				
Cash contributions	313,000	188,000	937,500	1,438,500
In-kind contributions				
- Salaries	1,137,600	1,158,214	3,883,548	6,179,362
- Other	2,312,213	2,340,948	4,458,768	9,111,929
	3,762,813	3,687,162	9,279,816	16,729,791
ACLCA				
Cash contributions	5,000	-	10,000	15,000
In-kind contributions				
- Salaries	-	-	-	-
- Other	-	-	-	-
Total	5,000	-	10,000	15,000
Pacific Environment				
Cash contributions	-	-	-	-
In-kind contributions				
- Salaries	-	-	18,000	18,000
- Other	-	-	-	-
Total	-	-	18,000	18,000
Master Builders Australia				
Cash contributions	30,000	-	30,000	60,000
In-kind contributions				
- Salaries	-	-	-	-
- Other	-	-	-	-
Total	30,000	-	30,000	60,000

CRC CARE Pty Ltd

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Notes to the Financial Statements

For the Year Ended 30 June 2020

14 Participants' contributions (Cash basis ex GST as per note 2(b)) (cont'd)

	2020	2019	Cumulative 2005 to 2018	Total
Total Commonwealth Contributions				
Cash contributions	759,000	1,466,000	53,875,000	56,100,000
Total Contributions	-	-	-	-
Cash contributions	8,509,000	8,187,000	126,626,972	143,322,972
In-kind contributions	-	-	-	-
- Salaries	6,290,800	6,141,258	71,584,578	84,016,636
- Other	2,961,213	3,211,000	33,026,567	39,198,780
Total	**17,761,013**	**17,539,258**	**231,238,117**	**266,538,388**

15 Remuneration of Auditors'

	2020 $	2019 $
Remuneration of the auditor for:		
- auditing or reviewing the financial statements	**24,500**	24,500

16 Commitments for expenditure

At balance date the entity had the following commitments for expenditure:

- Funding obligations in relation to the appointment of research staff to address research areas that are relevant to the Company's obligations under the terms of the Commonwealth Agreement. The sum of the cash obligations is $3,960,306 (2019: $2,532,492).

- Non-staff component of Research projects to the extent of cash $1,076,660 (2019: $1,196,705) subject to satisfactory performance as evaluated on a 3 monthly basis.

- Funding obligations for the secondment of employees to provide services to the company for the period to 30 June 2021. The total sum of the obligations are $386,923 (2019: $398,357).

	2020 $	2019 $
Payable within 1 year	**5,423,889**	4,127,554

CRC CARE Pty Ltd

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Notes to the Financial Statements

For the Year Ended 30 June 2020

17 Contingencies

CRC CARE Pty Ltd had the following contingent liabilities at the end of the reporting period:

Under the terms of the Participants Agreement entered into by the Company on 6 July 2011, certain Participants, who are not shareholders of the Company, have agreed to make defined contributions (both cash and in-kind) to the Company in return for an interest in any intellectual property and income from commercialisation arising from the projects to which the Company applied the relevant contributions.

At balance date, the interest of Participants, other than shareholders, in any intellectual property and income from commercialisation arising from projects funded by the Company is calculated to be 16.45% (2019: 16.16%) based on total contributions, both cash and in-kind, from the inception of CRC CARE in 2005.

18 Related Party Transactions

(a) Research and consultancy services

The Company engaged related parties that are either shareholders and/or Participants to carry out research activities funded by the Company.

The Company also, on occasion engages related parties to provide consultancy services to the Company.

The Company's commitments in relation to research and consultancy services provided or to be provided by Participants are included in note 16.

(b) Management services

Subsequent to the move of operations of CRC CARE to the University of Newcastle, the Managing Director is engaged via a secondment agreement from the University of Newcastle, a Participant. The agreement provides for the Managing Director to act as the Founding Director of the Global Centre for Environmental Remediation ("GCER") for 20% of his time. The balance of the Managing Director's time remains dedicated to the Company.

The Company has appropriate governance protocols and appropriate delegation of operational duties to deal with this relationship.

(c) In-kind transactions

The Company receives in-kind contributions, both staff and non-staff from Participants and applies these contributions to assist related parties to carry out research contracts entered into with the Company. During the year ended 30 June 2020 staff and non-staff in-kind contributions from Participants totaled $9,252,013 (2019: $9,352,258).

19 Subsequent events

No matter or circumstances has occurred subsequent to year end that has significantly affected, or may significantly affect, the operations of the Company, the results of those operations or the state of affairs of the Company or economic entity in subsequent financial years.

