CRC CARE

A safer, cleaner environmental future

CRC CARE:
Performance Review Impact Indicator Tool
Companion Document
March 2015

Contents

1. Introduction

This document serves as the 'Performance Review Impact Indicator Tool Companion Document' and supports a revised Impact Tool which has been provided for consideration as part of CRC CARE's Fourth Year Performance Review.

The document compares the original Impact Tool with the revised Impact Tool and provides an assessment of achievements, a discussion and rationale for changes and relevant actions taken by CRC CARE.

As described in our report delivered to the Department titled 'Key areas of investigation under the terms of reference' CRC CARE works collaboratively with end-users and research partners to strategically deliver on the research activities described in the original bid. As described by end user Paul Barrett, Deputy Executive Director at Australian Institute of Petroleum Ltd, CRC CARE applies a 'deliberate design for implementation' to its projects - an approach that has been refined since the inception of CRC CARE 1 and now contributes significantly towards the achievement of impacts which we are pleased to say have exceeded our original estimates.

2. Approach

CRC CARE's original and revised Impact Tool was developed on the basis of extensive consultation with end users and on conservative estimates. The original impact tool engaged end users from petroleum, defence, mining, practitioners (ACLCA) and regulators along with researchers to quantify usages and impacts and to determine their probability of occurring. The same approach was adopted to develop the revised impact tool, consulting with 19 end users from mining, defence and petroleum; government, regulators, SME technology organisations and numerous researchers. Over thirty projects were reviewed with end-users having an active role in the development, testing, refinement and quantification of impacts and the basis for their quantification. Assumptions were often drawn from demonstrated impacts evident at end user pilot projects. Changes to text and figures in the revised impact tool are coloured red.

3. Assessment Summary

The revised impact tool sees an overall cost-benefit ratio of 5.98 which is an increase upon the original estimate of 4.95 and based upon conservative impact estimates verified by end users. More broadly, CRC CARE has established a reputation as a trusted and credible organisation that brings value to the sector. This is a recurring theme reiterated by end users and is reflected in comments such as:

"Having the CRC and what it does is great for industry. It saves industry a huge amount of time and money with the production of guidance documents and conferences".

Peter Nadebaum, GHD

"They keep us at the forefront internationally and contribute to a big problem for all jurisdictions. Given the money spent in the area this is very important".

Andrew Pruszinski, EPA South Australia

"The CRC has saved the sector a fortune because it presents a smarter way of doing things. For the first time they brought the regulators along. In the past a consultant may have been dabbling in a bit of science but lacked the credibility or resources to have impact."

Terry Weston, former Department of Defence

In some areas CRC CARE has exceeded the original expectations, particularly in relation to education, training and communication including the development of a practitioner certification scheme and online access to 34 technical reports from CRC CARE I and II; development of evidence based novel remediation technologies; and NEPM's adoption of Health Screening Levels (HSL) for hydrocarbons and standard operating procedure for heavy metal(loid)s bioavailability. More broadly, CRC CARE has exceeded expectations in terms of establishing a critical mass of research, industry, regulatory and practitioner expertise that by applying scientific rigour, has established an innovative and progressive sector that is able to better manage and reduce the environmental consequences from their operations.

Figure 1 provides an overview of original and revised benefit-cost ratios and Figure 2 provides an overview of net present value (NPV) differences between the revised and original impact tool. Following this is a rationale and explanation of major changes.

Figure 1 Summary of cost-benefit ratio in original and revised impact tool

	Original	Revised
Program 1	6.81	3.46
Program 2	3.16	4.38
Program 3	10.43	3.13
Program 4	2.76	7.04
Over-all	4.95	5.98

Figure 2 Summary of differences in inputs, usages and impacts between the revised and original impact tool

	Input Costs		Usage Costs		Impacts	
	Total Inputs	Total NPV	Total NPV	Expected (risk-adjusted) NPV	Total NPV	Expected (risk-adjusted) NPV
Original Impact Tool	**166,082,000**	**$ 132,347,440**	**$ 3,833,931**	**$ 1,652,418**	**$ 5,143,313,436**	**$ 663,557,024**
Program 1	-$ 1,066,236	-$ 1,380,712				
Program 2	-$ 5,243,213	-$ 5,245,990				
Program 3	$ 1,449,647	$ 1,169,782				
Program 4	15,312,413	$ 13,397,357				
Program 1			$ 814,893	$ 456,340		
Program 2			$ 21,766,907	$ 10,735,590		
Program 3			$ 159,307,973	$ 42,853,845		
Program 4			$ 884,569,498	$ 255,394,112		
Program 1					-$ 1,241,685,034	-$ 99,719,144
Program 2					-$ 320,059,731	$ 74,537,287
Program 3					-$ 1,126,568,072	-$ 14,647,847
Program 4					$ 9,021,855,614	$ 2,074,954,201
Revised Impact Tool	**$ 176,534,611**	**$ 140,287,877**	**$ 1,070,293,202**	**$ 311,092,305**	**$ 11,476,856,212**	**$ 2,698,681,521**

Our updated impact assessment reveals that CRC CARE will contribute $2.7 billion dollars of direct economic impact, which is over and above the input and usage costs of realising these impacts. These impacts are more than 4 times the original impacts that CRC CARE had hoped to achieve; represent a 15 fold return on inputs and include significant non-financial benefits associated with reduced risk to human health and the environment and improved environmental practices. Usage costs have increased significantly in the revised Impact Tool as CRC CARE has developed new technologies that have demonstrated that contaminated land and water that couldn't be economically remediated under conventional approaches now can be, making the land available for re-use.

These impacts have been developed by an independent consultant engaged by CRC CARE who has developed risk adjusted estimates in collaboration with end users and other stakeholders.

4. Key Rationale for Changes

4.1 COST-BENEFIT RATIO

The overall cost-benefit ratio varied from the original impact tool assessment because:

- Input costs are $10.453 million more than the original estimates;
- End users recommended changes to the allocation of impacts across the four programs;
- New impacts were included such as impacts from the Certified Practitioner Scheme and employment of PhDs; and
- End users used data from demonstration projects to calculate estimated usage costs, savings and impacts from CRC CARE technologies which exceeded original usage and impact estimates.

4.2 INPUT FIGURES

Input costs are $10.453 million more over the nine years than the original figures. This is from a combination of factors that saw the total value of the CRC's inputs decrease as:

- The original impact tool was based on the premise of an additional $10.8 million in commonwealth funding which wasn't awarded; and
- That projects began later in the first year due to the time taken to establish CRC CARE agreements, meaning that approximately $5 million less in in-kind contributions was devoted to project work than anticipated.

Factors that have resulted in the CRC's inputs increasing are:

- Contributions from three new participants, RMIT, University of Newcastle and University of Western Sydney, will provide $2.6 million in cash and $10.7 million in in-kind contributions over the life of the CRC; and
- Fluctuations in cash contributions over years 1 to 3, most notably from the Department of Defence, resulted in a net increase of $7.886 million over the 3 year period.

CRC CARE strategically revised projects and budgets in accordance with changes to inputs to ensure delivery upon milestones specified in the Commonwealth Agreement and to meet end user needs.

4.3 USAGE FIGURES

Usage costs have increased significantly in the revised impact tool. This is driven by CRC CARE's demonstration projects which provided evidence on the benefits of specific remediation technologies, meaning that land and water which previously couldn't be remediated now can be. Users will invest in the capital and operational expenses for the respective technologies; save costs such as storage of contaminated soil and monitoring ground water contamination; and cost effectively remediate to re-use the land. For example, matCARE™ provides a cost effective approach to the remediation of fire fighting contaminants such as PFOS and PFOA for which there is currently no remediation alternative. The current approach is to store the contaminated soil on site and monitor the contaminated ground water, meaning that the land cannot be used for other productive use, organisations have to pay for monitoring and storage

which is reflected as a liability on their balance sheets. Remediation, through the application of matCARE™, means that the land can be used for other purposes, organisations can save on storage and monitoring costs, and the potential risk to human health and the environment is removed.