CRC CARE Pty Ltd

ACN 113 908 044

Notes to the Financial Statements

For the Year Ended 30 June 2020

20 Economic Dependency and continuance of operations

The Company depends upon continued support from Participants and the Commonwealth of Australia for its ongoing operations. During the period ending 30 June 2020 approximately 91% (2019: 82%) of the Company's cash contributions of $8,509,000 (2019: $8,187,000) was sourced from Participants and 9% (2019: 18%) from the Commonwealth of Australia.

21 Cash Flow Information

(a) Reconciliation of net cash flows from operating activities to operating profit after income tax

	2020 $	2019 $
Profit for the year	-	-
Depreciation	14,437	17,158
Reclassification of non-current assets	74,781	-
Changes in assets and liabilities:		
- decrease/(increase) in trade and other receivables	192,454	(326,434)
- increase in assets held for sale	(74,781)	-
- decrease/(increase) in other current assets	211,957	(171,276)
- decrease/(increase) in tax liability	25,000	(27,320)
- (decrease)/increase in payables	(688,663)	54,138
- increase/(decrease) in provisions	37,401	(2,444)
- increase in accrued expenses	92,164	346,198
- (decrease)/increase in deferred revenue	(2,666,757)	133,809
Cashflows from operations	**(2,782,007)**	**23,829**

22 Statutory Information

The registered office and principal place of business of the company is:

CRC CARE Pty Ltd
IDC Building
University of Newcastle
Callaghan NSW 2308

CRC CARE Pty Ltd

ACN 113 908 044

Directors' Declaration

The directors have determined that the Company is not a reporting entity and that this special purpose financial report should be prepared in accordance with the accounting policies described in Note 2 to the financial statements.

The directors of the Company declare that:

1. The financial statements and notes, as set out on pages 5 to 29, are in accordance with the *Corporations Act 2001* and:

   (a) comply with Accounting Standards as stated in Note 1; and

   (b) give a true and fair view of the Company's financial position as at 30 June 2020 and of its performance for the year ended on that date in accordance with the accounting policies described in Note 2 to the financial statements.

2. In the directors' opinion, there are reasonable grounds to believe that the Company will be able to pay its debts as and when they become due and payable.

This declaration is made in accordance with a resolution of the Board of Directors.

Chairman of Board of Directors .....
Dr Paul Vogel

CEO & Managing Director .....
Prof Ravi Naidu

Dated 12 October 2020

PKF

INDEPENDENT AUDITOR'S REPORT

TO THE MEMBERS OF CRC CARE PTY LTD

Report on the Audit of the Financial Report

Opinion

We have audited the financial report of CRC CARE Pty Ltd (the Company), which comprises the statement of financial position as at 30 June 2020, the statement of profit or loss and other comprehensive income, statement of changes in equity and statement of cash flows for the year then ended, and notes to the financial statements, including a summary of significant accounting policies, and the directors' declaration.

In our opinion, the accompanying financial report of CRC CARE Pty Ltd is in accordance with the Corporations Act 2001, including:

(a) giving a true and fair view of the Company's financial position as at 30 June 2020 and of its performance for the year then ended; and

(b) complying with Australian Accounting Standards to the extent described in Note 1, and the Corporations Regulations 2001.

Basis for Opinion

We conducted our audit in accordance with Australian Auditing Standards. Our responsibilities under those standards are further described in the Auditor's Responsibilities for the Audit of the Financial Report section of our report.

We believe that the audit evidence we have obtained is sufficient and appropriate to provide a basis for our opinion.

Emphasis of Matter – Basis of Accounting

We draw attention to Note 1 to the financial report, which describes the basis of accounting. The financial report has been prepared for the purpose of fulfilling the directors' financial reporting responsibilities under the Corporations Act 2001. As a result, the financial report may not be suitable for another purpose. Our opinion is not modified in respect of this matter.

Independence

We are independent of the Company in accordance with the auditor independence requirements of the Corporations Act 2001 and the ethical requirements of the Accounting Professional and Ethical Standards Board's APES 110 Code of Ethics for Professional Accountants (including Independence Standards) (the Code) that are relevant to our audit of the financial report in Australia. We have also fulfilled our other ethical responsibilities in accordance with the Code.

We confirm that the independence declaration required by the Corporations Act 2001, which has been given to the directors of the Company, would be in the same terms if given to the directors as at the time of this auditor's report.

PKF

Responsibilities of the Directors for the Financial Report

The directors of the Company are responsible for the preparation of the financial report that gives a true and fair view and have determined that the basis of preparation described in Note 1 to the financial report is appropriate to meet the requirements of the Corporations Act 2001 and is appropriate to meet the needs of the members. The directors' responsibility also includes such internal control as the directors determine is necessary to enable the preparation of a financial report that gives a true and fair view and is free from material misstatement, whether due to fraud or error.