4.4 PROGRAM 1: BEST PRACTICE POLICY

End users noted that original Impact Tool assumptions for Program 1 were very conservative. They expect significant impacts will be generated, particularly from the National Remediation Framework and recommended two changes to the impacts:

1. Sector wide impacts be allocated to Program 1 and Program 3 thus contributing to a lower benefit-cost ratio for both affected programs; and
2. The estimated savings be reduced. The reason being that the National Remediation Framework will enhance clarity and consistency across jurisdictions providing most benefit to industry from spending less time navigating different jurisdictions. The CRC CARE work from Program 1 and Program 3 will pave the way for greater uptake of novel technologies (Program 4).

Industry expects significant advantages from the National Remediation Framework which was described by Paul Barrett, AIP as *'a quantum step forward for the industry'* with benefits including greater regulatory certainty, improved community acceptance and lower costs to industry. The end users considered this project to have a very high probability of success with respect to research outputs, usage and implementation citing the main reason being the project approach, which was designed at the outset with implementation in mind. It applied the CRC CARE's successful approach which saw NEPM adoption of recommended guidelines, involving all relevant stakeholders, including regulators.

Insights from EPA Western Australian Chairman, Dr Paul Vogel indicated that engagement of all relevant stakeholders, including heads of regulatory bodies, meant that the National Remediation Framework would very likely be adopted. He stated the approach, *"predicated on engagement and implementation with comprehensive representation means that all parties are on the same page".* Dr Vogel also noted that harmonising environmental regulation has been a common theme at the federal government level and on Monday, 23 February 2015, the Standing Committee on the Environment tabled its report – *Streamlining environmental legislation – Inquiry into streamlining environmental regulation, 'green tape', and one stop shops.*

A new impact was included in all Programs to reflect economic benefits from the employment of PhDs. Program 1's education and training impact also included forecast benefits from the Certified Practitioner Scheme. The scheme was initiated from a need identified by industry and regulators to develop quality standards for practitioner assessments and developed collaboratively over a two year period. The approach adopted CRC CARE's deliberate design for implementation by involving industry, regulators and practitioners who informed the program, assessment and governance. The scheme was launched in November 2014 and is already incorporated into EPA Tasmania's business processes and included as an item to address in some large request for tenders.

4.5 PROGRAM 2: BETTER MEASUREMENT

Program 2's revised cost-benefit ratio has increased due to impacts modelled on successful demonstration projects and to project changes as described below.

Impact 2.02 is significantly higher than original estimates and now includes estimated impacts from the application of lidar, a laser radar system, to enhance the accuracy of wind farm energy yield and provide more accurate modelling and forecasting data. This project extends research conducted in CRC CARE I which saw the development of the technology to identify, track and quantify dust emissions from mining operations. Towards the end of CRC CARE I's term a detailed study was conducted at Port Hedland, Australia's largest bulk export port, to demonstrate the utility of the technology under operational settings. The research provided profound insights into the nature of the dust management challenge at the port, and the limitations with industry management practices and Government regulatory policy. Strategies to address the identified challenges were suggested and are currently being considered by the state government as part of the Port Hedland Dust Health Risk Assessment which is scheduled for release in July 2015. Meanwhile industry operating in the region, including BHP and Fortescue Metals Group, are evaluating the technology with a likelihood that they will adopt it to assist with dust monitoring.

The lidar technology has other potential applications such as assessment of wind shear detection at airports; detection of stealth aircraft; detection and tracking of dust and aerosols; and detection of gas leaks along pipelines. The calculated impact applies only to the estimated impact from using lidar to increase wind energy yields at wind farms.

Impact 2.03 was originally calculated from estimates provided by the Department of Defence. The particular project didn't eventuate and instead CRC CARE recently began a project with participants, EPA Victoria and RMIT, to develop integrated information management tools suitable for the Fishermen's Bend development project, with the intent that the tools will be suitable for use by EPA Victoria and other jurisdictions.