In preparing the financial report, the directors are responsible for assessing the Company's ability to continue as a going concern, disclosing, as applicable, matters relating to going concern and using the going concern basis of accounting unless the directors either intend to liquidate the Company or to cease operations, or have no realistic alternative but to do so.

Auditor's Responsibilities for the Audit of the Financial Report

Our objectives are to obtain reasonable assurance about whether the financial report as a whole is free from material misstatement, whether due to fraud or error, and to issue an auditor's report that includes our opinion. Reasonable assurance is a high level of assurance, but is not a guarantee that an audit conducted in accordance with the Australian Auditing Standards will always detect a material misstatement when it exists. Misstatements can arise from fraud or error and are considered material if, individually or in the aggregate, they could reasonably be expected to influence the economic decisions of users taken on the basis of this financial report.

As part of an audit in accordance with the Australian Auditing Standards, we exercise professional judgment and maintain professional scepticism throughout the audit. We also:

- Identify and assess the risks of material misstatement of the financial report, whether due to fraud or error, design and perform audit procedures responsive to those risks, and obtain audit evidence that is sufficient and appropriate to provide a basis for our opinion. The risk of not detecting a material misstatement resulting from fraud is higher than for one resulting from error, as fraud may involve collusion, forgery, intentional omissions, misrepresentations, or the override of internal control.

- Obtain an understanding of internal control relevant to the audit in order to design audit procedures that are appropriate in the circumstances, but not for the purpose of expressing an opinion on the effectiveness of the Company's internal control.

- Evaluate the appropriateness of accounting policies used and the reasonableness of accounting estimates and related disclosures made by the directors.

- Conclude on the appropriateness of the directors' use of the going concern basis of accounting and, based on the audit evidence obtained, whether a material uncertainty exists related to events or conditions that may cast significant doubt on the Company's ability to continue as a going concern. If we conclude that a material uncertainty exists, we are required to draw attention in our auditor's report to the related disclosures in the financial report or, if such disclosures are inadequate, to modify our opinion. Our conclusions are based on the audit evidence obtained up to the date of our auditor's report. However, future events or conditions may cause the Company to cease to continue as a going concern.

PKF

Auditor's Responsibilities for the Audit of the Financial Report (cont'd)

- Evaluate the overall presentation, structure and content of the financial report, including the disclosures, and whether the financial report represents the underlying transactions and events in a manner that achieves fair presentation.

We communicate with the directors regarding, among other matters, the planned scope and timing of the audit and significant audit findings, including any significant deficiencies in internal control that we identify during our audit.

We also provide the directors with a statement that we have complied with relevant ethical requirements regarding independence, and to communicate with them all relationships and other matters that may reasonably be thought to bear on our independence, and where applicable, action taken to eliminate threats or safeguards applied.

PKF

PKF

MARTIN MATTHEWS
PARTNER

12 OCTOBER 2020
NEWCASTLE NSW

CRC CARE PARTNERS

Agilent Technologies Australia Pty Ltd

Australian Contaminated Land Consultants Association Incorporated

Australian Institute of Petroleum Ltd

BHP

ChemCentre (WA)

Chevron Australia Pty Ltd

CSIRO

Curtin University

Department of Defence

Department of Environment and Resource Management (Queensland)

Department of Industry, Science, Energy and Resources – National Measurement Institute

Environment Protection Authority (SA)

Environment Protection Authority (Victoria)

EthicalChem

FibreCell Australia Pty Ltd

GHD Pty Ltd

HLM Asia Group Limited

JBS&G Pty Ltd

Master Builders Australia

Royal Melbourne Institute of Technology (RMIT)

Southern Cross University

Technological Resources Pty Ltd (Rio Tinto)

University of Newcastle

University of Queensland

University of South Australia

University of Technology, Sydney

University of Western Sydney

WA Department of Environment Regulation

UNIVERSITY OF TECHNOLOGY SYDNEY

RioTinto

BHP

Chevron

Agilent Technologies

Government of Western Australia Department of Environment Regulation

GHD

JBS&G

THE UNIVERSITY OF NEWCASTLE AUSTRALIA

ChemCentre EXPERT SOLUTIONS

EPA VICTORIA

EPA South Australia

EthicalChem An Ethical Solutions, LLC Division

UniSA

CSIRO

AIP Australian Institute of Petroleum

Australian Government Department of Defence

HLM ASIA GROUP LIMITED

FibreCell Australia Pty Ltd ACN 114 025 759

University of Western Sydney Bringing knowledge to life

Australian Government National Measurement Institute

ACLCA

RMIT UNIVERSITY

Queensland Government

Curtin University

Southern Cross UNIVERSITY A new way to think

MASTER BUILDERS AUSTRALIA

THE UNIVERSITY OF QUEENSLAND AUSTRALIA

CRC CARE
A safer, cleaner environmental future

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