The project's objectives, to streamline decision making, increase transparency and develop effective strategies to share data, align with challenges identified in the EPA Audit Reform which was initiated in 2012 when the EPA and the Victorian Competition and Efficiency Commission (VCEC) undertook a joint pilot study to review and identify opportunities to improve risk-based regulation in the area of environmental auditing of contaminated environments under the Environmental Protection Act 1970. Anne Northway, EPA Victoria noted that the project '*provides a great opportunity for the EPA, industry and the PhD candidate and has potential to generate significant impact*'. Very conservative estimates have been used to calculate the impact which is less than the original estimated impact from the Department of Defence project. EPA Victoria would be willing to measure impacts during the research project to update as it progresses.

Conservative impacts have been modelled using data collected for the EPA Audit Reform and include avoided delay costs associated with time taken to make 'clean up to the extent practicable' (CUTEP) decisions following submission / notification from an environmental auditor. The avoided delay costs will come predominantly from more streamlined and transparent risk based decision making. The EPA Audit Reform report estimated avoided delay costs per annum to range from $2.2 million to $7.1 million based on an average number of

assessments per annum in Victoria. The revised impact tool applied a portion of the medium range assumption of $3.9 million.

Industry will save on assessments as EPA Victoria will share data collected on the precinct's ground water. The data will be provided in user-friendly mediums and use geographic information systems. Not costed in the impacts is savings from avoiding development delays which will mean more timely completion of projects.

Impact 2.04 was originally estimated from *standards for sampling contaminated material* however during the initial consultation phase of the project following commencement of CARE II, end users noted that standards already existed both internationally, via the International Standard Organisation, and nationally, via Standards Australia, however there was a need to provide training on sampling design and techniques. The Managing Director (Chair, EP09) was also involved with the development of Standard's Australia method for sampling soils.

In collaboration with end users, the CRC will raise awareness and understanding of existing sampling guidelines through training on sampling design and methods for environmental managers. Industry end users estimated that many assessments had errors related to a lack of understanding sampling design and techniques incurring rework and delays to development. The revised impact for this new project is significantly higher than the original estimate.

4.6 PROGRAM 3: MINIMISING UNCERTAINTY IN RISK ASSESSMENT

The revised cost benefit for Program 3 is less than the original estimate as end users considered it more appropriate to split a sector wide impact across Programs 1 and 3, given the synergy between guidelines for assessment and remediation.

Whilst this resulted in a decreased impact for Programs 1 and 3 end users noted that novel technologies, such as those being developed in Program 4, are likely to be positively impacted from recent and future assessment recommendations from Programs 1 and 3.

4.7 PROGRAM 4: CLEANING UP

The cost benefit for Program 4 is significantly higher than the original cost benefit. Revised impacts include a range of 'green' remediation technologies and also the application of risk based management strategies, many of which have proven to be faster, cheaper clean up approaches than conventional techniques. Adoption of technologies is very conservative and likely to occur even without recommended guidelines on assessment and remediation from Programs 1 and 3.

These technologies not only mean that sites can be remediated more quickly and cheaply but also sites will be remediated that otherwise may not have been. This will reduce corporate and government liability, potential risk to human health and environmental damage and provide land available for re-use and development.

The industry feedback on the benefits of the novel technologies was extremely positive with comments such as:

"The in situ bioremediation of TCE ground water offers great promise to clean up TCE contaminated ground water as an alternative to traditional remediation methods which are disruptive and of limited practical use."

"S-ICSO TCE ground water remediation works well compared to other technologies. It solves something that couldn't previously be done meaning land that previously couldn't be remediated can now be remediated. This provides development potential, reduced risk to human health and potential liability."

"Monitored natural attenuation of TPH in ground water offers a proven technology. What may have been a $50 million clean-up can be done for $5 million and take ten to twenty percent of the time."

Former Department of Defence representatives

5. Detailed Changes

Figures 3 and 4 provide an overview of changes at the input, output, usage and impact level. Changes have been made in response to the evolving needs of end users, including regulators, petroleum, mining, and defence sectors; to align the revised impact tool with CRC CARE's revised Commonwealth Agreement; and to adjust to changes in input figures. Figure 3 addresses qualitative changes and Figure 4 addresses quantitative changes.

Figure 3 Changes to outputs, usages and impacts

Output 1.01	**National guidance for emergent and priority contaminants.** No significant changes to guidance for emergent and priority contaminants other than some detail added in the brief description as follows: • Developing guidance for assessment and remediation/management of priority contaminants; and • Guidance for flux (movement of a contaminant across a surface boundary per unit time) based end points. All milestones have been updated to reflect changes in the Commonwealth Agreement (CA). This includes an updated Education and Training output description and milestones. A 2013/14 Training and Education milestone was included which is additional to specified milestones in the CA. The milestone was delivery of industry information sessions.to 252 participants.
Usage 1.01	No material changes.
Impact 1.01	New insights and evidence from end users has altered impacts. Changes to 'Developing guidance for assessment and remediation management of priority contaminants' are: • To split the overall impact 50/50 between 1.01 and Program 3 impacts. • BHP impact is based on demonstrated savings from usage of biopile (Usage 1.01). This impact is now allocated to 1.01 and Program 4. Changes to impacts related to flux based end points are: • A conservative increase of industry wide savings from 5% to 10% based on end user interviews. • Removed reference in milestones years 6 to 15: 'Endpoints supported by next generation health and environmental screening levels'. This is relevant to Program 3.

Output 1.02	**National guidance framework for Australian remediation.** No material changes. Output description and milestones have been adjusted to align with CA. Training and Education milestones are included which are in addition to milestones specified in the CA and are related to delivery of industry information sessions.
Usage 1.02	No material changes. Milestones have been adjusted to align with the CA.
Impact 1.02	Based on end user interviews the original impact estimated for 1.04 on strategies for effective community engagement is now split between 1.02 and 1.04 however the two were not considered to be dependent. End users expect impacts will begin 1 year earlier than originally anticipated. This is because industry will use preliminary work to guide their remediation plans even if it is not yet formally endorsed by jurisdictions.
Output 1.03	**The classification and ranking of incentives for remediation and reduction of title blight.** No material changes. Milestones have been adjusted to align with the revised CA.
Usage 1.03	No material changes. Milestones have been adjusted to align with the revised CA.
Impact 1.03	Small change to impact calculation.
Output 1.04	**Strategies for selecting remediation technologies based on effective community engagement.** No material changes. Output description and milestones have been adjusted to align with the revised CA.
Usage 1.04	No material changes. Milestones have been adjusted to align with the revised CA. Noted that no usage costs will be incurred.
Impact 1.04	Based on end user interviews the original impact estimated from strategies for effective community engagement was considered more appropriate to split between 1.02 and 1.04 however the two were not considered to be dependent. Some small impacts were reported from implementation of preliminary strategies for effective community engagement by the petroleum industry. The end user recommended that original impact calculation remains unchanged. Due to a 1 year delay in output and usage milestones, the majority of impacts are delayed by one year, now beginning in 2015/16.
Output 1.05	**Education and training including the Certified Practitioner Scheme.** This is a new output to capture additional education and training milestones that CRC CARE has / will deliver above and beyond what is specified in the CA.

Usage 1.05		No material changes. Milestones have been adjusted to align with actual / expected deliverables. Usage costs included in the original impact tool are excluded as PhD costs are part of input costs.
Impact 1.05		This new impact is included to capture economic benefits from the employment of PhD graduates and impacts from the Certified Practitioner Scheme. The Certified Practitioner Scheme is an additional milestone to specifications in the CA. It was launched in November 2014 after two years of sector wide consultation to guide its development, assessment and governance. Impacts from PhD employment is now included. CRC CARE has a large Education and Training program and PhDs are highly valued employees in the sector. The salary differential between a graduate and post graduate salary was used to quantify the impact. Anecdotally, CRC CARE's PhD graduates have a faster salary progression than those without a PhD however this differential was not included in the calculated impact.
Program Non-Monetary Impact	1	No change
Output 2.01		**Sensitive analytical techniques for emerging and priority contaminants.** No material changes. Output description and milestones have been adjusted to align with the CA. Training and Education milestones in addition to specifications in the CA are included.
Usage 2.01		No material changes. Milestones have been adjusted to align with the revised CA.
Impact 2.01		No changes.
Output 2.02		**Novel assessment and remote online monitoring system.** No material changes. Milestones have been adjusted to align with the revised CA.
Usage 2.02		Usages have been adjusted to align with the revised CA. Usage costs have been altered to reflect the capital and operating costs associated with estimated lidar adoption.
Impact 2.02		This impact is estimated on actual and projected impacts from demonstration wind energy projects using lidar.

Output 2.03	**Integrated information management tools.** This output has changed to align with the revised CA. The original output was development of an integrated management tool for the Department of Defence. However due to concerns with confidentiality the project was changed and is now the development of integrated information management tools for the EPA Victoria to apply to the Fishermen's Bend development.	
Usage 2.03	Milestones have been adjusted to align with the revised CA which is reflective of the revised output. Usage costs have been excluded as input costs include development of the tool and databases that will be freely available to the public.	
Impact 2.03	As the original output 2.03 was changed so have the impacts. Impacts reflect estimated savings related to regulators' use of an integrated information management tool and a small saving to industry from access to ground water assessment data.	
Output 2.04	**Training on sampling standards.** The output has changed to align with the revised CA which is reflective of the revised output. The original output was development of sampling guidelines. Initial consultation revealed that national and international guidelines were already established however there were problems in the industry with poor sampling design.	
Usage 2.04	Usages have been adjusted to align with the revised CA and revised project. Usage costs related to participant training are included.	
Impact 2.04	This impact has changed due to the revised output. End user estimated impacts relate to industry savings from avoided rework.	
Output 2.05	**Education and Training.** This is a new output to capture additional education and training milestones that CRC CARE has / will deliver above and beyond what is specified in the CA.	
Usage 2.05	No material changes. Milestones have been adjusted to align with actual / expected deliverables.	
Impact 2.05	This new impact is included to capture economic benefits from the employment of PhD graduates. CRC CARE has a large Education and Training program and PhDs are highly valued employees in the sector.	
Program Non-Monetary Impact	2	Additional explanation on impacts and probability is provided in relation to reduced risk to human health from the lidar project at Port Hedland. This was work conducted predominantly in CRC CARE I with some PhDs completing their research during the CRC CARE II phase.

Output 3.01	**Quantifying contaminant toxicity and bioavailability.** No material changes. Milestones have been adjusted to align with the CA.
Usage 3.01	Milestones have been adjusted to align with the CA. Usage costs associated with matCARE™ have been included.
Impact 3.01	New insights from end users altered the allocation of impacts. A sector wide impact was split between 1.01, 3.01, 3.02, 3.03. Each related output contributes to the overall impact meaning that the related outputs are not interdependent. Impacts related to matCARE™ (also included in Program 4) were partly allocated in Impacts 3.01, 3.02 and 3.03 as related outputs defining recommendations associated with PFOS and PFOA will increase the adoption of the technology.
Output 3.02	**Reasonable risk and compliance model.** No material changes. Milestones have been adjusted to align with the CA.
Usage 3.02	Milestones have been adjusted to align with the CA. Usage costs associated with matCARE™ have been included.
Impact 3.02	New insights from end users altered the allocation of impacts. A sector wide impact was split between 1.01, 3.01, 3.02, 3.03. Each related output contributes to the overall impact meaning that the related outputs are not interdependent. Impacts related to matCARE™ (also included in Program 4) were also allocated to Impacts 3.01, 3.02 and 3.03 as related outputs defining recommendations associated with PFOS and PFOA will increase the adoption of the technology. Impacts related to monitoring network design and identification of contamination sources in ground water aquifers was included.
Output 3.03	**Quantifying pathways of exposure and transient risks.** No material changes. Milestones have been adjusted to align with the CA.
Usage 3.03	Milestones have been adjusted to align with the CA. Usage costs associated with matCARE™ have been included.
Impact 3.03	New insights from end users altered the allocation of impacts. A sector wide impact was split between 1.01, 3.01, 3.02, 3.03. Each related output contributes to the overall impact meaning that the related outputs are not interdependent. Impacts related to matCARE™ (also included in Program 4) were partly allocated in Impacts 3.01, 3.02 and 3.03 as related outputs defining recommendations associated with PFOS and PFOA will increase the adoption of the technology.

Output 3.04	**Education and Training.** This is a new output to capture additional education and training milestones that CRC CARE has / will deliver above and beyond what is specified in the CA.
Usage 3.04	No material changes. Milestones have been adjusted to align with actual / expected deliverables.
Impact 3.04	This new impact is included to capture economic benefits from the employment of PhD graduates. CRC CARE has a large Education and Training program and PhDs are highly valued employees in the sector.
Program 3 Non-Monetary Impact	Specific reference was made to impacts expected from: • The Port Hedland Dust Project with respect to reduced risk to human health and environmental damage; and • rankCARE™ which also reduces potential risk to human health and the environment through a risk management tool.
Output 4.01	**New remediation technologies for emerging and priority contaminants.** No material changes. Milestones have been adjusted to align with the CA.
Usage 4.01	Usage calculations included for: matCARE™, pooCARE™ and remediation via bioslurry.
Impact 4.01	Impacts have been calculated on evidence and estimates from pilot projects and includes: • Permeable reactive barriers for the remediation of TCE contaminated ground water. This field-site approach can used in combination with surfactant enhanced in situ oxidation (S-ISCO) which can remediate the source of the original contaminant spill. • matCARE™: a proven cost effective technology for field-scale treatment of AFFF-contaminated (e.g. PFOS / PFOA) waste water and soil • pooCARE™: A highly successful green remediation technology that has been piloted in Chinese piggeries and is also applicable to other sectors such as dairy and poultry. The technology remediates animal waste to produce clean biogas energy and fertiliser. • *In situ* chemical stabilisation of shooting range soils contaminated with lead. This technology can remove and recover lead from shooting ranges and immobilise spreading of contamination underground. The clean-up approach is cheaper and more effective than traditional methods. • Bioslurry: Quicker and cheaper remediation of hydrocarbon contamination. This *in situ* approach means that previously unremediated sites can now be remediated and developed. In cases where the site had to be remediated this process provides very significant savings compared with the conventional approach which included options such as transport

	to landfill or transport and treatment by a licenced waste contractor. Transport was a major cost given the location of some sites.
Output 4.02	**Develop, test and validate sustainable and green remediation technologies.** No material changes. Milestones have been adjusted to align with the CA.
Usage 4.02	Usage calculations included for: S-ISCO for trichloroethylene (TCE) ground water remediation, natural monitored attenuation and bioremediation of TCE contaminated ground water.
Impact 4.02	Impacts have been calculated on evidence and estimates from pilot projects and includes: • S-ISCO of TCE contaminated ground water. This technology is estimated to remediate TCE contaminated ground water ten times quicker and cheaper than conventional approaches. Given the expense of conventional methods some sites are not remediated. This technology will mean savings for organisations that must remediate, opportunity to develop land that may otherwise have remained contaminated; and reduced public health risk. • Biopile: A proven technology demonstrated on BHP sites. This impact is allocated to 1.01 (50%), Impact 4.02 (25%) and Impact 4.03 (25%). • Total petroleum hydrocarbon remediation of ground water using monitored natural attenuation. The conventional approach is expensive and time consuming, with this green technology up to ten times cheaper. Further research is required to be able to apply this technology in a wider range of conditions. • Bioremediation of TCE contaminated ground water through the use of bugs that speed up the remediation process. Another cheaper and quicker approach to conventional methods.
Usage 4.03	**New sustainable and green remediation technologies** Usage calculations included for: S-ISCO for TCE ground water remediation, total petroleum hydrocarbon remediation of ground water using monitored natural attenuation, bioremediation of TCE contaminated ground water and phyto-stabilisation.
Impact 4.03	Impacts have been calculated on evidence and estimates from pilot projects and includes: • S-ISCO • Remediation through biopile • Total petroleum hydrocarbon remediation of ground water using monitored natural attenuation. • Bioremediation of TCE contaminated ground water

	• Phyto-stabilisation of large contaminated or waste land. This approach was successfully demonstrated at the former Salisbury City Council landfill site. The innovative technology uses treated effluent to irrigate the land and harvest plants with extensive environmental tolerance ranges that successfully remediate the soil. The plants can be used to generate clean biomass energy, remove carbon dioxide from the atmosphere and replace oxygen into the atmosphere.
Output 4.04	**Education and Training.** This is a new output to capture additional education and training milestones that CRC CARE has / will deliver above and beyond what is specified in the CA.
Usage 4.04	No material changes. Milestones have been adjusted to align with actual / expected deliverables.
Impact 4.04	This new impact is included to capture economic benefits from the employment of PhD graduates. CRC CARE has a large Education and Training program and PhDs are highly valued employees in the sector.

Figure 4: Changes to Input costs NPV calculations at the input, usage and impact level

		Input Costs		Usage Costs		Impacts	
		Total Inputs	Total NPV	Total NPV	Expected (risk-adjusted) NPV	Total NPV	Expected (risk-adjusted) NPV
	Original Impact Tool	**166,082,000**	**$ 132,347,440**	**$ 3,833,931**	**$ 1,652,418**	**$ 5,143,313,436**	**$ 663,557,024**
Changes to Inputs	Program 1	-$ 1,066,236	-$ 1,380,712				
	Program 2	-$ 5,243,213	-$ 5,245,990				
	Program 3	$ 1,449,647	$ 1,169,782				
	Program 4	$ 15,312,413	$ 13,397,357				
Changes to Usages	1.01			$ -	$ -		
	1.02			$ -	$ -		
	1.03			$ -	$ -		
	1.04			$ -	$ -		
	1.05			$ 814,893	$ 456,340		
	2.01			$ -	$ -		
	2.02			$ 22,778,538	$ 10,933,699		
	2.03			-$ 1,178,367	-$ 318,159		
	2.04			$ 166,736	$ 120,050		
	2.05			$ -	$ -		
	3.01			$ 47,792,392	$ 26,763,739		
	3.02			$ 63,723,189	$ 8,921,247		
	3.03			$ 47,792,392	$ 7,168,859		
	3.04			$ -	$ -		
	4.01			$ 248,423,142	$ 79,495,405		
	4.02			$ 55,556,806	$ 13,333,633		
	4.03			$ 580,589,550	$ 162,565,074		
	4.04			$ -	$ -		
Changes to Impacts	1.01					-$ 37,236,384	-$ 6,255,712
	1.02					$ 88,880,818	$ 14,931,977
	1.03					$ 749,409	$ 121,404
	1.04					-$ 1,326,397,114	-$ 119,375,741
	1.05					$ 32,318,237	$ 10,858,928
	2.01					$ -	$ -
	2.02					$ 126,070,641	$ 48,411,126
	2.03					-$ 639,411,222	-$ 86,320,515
	2.04					$ 177,768,272	$ 102,394,525
	2.05					$ 15,512,578	$ 10,052,151
	3.01					$ 267,331,747	$ 119,764,623
	3.02					-$ 1,625,791,278	-$ 159,327,545
	3.03					$ 213,181,276	$ 12,790,876
	3.04					$ 18,710,183	$ 12,124,199
	4.01					$ 1,741,406,941	$ 445,800,177
	4.02					$ 320,501,912	$ 61,536,367
	4.03					$ 6,939,688,311	$ 1,554,490,182
	4.04					$ 20,258,450	$ 13,127,475
	Revised Impact Tool	**$ 176,534,611**	**$ 140,287,877**	**$ 1,070,293,202**	**$ 311,092,305**	**$ 11,476,856,212**	**$ 2,698,681,521**